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ΣΧΟΛΉ ΑΓΡΟΝΌΜΩΝ & ΤΟΠΟΓΡΆΦΩΝ ΜΗΧΑΝΙΚΏΝ

CONCEPTUALIZATION AND SEMANTIC DESCRIPTION IN DIGITIZED TANGIBLE/INTANGIBLE CONTENT

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Abstract

The dissertation investigates the visual interpretation of heritage objects and practices providing both a theoretical framework for understanding the process of meaning-assignment and a formal ontology for grounding propositions about visual objects into a constituent-based framework.

The thesis starts its investigation from the theory of the perception of heritage, taking a semiotic standpoint and proposing a new framework of understanding Jakobson's Cultural Model of Interpretation (JCMI). The model, based on Jakobson's model of communication, illustrate the nuclear components used in the process of interpretation of our heritage. JCMI focuses particularly on the reconstruction of the original meaning, providing to the reader a theory of interpretation as a way to understand how the meaning of the object is constructed. Building upon the work of Eco, the dissertation advances a functional theory for the classification of the perceptual experience, correlating perceived signals to situations and physical things. The theoretical work analyses the use of the correlation in three diverse scenarios: recognition of the known, enhancement of the known and identification of the unknown, outlining how we use diverse similarity-based recognitions for defining the constituents of a perceptual manifestation. The resulting structure helps to examine the meaning assignment of cultural content and to study the framing of both physical objects and performative actions in our everyday visual experience.

The broad relevance of the framework in the context of the heritage practice is made explicit through the analysis of the problem of instance vs type, which is illustrated using pictorial examples of a famous subject of Eastern and Western art: Saint George. Instances of the visual representations of the saint are used to demonstrate both the function of the theoretical framework as well as its alignment with some iconographical representation theories in Art History, specifically Panofsky's and Van Staten's image description frameworks. These two theories are integrated and grounded within Jakobson's Cultural Model of Interpretation, highlighting the necessary correlations and critiques.

The framework developed is then used to guide the formalisation of an ontology which is constructed as an extension of CIDOC-CRM and sustain the recording of statements about the diverse elements present in a visual representation on the base of their interpretation. The result, tested with artworks coming from the church of Asinou, a small Byzantine foundation in Cyprus, demonstrates the capacity of the formal ontology to sustain the recording of statements about the denotative and the connotative dimension of the church's iconographical objects, helping unveil their contextual meaning through the clarification of symbols and constituents, liturgical performances and historical influences.

The ontology is further linked and harmonised with 3D data annotations structures, providing a framework of operation for using the ontology to classify visual annotations within a three-dimensional environment. The core components of the standard annotation model, the W3C Web Annotation ontology, are presented and analysed with respect to their usability for 3D annotations, specifically examining the connection between object fragment and annotation. The fragment-object relation is scrutinised using examples of solutions used by 3D web annotation projects. Moreover, a proposal for the creation of a shared URI structure able to characterise single areas within a scene is outlined. The Web Annotation model is further tested against 3D data and used to provide possible information pipelines for the semantic annotation and interconnection of 2D-3D areas within the Aioli project. Additionally, supplementary uses of the ontology (e.g. data harmonisation and enhancement, semantic reasoning) are examined and presented.

After having provided and tested the feasibility of the ontology to document the meaning-assignment in visual work, the dissertation further elaborates on the validity of the recorded information, specifically the one grounded on digital mediations such as photographs or three-dimensional hyper-realistic reconstructions. In order to tackle the problem, a provenance-based framework for the documentation of reality-based recording is presented.

The framework provides a formalisation for recording the different steps of a digitisation workflow in order to document the accuracy and reliability of the digitisation as well as to frame the developed digital objects as scholarly product and not mere visual artefact. The framework analyses both the essential processes to be carried out and the metadata to be gathered in digital photogrammetry survey projects, breaking up a typical digitisation workflow into seven iterative and repeatable steps. The documentation of each step is achieved using key metadata registers that capture the main framework of data interactions, starting from the functional requirements until the scientific analysis of a digital documentation project.

The provenance framework is tested using the digitisation of a part of the church of Asinou as key study, and the output produced is modelled using CIDOC-CRM and extensions. The results are linked with the annotation model and the ontology to provide an example of a full semantic documentation of a digitised heritage object which includes and records its digitisation, data processing, three-dimensional annotation and cultural interpretation of that object. The result is a single graph of object, practice and meanings linked together.

Keyword: Iconography, Semantics, Cultural Heritage, CIDOC-CRM, Semiotics, 3D, Annotations, Provenance

Extended abstract

Η διατριβή εξετάζει την οπτική πρόσληψη των αντικειμένων πολιτιστικής κληρονομιάς παρέχοντας τόσο ένα θεωρητικό πλαίσιο, προκειμένου να γίνει κατανοητή η διαδικασία της απόδοσης νοήματος, όσο και μια τυπική οντολογία, προκειμένου να στηριχθούν λογικές προτάσεις για οπτικά αντικείμενα σε ένα πλαίσιο που να βασίζεται σε επιμέρους συστατικά.

Η διατριβή αρχίζει τη διερεύνηση από τη θεωρία πρόσληψης της πολιτιστικής κληρονομιάς, υιοθετώντας μια σημειολογική οπτική και προτείνοντας ένα νέο πλαίσιο κατανόησης: το Jakobson's Cultural Model of Interpretation (JCMI). Το μοντέλο αυτό, βασισμένο στο επικοινωνιακό μοντέλο του Jakobson, αποτυπώνει τα βασικά συστατικά που χρησιμοποιούνται στη διαδικασία πρόσληψης της κληρονομιάς μας, εντοπίζοντας έξι θεμελιώδη στοιχεία: το πλαίσιο αναφοράς, τον δίαυλο, τον επικοινωνιακό κώδικα, το μήνυμα, τον αποστολέα και τον παραλήπτη. Αφού παρουσιαστούν τα συστατικά στοιχεία του JCMI, η έρευνα επικεντρώνεται στην ανάλυση του επικοινωνιακού κώδικα, του μηχανισμού που διασφαλίζει την κατανόηση του αρχικού νοήματος. Ο κώδικας λειτουργεί ως μια γενετική γραμματική που καθιερώνει ένα σύνολο λειτουργιών, ικανών να συσχετίσουν το επίπεδο περιεχομένου ενός σήματος με ένα επίπεδο έκφρασης συνδέοντας τα στοιχεία ενός συστήματος με τέτοιο τρόπο ώστε ένα στοιχείο α να χρησιμοποιείται για να σημαίνει ένα στοιχείο β. Αυτή η λειτουργία είναι θεμελιώδους σημασίας για την όλη δομή της πρόσληψης, αλλά απαιτείται περαιτέρω διερεύνηση όσον αφορά τον τρόπο που ο συνειρμικός μηχανισμός λειτουργεί και αποδίδει νόημα στα οπτικά αντικείμενα.

Ένας τέτοιος συνειρμικός μηχανισμός αναλύεται εκκινώντας από το έργο του Eco, και συγκεκριμένα από την ανάλυσή του για τον γνωσιακό τύπο (Cognitive Type-CT) και την κατηγοριοποίηση. Η διατριβή υποστηρίζει μια λειτουργική θεωρία για την ταξινόμηση της αντιληπτικής εμπειρίας, εισάγοντας την έννοια των Σημασιολογικών Σημείων (Semantic Marks-SM), εσωτερικές κωδικοποιημένες λειτουργίες που συμβάλλουν στην ταξινόμηση εξωτερικών ερεθισμάτων, με γνώμονα τη φύση τους. Αν και ένα SM μπορεί να θεωρηθεί ως ένας άλλος τύπος σήματος, είναι αντί αυτού μια κωδικοποίηση του αντιληπτού με βάση μια ταξινόμηση η οποία επαναχρησιμοποιεί την εμπειρία μας και το κοινωνικό δεδομένο, προκειμένου να προσδιορίσει τη σημασία της πραγματικότητάς μας. Ένα Σημασιολογικό Σημείο είναι το αποτέλεσμα μιας σημειολογικής διαδικασίας που λειτουργεί με τρία συστατικά: (i) τουλάχιστον ένα σήμα, (ii) μια περίσταση και (iii) ένα αντικείμενο. Οι συνιστώσες του SM τυπικοποιούνται με τη χρήση της λογικής και του συνειρμικού μηχανισμού που αναλύθηκε, λαμβάνοντας υπόψην τρεις περιπτώσεις: την αναγνώριση του γνωστού, τη βελτίωση του γνωστού, και την αναγνώριση του αγνώστου. Οι προσδιορισμένες συνιστώσες για την αναγνώριση μιας αντιληπτικής εκδήλωσης η οποία βασίζεται στην ομοιότητα είναι οι αξίες των πληροφοριών που αφορούν την Τοπολογία, τα Χαρακτηριστικά, την Αξία και την Ευθυγράμμιση μέσα σε ένα συγκεκριμένο σύστημα, το οποίο συνίσταται σε μια ανάγνωση της οπτικής αναπαράστασης βασισμένη στην τοπολογία, την αξία, τα χαρακτηριστικά ή την ευθυγράμμιση.

Οι δυνατότητες και τα όρια του Cultural Model of Interpretation αναλύονται υπό το πρίσμα του παραστατικού πεδίου. Η ευρεία σχετικότητα του πλαισίου αναφοράς, στα συμφραζόμενα της πρακτικής της πολιτισμικής κληρονομιάς, καθίσταται σαφής αν αναλύσουμε το πρόβλημα του «στιγμιότυπου» σε σχέση με τον «τύπο». Η διατριβή

υποστηρίζει ότι η διαδικασία ταυτοποίησης, καθώς και η ανίχνευση των ομοιοτήτων μεταξύ διαφόρων αναπαραστάσεων, περιλαμβάνει την αναγνώριση των Σημασιολογικών Σημείων του αντικειμένου και τη διατύπωση συμπερασμάτων που βασίζονται στην ομοιότητα προς έναν CT (γνωσιακό τύπο). Πιο συγκεκριμένα, η αναγνώριση του γνωστού βασίζεται στα ίδια πρότυπα που χρησιμοποιούμε για να ανιχνεύσουμε την εγγύτητα και την ομοιότητα των οπτικών αναπαραστάσεων, και στη συνέχεια να καταλήξουμε σε συμπεράσματα σχετικά με τις μεταξύ τους σχέσεις και τον βαθμό αναφοράς τους στον ίδιο γνωσιακό τύπο. Το πρόβλημα παρουσιάζεται με τη βοήθεια εικαστικών παραδειγμάτων ενός δημοφιλούς θέματος της ανατολικής και της δυτικής τέχνης: του αγίου Γεωργίου. Οι απεικονίσεις του αγίου αναλύονται ως προς τις πληροφορίες Τοπολογικού χαρακτήρα, Χαρακτηριστικών, Αξίας και Ευθυγράμμισης, που καταδεικνύουν τη δυνατότητά μας να χρησιμοποιήσουμε μια πολυδιάστατη μήτρα για να συγκρίνουμε τις απεικονίσεις όσον αφορά τα σημασιολογικά τους σημάδια. Η θεωρία στη συνέχεια εξετάζεται συγκριτικά με ορισμένες θεωρίες εικονογραφικής αναπαράστασης από την Ιστορία της Τέχνης, και συγκεκριμένα τα πλαίσια περιγραφής εικόνων που χρησιμοποίησαν ο Panofsky και ο Van Straten. Αυτές οι δύο θεωρίες βασίζονται και ενσωματώνονται στο Jakobson's Cultural Model of Interpretation, υπογραμμίζοντας τις απαραίτητες συσχετίσεις και την απαραίτητη κριτική.

Το πλαίσιο που αναπτύχθηκε χρησιμοποιείται στη συνέχεια ως οδηγός για την τυποποίηση μιας οντολογίας, που ονομάζεται VIR και η οποία προκύπτει ως επέκταση της CIDOC-CRM. Η τυποποιημένη αυτή οντολογία εισάγει οκτώ νέες κλάσεις (Χαρακτήρας, Εικονογραφικό Άτομο, Ιδιότητα, Αναπαράσταση, Εξατομίκευση, Οπτική Αναγνώριση, Verso και Recto), καθώς και είκοσι ιδιότητες. Η νέα οντολογία υποστηρίζει λογικές διατυπώσεις σχετικές με τη φύση των οπτικών στοιχείων και επιτρέπει τη δημοσίευση αυτών των περιγραφών στο διαδίκτυο. Με τον όρο «οπτικό στοιχείο» εννοούμε εκείνα τα σημάδια που προσδιορίζονται στον οπτικό χώρο ως ξεχωριστές και τεκμηριωμένες μονάδες, οι οποίες υπόκεινται σε μια αναλυτική ερμηνεία. Το αντικείμενο αυτής της οντολογίας περιλαμβάνει τη διαμόρφωση ενός πλαισίου που θα υποστηρίξει την αναγνώριση, το σχολιασμό και τις διασυνδέσεις μεταξύ των διαφόρων οπτικών στοιχείων και θα βοηθήσει στην τεκμηρίωση και την ανάκτησή τους. Συγκεκριμένα, το μοντέλο επιδιώκει να αποσαφηνίσει την ταυτότητα και τη σχέση αυτών των οπτικών σημείων, παρέχοντας τις απαραίτητες κλάσεις προκειμένου να χαρακτηριστούν τα συστατικά τους στοιχεία, η αναφορά, το συμβολικό περιεχόμενο και η πηγή πρόσληψής τους.

Η οντολογία χρησιμοποιείται για να περιγράψει έργα τέχνης που προέρχονται από την εκκλησία της Παναγίας της Ασίνου, ένα μικρό βυζαντινό εκκλησιαστικό ίδρυμα στην Κύπρο, και αποδεικνύει τη δυνατότητα της επίσημης οντολογίας να υποστηρίξει την καταγραφή των δηλώσεων των σχετικών με τη δηλωτική και τη συνυποδηλωτική διάσταση των εικονογραφικών αντικειμένων της εκκλησίας, βοηθώντας τα έτσι να αποκαλύψουν το συμφραστικό νόημά τους μέσω της αποσαφήνισης των συμβόλων και των συστατικών τους. Επιπλέον, η οντολογία χρησιμοποιήθηκε για να περιγράψει τη διασύνδεση μεταξύ των οπτικών στοιχείων και των ιστορικών τους επιρροών. Προκειμένου μια αναπαράσταση να περιγραφεί με ακρίβεια ως προϊόν του καιρού και του τόπου του, και να συνδεθεί με συγκεκριμένες παραδόσεις ή μια οπτική κουλτούρα, είναι απαραίτητο οι οπτικές πληροφορίες να ενταχθούν σε ένα ευρύτερο ιστορικό πλαίσιο. Ο πίνακας με τη Θεοτόκο Ελεούσα και τους λατίνους δωρητές στην εκκλησία της Ασίνου επιλέγεται προκειμένου να τεκμηριωθούν οι αισθητικές πληροφορίες εντός του ιστορικού πλαισίου παραγωγής, που συνδέεται με την κυριαρχία του Οίκου των Λουζινιάν στην Κύπρο, η οποία επηρέασε την επιλογή του τύπου και του ύφους της τοιχογραφίας. Επιπλέον, οι εικόνες στον νάρθηκα της εκκλησίας που εξετάζεται απεικονίζουν πασίγνωστες σκηνές βιβλικής προέλευσης και εσχατολογικών οραμάτων. Γνωστά και τυπικά παραδείγματα είναι αυτά που συνθέτουν την Τελική Κρίση: ο άγγελος που τυλίγει την περγαμηνή, ο πύρινος ποταμός και η προετοιμασία του θρόνου. Κάποιοι από τους εικονογραφικούς τύπους που συνθέτουν το θέμα της Τελικής Κρίσεως μνημονεύονται σε μερικά από τα λειτουργικά βιβλία που ορίζουν ποιες προσευχές και ύμνοι θα ακουστούν κατά τη λειτουργία της Κυριακής των Απόκρεω (την Κυριακή πριν από την έναρξη της Σαρακοστής). Η σημαντικότερη πηγή για τον 12ο, 13ο και 14ο αιώνα, την περίοδο που επηρέασε περισσότερο τα παραστατικά θέματα στην Ασίνου, είναι το Τριώδιον, ένα υμνολόγιο του 9ου αιώνα για την περίοδο της Μεγάλης Σαρακοστής. Πολλές από τις τοιχογραφίες στην εκκλησία της Ασίνου συνδέονται με το θέμα της Δευτέρας Παρουσίας και απεικονίζουν σκηνές από εδάφια βιβλικών κειμένων. Ορισμένες αναπαραστάσεις, ωστόσο, δεν απεικονίζουν απλώς ένα βιβλικό κείμενο αλλά αναφέρονται και εντός της λειτουργίας. Η οντολογία χρησιμοποιήθηκε για να μοντελοποιήσει και να συνδέσει αυτά τα σύνολα πληροφοριών τα σχετικά με τις τοιχογραφίες της Ασίνου με τα θρησκευτικά τελετουργικά, αλλά και τα λειτουργικά βιβλία που τις αναφέρουν.

Όλα αυτά τα παραδείγματα καταδεικνύουν πόσο θεμελιώδες είναι το χωρικό στοιχείο για την ανάλυση και την περιγραφή των εκδηλώσεων παραστατικού χαρακτήρα (π.χ. της σύναξης των πιστών για τη λειτουργία), των οπτικών μονάδων (π.χ. την κατανεμημένη στο χώρο Δέηση), τη μορφολογία και τη θέση του οπτικού στοιχείου σε σχέση με την όλη δομή.

Προκειμένου να χωροθετηθούν οι προσδιορισμένες σημασιολογικές πληροφορίες, η οντολογία συνδέεται περαιτέρω και εναρμονίζεται με δομές σχολιασμού 3D δεδομένων, παρέχοντας ένα πλαίσιο λειτουργίας ώστε η οντολογία να χρησιμοποιηθεί στην ταξινόμηση των οπτικών σχολιασμών μέσα σε ένα τρισδιάστατο περιβάλλον. Η εναρμόνιση των 3D δεδομένων και της οπτικής πληροφορίας χρησιμοποιεί ως βασικό συστατικό την οντολογία W3C Web Annotation, μοντέλο που παρέχει ένα πλαίσιο το οποίο επιτρέπει την έκφραση της σχέσης ανάμεσα σε μια τριάδα συνδεδεμένων πόρων: τον σχολιασμό, το σώμα του και τον στόχο του. Ο σχολιασμός ορίζεται ως μια δήλωση αναφορικότητας, ένας τρόπος που μια πληροφορία σχετίζεται με ένα υπό μελέτη θέμα. Το υπό μελέτη θέμα είναι, σε αυτή την τριάδα, ο στόχος, ένας ψηφιακός πόρος που υπόκειται στο σχολιασμό. Το τρίτο μέρος της τριάδας είναι το σώμα, το περιεχόμενο του σχολιασμού, οι πληροφορίες που σχετίζονται με το στόχο. Το μοντέλο που προκύπτει είναι μια ευέλικτη τριμερής δομή, η οποία μπορεί να επεκταθεί περαιτέρω ώστε να συμπεριλάβει πληροφορίες σχετικές με τη δημιουργία, το κίνητρο και την άδεια ενός από αυτά τα τρία στοιχεία. Ένα σημαντικό εμπόδιο που έχει επιβραδύνει την ανάπτυξη συστημάτων σχολιασμού είναι η προβληματική διασύνδεση μεταξύ σχολιασμού και πόρου. Το τι θα καθοριστεί ως στόχος, και πώς αυτός επιλέγεται, εξαρτάται από τον τύπο του στοχοθετημένου αντικειμένου. Κάθε μέσο και κωδικοποίηση είναι δομημένα διαφορετικά, και απαιτούνται κατάλληλες υπολογιστικές μέθοδοι για τον προσδιορισμό του τμήματός του. Αφού επιλεγεί, για να χρησιμοποιηθεί μαζί με το Web Annotation data model, το τμήμα πρέπει να προσδιοριστεί χρησιμοποιώντας έναν επιλογέα τμημάτων (Fragment URI), μια σύντομη ακολουθία χαρακτήρων που προσδιορίζει κάτι συγκεκριμένο ως λειτουργία του εγγράφου.

Η σχέση τμήματος-αντικειμένου ελέγχεται με τη χρήση παραδειγμάτων λύσεων που χρησιμοποιούνται από διαδικτυακά πρότζεκτ 3D σχολιασμού, συμπεριλαμβανομένου του 3D Heritage Online Presenter (3DHOP), του Sketchfab και του νέου Smithsonian Voyager, ενός λογισμικού 3D οπτικής απεικόνισης και σχολιασμού που είναι ανοιχτού κώδικα. Λόγω της έλλειψης μιας κοινώς γνωστής δομής URI για τον εντοπισμό 3D περιοχών, σκιαγραφείται μια νέα πρόταση για τη δημιουργία μιας τμηματικής δομής URI ικανής να χαρακτηρίσει 3D σημεία, επιφάνειες και όγκους. Το Web Annotation model δοκιμάζεται περαιτέρω σε 3D δεδομένα, και χρησιμοποιείται επίσης για τον καθορισμό πιθανών καναλιών διοχέτευσης πληροφορίας για τον σημασιολογικό σχολιασμό και τη διασύνδεση 2D-3D περιοχών, στο πλαίσιο του πρότζεκτ Aioli. Το Aioli είναι ένα νέο σύστημα, το οποίο αναπτύχθηκε από το εργαστήριο CNRS MAP και παρέχει ένα κανάλι διοχέτευσης για τη δημιουργία, τον σχολιασμό και την κοινή χρήση 3D μοντέλων. Ο χρήστης είναι σε θέση να μεταφορτώσει το αποτέλεσμα μιας διαδικασίας πρόσκτησης δεδομένων, και το σύστημα δημιουργεί αυτόματα, χρησιμοποιώντας το micmac στο backend, ένα νέφος σημείων (point cloud) του ψηφιοποιημένου αντικειμένου. Μόλις υπολογιστεί το νέφος σημείων, μπορεί να σχολιαστεί χρησιμοποιώντας τις αρχικές 2D εικόνες. Ο σχολιασμός που δημιουργείται πάνω από μια εικόνα προβάλλεται αυτόματα πάνω από τη δομή 3D και τις 2D εικόνες που καλύπτουν χωρικά το σχολιασμό. Ένα σημαντικό χαρακτηριστικό αυτής της διαδικτυακής εφαρμογής είναι ο συνδυασμός και οι διασυνδέσεις μεταξύ 2D και 3D, η δημιουργία συνδέσεων ανάμεσα στην αρχική πρόσκτηση δεδομένων και στο τρισδιάστατο αποτέλεσμα.

Το πρότζεκτ Aioli χρησιμοποιείται ως δοκιμαστική περίπτωση για να αναδειχθεί η διασύνδεση μεταξύ της VIR και του Web Annotation data model, περιγράφοντας το υπολογιστικό μέρος της διαδικασίας σχολιασμού χρησιμοποιώντας το Web Annotation data model, ενώ ο οργανισμός, οι ενέργειες και οι διασυνδέσεις με δεδομένα πολιτισμικής κληρονομιάς περιγράφονται πλήρως χρησιμοποιώντας τη VIR και τη CIDOC-CRM. Χρησιμοποιώντας την προτεινόμενη δομή, μπορούμε να συνδέσουμε ένα οπτικό στοιχείο, όπως μια τοιχογραφία, με μια 3D δομή, και επιπλέον να καταγράψουμε την πηγή του σχολιασμού και τον οργανισμό του δημιουργού του. Επιπλέον, η καταχώριση των διαλογέων μπορεί να μας βοηθήσει να εντοπίσουμε τη διαστατικότητα της σχολιασμένης περιοχής σε ένα σύνολο δεδομένων.

Επιπρόσθετα, εξετάζονται και παρουσιάζονται συμπληρωματικές χρήσεις της οντολογίας για διαδικασίες ETL (π.χ. εναρμόνιση και βελτίωση δεδομένων, σημασιολογική συλλογιστική).

Αφού διατύπωσε και έλεγξε τη δυνατότητα της οντολογίας να τεκμηριώσει την απόδοση νοήματος στα οπτικά έργα και να χωροθετήσει το νόημα αυτό μέσα σε μια ψηφιακή αναπαραγωγή, η διατριβή πραγματεύεται περαιτέρω την εγκυρότητα των καταγεγραμμένων πληροφοριών, συγκεκριμένα αυτή που βασίζεται στη μεσολάβηση ψηφιακών μέσων, όπως είναι φωτογραφίες ή οι τρισδιάστατες υπερρεαλιστικές ανακατασκευές. Οι ψηφιακές ανακατασκευές σε όλες τις μορφές τους φαίνονται να είναι ακριβείς αναπαραγωγές, ωστόσο, και αυτό ισχύει και για τις αναλογικές, πρόκειται για αναπαραστάσεις ενός συγκεκριμένου φυσικού αντικειμένου σε ένα συγκεκριμένο περιβάλλον και χρόνο. Μια ψηφιακή εικόνα, μια ψηφιακή σάρωση ή ένα ψηφιακό 3D αντικείμενο θα αποτελεί πάντοτε το στιγμιότυπο ενός αντικειμένου, το οποίο βασίζεται σε μια γραμματική και ένα σύνολο επιλογών. Η φύση της ψηφιακής εικόνας υπονοεί μια τέτοια υποκείμενη γραμματική, η οποία είναι μέρος του ίδιου του μέσου. Ένα αντικείμενο, στην πραγματικότητα, μπορεί να πλαισιωθεί χρησιμοποιώντας ποικίλες διαστατικότητες· μια ψηφιακή εικόνα απεικονίζει μόνο ένα σύνολο από αυτές τις διαστάσεις, με σκοπό να δημιουργήσει μια απεικόνιση του αντικειμένου που να φαίνεται όσο το δυνατόν πιο κοντά στον κοινό τρόπο με τον οποίο εμείς το κατανοούμε. Επομένως, οι αναπαραστάσεις δεν πρέπει να αντιμετωπίζονται απλώς ως έξοδος μιας ψηφιακής διαδικασίας, αλλά ως αντικείμενα μελέτης καθαυτά, και για τέτοιους λόγους είναι ζωτικής σημασίας να διευκρινιστεί η διαδικασία παραγωγής τους. Ως εκ τούτου, είναι απαραίτητο να δημιουργηθούν πλαίσια για την καταγραφή και την τεκμηρίωση των πληροφοριών προέλευσης πάνω σε ψηφιακά οπτικά αντικείμενα.

Προκειμένου να αντιμετωπιστεί το πρόβλημα, παρουσιάζεται ένα πλαίσιο το οποίο βασίζεται στην προέλευση για να τεκμηριώσει την καταγραφή που βασίζεται στην πραγματικότητα.

Το πλαίσιο παρέχει ένα κανάλι διοχέτευσης για την καταγραφή των διαφόρων βημάτων κατά τη ροής μιας εργασίας ψηφιοποίησης, προκειμένου να τεκμηριωθεί η ακρίβεια και η αξιοπιστία της ψηφιοποίησης, καθώς και να πλαισιωθούν τα ανεπτυγμένα ψηφιακά αντικείμενα ως ακαδημαϊκά προϊόντα και όχι απλώς ως οπτικά τεχνουργήματα. Το πλαίσιο αναλύει τόσο τις βασικές διεργασίες που πρέπει να διεξαχθούν όσο και τα μεταδεδομένα που πρέπει να συλλεχθούν σε έρευνες ψηφιακής φωτογραμμετρίας, χωρίζοντας την τυπική ροή εργασίας μιας ψηφιοποίησης σε επτά επαναληπτικά και επαναλήψιμα βήματα. Η τεκμηρίωση κάθε βήματος επιτυγχάνεται με τη χρήση σημαντικών μητρώων μεταδεδομένων, τα οποία καταγράφουν το κύριο πλαίσιο των αλληλεπιδράσεων των δεδομένων, ξεκινώντας από τις λειτουργικές απαιτήσεις και φτάνοντας μέχρι την επιστημονική ανάλυση ενός πρότζεκτ ψηφιακής τεκμηρίωσης. Το πλαίσιο επιτρέπει την παρακολούθηση της διαδικασίας ψηφιοποίησης, που οδηγεί στο ψηφιακό προϊόν και καθιστά δυνατή την πραγμάτωσή του, μέσω της πλήρους φωτογραμμετρικής ροής εργασίας, από τον πλήρη σχεδιασμό της πρόσκτησης δεδομένων, την επεξεργασία και την ανάλυση μέχρι τη διάδοσή του. Το πλαίσιο προέλευσης εξετάζεται χρησιμοποιώντας την ψηφιοποίηση της εκκλησίας της Ασίνου ως μελέτη κλειδί. Οι παράμετροι πρόσκτησης δεδομένων και οι πληροφορίες επεξεργασίας καταγράφονται και δηλώνονται. Προκειμένου να ενταχθεί η έξοδος της διαδικασίας μέσα στο σημασιολογικό πλαίσιο που αναπτύχθηκε παραπάνω, η παραγόμενη έξοδος διαμορφώνεται χρησιμοποιώντας τη CIDOC-CRM και τις επεκτάσεις της. Η έξοδος που προκύπτει συνδέεται με το μοντέλο σχολιασμού και την οντολογία, για να δώσει ένα παράδειγμα πλήρους σημασιολογικής τεκμηρίωσης ενός ψηφιοποιημένου αντικειμένου πολιτιστικής κληρονομιάς που περιλαμβάνει και καταγράφει την ψηφιοποίησή του, την επεξεργασία δεδομένων, τον τρισδιάστατο σχολιασμό και την πολιτισμική πρόσληψή του.

Το τελικό αποτέλεσμα είναι ένα ενιαίο γράφημα, στο οποίο συνυπάρχουν συνδεδεμένα τα αντικείμενα, οι πρακτικές και τα νοήματα.

Preface

The purpose of this thesis is to provide the foundation for the construction of a digital iconographical/iconological method for tracking and analysing the global evolution of representations and their qualitative and quantitative attributes over time and space. The thesis introduces a new approach which is grounded in formal ontology link to the possibility to use graph technologies for the storage of multiple types of information about the object visual or informative dimension.

This work stemmed from the collaboration within ITN-DCH project, the CNRS MAP Laboratory, the Laboratory of Photogrammetry in NTUA and personal passions towards the visual aspects of the heritage discipline. The thesis has been hosted within the Laboratory of Photogrammetry, School of Rural and Surveying Engineering, National Technical University of Athens (NTUA) and carried out together with the Modèles Et Simulations Pour L'architecture Et Le Patrimoine (MAP) Laboratory within the Centre National De La Recherche Scientifique (CNRS). Both laboratories analyse diverse aspects of the digitisation and study of the heritage object and the integration of the knowledge coming from these two important institutions has been fundamental for the success of this thesis.

This dissertation, multidisciplinary at its core, should be of interest to several disciplines that gravitate around the heritage object, and it is particularly aimed to semantic web researchers, art theorists and digitisation specialists; however, some of its parts can be of interest to high-level decision-makers in local and national museum and heritage institutions looking to define new solutions for digitising their collection, or make a better use of their inventories.

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Introduction

"And the bird called, in response to
The unheard music hidden in the shrubbery,
And the unseen eyebeam crossed, for the roses
Had the look of flowers that are looked at."

— T.S. Eliot, *Four Quartets*

1.1 Introduction

The cultural heritage domain in recent years has seen novel developments that have broadened up its field of action with respect to both its subject and its methods. One of the major driving forces that has helped the field regain its central position within the humanities is the use and mastery of computational methods. The partnership between heritage science researchers and information technologists has helped develop new perspectives and approaches, creating new challenges and possibilities. This "revolution", still at its beginning, has forced a change in paradigm, which entailed a new active participation to the conservation, classification, preservation and democratisation of the heritage objects, engaging the public with new digital tools and experiences. Many heritage institutions jumped aboard of this new digital adventure, financing and collaborating with local and international companies or research institute to develop new ways of engaging users, opening up their warehouse and transforming them into digital factories, able to create digital reproductions of their collections. While digital objects, in the form of 2D/3D representations, have not yet become common exchange goods between researcher and memory institutions, their presence continues to grow and with that the many problems we encounter when dealing with such a large quantity of digital resources.

While many are the issues arising when dealing with the creation of digital objects, the most common problem faced by many institutions is probably the one of curation. The creation of a large number of digital assets has forced the heritage community to search for a way to organise and, in a later stage, retrieve and cluster the produced digital objects on the base of their inner characteristics. While it is not a difficult task by itself, it becomes extremely troublesome when we deal with a large set of objects. Novel instruments and methods for the cataloguing of a large number of resources have been developed in the latest years and have helped organise and keep track of the propagation of digital assets. Entangled with such an effort, novel ways to look, interpret, and analyse digital objects have emerged. Digital resources have slowly become the counterparts of their physical ones and, as such, the real object of analysis. The reasons for this turn are quite easy to grasp and are mostly related to the fact that it is easier to collect and analyse multiple objects in their digital format, and more importantly, it is easier to compare and cluster information about hundreds or thousands of digital objects. Performing the same task using physical items would be an endless and daunting (however not impossible) operation.

Due to the clear advantages for users and administrators of memory institutions provided by the creation of digital inventories, the largest chunk of the digital shift has been dedicated to the transformation of catalogues and other information resources (e.g. thesauri, controlled vocabularies) in a digital format. The focus has been, for many years, on the examination and creation of methodologies to reproduce the information pipeline that we are accustomed to in our daily administrative tasks. The emphasis on the reproduction and amelioration of these information-based procedures have devoured numerous resources, stirring the research conversation towards the production of information-based artefacts. The information-emphasis has prompted a split within the domain which now appears to be driven by two parallel research lines: one concerned with the digital heritage object, and the other one focused on what we would call for clarity information object.

Digital heritage objects are the result of the digitisation of a heritage item which produces a replica of the object itself as an inert item using a specific representational language. The starting point is a physical object, a three-dimensional structure which is being re-created digitally as a visual item using forms and colours expressed in 2D or 3D coordinates. It is purely a geometrical object containing data about the morphology, colour, and (in some instances) depth of the original cultural item. The emphasis of the reproduction is on the shape and appearance. The purpose is to recreate it as faithful as possible to the original in order to use it for spatial and conservation analysis.

Information objects instead are formed by a series of propositions, usually in written form, which describe, interpret, discuss, refer to the heritage item or to entities related to it by some properties or characteristics. Information objects are pure content, and we assess their importance only with respect to their informative value. The content encoded in an information object reflects the understanding that one or more communities have over a heritage item. The formalisation of the content of an information object within a computational environment serves primarily the retrieval purpose.

The theoretical and practical issues encountered in the digital transformation and use of information and digital heritage objects have been the subject of two distinct lines of research. Each of them perfected their scope to deal with problems related to just one of these two objects. While separated, these research lines have been running in parallel, at a different speed and using diverse paths continuing, each of them in their own way, to construct innovative ways to analyse, manage and discuss cultural heritage.

The research line interested in information have analysed classification schemas and experimented with novel ways to better describe and integrate heritage data, in order to create a browsable network of information capable of presenting the history and usage of an artefact. The popularity of these standard models has grown hand in hand with the demands for new ways to describe and aggregate information about our heritage, making the data coming from memory institutions quite a valuable currency in what is known as digital cultural heritage domain. The initial focus of this research line has shifted from the simple data collection for documentary practice to an analytical approach which enables researchers to cross-examine the information and find global interconnections using clustering techniques.

The research line interested in the object has been focusing on methods and workflows able to create perfect replicas of complex items, ameliorate or speed-up the process and establish low-cost digitisation pipelines. Moreover, the research community has focused on the development of new applications and algorithms to create better digital replicas as well as concentrated their efforts on creating visualisation environment to fully reconstruct the digitised objects (e.g. VR/AR and web). The computational novelties did not encompass only new machineries or applications, but also standard architectures for the presentation of images throughout common API infrastructure.

1.2 Representation

The result of the research line focusing on the object encompasses a series of representations in the form of models of buildings constructed using a CAD system, three-dimensional collection of points, drawings, maps, pictures as well as objects in a virtual or augmented environment. All of these types of representations are the reflection of different languages and encoding we use for depicting reality. The same single rectangular room, for example, can be represented in various ways, using simple points and lines, as a set of multiple points, as a map or even as a 360° photo.
For as much as the representational languages are very much different, we use to recognise in each of these depictions instances of the same object, identifying the points and lines as walls and angles, the set of points as surfaces, a map as a stylization of a building and a 360° photo as the panoramic distortion of a quadrilateral room.

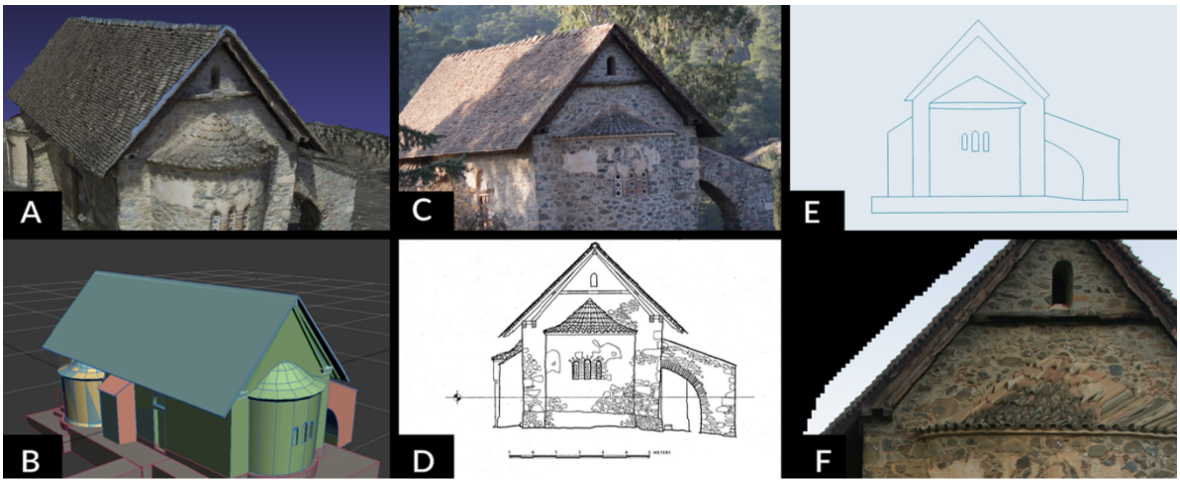

Figure 1. Diverse representation of the church of Panagia Phorbiotissa of Asinou, Cyprus. Figure A - mesh constructed following a UAV photogrammetric acquisition. Figure B - reconstruction in 3D Studio Max developed by Marleen de Kramer (Coughenour et al. 2015). Figure C - photo of the exterior of the apse of church. Figure D - east elevation of the church. Drawing by Richard Anderson, Dumbarton Oaks BF. F.1993.F0909. Figure E - simplified CAD drawing of the church. Figure F - rectified version of the exterior of the apse of church (Sofocleous et al. 2006).

Each of these representations is modelled with respect to the interests of a group of users and capabilities of the producer, and all of them reflect some aspects of the real object. While it is clear that the representations are not the same, each of them could be used to depict the object using a chosen set of metrics. The degree of representational truthfulness of the set of metrics determines the faithfulness with respect to the real object. Figure 1, for example, presents six different representations of the same single vaulted church, and each of them could easily be the subject of a digital heritage project. While some representations are more faithful to the architecture of the church, they are still not perfect, and their degree of faithfulness depends on a series of variables which range from environmental light, colours, capabilities of our recording hardware, aims, acquisition time and accessibility of the object, but also interpretation and understanding of the language used for its creation. Figure 1.E, for example, is a two-dimensional flat representation of a complex three-dimensional structure, nevertheless, due to our shared experience of this representational language, we are able to understand it. This issue is not limited to architectural structures, but it is also common in the figurative domain where languages and perceptions have evolved through the years and the experience of space has changed in respect to both the way of depiction (reverse perspective vs linear perspective) and its conceptualisation.

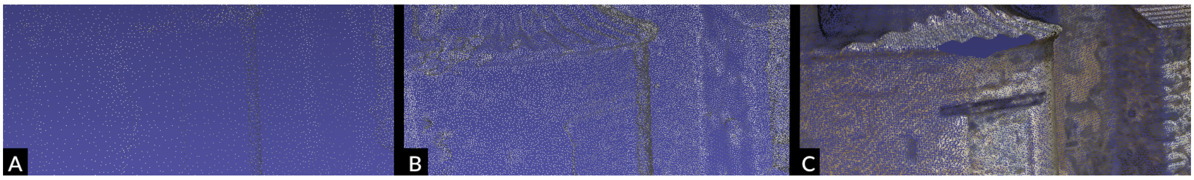

Figure 2. Three different point clouds representing part of the closed south door of the narthex of the church of Asinou.

Within the digital heritage domain, it appears from the literature that reality-based three-dimensional representations are considered the most accurate renditions of a visual element. It is, however, important to emphasise that the capabilities to illustrate a shape depend on the accuracy of a survey, the information recorded, their processing and the aim of the final product. The use of a three-dimensional representation does not imply *de facto* faithfulness in the rendition, but it has to be considered only another representational model. Figure 2 can help clarifying that argument. It shows three different point clouds representing part of the closed south door of the narthex of the church of Asinou with variances in respect to number and type of points recorded. The differences in the recorded information have heavily influenced the representational capabilities of the three-dimensional model. In figure 2.A, for example, the shape is barely visible and could be used just as a pointer to attach some texture, but its representational capabilities are limited by the lack of information. While figure 2.B presents a better recording of the shape, it still does not give us a clear understanding of the components of the object (e.g. the presence of the lintel it is not clear).

The light, material, and colour variations can also be disruptive for the representational purpose of these depictions. Not being able to record important colour variations or using artificial light could create an unnatural effect, rendering very different the appearance of the whole object and affecting further analysis. Whatever method we rely on, geometrical discrepancy could still be an important issue if the survey has not been thoroughly performed, or the post-processing has been too heavy (e.g. hole filling), providing users and experts with an unrealistic representation closer to a videogame model than a scholarly product. These issues affect both reality-based model, and even more critically iconographically-based three-dimensional representations, where the uncertainty, the bias of the modeller, and the sources used can heavily influence the quality and scientificity of the results.

While initially the representational discrepancy could be seen only as a technical issue, after further analysis we realise that it has its roots in our understanding and use of digital heritage resources. The purpose of these representations, in fact, is not only to display and interact with a simulacrum of the heritage object, but to actually use them as instruments of analysis, to make statements about the world through them, to find metrics to compare objects, to study their behaviour, to subdivide them into units, to reconstruct their holes, to re-define their existence, to put them into their historical context, to study how they interact with their ecology and how they shape it or to show how the object could be. Representations of this type are not treated as simple depictions but are instrumental to the knowledge we derive from our past, because we have the tendency to assign them the status of digital counterparts of heritage objects.

Therefore, representations should not be treated as just an output of a digital process, but as objects of study of their own, and for such reasons, it is crucial to clarify the layer we use to interpret them documenting both their production and how we assign them meaning.

The recording of production parameters for keeping tracks of the operations over the digitalisation of an object is not, however, enough. Of the foremost importance to include such analysis in a framework which documents and makes transparent what it represents and under which condition.

While this could seem trivial at first, there is a whole set of actions which assign meaning to the object on the basis of not clear, shared or formalised parameters. A great number of examples can be found in operations the likes of image classification, scene semantic segmentation, object detection, HBIM and human computation, where the initial bias of the content producer and operator drive the meaning-assignment to the objects, without the necessary documentation of the implicit knowledge used for carrying out the classificatory act.

The implementation of the defined classification act in re-usable algorithms or datasets can disseminate the initial bias establishing a dangerous ground truth. It is the case of supervised machine learning approaches.

It is important to stress that within every act that implies a subdivision of a whole into units for the purpose of labelling or structuring them, we are driven by our understanding of reality as well as by the mechanism to cope with its intrinsic vagueness. While this is true for every classification and segmentation act, it is even more complex when we use heritage objects as subjects of our classification. These types of objects are, in fact, carriers of values for a specific community, and their unity and meaning is given, not intrinsically linked to the object.

This complexity is quite evident in the figurative domain. The description of figures and compositions depends on levels of subdivision that an examiner has determined and thus depends entirely upon his knowledge of the examined object. The recognition of a particular symbol in a visual culture (grounded in time and space) depends on the level of knowledge that the viewer has about that culture, plus the knowledge of artistic motifs and subjects. In order to make clear the implicit complexity of a classificatory act, we will use the example in figure 3 which presents an image of the iconographical type of the Virgin Paraklesis interceding with Christ on behalf of the humanity. This depiction is generally identified as Paraklesis, but the epithet may change and in Asinou it is named "Eleousa", the merciful. An automatic subdivision could probably recognise the depiction as a single pictorial unit, we could even classify it as portraying a human (fortunately it is not a personification in this instance), but how would we proceed from there? The epithet Paraklesis is only relevant if, and only if, the Virgin accompanies Christ and John the Forerunner (Eastern Christian name of John the Baptist), and in that case, is a part of a composition called Deesis. In the east lunette the narthex of the church of Panagia Phorbiotissa these three characters are present, but separated by a door (Figure 4.A) and not appearing in their usual configuration (Figure 4.B). There is spatial distance between the parts of the compositions, and an automatic, or even a manual segmentation, performed by a non-expert, would not probably take into account such an example, failing to recognise what to an expert would seem a typical structure. Furthermore, the Deesis is itself a unit of a bigger and larger composition: the Last Judgment. A great number of representations in the narthex of the church are part of this composition, but not each and every one of them, and not following a specific order. Figure 5 highlights all the units which compose the Last Judgment, and as it is possible to notice, the depictions are spatially spread throughout all the narthex and adjacent pictures can belong to completely different themes.

Figure 3. Virgin Paraklesis, from the east lunette the narthex of the church of Panagia Phorbiotissa in Asinou, Cyprus.

A Deesis is present also in the Naos of the church (Figure 4.C). In this instance, the figure of the Virgin Paraklesis is depicted together with John the Forerunner, in a very different schema than the usual tri-partition where John and the Virgin are on the opposite side of Christ. Moreover, also in the Deesis in the naos, the figure of the Virgin and John the Forerunner are spatially separated from the figure of Christ. While in the narthex, the Deesis was part of a bigger theme, the Last Judgment, it is not the case in the Naos.

We have, therefore, the same type of representation, a Deesis, depicted very differently both within the same church and in respect to the classical representation and, moreover, belonging to two different themes.

Figure 4. Examples of Deesis. Figure A - Asinou Narthex, Cyprus. Figure B - Hagia Sophia, Istanbul, Turkey. Figure C - Asinou Naos, Cyprus.

These examples underline the complexity of the scene and the uniqueness of each composition which, in this case, takes advantages of the morphology of the church to overcome traditional panel structurisation and to expand its reach in space. It is clear that, if we want to tackle such complex cases, techniques, such as image classification, scene semantic segmentation and object detection do not only need to be supervised, but they should record the status assignment as an interpretation over the visual and not just assign mere label to a resource. Each classificatory act is, in fact, an assignment of meaning which depends on our capabilities to understand what is portrayed, the geometry of the scene, its subject and theme. Following the example above, defining the presence of the Virgin, Christ and John the Forerunner in three different panels is not incorrect or imprecise, but delivers incomplete information.

In order to tackle this complexity, and incorporate these aspects within the description of an object, it is crucial to have flexible instruments able to sustain multiple classifications over the same visual units, linking spatially separated wholes as part of the same instance and constructing system able to fuse object and content together, spatialising the heritage information and encoding the morphology of the object. Without such links, we would not be able to cluster visual object for their real multi-dimensional characteristics, but only create systems able to indicate the existence of a sign signifing something without being able to characterise the properties of the sign itself. It would be a crippled system unable to perform the level of analysis necessary to fully comprehend our cultural heritage.

Figure 5. Wall paintings from the narthex of the church of Panagia Phorbiotissa in Asinou, Cyprus.

In order to avoid building such a system, we need first and foremost to understand the primary elements that compose such an elaborate framework, and for doing so we must ask ourselves:

1. How do we assign meaning to the visual heritage?

The answer to this question should reveal how to create the connection between content and object and how much universality can be extrapolated from that answer. This question is particularly important if we consider that the framework should be re-used for computational purposes and should take into account a multiplicity of visions. It is not useful to just define a tailor-made formula for a community, but what is necessary is to understand the characteristic of the process in order to define the elements that are used to assign meaning. While the problem seems to appear very philosophical in nature, it has some quite real consequences. The identification and definition of the features of the meaning-assignment process can help

replicate its traits within an information pipeline which could reuse these features to record the social and contextual characteristics used for an assignment of status.
However, if we want to use the answer to our first query to define a computational method, we must ask ourselves a following question:

2. How do we formalise the relationship between meaning and visual heritage?

This second question is cardinal to transpose the initial philosophical enquiry into a formalisation which could be exploited by a computer in order to aggregate, harmonise and link datasets together, enabling the user to specify new questions and reveal new trends. While the final formalisation could be enough to define new ways of using and linking our collections of digitised cultural objects, it is not fully complete. In order to overcome the traditional object-representation dichotomy, we need to spatialise the visual characteristics of a heritage object within a digital representation. It is, therefore, essential to further ask ourselves:

3. How do we spatialise semantic information in a three-dimensional representation?

The answer to this third question should reveal methods to ground the semantic information within a three-dimensional structure, interlinking geometrical and morphologic features with representational values. The completion of this passage can help aggregate and compare objects not only for their visual features but also for their dimensional ones, transforming the 3D object into an information hub. This new scenario introduces new challenges and opportunities to interact with the digital. One of the possible challenges regards the assessment of the produced three-dimensional representations. If we introduce the use of the dimensional properties as a driver for similarity research, it is important to ensure the accuracy of the data. It is crucial to look at the problem asking ourselves:

4. How do we assess the relationship between the digitised visual heritage and the original artefact?

The answer to the last question is essential to ensure the scholarly use of this new information pipeline we are proposing in this work. These four questions are going to be further analysed in more detail in section 1.3.

1.3 Objectives

1.3.1 Objective #1 - How do we assign meaning to the visual heritage?

The first objective is to develop a theory for the construction of meaning with respect to visual objects, in short to construct a theory of interpretation. This passage is fundamental for the global understanding of the visual phenomenology and it is paramount to identify and characterise the necessary elements that define the diversities of our interpretation. An answer to this objective can be found in the chapter 4 and 5 which develop, following and expanding on the researches carried out by Floridi, Eco, Jakobson and Hjelmslev, a framework explaining and defining the characters and elements of the visual interpretation of a cultural object. The framework starts with the re-use and modification of Jakobson communication model, slightly altered to create a Cultural Model of Interpretation able to explain the phases and interactions that characterise the recognition of the visual heritage. The model starts assessing the elements we use for the interpretation of a heritage object: from the identification of the visual information itself (which is not apparent) to the major problem faced by this process, the association between visual sign and concept that constitute the recognition. Re-using and expanding on Eco's theory of interpretation outlined in Kant and the Playtus (2000) a new theory explaining the associative mechanism between visual information, type and context is presented. The new theory underlines strongly the situational role of the context as well as of experiences (in the form of past experience and classificatory habits of a social group) and defined a series of attributes of the interpretation.

We further test the theory within the complex domain of visual art (section 5), using Saint George as the primary example for demonstrating the complexity of the visual recognition in diverse contexts. We examine the problem of the identification of the diverse depictions of the saint present in the different representations of Western and Eastern artistic traditions. Using the theory developed in section 4 the characteristics for the recognition are identified and an example of their relationship in respect to a set of depictions of Saint George is provided, thus making clear the basic shared set of elements that we used to reference the saint. The developed theory is further related to comprehensive art historical theories of interpretation and assignment of visual meaning, making clear their commonalities as well as differences.

1.3.2 Objective #2 - How do we formalise the relationship between meaning and visual heritage?

The second objective builds up from the first and defines how we can use the elements of meaning-construct identified in the previous objective to formalise a knowledge model to describe heritage objects. The purpose of this computational model is to develop multi-agent systems able to search, cluster, and identify common features between visual objects. The answer to the question raised in objective #2 is given in chapter 6 where, by re-using the initial theory, a model for the annotation and classification of visual objects is presented. The model, constructed as an extension of the ISO ontology for cultural heritage CIDOC-CRM, is grounded in the difference between sign and reference, and enable users to define visual knowledge in a specific context. Example of its use have been tested for the classification of wall paintings from the church of Panagia Phorbiotissa in Asinou presented in section 3. Diverse paintings, themes or spatial aggregations present in the church are classified with the ontology, and further modelling examples are provided in respect to the historical context of production. Moreover,

the model is used to describe the generative or descriptive interconnections between visual and text, as well as between performative actions and pictorial elements. Using the byzantine rites as an example of a performance carried out in the church of Asinou we demonstrate the possibility to define performative or textual elements as a carrier of meaning for the representations, linking it with religious rites and other type of situations which better define the context where the meaning of the visual heritage is assigned or re-defined.
The modelling example demonstrates how the meaning of the visual heritage, and its characterising elements, can be annotated, linked together and clustered with similar items which share the same denotative or symbolic meaning using formal ontologies.

1.3.3 Objective #3 - How do we spatialise semantic information in a three-dimensional representation?

The third objective is discussed in chapter 7 which explores methods to ground the semantic information produced using the results of objective #2 within a geometrical recomposition of the heritage object. A three-dimensional model is chosen as a medium of reference to spatialise the information for its capabilities to reproduce physical 3D measurements as well as texture, creating explorable spatial environment which closely reproduce the original object or scene. An annotation-based method is chosen for the spatialisation of information in the 3D model, and a harmonisation between the ontology presented in #objective 2 and a standard W3C annotation ontology is provided. The chapter further discusses the problem of interconnecting semantic with 3D information providing an information-based solution to link the target of the annotation in 3D space with entities and information stored in a graph. The solution comprises the definition of targets and the recording in the graph of the geometrical information about the defined annotated volumes, linking the representational and geometrical values.

1.3.4 Objective #4 - How do we assess the relationship between the digitised visual heritage and the original artefact?

The fourth and last objective, discussed in section 8, examines the assessment of the produced three-dimensional representations in respect to the original object. The question stems from the possible use of the combination of geometrical data and representation values as a scholar analytical tool.
It is clear that the validity of the outcome of the possible analysis performed using the combination of these information must be validated against their sources and processes. While there is an ample literature about the treatment of source data in humanities studies, it is necessary to define methods of assessment usable in the domains which concern themselves with the digitisation of heritage artefacts. The concept of knowledge provenance is used to explain possible verification pipelines. The section further provides a methodology for the meta-documentation of the digitised object, making clear the initial assessments, chosen methods, issues and solutions encountered. The result is a meta-level of documentation which clarify how

the digitised object relate to reality and, therefore, how our meaning assignment can relate not only to a specific digitisation but to the actual original object. The developed method is tested with the digitisation of part of the case study, the church of Panagia Phorbiotissa in Asinou, showing it in action. A formalisation of the method using CIDOC-CRM is provided demonstrating how, using spatial annotations, we can relate the original object to the assigned meaning throughout a pipeline that enable its verification and spatialisation.

1.4 The Context: ITN-DCH

This work has been developed within the ITN-DCH (Initial Training Network for Digital Cultural Heritage) project, a European Marie Curie project in the area of digital documentation and preservation of cultural heritage. The project aimed to analyse, design, research, develop and validate a framework comprising the whole life-cycle of the Digital Cultural Heritage research.

The project included contributions from a multi-disciplinary team that was involved in the different steps for the creation and examination of a digital heritage object. Data acquisition and processing, data modelling, semantics documentation of the material and immaterial aspects of the object, querying, visualisation, multimedia interface or mixed/augmented reality applications were some of the aspects analysed within ITN-DCH.

The ITN-DCH project identified three major research areas:

- Data Creation: the acquisition and processing throughout the use of photogrammetry or laser scanning techniques of a heritage object. This research direction aimed at the development of novel documentation methods such as the integration of multiple data sources for the creation of a final model, or the comparison, integration and development of processing pipeline able to exploit the strengths of the various softwares or algorithms in the market. Part of the research in this area was devoted to the comparison of the results between diverse acquisition methodologies and sources.
- Data Modelling: the documentation of the resulting digital data using semantic methods. This research direction focused on testing current semantic models such as CIDOC-CRM or others for the description of complex cases and information, exploring the possibility to annotate geometric and provenance information, as well as develop new techniques and structures for the modelling of specific type of objects.
- Visualisation: the exposure of the results of the acquisition and modelling phase. This research area focused on the use of computational techniques to visualise complex and large geometries using basic instruments such as the browser, or the visualisation of elaborate information within 3D structure, such as historical transformations. Research on the visualisation was made in respect to the information, the support, and the visual.

Several research centres, companies and universities across Europe were working towards the creation of novel contributions on the above subjects. Major partners were:

- Cyprus University of Technology (CUT) - Cyprus
- National Technical University of Athens (NTUA) - Greece
- MAP Laboratory at the Centre National de la Recherche Scientifique - France
- MiraLab at the University of Genève - Switzerland
- Fondazione Bruno Kessler - Italy
- University of Stuttgart - Germany
- University of Ljubljana - Slovenia
- Foundation for Research and Technology Hellas (FORTH) - Greece
- Fraunhofer IGD - Germany
- ArcTron 3D - Germany
- 7Reasons Medien Gmbh - Austria
- Katholieke Universiteit Leuven - Belgium
- Universidad de Murcia - Spain
- University of Warwick - United Kingdom

Each of the partners had diverse expertise on one or several aspects of the project and the collaboration between the institutions were insured by the presence of common objectives and tasks. The collaboration was particularly developed across four diverse case studies which were chosen to better develop the envisioned Digital Cultural Heritage workflow and comprises:

- The church of Panagia Phorbiotissa in Asinou. A small byzantine foundation in the mountain of Troodos in Cyprus. This church, built around 1105, has been fully decorated by diverse painting cycles and perfectly represents the diverse influences and phases of the byzantine tradition in the island. We are going to look at this church more in detail in the following sections.
- Ilmendorf, an early iron age burial discovered in 2010 in South Bavaria, Germany. The findings in the site encompass human remains, several large wood fragments as well as a series of grave goods that were the subject of an acquisition campaign. The latter consisted mainly of jewellery and beads made of gold, glass, amber, frit and bronze, averaging only a few centimetres in size. The artefacts are preserved and stored in the Archaeological State Collection in Munich, Germany.
- Carnuntum, a Roman legionary fortress in Lower Austria once the capital of the Pannonia Superior province. Important castrum along the frontier of the Roman Empire was founded in 6 CE and once housed 50,000 people. In respect to many other site, much of Carnuntuum town's structure remains intact, and it is still not yet fully excavated.
- The Castle Hill of Donaustauf ("Burgberg von Donaustauf") is a castle sitting on a hilltop, in the township of Donaustauf, 10 km east of Regensburg. The first documents

preserved that mention the castle date from the beginning of the 10^{th} century, although archaeological excavations have revealed the presence of previous Celtic settlements. The castle was destroyed in 1648 and since then remains in ruins.

The church of Panagia Phorbiotissa in Asinou was the one chosen by most institutes to develop their methodology, and this work follow the same path, focusing on one specific aspect, which is the description of the visual information. The church of Panagia Phorbiotissa in Asinou was chosen as the main case study of this work because it was the one which had the largest amount visual representations coming from different periods and presenting diverse influences. The work presented here have to be, therefore, understood as part of the bigger framework which has been developed by the whole ITN-DCH consortium, and part of its scope is fulfilled by the integration with the rest of the relevant work within the project.

1.5 Overview

The present work is organised as follows:

Chapter two provides a general overview of techniques and instruments for the digitisation of 3D objects, traditional knowledge organisation systems, knowledge representation and ontologies for the description of a cultural object. Three-dimensional annotation systems are presented and briefly discussed.

Chapter three introduces the problem related to the characterisation and classification of a representation. The chapter analyses the complexity of the figurative domain, clarifying how the same representational value can be derived from diverse types of digitisation processes and highlighting the current problem and issues present in respect to their aggregation and identification.

Chapter four presents the case study used across the thesis, the church of Panagia Phorbiotissa in Asinou. The church is described with respect to its history and the various painting cycles. Some important wall-paintings, which are going to be used as an example across the thesis, are introduced.

Chapter five delves deep into the theory of interpretation, providing an overview of the problem and defining a theory of reference. The classificatory elements identified in the theory are analysed and formalised in a logic-based structure.

Chapter six reuse the elements identified in chapter five in order to find commonalities and diversity in an iconographical representation using Saint George as the primary example. Further, the theory elaborated in chapter five is linked and relate to common art-historical model of interpretation.

Chapter seven provides a computational model of the elements of the theory using formal ontology. The new ontology is tested against several examples coming from the church of Asinou. Visual, performative and historical information are linked with each other in order to define the meaning of the visual item.

Chapter eight demonstrate the possible interconnection between the developed ontology and an annotation system, discussing possibilities and defining an annotation model integrating three-dimensional annotations and cultural object information. An overview of other practical uses of the ontology, including data harmonisation and semantic reasoning, is provided.

Chapter nine presents a methodology for the assessment of the constructed model and the link between digital parts, meaning and physical object, using provenance-based pipeline to track the link between digital and physical. A framework is proposed and formalised as ontology.

Annex A presents the classes and properties of the developed ontology introduced in chapter seven. The annex list and define classes and properties and provide an encoded version of the ontology in RDF, using the Turtle format representation.

Annex B introduce the process methodology for obtaining the models defined in chapter nine, listing and introducing all the identified elements.

Annex C presents, in the form of graph, the model that demonstrate the integration of the representation of the object, physical object, its constituents, annotation, and the resulting encoded knowledge.

2 Literature review

> “*What looks to you like a barber’s basin looks to me like Mambrino’s helmet and will look like something else to another person*”
>
> — Cervantes , *Don Quixote*

2.1 Introduction

The documentation of a cultural object includes the collection of information about it, comprising its history and its physical characteristics, as well as the interpretation and management of the recorded information.
The importance of such practice has been thoroughly recognised by the many international and national charters, treaties and recommendations that have been discussed and agreed on. The Athens Charter in 1933, the Venice Charter in 1964 (Erder 1986; Vecco 2010) and the Burra Charter in 1999 are surely the most important, but not the only ones. The "Convention for the Protection of the Cultural and Natural World Heritage" of 1972 command the establishment of a World Heritage Committee with the purpose to create an inventory of the heritage objects in each state. On the base of this text the Council of Europe have defined recommendations and programmes asking each of the parties who signed the document the establishment of inventories and documentation about their cultural objects (Erder 1986; Vecco 2010).
The reasons listed in these documents to engage in such type of documentary activity are manifold, but can be summarised in (i) the necessity to list the significant heritage objects, (ii) the creation of record useful to manage them, (iii) the assessment of their conservation status. The creation of a good documentation enables first and foremost a better understanding of a country's history, creating a stronger national sentiment which become associated with the tangible heritage of that country. The listing becomes, therefore, not only a pure conservation effort but an endeavour which encompass economic, political, historical, aesthetic and social values. The documentation enables, moreover, the management of a set of cultural objects, which can be finally tracked and preserved. Constant monitoring can be performed and interventions and treatments can be planned, measuring the results with similar sites both nationally and internationally.

The current research panorama in the domain Digital Cultural Heritage (DCH) reflect the outcome of these treaties and charters, which have pushed the research activities of the field towards the analysis of newer forms of documentation. The bifurcation of the needs towards the creation and management of the heritage documentation is one of the drive that have brought to the subdivision of the domain in two diverse halves concern with two aspects of the heritage object: creation and classification.
The creation phase encompasses all the steps necessary for the creation of a 2D/3D resource starting from the basic step (recording) to the manipulation of the resulting images through process pipelines which creates digital artefact.
The classification phase includes the creation of systems able to retrieve and organise information about the original physical object which has been digitised. We will look at these two processes in details in sections 2.2 and 2.3.

2.2 Creation

In the previous section we listed some of the most important international resolutions which have shaped the purpose and type of documentation applied to our heritage resource. One of them, the Venice Charter, is particularly important because it was the first one to demand "precise documentation". The charter in a small passage made clear the necessity to rely on a geometric documentation workflow able to precisely record the characteristics of the heritage object. With the term geometric documentation we refers to the recording of metric information describing shape, size and position of an object formalised as orthoimages, vector drawings or 3D models (Georgopoulos and Stathopoulou 2017). Geometric information has been traditionally recorded as section or vector plan to be used in situ by the heritage professional, however, the more recents development in 3D acquisition has lower the cost of this technique opening it up to new communities. In the recent years the 3D documentation for heritage object has become an important step to preserve and archive cultural objects (Remondino and El-Hakim 2006). The reasons are manifold and includes the capabilities to have an easy-to-inspect contactless geometric account of an object, the possibility to use the 3D object within multimedia products as well as manipulate it to derive 2D digital documents such as ortohotos or sections.
This section will present a very brief account of techniques for the creation of "precise documentation" which can be used to document a heritage object.

2.2.1 Active Sensors

Different methods can be used to compute the 3D coordinates of a cultural heritage object. The current reality-based 3D acquisition use primarily uses two techniques for recording information: active or passive sensors (Remondino and El-Hakim 2006). Active recording does not rely, as Passive recording does, to the light present in a scene, but controlled projection of light to derive surface-feature (Godin et al. 2002). Two basic active systems can be identified: Time-of-Flight and Triangulation.
Triangulation scanners functions by projecting a laser beam on the surface of the object and measuring the returning direction throughout a known observation point (a camera). Knowing the baseline and the orientation of the laser and the sensor we can define a triangle which is used to compute the 3D coordinates of the projected point in respect to the system (Godin et al. 2002; Blais 2004). Moving the laser spot across the object, we are able to record and calculate thousands of known points. A triangulation scanner can be used to project patterns instead of points. It is the case of the Structured Light 3D scanner, which function using pattern projection which deform when striking a surface, deriving the geometric information from the degree of deformation of the pattern. It is dependent on the object surface reflectivity and colour and on optimal calibration. Diverse patterns (e.g. time-coded and grey-coded) and filters (e.g. polarising) can be used modulate the acquisition in respect to the object. The results are optimal indoors because of the lack of direct sunlight (Godin et al. 2002; Remondino and El-Hakim 2006; Boehler et al. 2002).

Another very important active system is Time-of-Flight (ToF). ToF is the most popular and used active system for scanning heritage object (Yastikli 2007). Time-of-Flight scanners functions by measuring the delay between the emission and detection of a beam of light reflected by the object surface. Using the speed of light as a constant, it is possible to calculate the point position in the object (Godin et al. 2002). The beam of light can be a pulsed wave (PW) or a continuous wave (CW). The former techniques use short light pulses for computing the object coordinates, while the CW technique use a continuous light wave and calculate the object coordinates by observing the phase shift of a between the ongoing and returning wave (Georgopoulos and Stathopoulou 2017).

ToF laser scanners are able to records dense point representation of small and very large object. The range and flexibility of this sensor has enabled its use in airborne devices, using techniques such as LIDAR (Light Detection and Ranging) to create Digital Terrain Models as well as in other type of devices (e.g. cars, UAV, backpacks).

2.2.2 Passive sensors

Passive methods differ from active ones because they rely on the light present in a scene. No light is projected from the recording device, but the measurements use natural or artificial light reflected from the object (Godin et al. 2002).

Passive methods create 3D measurements using multiple views of the object, computing the coordinates only through the processing of the created images (Remondino and El-Hakim 2006). Using the interior parameters it is possible to apply triangulation technique to calculate the triangle which is formed by the baseline between the two cameras and the angle formed by the camera rays. (for further explanation about the technical aspect of the calculation see (Georgopoulos and Stathopoulou 2017)).

As mentioned above, photogrammetry requires processing to calculate the 3D coordinates of the recorded scene. The procedure, called Structure from Motion (SfM), use changes in the camera pose in 2D images to calculate the object' structure and producing a sparse point cloud and calculating the camera parameters. The use of Multi-view Stereo (MVS) algorithms enable the production of a densified version of the produced point cloud and further processes can project textures over it (Furukawa and Hernández 2015; Pierrot-Deseilligny and De Luca 2011).

2.2.3 Integration

The result of active and passive acquisitions can be merged together in order to overcome the limitations of active/passive technology and created a richer representation that better document the cultural object. The series of operations that combine and merge datasets originates from diverse sources are defined under the umbrella term data fusion (Ramos and Remondino 2015; Weckenmann et al. 2009). While often use for the creation of a more precise model, the integration of diverse data sources can be particularly useful to create multilayered representations which encompass dimensions useful to diverse heritage operators (Pamart et al.

2017). The integration and combinations of datasets continue to be analysed by the community (Karachaliou et al. 2019; Farella et al. 2019; Serna et al. 2015; Leach et al. 2018; Calantropio et al. 2019; Guidi et al. 2018) together with other techniques that can help integrate acquisition with further information that can help the recording of the measurements (Stathopoulou and Remondino 2019).

2.3 Classification

While the creation of the digital resource is surely an important step, it is not enough for the documentation of the heritage objects which requires, as highlighted in section 2.1, the establishment of inventories able to retrieve and connect information about cultural objects.
This noble aim, however, can be quite challenging because data in the cultural heritage community comes in many shape and size, due to their belonging to different disciplines and traditions which lead both to different forms for the data. Diverse data can be also the results of the use of diverse technologies or recording techniques which can produce incompatible datasets. Problems can also be caused by the use of legacy data system which cannot be changed, and therefore, constrain their user to a specific data regime. A large amount of data heterogeneity is the result of different data recording and retrieval traditions. This wide range of possibilities is a constitutional condition of the heritage domain and reflect its vastity and multidimensionality.
When considered together the output of the cultural heritage domain forms a latent pool of information with the capacity, when integrated, to support potential knowledge generation relative to any period, geographic location and aspect of human activity in the past.
The integration of information that can reveal so much about our past have to start from the inventories of heritage object, the ones that, institutionally or for research reasons, have been collecting and analysed our material past. Very different methods have been tested in the past, and only recent computing developments have been able to tackle the challenge at scale using semantics systems which formalise in logic terms the inventories' information. However, such systems are not yet widespread and still the object of research, and many more still use what we have defined as Traditional Knowledge Organization Systems (KOS) (Bruseker et al. 2017). We will take a brief look at some of these systems not only because they are still in use today, but also because they are still in use today, but because formal systems have to be thought as a continuation of KOS. Moreover, some of this systems are complementary to formal methods and can still be used together.

2.3.1 Traditional Knowledge Organization Systems

2.3.1.1 Controlled Vocabulary

A Controlled vocabulary is an "organized arrangement of words and phrases used to index content" (Baca et al. 2006). In its basic version, it is a simple flat terminological list which provides a set of controlled terms that can be used to specify something about an object, its subject for example. Controlled vocabularies can also be more structured, including equivalent terms (context-based synset) and, in case of two or more variants, a preferred term is chosen (e.g.: USE Salinity for saltiness) (National Information Standards Organization 2005). Authoritative controls over the vocabulary distinguish it from other forms of free listing of terms, like folksonomy. Vocabulary control is used to standardize naming and improve indexing, browsing, uniformity and retrieval of the data described (Vállez et al. 2015). The classical case of vocabulary control happens in libraries, where the bibliographic records are organized based on a process called authority control. In this instance, the form of the name of the authors is closely controlled in order to relate their work to a standardized version of their name. Changes in the form of an actor's name can happen for many reasons, commonly including artistic ends (Prince Rogers Nelson or Prince or Joey Coco or The Artist Formerly Known As Prince) and personal reasons (maiden or marriage name). In any every case, the use of a controlled vocabulary maintains a consistent means of referring to the same entity with the same name within the bibliographic catalogue, while also accounting for variants which should refer back to the standardized name form.

2.3.1.2 Taxonomy

A taxonomy is a "cognitive model of a particular kind [..] built into languages throughout the world" (Lakoff 2008). It is built up by classical non-overlapping categories defined by their features. Structurally, a taxonomy relies on a controlled vocabulary and on the use of subsumption relationships for ordering a diverse set of entities. It is usually used to relate an individual to a species, therefore creating a generic-individual type of relationship, or to express the membership of a subset within a superset as in a generic-generic relationship. In the former case, we express a type of predication, for example, when we assert that Socrates is a man, while in the generic-generic case we assert a subtype relationship, for example, when we declare that a penguin is a bird . They enable standardized classification terms. Taxonomies are used in very controlled information environments. A classical case of the application of taxonomy in the CH domain is related to the natural sciences community. Curators and researchers build and maintain taxonomies of species and particularly track the creation and variant naming of taxa. This evolving structure is related back to specimen evidence and allows curators and researchers to find and re-examine evidence and test conclusions. Taxonomic relationships are also used for constructing certain classification schemes intended to be used as large taxonomies which rely on a notation language to provide information about their status. An example is the Decimal Dewey Classification, which aims to catalogue the subject matter of any book into one of its categories, assuming that would fit the aboutness of the book in question. Taxonomies resemble ontologies in their strong ontological commitment. They are developed generally on a correspondence model between information structure and world, where the information produced aims to mirror objective reality. Two main differences, which we will explore below, are on the nature of the ontological commitment and the exploration of relations in the world over classification. Being highly structured and regular data, taxonomies are perfect structures for adaptation into information aggregation scenarios.

2.3.1.3 Thesauri

A thesaurus is a type of controlled vocabulary that relates its terms using taxonomic and semantic relationships, and it is defined as "a controlled vocabulary arranged in a known order and structured so that equivalence, homographic, hierarchical, and associative relationships among terms are displayed clearly and identified by standardized relationship indicators that are employed reciprocally" (National Information Standards Organization 2005). At a functional level it is used for enhancing the retrieval of information from a system (Moreira et al. 2004). Thesauri, too, begin to move towards an information structure that would resemble an ontology. Both subsumption relations (BT/NT)[1] and horizontal relations (RT/UF)[2] can be expressed in thesauri, but they remain an exploration of terminology rather than clearly formalized conceptual entities, moreover there is not a strong focus on the definition of the functions that relate terms, underlining the lack of ontological commitment which would make this type of information structure subject to a number of pitfalls described below.

Thesauri can be developed to deal with the naming of a broader or narrower range of subjects and applied to control data consistency and retrieval. Examples in the domain of cultural heritage might be the targeted thesauri developed by the British Museum organizing terms for describing object names or material. Examples of broader scale initiatives would be the Getty thesauri: Art and Architecture Thesaurus, the Getty Thesaurus of Geographic Names, the Cultural Objects Name Authority and the Union List of Artist Names.[3] These thesauri, having a wider range, apply techniques of faceting. A recent European wide example is the work of DARIAH in developing local and backbone thesauri, which attempt to provide both very specialization-oriented thesauri linking to a broader back bone of terms. Within the scope of developing common terms for reference to sub-classes of objects to particular specialists, and providing homogeneously generated data for further analysis, thesauri execute an important role in the production of standardized data for reuse within aggregation structures.

2.3.1.4 Metadata and data schemas

With the advent of the relational database, and the ability to rapidly create bespoke data structures for data organization, standardized metadata and data schemas have been designed as a means to suggest appropriate models for capturing information in particular domains of interest. The schemas are the result of an interpretation of a domain resulting in an intentional model which delimits the finite set of descriptions that can be assigned within a specific setting (Falkenberg et al. 1998). A schema therefore formalizes, often implicitly, a view of a domain which can have different levels of complexity in relation to the granularity of the initial

[1] Broader Term/Narrower Term
[2] Related Term/Use For
[3] http://www.getty.edu/research/tools/vocabularies/

investigation and its function in the actual world. The complexity to use a schema, their specific nature, and the usually under-analyzed relation between the data structure and the objective world it describes, strongly limits the possibility of their use in large-scale data integration. The complete replication of such complex schemas from one environment to another is rarely a viable solution even if the purpose of two information systems is the same, given the variable needs and traditions of local contexts. For this reason, another solution suggested in order to capture at least a core of the generic conceptualization of a field and thereby enhance the interoperability between different systems is the metadata schema.

Metadata schema are intended to increase, "the ability of multiple systems with different hardware and software platforms, data structures, and interfaces to exchange data with minimal loss of content and functionality" (National Information Standards Organization 2004). A metadata schema consists in a flat formalized set of elements, usually in the form of structured textual information, which standardizes the description of the core elements used to documenting a specific type of information resource (text, video etc.) or one of its aspects (administration, preservation). Sometimes there are cases where one aspect of a metadata set is considered so important that it is given a unique name, like in the case of paradata. It is important to underline, however, that in these cases, we continue to talk about metadata, under a new name. In the case of paradata the functional aspect of the metadata for tracking provenance of data is emphasized. Using a standard metadata schema allows for the partial preservation of an aspect of the richness of different data schema between diverse databases, thus enabling federated query functionality over this reduced set. It is important to underline that both the data and the metadata schemas do not have a formal commitment to the explicit representation of their scope. Well-known examples of metadata schemas include Dublin Core (Baker 2000) and METS (Cundiff 2004). These schemas serve a functional role within specific contexts for the purpose of providing a structure composed of multiple descriptors that allow the documentation and the retrieval of an item. Applied at this level, in conjunction with other Knowledge Information Systems like classification schemas, taxonomies or thesauri, metadata schemas reduce the overall level of heterogeneity within the information space by providing access points towards a small set of standardized information of an object, and allowing an initial analysis of the information coming from systems deploying schema using different conceptualizations.

2.3.1.5 Limitations

What can be said to be common among the traditional approaches is the creation of pre-established information frame that specifies possible documentation of the object and try to provide a unique description limiting the semantic expressivity of the information we can document. The use of a standardized knowledge frame to align data together it is not a solution, because it forces perspectives over the information, making them ultimately unusable.

The problem is quite easy to see and indeed very practical. Classical hierarchical classification systems such as classificatory schemas, taxonomies and thesauri are inappropriate to the task of large scale data integration due to the constraints imposed by language itself and the intellectual architecture by which they are expressed. Such systems are stymied in the task of integration by basic linguistic problems, especially the issues of homonymy and polysemy. In the former the words are pronounced alike but they have different meanings, while in the latter they are systematically related. Examples of both are given by Lakoff (2008). He offers for homonym the example of the word “bank”, which refers both to the institution and the edge of a river, while he shows the problem of polysemy by reference to the case of ‘warm’, which stands for the temperature and also the type of clothing that allow you to keep such temperature. The inability to differentiate the meanings of the word causes the classical retrieval/description problem, in which producer and users cannot communicate or research the same content because no relation to the entity that the term is supposed to represent is established. The effectiveness of such systems can be enhanced by the use of hierarchical structure, which would define the words within a particular category, or by the use of textual qualifiers that define its role within the system. The qualifiers could help resolve the issue, but only during the manual browsing of the information structure (Svenonius 2000). In reference to the hierarchical solution, it could help disambiguate some basic terms, but the problem would not be resolved with the vaguer ones. It would be quite challenging for example to force the term “beauty” within a specific category. Moreover, a hierarchical structure is always the product of a context, and therefore the choice of what is to be categorized, the recognition of a gestalt as well as the salience of the word used for constructing the information structure are always context-dependent and they always rely on some modeling-choice, which are usually not clearly stated.

Furthermore, the classical hierarchical categorization systems lack the means to distinguish different types of fundamental relations. The problem arises from treating classes as if they act in the same ways as sets, therefore conceiving a subclass as a subset, which, per se, implies a subsumptive relationship. Guarino and Welty (Guarino and Welty 2002) illustrate this problem using the example of the relationships between an engine and a car, where the former is sometimes described as subclass of the latter, even if, even with a quick overview, we can easily recognize that they share different properties and their relationships should be described using mereology.

It is easy to see how due to the polysemy of language and the seeming impossibility of formal correspondence between the world, or the state of affairs described, and the schema used, such methods are not appropriate to the task of wide scale data integration. It is, however, important to underline that all of these tools are still enormously useful for indexing data at a local level, playing a pivotal role for the production of structure data.

In order to overcome the limitation of traditional KOS, it is necessary to rely on solutions which allow for the expression of the domain conceptualizations, divorced from its linguistic features, discarding, moreover, the notion of a final classificatory system and, rather the attempt to deploy the new more flexible understanding of categories developed in the past years. Finally, this work on reimagining categorization would have to be expressed in a formal language separated from particular linguistic expression or closed domain expressions. It is to the question of how to achieve this that we turn in the next section.

2.3.2 Knowledge Representation Systems

2.3.2.1 Knowledge Representation

The tradition of formalising propositions in a natural language independent formalism, with the aim of providing a neutral means of presenting conceptualisations and allowing reasoning and description in a specific domain is the typical work of logic and mathematics. During the second half of the 20th century, and mostly from the 70's (Hoekstra 2009) computer science, and in particular the sub-field of AI, begins to adopt these tools in order to try to develop systems able to exploit the definition of formal propositions with the aim of building rich knowledge bases.

The field has come to be known as knowledge representation, which has been defined as "*the application of logic and ontology to the task of constructing computable models for some domain*" (Sowa 2000). The definition of the ontology, and therefore the specifications of our model, is the job of the knowledge engineer (Brachman and Levesque 2004)

The method proposed for building such structures is the generation of a formalisation of a conceptual domain. Concretely this means attempting to engage with and describe the fundamental principles, objects and relations appealed to and invoked by a group of users within a wide domain context (Smith 2006). It involves an interdisciplinary dialogue between domain specialists, computer scientists and knowledge engineers (Sure et al. 2009). This forms a fundamental task of understanding and conceptual design wherein the scope of a domain is investigated as to its meaning and with regards to its typical contents and arguments. The method aims to describe the so-called 'ontological commitment' of the user community. As Guarino (1998) puts it, the product of this effort is a formal ontology which is,

> "logical theory accounting for the intended meaning of a formal vocabulary, i.e. its ontological commitment to a particular conceptualization of the world. The intended models of a logical language using such a vocabulary are constrained by its ontological commitment. An ontology indirectly reflects this commitment (and the underlying conceptualization) by approximating these intended models."

By its very manner of construction, a formal ontology attempts to avoid the traps for data integration associated with classical categorisation efforts. It does not attempt to provide a universal, one-to-one objective correspondence of its categories, nor present itself as a data surrogate for the world described. The purpose of a formal ontology is functional (Zúñiga 2001). It specifically focuses on finding and describing the particular view of the community of users it aims to help structure data for, and to model this explicitly. It does not present a neutral view, but by making its commitments explicit, it neutralises the ambiguity and overreach problems reviewed above. The goal is not a perfect representation of knowledge, but one adequate to the aims of the domain users and consistent with reality. It is important to highlight that this kind of approach would differentiate between the ontology, the conceptualisation that it is committed to, the language used for its implementation and the objective world that it refers to. The method deliberately eschews an interest in any particular implementation either with regards to individual projects and even with regards to particular types of encoding (Davis et al. 1993). The work in creating a formalisation is an entirely conceptual work undertaken by knowledge engineers in close collaboration with the user community.

The technical means that enable the work of knowledge engineers to develop tractable formalisations from such a process are the expression of domain knowledge in terms of well-defined classes and properties ordered in an isA hierarchy, that will be used as the backbone of a formal ontology. A formal ontology has as its substance a declaration of its scope and a series of classes and relations that result from the generalisation work done in the dialogue/research described above.

The scope of the formal ontology describes the domain which is to be taken into account for the construction of the ontological model. It must be explicitly declared in order to limit the intended domain of application of the overall formalisation.

A class is "*a category of items that share one or more common traits serving as criteria to identify the items belonging to the class*" (Bekiari et al. 2015), and serves as a documentation unit that is described by a scope note, which textually indicates the intension of that class. The intension of a class is a description of the essence of that category such that a human being can read the description and identify instances of it. The clarity of such descriptions is paramount for the effectiveness of an ontology (Guarino and Welty 2000). Properties or relations are generalisations of kinds of relationships that can exist between classes. Their formalisation results from research into how users actually do reason over and relate objects in the domain. The discovery of properties is crucial, and even prior in importance to the declaration of classes, as they form the basis for the latter's declaration. It is moreover important for each of them to be given an intensional definition to ensure their proper application. Properties are additionally restricted according to a domain and range of classes (Doerr et al. 2007). That is to say each relation's domain and range scope, that of which it can be said sensibly, is explicitly specified in the formalisation, thereby delimiting the types of acceptable propositions that can be made through data encoded in this structure. The specification of these relations is the basis of the possibility of reasoning over the data at later stages.

The central tool for gaining expressive power, however, within the ontology is the application of an IsA hierarchy over the classes and relations. Formal ontologies make use of a function of

inheritance provided by the IsA relation in order to be able to order classes from more general to more specific, attributing and restricting along the way the relations that can be used to describe entities at a more general level and those which, when added, create a new functional unity for the class and determine a new level in the IsA hierarchy.
This method of constructing the classes, which can be encoded and reasoned upon, delivers a number of advantages in providing integrative data structures. It allows describing relations that pertain to a broad number of classes at a very generic level just once, and to use these generic relations to model specialising subclasses and relations of any depth.

Having built up an ontology as a conceptual tool it must be encoded in a formal language. Due to possible ambiguity in understanding, it is important to specify that the formalisation of an ontology in a particular language results in an information artefact that is a representation of the initial ontology, but is distinct from the latter. Representing the ontology in some formal language necessarily imposes constraints on modelling practice and inexorably alters the initial statements in order to fit them to the grammar of the chosen language.
That being said, it is through this trade-off with pragmatics that functional automated reasoning through ontologies can be achieved. It is therefore of use to telescopically present some common methods for formalising knowledge. While during the past 40 years several languages have been proposed and studied (KIF, KIR, KL-ONE among others) with the aim to meet this end with the knowledge representation (KR) community (Hoekstra 2009), it only is during the last fifteen years that, thanks to the practical needs brought forward by the semantic web community, a language of this type reaches a wider and more general public, more specifically with the development of RDF. Below we are going to give a concise account of a select subset of languages used to describe web resources.
RDF is the acronym of “Resource Description Framework”, a data model for representing statements about resources in the semantic web. The assertions encoded in RDF take the form of subject, predicate, object <s,p,o>, where the predicate is a relation between the subject and the object, where both resources are available on the web. Such assertions are called triples. A collection of linked triples constitutes a graph, with the subject and the object of the assertions acting as nodes and properties as edges.
In order to keep a stable identity for the assertions created, each object is identified with a stable Web identifier, a Unicode string called an IRI (Internationalized Resource Identifier); URL (Uniform Resource Locator) and URN (Uniform Resource Name) are particular types of IRI. The use of an identifier with a global scope is quite important because it helps in resolving the identity problem in the harmonisation of different data sources. RDF also provides machine processable XML-based syntaxes (RDF/XML, Turtle, N-Triples) for recording and exchanging the propositions (Allemang and Hendler 2011; Manola et al. 2004).
It is important to underline that RDF itself does not define the meaning of a resource; for this task, we should employ an ontology, which can be encoded with RDF syntax using the RDFS (RDF Schema) vocabulary. Even if the vocabulary employed in RDFS is quite small, it allows the

definition of classes and basic taxonomical relationships. Moreover, it provides the possibility to define property and subproperties, as well as specify their domain and range, providing therefore a basic tool for the encoding of an ontology (Hyvönen et al. 2009).
The syntax and semantics of RDFS, as well as its meta-architecture, were in some cases not considered rich enough, and therefore other proposals for the construction of a KR language for the web have been made. The most successful attempt has been OWL (Ontology Web Language), a product of the Web Ontology Working Group of W3C, built upon RDF and RDFS. OWL is a richer language, and it allows to define features like the local scope of properties, cardinality restrictions, disjointness of classes and special properties (e.g. Transitive, Symmetric and others). It has three main varieties, OWL Full, OWL DL, and OWL Lite. Some of the main distinctions are the compatibility with RDFS, the restriction in the language and the efficiency in computation. Only OWL Full is fully backward compatible with RDFS (Allemang and Hendler 2011; Uschold 2018) but it is also the less efficient with respect to computational reasoning.
This excursus into some well-known encoding languages for formal ontology aims to underline that given the restrictions entailed by these languages, they should be chosen carefully, with the final application in mind. The use of OWL instead of RDFS, for example, could restrict the expressiveness of our statements in exchange for making them more computable. Even the simple use of an XML-based language forces everything into a nested data structure.
It is also salient to highlight that the use of a particular language for expressing a data model does not automatically make the outcome an ontology. Having an OWL encoded file does not entail that it or the data therein is an expression of an ontology. It can, for example, simply mean that one has a taxonomy which is encoded in that specific language. Ontologies cannot be identified by a certain encoding, but rather, by whether or not they aim to explicitly represent an ontological commitment in some domain.

Ontology and Knowledge Representation seems to be the perfect grounding for recording multi-actor perspectives with respect to cultural information. The main advantages are both theoretical and practical.
From a theoretical standpoint, a good initial modelling would sustain and classify the diverse propositions over the conceptual and physical world, classifying statements in respect to their validity in the personal, social or physical domain. The interpretative nature of the visual can be easily translated as statements which are valid only within the person's reasoning, or only within a social context, without classifying them as imperative physical evidence of a process.
Moreover, the development of a flexible-enough ontological model would not enforce one specific schemata, but maintain the different levels of information which are naturally present when making *a posteriori* statements.
On the other hand, the logic grounding is essential to the practical task at hand: the real integration of multi-actor information. A logic-based language, in fact, has the advantage that while constraining the form of the language, it forces its users to respect specific rules which,

pre-defined by the knowledge engineer, validate and classify the recorded statements. The possibility of information integration is given precisely by this grounding, which supports the possibility to harmonise data without a semantic loss.

2.3.2.2 CIDOC-CRM

Ontologies and Knowledge Representation methods have been applied to a wide range of domains. While it is essential to re-use existing structures, the capacity to adapt a formal ontology from one domain to another is dependent on the specific requirements of the use cases of that domain. In the field of cultural heritage, while there are a number of widely known upper ontologies that can be brought to bear, the one which has the widest and official acceptance is CIDOC CRM. At present, a great deal of research and implementation is happening around the CRM ontology extending it conceptually, applying it in new scenarios and developing large-scale implementations (Bruseker et al. 2017).

The design strategy of the CIDOC CRM was explicitly set as empirical in two basic senses. On the one hand, modelling is done only on the basis of existing information structures and their explanation by expert domain users. Information modelling always proceeds from practical examples and real use cases. Information structures are not built based on a priori theories whose concepts should be linked to the data structures to be modelled, but rather concepts are only derived from the input data structures. If there is no use case, then there is no basis for including a concept within the model, because there is no means against which to check the validity of the representation proposed. On the other hand, some specific design principles need to be followed.

The first design principle is symmetry (Doerr and Crofts 1998). The classes are modelled as neutral to a specific point of view within the domain, in order to prevent the description of identical facts as different ones only on the base on the perspective of the documenting actor. The prototypical example is that of E8 Acquisition Event, where the scope note clarifies that every transfer of legal ownership, comprising beginning or end of ownership, can be documented as an acquisition event. In this case, the class itself it is constructed in order to avoid modelling the transaction from the perspective of one party or another (acquisition or deaccession), using instead the properties for disambiguating between who surrenders and who acquires the legal ownership of a physical object.

This kind of approach helps establish an ambiguity-free model, and moreover helps to introduce a second design principle of CRM, the context-free interpretation (Doerr 2003). The principle is to allow a clear interpretation of individual recorded propositions without any other type of contextual data. Thus, for example, saying that 'John hasRole Buyer' does not really say anything about the action, and a context is required to understand the proposition. On the contrary, if we encode that 'John hasParticipedIn Activity' and link the buyer role to the form of participation it has a stronger information value, allowing greater integration of different information sources relative to the buying of what, from who, when' and others. The assertions we represent with CRM are therefore structured purposefully to achieve this context-free status.

These principles made CIDOC CRM consistent, a quality which is further ensured by its curation by the SIG. The Special Interest Group helps the decision-making process, keeping the modelling consistent and proposing revisions and additions, in order to keep the CRM useful for all of its users and avoid running after new construct for the sole functional purpose. Thanks to this type of work the ontology become an ISO standard for the cultural heritage domain.

Another significant advantage of CIDOC CRM is the possibility to expand it with extensions or to use different modules, which have been already developed, such as CRMGeo for the description of spatial information and FRBRoo for the documentation of bibliographic information (Bruseker et al. 2017).

The foundation within the heritage practice together with the advantages of having an ISO standardisation seems to provide us with the perfect platform for developing an ontological extension which takes into account the constraints we need to assume when we computationally classify and make assertions about cultural objects.

2.3.2.3 Other ontologies for the description of heritage artefacts

CIDOC-CRM it is not the only ontology or schema which can be used to encode formal statements about cultural heritage. There are several resources which, even if not as complete as CIDOC-CRM, are surely worth mentioning.

The Europeana Data Model (EDM), the ontology that drives Europeana, a data portal that aggregates content from diverse museums and other memory institutions across Europe. EDM keeps a strict division between object, digital representation (edm:isShownBy) and metadata, linking object information to its representation and giving much attention to the provenance of the data (as it would be expected by an aggregator). The role of the institution shape the ontology and it strongly focus on linking item aggregation to original provider (Isaac and Haslhofer 2013; Peroni et al. 2012).

ArCO is a newly specified upper ontology for the description of cultural objects, sites, and events. It has been developed together with the Italian Ministry of Cultural Heritage and Activities and Tourism under the umbrella of the ArCo project, an Italian Cultural Heritage knowledge graph comprising 169 million triples about 820 thousand cultural entities. The ArCO ontology is modular and consists of a shared core and five additional modules (catalogue, location, denotative description, context description, cultural events). (Carriero et al. 2019)

DOLCE (Gangemi et al. 2002) is another important upper level ontology used across several domains. DOLCE is based on the distinction between endurant and perdurant and provide classes and properties for talking about physical and not-physical object (e.g. social and mental object). CIDOC-CRM and DOLCE are not the only upper level ontologies which can be used in the heritage domain, many more do exist and are flexible enough to be used for a basic description of cultural objects (Mascardi et al. 2007), however, very few institutions decided to rely on them and the community is more and more oriented towards the use of CIDOC-CRM or, in alternative, a simple domain-specific ontology.

An example of an easier formalised schema, but still quite complete for basic documentation scenarios, is the Light Information Describing Objects (LIDO) standard, LIDO is a product of the ICOM-CIDOC Data Harvesting and Interchange Working Group and it is a CIDOC-CRM compatible XML schema that it is used to encode basic metadata about an object. LIDO is a set of fourteen elements which encode five types of information: (i) Object Classification, (ii) Object Identifications (iii) Events, (iv) Relations and (v) Administrative metadata. LIDO has been developed to enhance and redesign Categories for the Description of Works of Art Lite (CDWA-Lite) and museumdat (Stein and Coburn 2008) as well as follow the recommendation of the Standard Procedures for Collections Recording Used in Museum (SPECTRUM).
Dublin Core (DC) Metadata Element Set is a formal schema widely used by the community for general metadata purposes. It provides 15 standardized elements (e.g. creator, publisher, format) for basic resource description with additional element refinements (Baker 2000). Dublin core is used for large number of application profiles and as a base for other cultural metadata schemas. The Visual Resource Association's (VRA) schema, for example, redefined their elements as subproperties of corresponding DC elements (Hyvönen 2009).

2.3.2.4 Ontologies for the description of digital resources

An important type of domain ontologies we should examine in more detail, are the ones which deal specifically with the digital domain and can be used to describe 2D and 3D resources. Two suitable ontologies were identified: CARARE and CRMdig.

CARARE started as a three-year European project that focused on the aggregation of content from the archaeological and architectural domains. The project, initially established a service aggregator for the delivery of 3D resources to Europeana, developed a new metadata schema to describe the 3D content. The aim of the schema was to ensure interoperability between content producers and Europeana. CARARE is based on various standards, like MIDAS, LIDO and CIDOC-CRM, and it reuse several elements of the Europeana EDM ontology. CARARE was further developed, reaching version 2.0, within the 3D ICONS project, where it was used to link together different media and representations of a cultural object as well as the activities that produced them (Hansen and Fernie 2010).
The schema is based on the distinction and description of four information categories: "Heritage assets", "Digital resource", "Collection information" and "Activities". The category "Heritage asset" is devoted to the description of physical cultural heritage objects. The category "Digital resource" provides information about type, format and location of a digital file. The category "Collection information" details the information of the content producer. The "Activities" category describes diverse types of events which had as a subject the documented heritage object, comprising alterations or excavations. The "Activity" facet can also be used to describe any type of historical events related to the object. CARARE 2.0 extended this schema to include characterisation of activities (eventType), the methods used to perform them (Methods) and the technique used (Technique) (D'Andrea and Fernie 2013). While the two fields are fairly

useful, they are not enough to record the complexity of the digitisation process, specifically when talking about photogrammetric data.

CRMdig is a model extending CIDOC-CRM for the description of data generated by digitization processes. Originally developed in the EU funded project 3D-COFORM, the model has been successfully deployed in the Greek national project 3D-SYSTEK, in an NSF-funded project for RTI tools led by Cultural Heritage Imaging, San Francisco, in the ARIADNE project for scientific data in archaeology and in InGeoClouds for geological observational data. It is founded on the processes proposed by the Open Archival Information System (OAIS), customised and improved for covering the workflow for the 3D model construction. CRMdig provides class and properties to trace the various steps and procedures which result in the digitisation process of an heritage object. CRMdig includes properties that can be used to specify the parameters used at each step, treating the digitisation as part of the history of the objects itself. These facts lead to a modelling of this process which is uniquely concerned with the provenance, from the moment of transition between the physical and digital world to the many transformations that occur to digital objects once stored in some digital environment (Pitzalis et al. 2010).
Digital objects are modelled with a new class D1 Digital Object defined as a subtype of the CRM class E73 Information Object, pointing to its substance as encoded information whose identity is in the information held and its particular encoding, not the particular carrier (e.g. a file). Likewise, a distinct class is proposed for documenting the particular carrier(s) on which digital objects are stored, D13 Digital Information Carrier. The strong innovation of the model, however, is in representing the relevant events which lead to the creation of such objects. Events leading to the creation and modification of instances of D1 Digital Object are modelled under a D7 Digital Machine Event class which is purposively modelled as either the result of a human action. This is to underline that deciding factors in the digitisation process are given by human actors, who are the responsible agents for such process. It is important to underline that this approach contrast with the one held by other important provenance ontologies, such as the W3C PROV-O (Missier et al. 2013), which do presents classes and properties to annotate computational process that do take place without any human interactions or responsibility.

2.4 Annotation System

A key objective of this study to formalise a relationship between the digital object and its conceptualisation. As we are going to describe in greater length in section Visual Annotation, we are going to achieve such objective using an annotation-based approach. Annotations are not a novelty and have been a tool used by scholars and intellectuals for many years and are a fundamental scholarly practice common across disciplines (Unsworth 2000; Bradley and Vetch 2007). In a digital context annotations can facilitate research, enabling richer knowledge exchange in a collaborative setting (Simon et al. 2017).

Many digital annotation tools have been developed during the latest years, as commenting tools, wiki-bases systems, digital libraries tools or textual analytical systems (Hinze et al. 2019). While a large part of the development of annotation tools have been committed to reproduce the easiness of text marginalia in a digital setting, there were also attempts to create digital annotations framework for three-dimensional objects.
However, the term annotation in the 3D realm is a fuzzy one, and it can describe two different activities: (i) semantic segmentation and (ii) user-driven annotation.
Semantic segmentation is the process of dividing the 3D model into structural parts using automatic or semi-automatic algorithms that provide shape characterisation. The result is a partitioning of the 3D model into segmented parts.
The user-driven annotations are the product of the selection by a user of a portion of a representation and the (optional) interconnection with a related subject matter.
In this section, and in general in this work, we will only consider as annotation the one generated by users.

Already in 1999 Jung at al. (1999) developed a 3D annotation tool for reviewing architectural models. The tool used VRML (Virtual Reality Modeling Language) scene description language which served to specify object behaviours and provide geometrical rendering. It was automated and available online thanks to Perl script and Java applets. In the implementation it was possible to interact with the scene, changing design elements and colours, as well as create annotations as numbered coloured spheres. The spheres were linked to textual annotations together with the identity of their authors and loaded separately as a layer on top of the scene (Jung et al. 2002).

Several years later, in 2005, Bilasco et al. (2005) developed 3DSEAM (3D SEmantics Annotation Model) for indexing 3D data with respect to their semantic aspects. The article poses the problem of semantic retrieval, lamenting that signal-based retrieval systems are not enough for a successful use and reuse of 3D content. The article proceeds to details the process of creation of a 3D scene using X3D and continue analysing the use of XPATH for the selection of an object in the scene. XPATH enable the creation of an information path able to point or retrieve the data from an X3D model. The same process can be used to link to the object in X3D. This work extended MPEG-7, a multimedia object standard, with specific descriptors for geometric, visual and semantic features which are linked with the corresponding X3D elements.

A similar approach was used by Pittarello and De Faveri [[-Pittarello and De Faveri, 2006, #43853]], which however used semantic web standards to link directly with the X3D encoded information. The authors produce a series of ontologies which connected to “X3D primitives”, geometrical objects defined in the X3D. The approach associates basic metadata to specific geometrical references and uses ontologies to organise their relationships. The ontology is linked within the X3D header and used to make sense of the attributes, encoded in the form of common names (door, wall, knob), which are embedded within the X3D file. The approach the association of vocabulary elements expressed in RDF to geometric elements defined in the model.

In the same year, a very different approach to the problem of 3D annotation was taken by Kadobayashi et al. (2006) when they proposed a prototype for a collaborative 3D environments where multiple authors, from diverse viewpoints, would be able to annotate 3D objects. Such contribution, even with a very limited scope, raised another challenge in the field: how to create a collaboratory annotation environment. In order to achieve that, the authors produced a prototype using Croquet, a collaborative peer-to-peer network architecture for the development of virtual world applications. Croquet allow the creation of virtual spaces that can be linked together using views called portals. The prototype follows the Croquet's logic of the portals, to create physical and conceptual annotations, where the physical one are perspective of the objects that is present in the world while the conceptual ones are annotation paths which say something about the object in respect of one topic. The idea is to have overlapping annotations which would together reveal diverse truths about a digital object.

Maass and Döllner (2006) developed a technique for the dynamic display of annotation in 3D scenes. In respect to other techniques, the approach of the authors treat annotation as 3D dynamic scene elements which are not encoded with the main 3D scene, but loaded as external elements. The annotations are represented as billboards and they are automatically positioned according to the shape of the object and the camera, in order to always be present in the scene. The approach was quite innovative, but it had the peculiarities that the full elements would always be covered by the annotations, therefore, cluttering the scene.

Collaborative annotation environments were also examined, in the biochemical domain, by Hunter et al. (2007). The authors developed the AnnoCryst system which enabled collaborators to discuss and annotate with textual or media file 3D crystallographic models retrieved in a local repository or in a public database. The AnnoCryst system allow groups of colleagues to remotely access the system and use the 3D object as anchors for the debate. Moreover, the system would enable the inclusion or exclusion of a person from viewing the model and the discussion, ensuing license protection in respect of the used data. The system used Annotea, an initial attempt of an annotation model by the W3C, and other ontologies for the encoding of the annotations. The 3D viewer used was J-mol, a free open-source Java molecule viewer for 3D chemical structures. Using a plugin for internet explorer it was possible to load a sidebar next to the 3D viewer where to create or search for an annotation.

Goldfeder and Allen (2008) analysed the annotations problem from a diverse perspective, asking if we can propagate information based on similarity. The objective is to overcome the lack of descriptors in large databases of 3D structures automatising the annotation process. The proposed solution relies on an initial corpus of tagged 3D models (Google 3DWarehouse) to compute similarities with newer ones, automatically assigning them the tag of the 3D model they are similar to. It is important to underline that the annotation the paper talk about are not spatial, but simple descriptors or tags assigned to a model. However, the paper deserves to be listed here for the interesting problem that it poses, a problem which it is not yet given an answer to.

In the late 2000 the discussion between folksonomy vs formal structure was still ongoing as it is possible to see in the work of Moccozet (2008), where he explores the possibility to use folksonomy to retrieve 3D object parts. In this article, the author presents a prototype able to spatialise user created tags to 3D structure. In the same years the work of Attene et al. (2009) was exemplary in using formal structures to characterise pre-selected shape within a 3D model. Their tool, ShapeAnnotator automatically define object segment to be further annotated by a user using concept expressed in an ontology.

In 2009, the work of Havemann et al. (2009) presented an original and useful attempt to deal with the 3D annotation problem. The authors used TEI/XML (Text Encoding Initiative) to encode CIDOC-CRM statements about the object and linked these with a chosen region of interest in the 3D model. To achieve such result they used Collada, a 3D file format encoded in XML, and developed an authoring tool that enable a user of the system to create a "markup area", in the form of a three-dimensional sphere within the model. The newly create sphere, itself a Collada file, act as an anchor in the scene recording a link to the TEI information encoded by the user. In this instance, the annotation is spatialised, however, not without limitations. No dimensional information is recorded and the semantics is, unfortunately, quite loose. However, the method can help the retrieval of information, on the base of the annotation, in a large database of 3D objects.

Another important work to cite is the one of Rodriguez-Echavarria et al (2009) which present a semantic annotation pipeline which includes 3D data, a metadata server and a software, Tagg3D, which support the integration of semantic information coming from the metadata server in a 3D representation, encoded using Collada. As seen before, also in this instance the tags assigned using Tagg3D are stored in the 3D file itself, instead of being stored separately as linked resources.

Reusing the approach developed in Hunter et al. (2007) Hunter and Gerber (2010) designed another semantic Web annotation tool using Annotea as a data model, but this time oriented towards the heritage community. The system presented in this paper allow for linking to X3D objects using an Internet Explorer and Firefox plugin which connect the user to a MySQL database. The system enables the user to create annotations and assign keywords, using a refined version of the Art and Architecture Thesaurus (AAT), to a 3D object. No dimensional information is stored in the database, but only comments and keywords.

The Empire 3D project (Abbott et al. 2011) examined the creation and navigation of annotation in a large 3D scene. The paper describes the development of a web system to visualise the 3D reconstruction of the 1938 British Empire Exhibition in Glasgow, UK. The web system has been designed in order to navigate the reconstruction of the British Empire Exhibition and consult the original architectural plans as well as the original photos and drawings. These recorded research data were modelled using CIDOC-CRM and linked with the visualisation. The interface enabled the user to navigate the 3D scene and browse through spatial annotation information and resources related to each of the reconstructed buildings. In order to not clutter the scene, the annotations were shown as a floating pane or clickable point in the 3D scene. The graphical layer, comprising the annotation, is linked with an SQL database in the back-end.

An important work in the field of 3D annotation is the one carried out within the 3DCOFORM project. where a new software and data model for the annotation of 3D objects has been created (Serna et al. 2011). Within the project, an Integrated Viewer/Browser (IVR) for searching, querying, browsing, viewing, segmenting and annotating multimedia objects has been developed. The IVR enables the users of the system, provided as a computer application, to select segments of 3D objects and link them with annotations. The selection of a segment of a 3D object is not precise but use geometric shapes such as spheres or rectangles to define the selected area (Serna et al. 2012). The information about the 3D object, the metadata about it, the segment and the annotation are stored in an RDF triple store, encoded in CIDOC-CRM. The annotation model developed within this project, CRMdig, it is still actively used and it was presented in section 2.3.2.4.

Another project that reuse open models and resources is the one of David Yu and Jane Hunter (2014), which extended the Open Annotation Model in order to link it to X3D objects. The paper describes a new approach to the development of a web-based system for the annotation of 3D objects. The system, 3DSA, was composed by a object repository linked with a web portal, and an annotation client which enable the user to create annotation linked with a particular spatial area of the object. The annotations were encoded and stored in an RDF triple store (Sesame). Each annotation object created in the system was linked with the spatial information encoded in the X3D, storing the dimensional values and spatial position in the triple store.

An important web platform for the analysis and documentation of heritage objects is Nubes (Stefani et al. 2014). The platform, specifically targeted to architectural object, is a complete 3D information system designed to relate and visualise heterogeneous information. The platform store models and information in a MySQL database and uses a web interface to present them. Once a model is loaded it is possible to create spatial annotations reusing terms from controlled vocabularies. Nubes does not focus only on 3D models, but it is able to load and relate model 2D images, such as ortophotos, which can be automatic or semi-automatic projected within the model. Previously created annotation on the 3D surface would be re-projected and spatialised within the newly inserted 2D image.

It is quite interesting the approach followed by CHER-Ob (Shi et al. 2016) an open source stand-alone system developed to visualise, analyse and annotate 2D/3D object. CHER-Ob use a variety of annotation mechanism with one thing in common: user-selection. Annotations in 2D images are based on pixel area, while in 3D models it is possible to select vertices, surfaces of volumes. Selection can be color coded, recorded using a subset of the CDWA metadata and annotated. The annotations are saved as a text file together with metadata, user information and associated images (Wang et al. 2018). No specific encoding for the annotation is chosen that are recorded in the hard drive as simple textual files.

Another stand-alone system developed in the recent years is Agata (Soler et al. 2017), a software that creates a three-dimensional environment for annotating 3D models with textual or graphical information. The software also provides some analytical functions, and it is possible to automatically compute layers for estimating risk scenarios. Agata relies on a XML database to store the annotations and metadata about each object. The database uses a CIDOC-CRM compliant XML schema and supports XQuery as a query language. However, no specifications are given on how the annotation is related to the three-dimensional model.

Recently, a new platform for 3D annotation, called annotation trimming with Clipping Volumes (in brief ClippingVolumes) has been presented (Ponchio et al. 2019). This web-based platform is designed to annotate 3D volumes. The model is first loaded into a web interface where the users can select, using a polyline, the interesting area and further adjust it. Once the selection is complete, the system computes a bounding volume and the annotation is recorded. The web platform does not work with the full mesh, but with a lighter representation, therefore the annotations' information are transferred to a server which recreate the annotation on the full mesh. The specification of the annotation (perimeter and area) are recorded into a database but the specific encoding or the use of a semantic system has not yet being taken into account.

This brief overview had the purpose to present diverse annotation methodologies and their evolution in history. The idea itself what is the purpose of a visual annotation has evolved very much during the last twenty years. Initially, an annotation would take the form of a simple text or tag associated to an object, with the purpose of explaining or better retrieve the 3D model. The use of controlled vocabularies has slowly demonstrated its usefulness over the simple use of tags. This important transition opened the door to systems based on formal semantic structure, able to reuse external semantic authorities.
At the same time the community become more aware of the potentiality of a collaboration platform, where multiple actors would be able to exchange ideas and opinion over the object, using it to anchor interpretation and discussion. When the object becomes the custodian of

research opinion, newer research has tried to embed this opinion in the object. Working mostly with XML-complaint files (Collada or X3D), the community has tried to create links between information systems and 3D geometries, embedding information in the object, or linking it to the source.

Slowly a shift took place. Initially the object was the central element and the annotations would always be about one of its characteristics or about a label assigned to it. Over the years, the annotation themselves acquired a different status, with more systems treating them not only as useful information about the object, but as useful information in themselves, which deserve to be recorded and not embedded. Their recording as a different entity in respect of the object enable an annotation to be annotated, as well as to be studied and preserved as a social object.

3 On the church of Asinou

“*'When I use a word,' Humpty Dumpty said, in rather a scornful tone, 'it means just what I choose it to mean — neither more nor less*”

— Lewis Carroll, *Through the Looking-Glass, and What Alice Found There*

3.1 Introduction

During different sections of this contribution we will refer to one church which we adopted as a use case, the church of Panagia (Mother of God) Phorbiotissa in Cyprus (Fig. 6), commonly known as Asinou, because it was built in the now vanished village and river with the name Asine. The church, built in the picturesque setting of the lower Troodos mountain in central Cyprus, around twenty kilometres from Nicosia, and served the monastery of Mother of God ton Phorbion. The internal walls of the church are richly decorated (Fig. 7) and displays a wide variety of frescoes ranging from twelfth (foundation) to the early seventeenth century, reflecting and documenting the life of an Orthodox monastery during three different regimes and status. When the first frescoes appeared in the church, Cyprus was an essential piece for the Byzantine naval power. In 1191 the island was conquered by Lusignan family, and it becomes a colony of Venice in 1474 until the Ottoman conquest of 1570/71. During these years, the church has been reshaped, have found new donors, have seen new influences and has proven to be a testament of the history of the island. For its stylistic and social value, it has been recognised as UNESCO World Heritage Site since 1985, together with nine others richly decorated rural churches and monasteries in the area, which have been grouped by the UNESCO as "Troodos Painted Churches Group" (Stylianou and Stylianou 1985).

Figure 6. Asinou Church, Cyprus.

3.2 The church

The exact date of the foundation of the church is unknown, but a dedicatory inscription presents in a wall painting within the church itself report the date of 1105/1106. The inscription is, unfortunately, masked thus it is unclear if it does report the date of foundation (was built) or the date of the first painted cycle (was adorned with images). It is, however, widely accepted that the date of the foundation is within 1099 to 1105/06 (Carr and Nicolaïdès 2012, 53). The inscriptions also reveal the name of magistros Nikephoros Ischyrios as the founder of the church. Its portrait is present in a votive panel in south wall of the central bay of the Naos where he is pictured presenting the church to Christ with the Virgin as intercessor with the accompanying inscription "Having been blessed in life with many things of which thou, oh Virgin, wast seen to be the provider, I, Nicephorus Magistros, a pitiful suppliant, erected this church with longing, in return for which I pray that I may find thee my patron in the terrible day of the Judgment" (Stylianou and Stylianou 1985, 114).

Figure 7. Wall painting in the vault of the Naos. Asinou Church, Cyprus.

This votive panel depicts the initial architecture of the church, a simple barrel-vaulted church formed by a barred vaulted rectangle of three bays with an Eastern apse, a simple plan already in use by 4th century CE in many Asia Minor regions as well as Greece. The original architecture was modified one century after the foundation (1115) with the addition, to the original structure of the church, of a narthex with a north and south apsidal end. (Carr and Nicolaïdès 2012, 19). Three entrances, in the south, north and west wall of the narthex, were initially built, but the south door was quickly closed in order to make space for the famous wall painting of Saint George.

The initial architectural form of the narthex has not lasted until today without modifications. Damages were provoked by the frequent earthquakes that have struck the island. Buttresses

were built on the south and north wall to strengthen the stability of the church. The original semi-dome of the apse collapsed and was replaced with a deeper conch and supports. Some structural failure happened, most probably in the thirteenth century, also in the naos. Following the incident, the structure of the Easter and the central bay was reinforced with two responds and two transverse arches were constructed beneath the original vault, dividing the space into three bays.
The architectural history of the church was tormented by several incidents, which have caused modifications and additions. The figurative history was no different.
The original decoration of the church has been carried out by an anonymous painter which we know only with the name of Asinou Master, but only two-thirds of the original decorations have been fully preserved. In fact, following the structural failures in the Naos, the new responds and apse were painted in the late thirteenth century. However, around fifty years later, in the middle of the 14th century, the entire central bay was repainted anew, covering walls, the vault, inner faces of the responds and the transverse arches. This last work has created new imagery (arches and responds) but also repainted over parts of the barrel vault and the walls covering surfaces which had been already painted by the Asinou Master. While we do not know the name of the initial painter, we do have some significant details about the possible identity of the one that redecorated the central bay of the nave. The stylistic choice and details have convinced some art historians to look at Deacon Leontios as the author, an artist who also frescoed the narthex of Lagoudera, and there left his name in an epigram outside the north door.

As mentioned above, the Narthex has been a later addition to the church, and it was initially only partially painted. The remains of these paintings, with the exclusion of the panel of St. George on a horseback, which is still intact, they appear now only as fragments, visible only where the plaster of the new paintings has been scrapped (ibid pag. 93). This space seems to have served almost as a private chapel for individual devotion (ibid pag. 130). At the exception of three paintings in the south apse, a new comprehensive program draped the narthex in 1332/33 CE. The dating is given by an inscription in the lintel on the door leading from the narthex to the nave (Stylianou and Stylianou 1985, 134).

3.3 The iconography

The church is very rich in iconography. The narthex has been adorned with various subjects ranging from donors to local saints, with a beautiful depiction of the Christ Pantocrator in the drumless dome.
While the iconographical description is a fascinating subject, specifically in reference to his themes, it is not the purpose of this contributions to describe each and every one of the figures and depictions present in the church. For this reason, in the following section, we will provide a very brief overview of the some of the ones which would be cited within this work and testify the peculiarities of this small church.

3.3.1 Saint George

Possibly the most well-known depiction within the church is Saint George, a mural in the south conch of the narthex. The wall painting (Figure 8) picture Saint George, portrayed in opulent materials riding eastwards a white horse in a golden saddle and holding with his left hand a lance, while with its right end the reins of his horse. The representation does not portray any dragon or princess as would be common in a later stage, but only the saint in a spare landscape. George is dressed using a military attire of the Komnenian era, which characterise him as a warrior saint and not a crusader. The military attire symbolises its thaumaturgic power. However, the saint was not only a warrior but also a protector of the cattle. Considering that the icon's donor, Nikephoros, was a veterinarian, this was probably the primary objective behind of the depiction.

Figure 8. Saint George, south apse of the narthex of the Asinou Church, Cyprus.

The wall painting reflects elements of a later iconographical type, the one of Diasorites. Typically, portraying Saint George on a horseback, the iconographical type, however, sometimes included a boy from Mytilene the saint has saved from the Saracen. Nevertheless, this is not this the case, no children are portrayed, and the saint it is not a crusader (as when he saves the boy from Mytilene), but a protector of the narthex.

Exactly for this reason, the position of the wall painting in the south apse of the narthex it is probably not casual. The monastery was, in fact, located north of the church, thus, the monks entering the narthex would be faced with this icon, who would welcome them while coming from the northern entrance with a clear sign of protection. The date of the painting is uncertain, and it has been heavily discussed. Andreas Nicolaides (Carr and Nicolaïdès 2012) suggests that the icon must be dated between 1164 and 1192.

3.3.2 Last Judgment

The overarching iconographical theme in the narthex is the Last Judgment and the Second Coming. Painted in 1332/33 it is spread across the vaults, lunette and arches of the narthex and represents several eschatological visions and apocalyptic elements of the middle Byzantine period. Between typical iconographical subjects of the Last Judgment that we found also in Asinou are the Heavenly Court, the River of Fire (or Fiery Stream), the Preparation of the Throne (Hetoimasia), the Angel's Trumpet (figure 9), the Personification of the Sea and the Earth, the Angel Rolling up the Scroll, the Weighing of Souls, the Collective and Individual Torments, the Choirs of the Elect the Garden of Paradise and the Deesis (figure 4).

While the representations are deeply rooted in the middle Byzantine iconographic tradition, the disposition has in Asinou a very distinctive character, because the scene adapts to the morphology of the church, rearranging figures and compositions. Traditionally the Heavenly Court consists in the figure of Christ ready to judge the dead. He is arranged on a high throne in a vesica piscis with the apostles seated next to him together with an army of angels and one archangel dressed with the imperial loros. Next to Christ, forming the Deesis, the two figures of the Virgin and John the Forerunner (Patterson Ševčenko 2009).

Due to lack of available space, the author of the 1332/33 cycle in Asinou had to make some adaptations in the composition. Instead of the classical configuration, the elements of the Heavenly Court are dispersed across the dome, pendentives and east wall. Thus, the Christ Pantokrator is the centre of the scene, surrounded by twelve medallions of angels and archangels. The apostles are depicted, divided in group of three, in the pendentives, while the Deesis is separated in the east wall in three different panels. All the figures of the Heavenly Court are depicted but are rendered in a dome composition. The scene appears scattered, but the figures are linked together by their gaze. The Apostles in the pendentives look at each other, as much as in the Deesis the Virgin and St. John the Forerunner look across their panels to the figure of Christ. Using this pictorial schema, the artist is able to create a stronger bond between the dispersed elements of the composition.

Figure 9. From right top left: Angel's Trumpet, Adam and Eve, the Preparation of the Throne, the Fiery Stream, Hades. West lunette, narthex of the church of Asinou, Cyprus (photo courtesy of The Byzantine Institute, The Byzantine Institute and Dumbarton Oaks Fieldwork Records and Papers, ca. late 1920s, Dumbarton Oaks, Trustees for Harvard University, Washington, D.C.).

3.3.3 Donors portraits

3.3.3.1 Saint Anastasia

The narthex of the church hosts many donor's portraits important for our analysis. In the south apse, on the right of Saint George is pictured the panel of St. Anastasia Pharmakolytria with the donor Anastasia Saramalina (Figure 10).

The panel presents the saint holding a bottle of medicine in her left hand and cross of martyrdom in her right. This iconography is linked with her healing power, but also to the resurrection of Christ, with the last judgment and descent into hell, as well as with funerary context. She is usually painted with medical saints, therefore she expresses healing, salvation and resurrection. The donor next to her, Anastasia Saramalina dress in a typical byzantine attire which widely recur across the Mediterranean area in donor's portrait. The dating of this panel is of later date the one of Saint George, but it is earlier than the 1332/1333 cycle and has been linked with the murals of the bema, which appears to be from the same hand.

Figure 10. Figure A - St. Anastasia Pharmakolytria with the donor Anastasia Saramalina, south apse of the narthex of the Asinou Church, Cyprus. Figure B - Mother of God between Archangels, Apse, north side of the Asinou church, Cyprus.

3.3.3.2 Latin Donor

The semi-dome of the south apse of the narthex of the church presents a depiction of another important donor, the Virgin of Mercy and Latin Donor (Figure 11). The virgin is holding the Christ child at the centre of the panel, with a kneeling woman on her right and two young persons on her right. While the virgin stretches her maporhion towards the kneeling woman, Christ ben his arm blessing her. The virgin in this depiction belong to an iconographical type originated in Italy, the Madonna della Misericordia, which have been spread in the Latin east by the Venetian rules. It is not the first example of this depiction in Cyprus, but it is important given the position of the church. The female supplicant is the Latin donor, and her presence with two young boys indicate that she is a widowed mother. Her posture and hands closed in prayer are typically western. She is dressed in a scarlet dress called "cotte", originally from France, which has been in fashion among Latin women in Cyprus.
While the character of the composition is western, the realisation follows stylistic features found in the panel of St. Anastasia in the murals of the bema and, for such reasons, have been attributed to the same workshop.

Figure 11. Panel of the Virgin of Mercy and Latin Donor. Semidome of the south apse of the narthex of the Asinou Church, Cyprus.

3.3.3.3 Nikephoros

This donor's portrait depicts the Virgin, together with the founder of the church, Nikephoros, accompanied by the small figure of Gephyra, which held in his hands the church of Asinou offering it, through the mediation of the Virgin, to the figure of Christ surrounded by angels. The Virgin is interceding with the Christ in favour of Nikephoros, passing his words to Christ, who gesture affirmatively back to her.

While it appears that has been a donor's portrait originally in the church, the depiction (Figure 12) which has survived until today characterised by 12th century stylistic choices, such as Nikephoros's costume as well as the epigram present in the panel which conforms to 12th century usage. It is probable that the original panel occupied the same position and have been repainted. The position of the panel closed to the bema is deliberate, because it could be seen and addressed during the ceremony.

Figure 12. Panel of donor's portrait. Naos, central bay, south lunette. Asinou Church, Cyprus.

3.4 Conclusion

Asinou is a small foundation with a rich history and in a country of strategic importance for the intricate relation between east and west, a container of influences which have been drained by so many diverse visual cultures. The diversity of customs and the new rules had an impact on the culture of the island, and their visual works testify such influences. In Asinou, we can see women in western dresses, Frankish donor and western iconographical types next to typical Byzantine imagery with ties to Syrian or Constantinople traditions. The presence of such influences in a small rural church located in the mountain above Nicosia, bear witness not only how the new culture had reached the core of the country, but it also presents us with the challenge to give a name and type to such new representations. The diversity in imagery gives us the change to pinpoint precisely on how the new custom come into being, what they represent and how we can describe them without overlooking their intrinsic characteristics.

4 On the phenomenology of interpretation

"I fully agree with you about the significance and educational value of methodology as well as history and philosophy of science. So many people today—and even professional scientists—seem to me like somebody who has seen thousands of trees but has never seen a forest. A knowledge of the historic and philosophical background gives that kind of independence from prejudices of his generation from which most scientists are suffering. This independence created by philosophical insight is—in my opinion—the mark of distinction between a mere artisan or specialist and a real seeker after truth"

— Einstein to Thornton, *7 December 1944, EA 61-574*

4.1 Interpretation of information in Cultural Heritage: literature and major analysis

4.1.1 Jakobson and communication

Talking of information and cultural heritage means discussing about a social discourse that is undertaken by heritage managers, archaeologists, architects, curators, archivists and other experts with the aim of managing and preserving our past. The overall system is based on the interpretation of the material traces of an event throughout a code which is constantly used for their signification.

To investigate this process, and understand how we relate content with an expression to produce perceptual judgements over physical objects, we decided to examine the interpretation in its most granular terms. We chose to focus on how the informative content gets its meaning, and drawing from the theory of code production we opted to use a framework on understanding which is the closest to our needs: the Jakobson's communication model. Jakobson's model already contains, in fact, some of the nuclear elements that we determined to be fundamental in the explanation of the interpretation of visual items.

Moreover, communication and interpretation are very much alike. The latter is nothing else than an asynchronous and indirect communication process which involve an addresser, a cultural object or phenomenon and an addressee which is responsible for providing a signification to the object/phenomenon. Classifying it as a cousin of a communication process does not mean, however, as someone carelessly expressed, that "*the monument talks to us*", but just that the elements in play are quite similar in structure and significance within the process. Both the communication and the interpretation rely, in fact, on code production for the meaning assignment within a community.

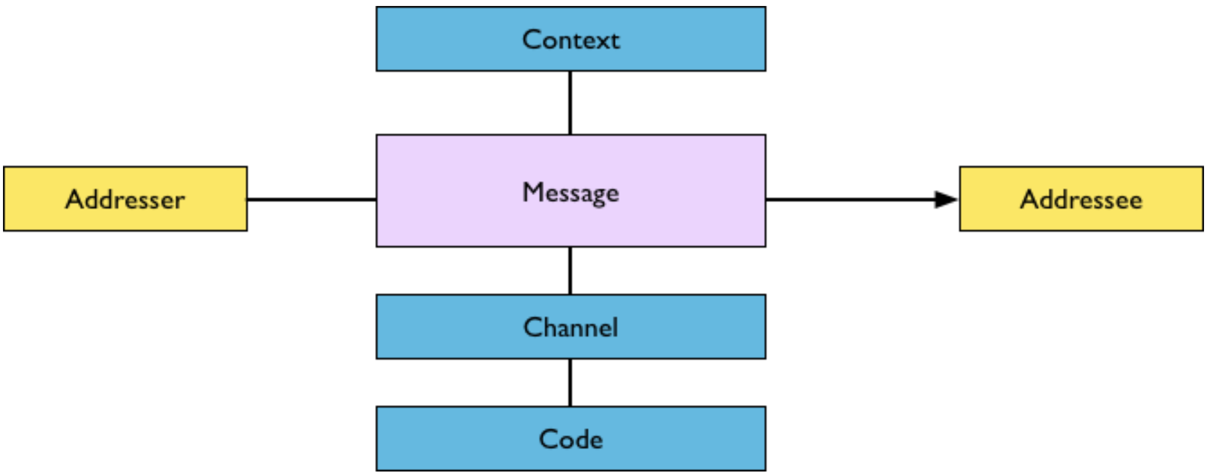

Figure 13. Jakobson's communication model.

In order to express an interpretation as a particular type of communication process, we adapted the Jakobson's model of communication (Jakobson 1960) (Fig. 13) transforming it into an asynchronous two-step process (Fig. 14) where the initial addresser's message and the addressee's interpretation happen in two different points in time (respectively called T1 and T2). We called this new model Jakobson's Cultural Model of Interpretation (JCMI).

To better fit with the heritage practice, we preferred renaming the addresser as Creator and the addressee as Interpreter. Creator refers to people, both as individual or group, who, known or unknown, are behind a creative cultural performance of any kind. This expression does not aim to restrict the subject to a specific kind of cultural practice. We do not wish to distinguish between tangible or intangible heritage, and we do not aim to classify the degree of creativity of any activity; cultural performance should be understood as merely an act aimed to create a cultural content. No other distinction is needed at this stage because whichever type is the cultural content created it will still follow the same type of pattern as a matter of interpretation process.

The product of the creative cultural performance is a visual Message, which is also the object of the act of interpretation.

The Interpreter is the agent which will examine and, indeed, interpret the visual message in a different moment (T2) from the one of its creation (T1), and on the base on his judgement and experience will assign his meaning to it. The result is influenced by the Code and the Context used by both the Creator and the Interpreter. For example, in case of an inclination towards a reconstruction of the original meaning (as in the case of heritage scientist), the Code and the Context in T2 would tend to overlap with the one in T1. Nevertheless, they could also remain entirely separated if too much time has passed and no effort has been made to reconstruct the original (T1) socio-cultural environment.

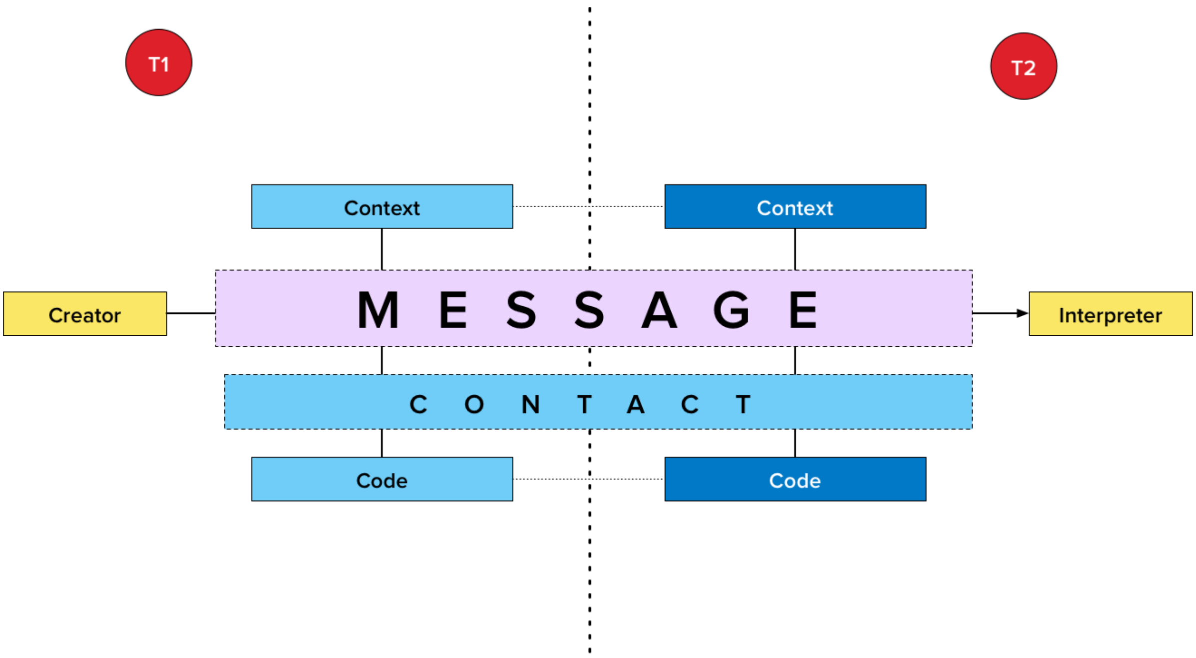

Figure 14. Jakobson's Cultural Model of Interpretation (JCMI).

The Contact, together with the Message, is the other unaltered and stable element within JCMI. Although the name could be deceiving, the Contact is nothing else than the channel used by Creator and Interpreter to communicate with each other. The original Jakobson's model took into account the possibility that the communication channels would change over time throughout a re-formulation of the original message. The typical example of this case "*is the link postulated between a pair of communicating Native Americans, such that one, the source, moves a blanket over a fire, while the other, the destination, observes the resulting message cast, or coded, in smoke*" (Sebeok 1991, 27). In this example, the transmissions would have to be rearranged and adjusted to the channel used to convey a meaningful message.
However, if this complexity fits perfectly within a semiotic theory of information transmission which includes numerous channels, our case uses exclusively visual means to interpret information. Hence, the channel used to deliver the visual message would be the material support that the Creator used in its original creation. A re-arrangement of the disposition of the visual message in another channel should be treated as a different manifestation of the work. An exact copy of the work (a photograph for example) carries a different informative content. That is the main reason why the contact, together with the message, need to remain a stable element in JCMI.

Two other elements are essential for our interpretation model: the Context and the Code. The Context in Jakobson original model does not denote the circumstances around the message but its referent "*seizable by the addressee*" (Jakobson 1960). In JCMI the referent can significantly change between two points in time, losing its original denotation or acquiring an entirely new one, and that is why is present as a single element in both T1 and T2.
The Code is the encoding shared by a Creator and an Interpreter which ensures the comprehension of the message. Similarly to the context, it can change over time.

Missing from the original model is a theory of interpretation, a way to understand the mechanic of it. Specifically, we need to expand on how the code is used, and meaning is constructed, making sense of the manifold of experience. To untangle these problems, we will analyse how the code function as a generative grammar for establishing a set of functions, able to correlate the content plane of a signal to an expression plane linking together elements of a system such as an element *a* is used to stand for an element *b*. Hjelmslev (1963) called these type of functions "*sign-function*", and define its two constitutive elements as functive.
We determined that the capability to construct sign-function is the primary attribute of the Code. Working as the semiotic associative mechanism, it allows us to link the visual cues with the object recognition through the process of perception. To unravel how such outcome is achieved, we should look more comprehensively to such process and examine its relation to the meaning assignment of a visual object.

In the following sections, we will see how visual messages are encoded and shared between agents, and how the communication of the Message is constricted by the elements in the JCMI, creating that variance which is the base of the richness of our visual experience. A considerable amount of space is going to be dedicated to the Code, which appears to be the more troubling element of the JCMI. Specifically, we will face the recognition of the elements used for encoding a visual message between agents in section 4.1.2, Cognitive Type, Semantic Marks and Semantic-Perceptive Field, while in Reference we are going to shed some lights on the Context.

4.1.2 Shared Perspective

A thorough explanation of the Jakobson's Cultural Model of Interpretation compels us to define the objects which the code acts on during the function generation. To do so, we are faced immediately with the challenge of visual representation and, therefore, with the one of perception.
What it is to perceive something is a fundamental question which emerged and become popular in the philosophical debates among the ancient Greeks. The Atomists were the first to propose a doctrine of light and vision, followed shortly by Euclid and Ptolemy who started to employ geometry for their analysis. Intertwined with the theory of knowledge the question remained a critical topic in the medical, philosophical and geometrical debate ever since, collecting contributions from scholars of the likes of Alhazen, Descartes, Berkeley and many others (Lindberg 1981; Hatfield and Epstein 1979). The content of perception is, in fact, the very first form of knowledge and its nature, as well as its relationship with the sense and the outside world it is highly debated and studied.
We will continue this tradition taking the semiotic stance. Following several scholars before us, we argue that perception does not have to be reduced to a mere sensation because it is always an assignment of meaning. It is not merely a "*becoming aware of the external world through the action of the senses*" (Pizlo 2008) but it is an active semiotic process of collecting and relating sense data to a (conceptual and semantic) model (Eco 2000). Perception should not be confused with sensation because to perceive something it is always a type of inference, which is implicit in the classification of the percept as "something". Even when something is defined as a completely unknown, there is still an inferential process that defines it as a thing which we do not know how to classify, but it is, indeed, still thought as a thing, which is a categorical object. However, when everything is taken into consideration, there is little close to nothing that is visually unknown, because we have a tendency, as will we see in the section Cognitive Type, to perceive similarities between things in order to make sense of the manifold of reality.
If perception is not just a sensation but a collection of information from the continuum of reality, what is the percept and how we identify it? Initially, and a for a long time, the percept was associated with the boundaries of the perceived physical object. It was quite later that appear evident that the vision is a mediation where:

> "The shape of an object we see does not, however, depend only on its

> retinal projection at a given moment. Strictly speaking, the image is deter-mined by the totality of visual experiences we have had with that object, or with that kind of object, during our lifetime (Arnheim 2004)"

The visual experience includes diverse factors which influence each other such as perspective, spectrum, environmental condition, spatial position as well as the framing or the closeness to other shapes (Fig 15). The boundaries too sometimes are not necessary because we use our previous experiences to reconstruct the boundless figure (Arnheim 2004; Gombrich 2004). Even 2D or 3D representations, such as photographs and reality-based 3D models that we assume are flawless in their way of capturing the physicality of an object, provide just a selected or limited set of information based on the environment, hardware, software settings and projective system chosen as a medium.

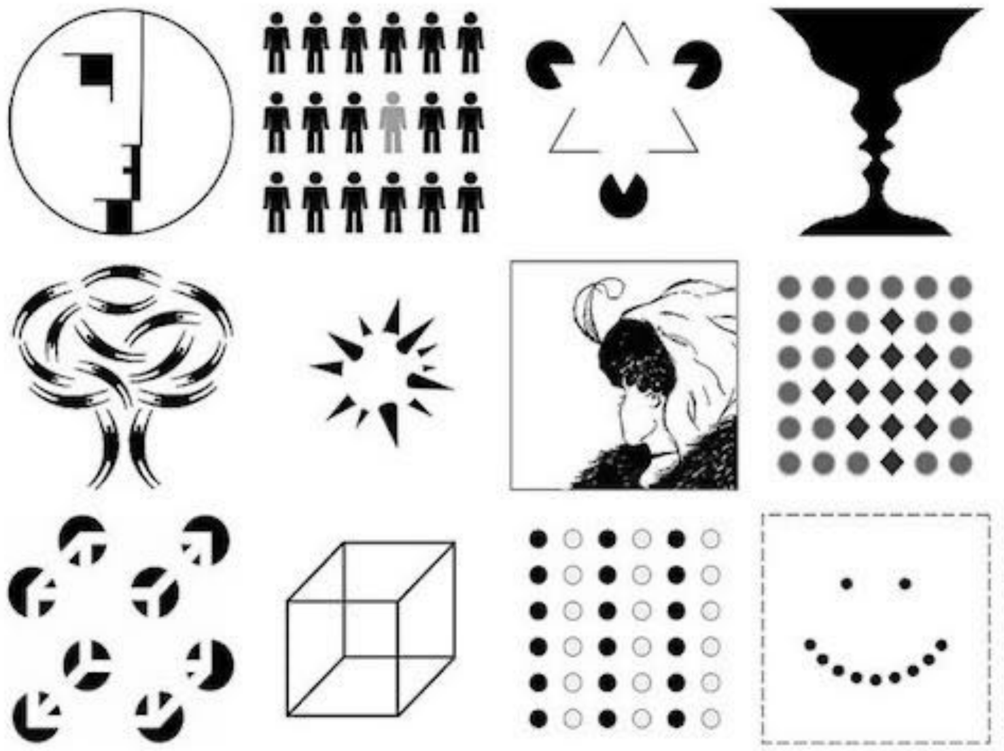

Figure 15. The Gestalt Principles Composition highlight the role of the mind in the perception of an object.

Thanks to the studies in Gestalt Psychology we started to be aware that are many features that affect our understanding of an object. However, if this historical development helped the scientific community comprehend the problem, and understand how difficult the identification of a percept is, it did not provide us with a method we can rely on nor a point of departure for our analysis.

A more reliable way of discerning something in the continuum of reality was lately suggested by Floridi (2011). While providing the epistemological foundation for its new discipline, Philosophy of Information, Floridi reformulated and expanded on the work of MacKay (1969) and Bateson (1972) arguing that it is not the presence of a thing, but the lack of it, which suggest the existence of something. He introduced the concept of datum, which he defines as:

> "datum = def. *x* being distinct from *y*.
> where *x* and *y* are two uninterpreted variables and the relation of `being distinct', as well as the domain, are left open to further interpretation."
> (Floridi 2011, 85)

The concept of datum is extremely useful for us because we can use it to develop a definition of a percept.
The propriety of being distinct, which Floridi mention, is the first and foremost important thing we need to use to define a percept. Being distinct it is, however, not enough. It has to be distinct in some way. The type of distinction it is far from necessary, what we have to value is the dimensional mapping of it as well as the reference system where it is distinct. With these elements, we can finally have a percept that acts as the primary block in our phenomenology.

Having determined the object of the perception, we finally can analyse how the basic atoms present in a visual item are used, together with the code, by an interpreter to form a sign-function. To do so, we need to switch the focus of our analysis to the connection of the sense data to a model. A percept can be interpreted differently from person to person depending not only on their social and cultural background but also on their disposition in regards to the percept. One of the easiest and probably more famous introductory experiment to prove the interpretative nature of the perception is given in Fig. 16. It is the "duck-rabbit" picture made famous by Ludwig Wittgenstein in his Philosophical Investigations (1963) as a means of describing two different ways of seeing an image.

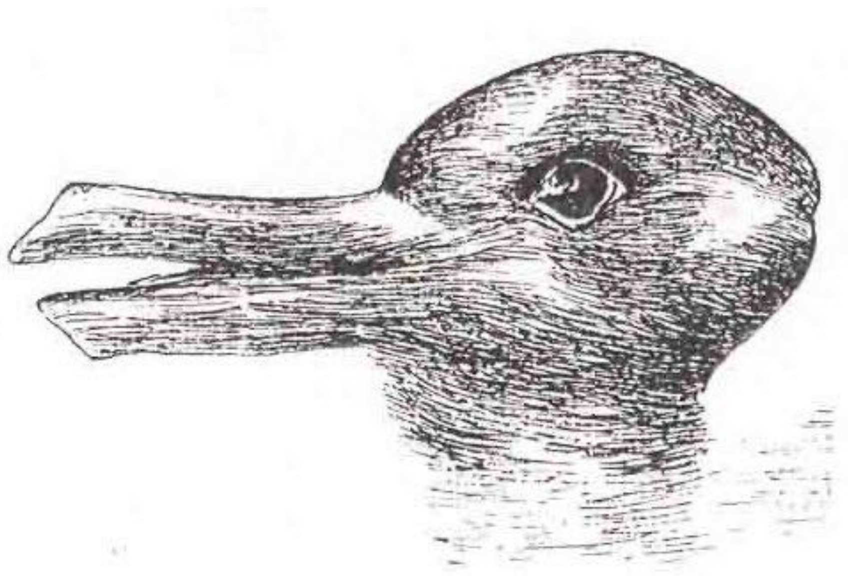

Figure 16. The duck-rabbit illusion.

Looking at this picture, the viewer it is, in fact, prone to perceive only specific aspects of it, which would lead him to recognise a duck or a rabbit. The viewer will have a more fruitful perceptual experience and see them both only when he fixes his attention on it and develop a better comprehension of the Code used by its Creator to construct the picture.
This example quickly shows both how the retinal images are not the only instruments people use to understand something and how representations are always mediated by a code.

4.1.3 Eco and the genesis of Cognitive Type

The interpretation of a visual message requires the connection of the sense data to a model using a specific visual code. This process relies heavily on an act of recognition, classification and reference which necessitate an understanding of the equivalences between an object, or at least some of its characteristics, and a similar type that we had experienced in the past.
In order to better explain our stance, we will reuse and expand on a theory formulated by Eco (2000). After reviewing the theory of classification and recognition, Eco suggested that for the comprehension of the known we should look at the unknown, thus laying down the ground for our exploration. We will delve deeper into his thesis, focusing on the nuclear elements which are necessary for a shared understanding of our reality. For such reason, it is of paramount importance to firstly introduce, analyse and explain his theory.
Eco ask himself, and his readers, how we would be able to interpret and socially talk about something if we would see it for the first time. He proposes a thought experiment using the Aztecs' first encounter with the Spanish knights. During this occasion, the Aztecs were faced with an entirely new animal mounted by individual completely covered by metal plates and

> “Oriented therefore by a system of previous knowledge but trying to coordinate it with what they were seeing, they must have soon worked out a perceptual judgment. An animal has appeared before us that seems like a deer but isn't. Likewise they must not have thought that each Spaniard was riding an animal of a different species, even though the horses brought by the men of Cortes had diverse coats. They must therefore have got a certain idea of that animal, which at first they called *macatl*, which is the word they used not only for deer but for all quadrupeds in general” (Eco 2000, 128)

What is interesting from this passage is not just the recognition of the nature of a horse as an animal but the difficulties that such collective recognition impose on the exchanges between the messengers and the emperor. The former integrated their description with pictograms and performances aimed to describe not only the form of this new animal but also its behaviour. After listening to them the emperor had formed an idea of the *macatl* his messengers were talking about it, but it would be probably different from the one in the mind of his messengers. Nonetheless, it would be accurate enough to allow Montezuma to talk about a macatl, to be able to recognise one and differentiate it from the Spaniard riding it. Moreover, he was probably able to recognise not only the single *macatl* but the entirety of them as a single species, even if they had differences in colours, size or carried armour. Gradually he was able to acquire more and more knowledge about this macatl, about its usefulness in battle as well as its behaviour and origin (earthly or divine for example). Finally, the Aztec started using a specific word for it, modifying the Spanish word *caballo* into *cauayo* or *kawayo*

The story above presents an interesting perspective of the perceptual process, specifically on the recognition and categorisation of new objects, and it allows us to see how, on the base of the object ’s characteristics, we produce an idea of a percept. In his analysis, Eco (Eco 2000, 130) call this idea Cognitive Type (CT). In this case, the CT would be the concept that an Aztec used to recognise a horse as an exemplar of their kind. After having seen some horses the Aztec would have constructed a morphological schema of it, which does not comprise only an image-like concept of the horse, but it includes its peculiar characteristics such as the neigh, its motions, its capabilities of being mounted and perhaps even the smell. These elements are the base used for creating the CT of the horse, which appears to be then a multi-sensory idea of what we see.

For many readers, this concept would quite resemble the one of prototype (Rosch and Lloyd 1978; Lakoff 2008)

Eco does not delve into explaining in details how that would work and how we can use this grammar to relate sensing data to a semantic and conceptual model to achieve similarity-based recognition (we will develop them in Semantic Marks), but he instead focus on the concept of agreement and specifically on the alignment of the CTs between the agents. Coming back to the Aztec example, there was undoubtedly a time when the Aztecs, discussing the *macatl*, they reached an area of consensus between their private interpretation and the collective understanding, associating the content with the expression *macatl*. Initially, the agreement was probably disordered but they surely soon homologate the features they all identified into something public, circumscribing their meaning assigned to the animal *macatl*, therefore unifying their collective CT, which are private, to a set of public interpretants which Eco called Nuclear Content (NC) (Eco 2000, 137).

The NC originate by the harmonisation of CTs but, being a cultural trait, can also be socially transmitted, becoming the origin of the classification of the reality of a social group. In this way, a NC can be used to pass down instruction for the identification of an object or phenomena to the newer generation.

These two concepts are essential to the perception process and our social understanding of reality. Being privately and socially generated they are the foundation for our way of classifying the world and socially communicate about it.

The combination of CT and NC is quite similar to the "*structured and structuring structure*" which is Bourdieu's habitus (Grenfell 2008; Bourdieu 1977). Bourdieu affirms that the habitus is structured by its existence, and it is generative on the base of its structure, therefore, creating classifications and practices on the base of a preconceived structure which is socially generated in a specific field. We can easily see how the generative power of the CT and NC are just a more elaborate analysis of one-person dispositions towards a particular classification of the world. This classification is not innate (if not in the way of being structured in a certain way) but it is socially given, and it evolves within the social boundaries of one person's cultural arena.

Eco, continues his examination of the perceptual process and introduce another differentiation over the sets of information which are *necessary* for the recognition and the ones which are *not necessary*. An agent, in fact, can enrich his knowledge about an object over NC. The purpose of the latter is, in fact, only help to recognise and socially talk about something. Montezuma, for example, while initially only had a very few little information about the *macatl*, soon broadened up his knowledge into a more complex structure which included a set of information which is not necessary for the identification of a horse, such as they are breed in a precise manner. This information would not be as numerous as the one held by the Spanish, nor at the same level of precision as the one of a modern zoologist, but would be anyhow more encyclopaedic in nature. This knowledge and competence should be diversified from the NC, which is just a harmonisation of the CTs, and are to be call Molar Content (MC) (Eco 2000, 141).

4.2 A new proposal

4.2.1 Encoding the visual: the Semantic Marks

The creation of the CT implies the collection of a series of multi-sensory data that allow us to form an idea of a physical object. Unfortunately, Eco does not explain precisely how it would be done. While for Eco this information was not relevant, it is for us. The research of the nuclear elements of the process is essential for defining how their interactions affect our visual understanding. In order to explain how the process work, and specifically how it works within the Jakobson's Cultural Model of Interpretation's Code, we introduce the concept of Semantic Marks (SM). We define an SM as internal encoded functions which help classify external stimuli, discerning their nature.

SM are sense based and help classify the perceptual experience correlating perceived signals to the CT of a situation, plus to the CT of a physical thing. Both of them are based on an equivalence-based criteria between the percept and a situation/object which are similar to. Further recognitions are achieved by a similarity-based degree of the newly perceived SMs and the SMs that characterise a previously constructed CT.

SMs function as attributes of the identity of a percept. The number of the signals received by the senses can be numerous, but the chosen ones that are used for the identification are a fewer numbers and, they present themselves as constituents of a perceptual manifestation. While a SM can be seen as another type of sign, is instead an encoding of the percept on the base of a classification, which reuses our experience and social ground for determining the significance of our reality.

Having outlined the gist of it, it is best to start formulate a formal analysis, because only through their definition we can comprehend their role in the perception process. A SM is the result of a semiotic process which works with three components:

- At least one signal.
- A situation.
- An object.

The very first component is the signal, which is an external stimulus, a datum identified on the base of its difference and its form. We will flatten its definition, for a functional purpose, using logic as:

Def. 1) $\forall signal(x) \rightarrow \forall x.((hasDimension(x,\ N) \land isPartOf(x,\ System)) \land different(x,\ Surrounding))$

Where x is the signal which is identified by a dimension (N) in a specific *System* (could be a specific projection system as well as a topological relationship). The identity of the signal is, moreover, defined by its differences from the *Surrounding* area because, it is exactly this element

which ground its identification into a single unit.
A set of signals is a set of uninterpreted data, but for their identification we should look over to the other components of an SM: situation and object.

The notion of a situation is quite fuzzy. Situation theory and its semantics was the subject of many academic debates (Stojanovic 2011; Devlin 2006; Zucchi 2015; Cooper 2012) in the last thirty years. Many have written on the topic, but there is no real agreement between the community on what exactly is and how to define a situation. Nonetheless, we used some of the elements discussed in those debates to build our definition of a situation *(s)* as:

Def. 2) $s_{def} = \{R, a_1, \ldots, a_n, \omega_x\}$

Where R is the relationship perceived by a viewer between a set of physical entities $(a_1,\ldots,a_n)$ in a specific spacetime volume (ω), a portion of the space-time continuum. The type of relationships *(R)* between the entities can be of diverse nature such as mereotopological or temporal (for a better account of those see (Smith and Varzi 2000; Smith 1996; Varzi 2003; Freksa 1992).
Situations, however, while carried their own identity are not unique temporal state which need to be determined every time, but can be approximated as an instance of a situation type (where the situation type is just the closest logical counterpart of the CT of a situation, useful here to determine its membership function), which is a prototypical situation we have experience of, and help us determine a specific perspective or a behavioural pattern to follow. The relation between a situation *s* and a situation type *S* is a degree of membership of the elements of *s* in *S* where:

Def. 3) A situation type *S* is a pair *(S, m)* where *S* is a set and $m{:}S \rightarrow [0,1]$ is the membership function. S is the universe of discourse and for each $s \in S$ the value *m(s)* is the grade of membership of *s* in *(S, m)*. The function $m = \mu(A)$ is the membership function of the fuzzy set A = (*S, m*).

Using the same logical notation, we can define the relationships between a physical thing *p* and its type *P*, such as that an object is the relationship of a set of physical parts identified by the combination of certain materials over time and *P* is:

Def. 4) A physical object type *P* is a pair *(P, n)* where *P* is a set, $n{:}P \rightarrow [0,1]$ is the membership function and for each $p \in P$ the value *n(p)* is the grade of membership of *p* in *(P, n)*. The function $n = \mu(B)$ is the membership function of the fuzzy set B = (P, n).

As mentioned before the resemblance is given by a degree of similarity. Therefore, the set A and B, which are respectively the set of all the matching situations, and the one of all the matching physical objects, which we can describe as:

5) $$A = \{s, \mu_A(s) \mid s \in S\}$$

6) $$B = \{p, \mu_B(p) \mid p \in P\}$$

Should use a membership function type which take as an input the value or a similarity-based degree calculation. However, similarity it is not, as commonly understood, a juxtaposition between two anatomically similar elements, but a more complex phenomenon. Nevertheless, it is possible to map the correlation between elements in a multi-quality dimension including, depending on the case, Topological, Feature, Alignment or Value information (Goldstone and Son 2012).

The Value information is used in social science to gather data about the closeness of certain qualities, such as political vision. However, we can easily assume that such type of reasoning can be applied to group elements based on different qualitative criteria, such as the material property, colour, size or reflectance. For example, two representations portraying two different subjects could be group together if both have a golden background, or if the objects portrayed have the same size.

Topological information relates to the closeness of two or more object in a specific reference space. It could be a local space, such as a portrait where two dots stand in proximity to each other, or a geographical space, such a country or a town. The metric closeness between the two objects for being grouped together it is determined by the viewer.

Feature similarity implies the presence of few distinctive features which are considered by the viewer more salient than others and are taken as key for grouping some objects. Could be the case of wearing a hat with a feather or carrying a Latin cross. In both cases we use these elements to say that two objects are similar.

The Alignment similarity indicate the likeness of one or multiple parts of an object with one or multiple parts of another object. It implies the possibility to juxtapose the two parts together. The part could be the same or not (transformation such as magnification or shifting could be used), but the effect is improved if it is the same.

We will not provide indication on which membership function should be chosen (Gaussian distribution function, the sigmoid curve, and quadratic and cubic polynomial curves etc.), because the methodology depends on what kind of similarity information are being taken into account. For a full account on the methods refer to great commentary on the subject given by Timothy J. Ross (2016).

At last, having finally determined what is the relation between situations, a physical thing and their CT (for functional purpose logically expressed as type) we have all the elements for defining what is the Semantic Mark of an object, which we define as a tuple:

Def. 7) $SM_x = \{(Sig_x, \ldots, Sig_n)\ \mathrm{A}, \mathrm{B}\}$

Where $(Sig_x, \ldots, Sig_n)$ is the set of signals identified, A and B are respectively the fuzzy set of all the matching situations, and the one of all the matching physical objects in respect to a set of signals which we used to contextualise the signal.

We define a Semantic Mark as the result of a function which relates the signals to a situation and a physical thing to create denotative expressions that link the initial signals to specific cultural content.

4.2.2 Identity construction and Semantic-Perceptive Field

We introduce the role of the Semantic Marks within the overall perceptual experience as attributes of the identity of a percept and components used for the identification of a visual item. We did not, however, examine how we use Semantic Marks to create denotative expression.

The identity of the object is given by a set of Semantic Marks which are chosen during a perceptual experience because they represent the characteristics that further help us recognise and identify a visual item. As we saw in Semantic Marks, we link the SMs to a CT to assign meaning to them and construct denotative expression.

In order for this process to occur we need to assume it exists a space where we collect the SMs which are essential for the formation of a specific CT, and map them to the corresponding type (Fig. 17). We called this space a Semantic-Perceptive Field (SPF), and we define it as a mental space we use to semantically segment our reality and link processed sense data (SM) to meaning-provider ordering structure (CT).

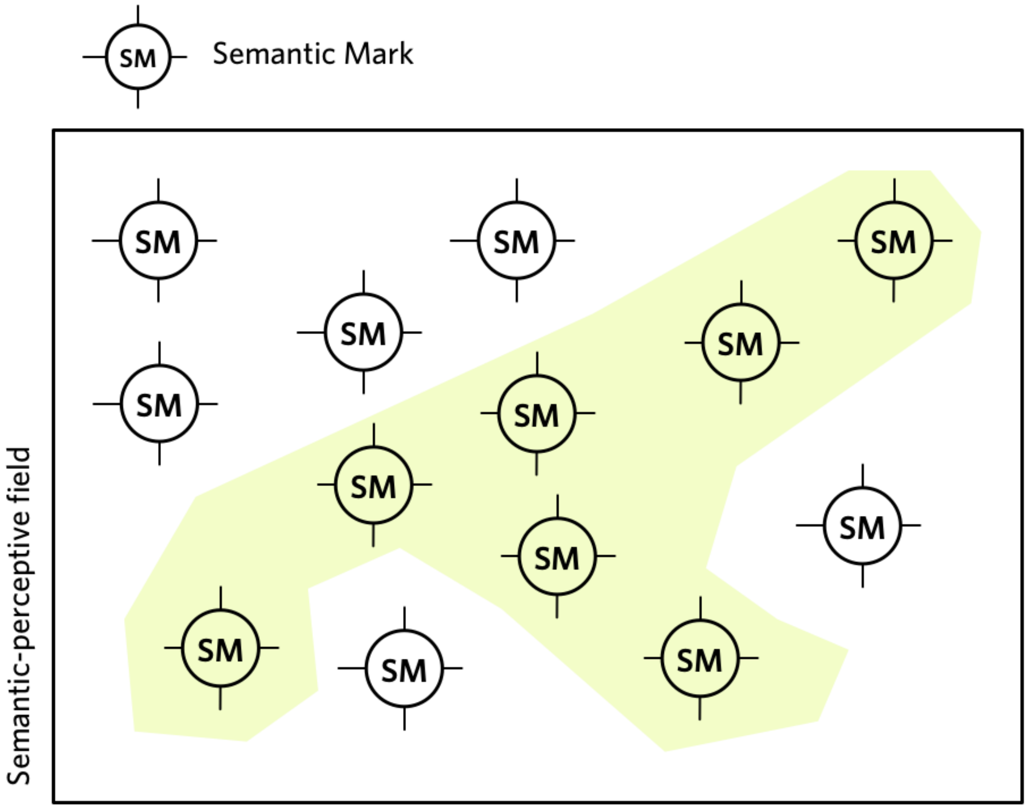

Figure 17. Composition of a CT

To better clarify the use of SM, SPF and CT we will see how we employ them. To demonstrate their use we determined three categories of perceptual experience:

a) The recognition of the known.
b) The enhancement of the known.
c) The identification of the unknown.

The very first (*a*) is the simplest one. For a felicitous recognition, we collect the SMs of the perceived object, and we compare them using a similarity-based degree, to the one belonging to the closest CT mapped in our SPF.
Quite different is the case of the enhancement of the known (*b*). An enriched perceptual experience, such as a diverse perspective, or a more profound analysis of an object, could lead to an improvement in details or a partial substitution of the features we use to identify something. In this case, we will have a reconfiguration of the mapped SMs using newer marks or just the selection of diverse ones. The modified CT will be composed of a new set of SMs which

represents our enhanced perceptual knowledge. The normalisation of the CT into a NC can also be explained in term of a social reconfiguration of SMs, which take input from diverse SPFs (Fig. 18).

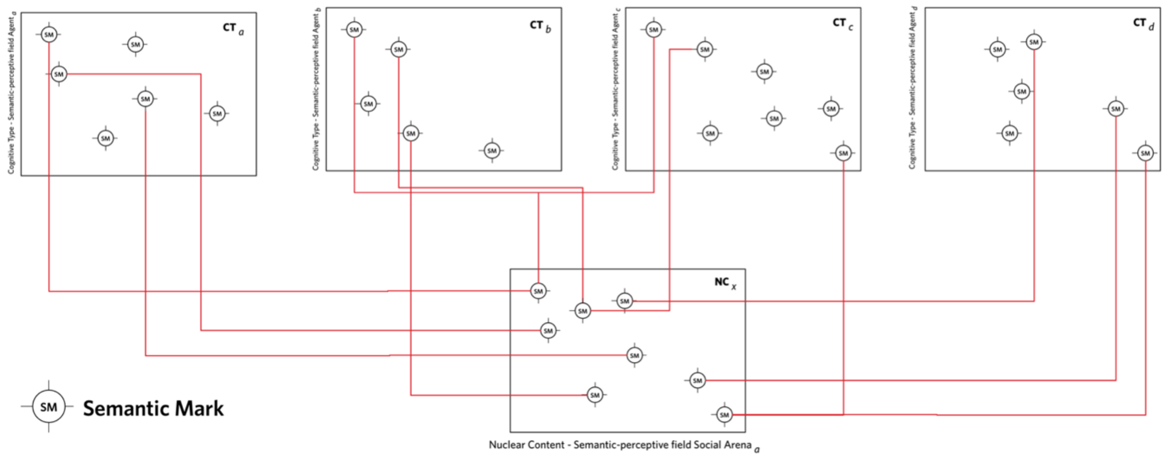

Figure 18. Normalisation of diverse CT into an NC.

The identification of the unknown (*c*) is the probably the most complex of the three. As we saw inCognitive Type, our first instinct is to classify something new using a close perceptual relative, so when are faced with the unknown we are just evaluating the degree of variance between what we have in front of our eyes and the SMs in our SPF. We search for the SMs' disposition which is close enough to the unknown and then we will identify it as such. Nevertheless, if the gap in the degree of variance between the known and the unknown is too high, we will construct a new CT and apply the SMs necessary for its identification. It is important to remark that the SMs we will assign to the new CT are still based on the CTs of object and situation we previously identified. That is the reason we used fuzzy logic to map the relationship between the object in front of our eyes and its corresponding CTs. In such way, when an unknown object would be encountered the identified SMs would be composed by chosen signals plus the degree of closeness ($m(s)$ and $n(p)$) of the chosen sense data to a previous object and situation. The result is a new CT with a degree of closeness to any previously registered ones which is determined by the sum of the degree of membership of its elements.

With these three examples we outlined the major use of SMs, CTs and SPF as the content of the referential process and as an underlined grammar for the construction of the Code. Before analysing the last step of the perceptual process, the reference, it is important to underline how the structure of the perception process is not only defined by the Code, but it is influenced heavily by another element: the Contact. The variances caused by these two elements can be sometimes confusing, and they obviously influence each other. To clarify any misunderstanding, it is better to explain their differences with an example involving a well-known Contact: a picture. If we look at a photo, what it represents and its counterpart in the physical world would be quite different. A picture of a dog and a real dog are quite distinct. There is a reduction of a 3D physical object to a 2D reconstruction on the base of a certain amount of chosen data. Nevertheless, we cannot deny their resemblance (a primary iconic base), as well as we cannot deny the fact that a picture (or a drawing for that matter) follows some language which could influence our understanding of the object which it depicts, such as the focus, perspective or the colour captured. The language used, as well as the possible variances of it, is defined by the Contact. It is important not to overlap such distinctions and do not treat the differences caused by the Contact as variances in the Code, even if they are obviously influencing each other. Volli (1972) help us clarifying this point when speaking about differences in graphical transcriptions that allow us to see diverse channels (picture and paintings for example) and still be able to recognise them. He speaks primarily about geometrical differences such as:

> "congruencies (which maintain unaltered all the characteristics of a figure, including metrical ones), homothetics or similitude (which renounce metrical identity), projective transformations (which retain characteristics like "being a straight line" or "being a second grade curve") and topological transformations (which retain only some elementary properties, such as the continuity of lines)." (Polidoro 2015)

The use and modification of these type of criteria are intrinsic to each Contact, which depending on the medium capabilities and the field tradition, is responsible for the extensionality of the Code. Therefore, the use of the same visual code in different contacts would produce different results, because there always would be a translation and an adaption to the new medium. When McLuhan talked about Medium as the Message (McLuhan 1964), he successfully points out that the role of what he called Medium is to shape the message into a form that is based on the possibilities given by the Medium itself. The Contact in our model is definitively not a Message, but we can comfortably state that it shapes its form and determine its expressive possibilities.

4.3 Integration with context: reference theory

Having finally discerned and analysed the problem of the code we should move forward with our theory of interpretation with the last constituent in the Jakobson's Cultural Model of Interpretation (JCMI): the Context.

The Context opens up the problem of reference in the interpretation theory. We already saw how we use the code, specifically SM and CT, as a function of correlation of a visual item to a corresponding reference in order to provide communicative meaning. What is the nature of the reference and what precisely those SMs are marking, however, it is not a simple question as it may sound. The understanding of the reference is frequently muddled by the use of Ogden and Richards' triangle (Fig. 19), which does oversimplify the complexity of the relationships relying on a correspondence between reference and referent. However, a visual item does not merely refer and denote something, but it conveys a cultural content, which is an abstract entity based on a cultural convention.

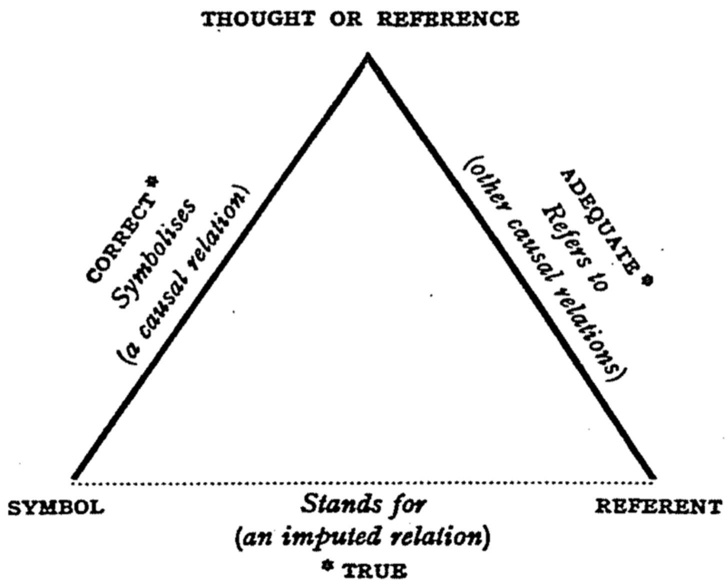

Figure 19. Ogden and Richards semiotic triangle.

Even overlooking the visual aspect, the referent-reference relationship in the Ogden and Richards' diagram still designate a cultural unit, because the reference is intended a category of objects (a referent would point not to a specific item, but to the class of all those items), which is a taxonomical class for the interpreter and, indeed, an abstract entity, which is only valid within a cultural convention. However we look at it, the referent points to a cultural unit, which is nothing else than a part of a semantic segmentation of the reality, which does not need a corresponding physical object in any possible world, but could be an abstract set of values or a mythological or religious creature (see Quine (1948)).
The relationships between a cultural unit and its reference can be determine mainly by two types of relationships: denotation and connotation (Martin and Ringham 2000). Visual semiotics discern denotation and connotation as two layers of meaning, where denotation express what is being depicted and the connotation express the values and ideas of what is represented (van Leeuwen 2001). This view has some scholar of the likes of Barthes within its supporter. He thought, for example, that there is not any encoding/decoding function within the denotative layer because our object recognition originates from some form of "*anthropological knowledge*" (Barthes and Heath 1977, 37). While appealing, this description seems tip-toeing around the subject, explaining a significant feature of the perception process using a fuzzy concept which it

is only grounded in itself. We stand instead with the definition given by Hjelmslev (1963, 114) of a "*semiotics whose is expression plane is a semiotic*" (Figure 20), so a function that relates the content of a signification to the expression of a further content.

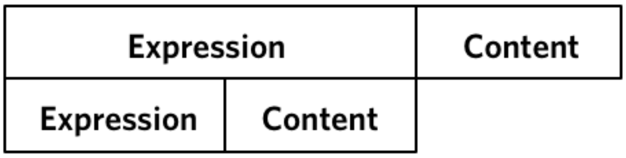

Figure 20. Semiotics whose is expression plane is a semiotic.

A Connotation is just another type of sign function such as the denotation, but it uses an already established sign-function as content. Connotations are founded only on code convention and time-wise are less stable than denotation, because their duration is influenced by the stability of the convention itself. However, when established a connotation is stable functive of a sign-function.

Hjelmslev's connotative definition clarifies the field from equivocal dichotomy such as "univocal" vs "vague" or "referential" vs "emotional" which stemmed from Barthes' definition, leaving the focus to the structural relationship between the two process of signification (Eco 1976, 56). Nevertheless, a connotation could easily link some values and emotions to a certain physical object, but it is important to underline that it is not its primary function, and it is not limited to these types of relationships.

4.4 Conclusion

A theory of Semantic Marks can help us understand how the recognition, and the differentiation between entities works. The model provides a combination of bottom-up and top-down approach to the problem of perception, relying on both the factual and collective perspective of our understanding of reality. It expands on the theory of code production and meaning creation, overcoming the recourse to an oversimplified diagram. Moreover, the usefulness of the proposition stands in both its integration with diverse theoretical stances and its functional perspective, which allows a description of the process in its core terms while sketching the different entities in play and their role in the phenomena.

Furthermore, the use of a communication model as a base for the JCMI allow us to avoid the referential trap, which tend to mask the processes behind the selection of the reference. We would like instead to focus on both parts of denotation, shedding some light not only on the connection between a reference and a referent but also on the selection of the percept that allows the reference to exist in the first place. That is the reason behind our emphasis on the perceptual process.

5 On art and identity

"*When we concentrate on a material object, whatever its situation, the very act of attention may lead to our involuntarily sinking into the history of that object*"

— Vladimir Nabokov, *Transparent Things*

5.1 Introduction

The Jakobson's Cultural Model of Interpretation (JCMI) shed some lights on how we use sign-functions in our everyday life to assign meaning to cultural content. As mentioned in section Cognitive Type the structures we create when perceiving something new are not limited to physical objects, but they help frame situations, scenes and gesture in our everyday visual experience. The framing of the visual can be, moreover, transmitted culturally, becoming part of a newer generation social structure. The sign-functions become themselves part of the canon of production of the cultural practices which distinguish a social arena, specifically becoming intrinsically part of the code that is necessary for the communicative process that each cultural product implies. The interpretation of a practice or of its products, as well as its characterisation within a historical period, relies on the comprehension of these sign-functions.

In order to discuss the application of JCMI we will analyse its potential and limits throughout the lenses of the figurative domain, focusing on its integration with the art historical tradition. The choice was due both for its clear focus on the visual and the history of representations, as well as the presence of a large amount of scholarly analysis that offered us some of the finest thoughts on the subject, thanks to the significant works by Warburg, Panofsky, Gombrich, Arasse and other scholars.

5.2 Imago

The use of CT and SM results in a formalisation over the creation of visual representation. Due partially because of a social normalisation process, and partially because of the communicative intent of the image, the effect is a series of formal structures used for representing tangible physical entities or intangible concepts.

This formalisation should not lead the readers to assume the existence of a series of homogenous representations, which it is certainly not the case. However, even if the differences are conspicuous, the likeness in the way a scene, a character or a gesture is depicted is evident. This likeness is the result of the derivation of the CT from the visual experience, but the similarities in the way of depiction can be traced equally to the ability of the viewer, committer and artist to agree and recognise a particular entity on the base of an internalised schema (the CT of it), as well as on a specific visual vocabulary.

The presence of similarity but the lack of homogeneity between two images implies the existence of a multiplicity of instances which even if not formalised are unconsciously recognised by agents coming from diverse disciplinary backgrounds.

The problem is specifically compelling in heritage where the multiplicity of the instances in relation to a (proto)type is an established issue which has puzzled many for so long. The digital shift has further muddled the problem, because in the digital domain we face such challenge not in relation to a small set of image, but at scale. The issue of unity and identity, if not formally expressed can, in fact, affect the retrievability and clusterisation of the data.

In order to illustrate the complexity of the problem, we examine the figurative art domain, focusing on a famous subject of Eastern and the western art who can help us frame the problem: Saint George (Fig. 21).

Figure 21. Painting of Saint George in the church of Panagia Phorbiotissa in Asinou, Cyprus.

Briefly, the legend state that St. George was a soldier in the reign of Diocletian who, after declaring his belief in Christ, was tortured. The listing of the torments is quite long, and includes being pressed into a box pierced with nails, impaled on sharp stakes, has his head crushed by a hammer, lacerated on a wheel of swords, cut into pieces, tied on an iron bed, and others. However, thanks to the intervention of God, George survived all of the tortures and deaths, and in doing so converted many individuals to Christianity (Didi-Huberman 1994).
The visual representations of St. George draw from this very legend and use these stories for visually representing his passion. Spanning from the sixth century to this very day, the representation of St. George depicts him as a haloed beardless knight in various poses and scenes. Initially painted standing in his military attire (Fig. 22), it was later represented in diverse scenes such as the laceration on the wheel, the resurrection of the dead and the destruction of idols, which are strongly linked to his biography and his legends (Busine and Sellink 2015).
While currently, the most widely known iconographical type is "St. George and the dragon", which portray the saint slaying a dragon and saving a princess, it was only from the 10th century that he started to be represented on a horseback killing a dragon. Initially, no princess was involved, if not in a unique case and in a very different role, as in the church of Panagia tou

Figure 22. Virgin between Saint Theodore and Saint George, Monastery of Saint Catherine, Sinai. VI Century.

Figure 23. Detail of altarpiece of the Virgin and Saint George: martyrdom of St. George (breaking wheel and rack) by Lluis Borrassa. Vilafranca del Penedes, Barcelona around 1390-1400.

Moutoulla, Cyprus, where the saint killed a crowned woman with the body of a snake (Stylianou and Stylianou 1985). It was only in the 12th century that the laceration on the wheel and the other torments started to get replaced by the rescue of the princess. The origin of this iconographical type can be traced back from a Georgian manuscript dated 11th century, and it is, indeed, in Georgia that we can detect the first representation of St. George saving a princess from a dragon (Walter 2003).

Figure 24. Horus on horseback. Louvre, Paris

It is important to underline at this point that the depiction of St. George slaying a dragon did not have any privileged uniqueness because several other characters were famous for slaying dragons (Garry and El-Shamy 2005, 73). A reasonably similar example would be Horus on the horseback, a small sculpture which depict the Egyptian god Horus (Fig. 24) about to stab the deity Setekh/Set, the Egyptian god of the desert, who adopted the form of a crocodile to escape his nephew (Busine and Sellink 2015). Within the catholic context instead, quite many

Figure 25 St. Michael. Folio 195 recto, Très Riches Heures du duc de Berry.

Figure 26. Icon with St. George and the youth of Mytilene. Mid 13th. British Museum.

were the saints who slew a dragon. The most famous ones are St. Andrews, St. Matthew and St. Philippe, St. Michael (Fig. 25), but they are not the only privileged ones, and many more can be listed.

In the history of representations many are the works of art depicting Saint George, with very different perspectives, stories, characters and stylistic choices. The whole list of these representations appears to be linked to one another, but what is the common denominator between them? How can we link these interpretations together and talk about them as a whole? How do we determine identity?

5.3 A proposal for analysing and encoding visual similarity

The identification process, and the detection of the sameness between the diverse representations, involve the recognition of the Semantic Marks of the object and the performance of similarity-based inferences towards a CT on the base of the criteria outlined in section Semantic Marks.

Particularly, the recognition of the known is based on the same norms we use for detecting the closeness and the sameness of visual representations, and therefore make inferences about their relationships and the attribution to the same CT. Topological, Feature, Value and Alignment information are the sets of identified signals that we use for comparing SMs on the base of their dimensional value (*N*) in a specific System, where the latter is a topological, value, feature-based or alignment-based reading of the visual representation.

The collection of images of St. George presented in section 5.2 can help us explain this process, examining the significance and use of SMs for the recognition and interpretation of visual items. Taking a look at one of the representations of St. George by Tintoretto (Fig. 29) we recognise a series of SMs which, as previously mentioned, we use to interpret the image as a portrait of St. George. For each of the representation of the saint we use the same criteria, using the SMs for defining who is St. George. However, we cannot immediately define what are precisely the identity conditions that a hypothetical visual configuration of point and lines needs to have in order to be alike to all the other St. George representations. We are aware, from JCMI, that a visual object is interpreted on the base of the code used by the Creator. Moreover, we recognised the fact that the Interpreter needs to reconstruct this Code in order to grasp its original meaning. This process does imply the existence of a "bridge" which could be crossed in order to define the substance and elements used in the Code and, therefore, pinpoint, more or less precisely, the SMs used for the interpretation of specific visual work. The same bridge can help us understand the sameness between diverse representation, and how they fit within the JCMI framework.

Our analysis cannot begin with the examination of the degree of likeness of a representation in respect to a Physical or a Situational Type, because such types are not so universal. As a result, we would not be able to proceed any longer. What could instead be done is an identification of shared SMs and a calculation of the degree of similarities between representations, defining the CT on the base of the representativeness of the characteristics in a set. In order to proceed down this road, we will need to reuse the four similarity dimensions outlined in section Semantic Marks: Feature [F], Alignment [A], Topology [T] and Value [V].

Figure 27. Particular of the Paumgartner altarpiece depicting St. George. Albrecht Dürer, c1500.

Figure 28 St. George. Donatello,1415-1417. Bargello Museum.

W e will start by taking a look at Fig. 22 and 21. We can immediately notice the diversity in the way of

Figure 21. Painting of Saint George in the church of Panagia Phorbiotissa in Asinou, Cyprus.

Figure 22. Virgin between Saint Theodore and Saint George, Monastery of Saint Catherine, Sinai. VI Century.

depiction, which is due to the historical gap present between the two images. Nevertheless, some common SMs are recognisable, and we can still use them to identify the characters.

From a Feature perspective [F] we can distinguish the presence of the same type of hair and halo, while from an Alignment perspective [A], the two faces appear quite similar.

For each of the representation the set [F] + [A] identify a set of signals which are initially interpreted on the base of their similarities with the CT of Saint George.

The same type of analysis can be done between St. George in Asinou (Fig. 21) and the famous St. George of Tintoretto (Fig. 29). These two paintings come from a very diverse period and tradition, however, we can recognise the presence of shared Features such as the Horse and the Spear. From a Topological perspective [T] we notice that the spear is connected to the hand (touch), and the cloak flutters towards the back of the horse (proximity). From a Value perspective [V] we can identify the same colour value for the horse (white) and the trousers/breeches (red) of the saint.

It is interesting to compare the St. George of Tintoretto (Fig. 29) with a miniature from the follower of the Masters of the Gold Scrolls (Fig. 30). We can quickly notice that they share many Feature information [F], specifically the horse, the princess, the dragon, the spear, the cross and the castle. Topologically speaking [T], they both portray the spear in the hand of the saint (touch) and the spear entering the head of the dragon (overlap). From the Value [V] perspective they share the same colour for the horse (white) and of the saddle (purple). The dresses of the two princesses can be linked. Both, in fact, wear a long purple dress. This analysis could be endless, so we should finish off our sample with a couple more representations, leaving it as an example of a methodology more than an extensive examination of all the saint depictions. Probably, the best way to continue would be to distribute the value made explicit above, together with new ones from other representations, in corresponding tables (Table 1, 2, 3). Such configuration would immediately show us the richness

Figure 29. St. George, Tintoretto. 1543-44.

Figure 30. St. George on horseback fighting the dragon. Fol. 8r: miniature, MMW, 10 F 11. The Hague.

and use of certain characteristics.

While this procedure is doable for the Feature, Value and Topology, it is not adapted to the alignment, unless we have clear dimensional information in respect to the physical object. Within the domain of digital images, methods to achieve such result are available, and we should reference the reader towards implementations (Manuel et al. 2016; Lo Buglio et al. 2013) that, if grounded in JCMI, would greatly enrich our analysis. What we can provide here it is just a mere substitution, a simple visual side-by-side comparison of the representations (Fig. 31), but better solutions should be implemented.

Figure 31. Particular (head) of Fig. 22, 21, 28, 26.

As showed by Table 1, 2, 3, it is possible to isolate the differences as well as the shared characteristics between the depictions of the saint. We could use the comparison and the recording of the information to express the weight carried by specific Feature, Values, Alignment and Topological information in the identification and understanding of a representation.

Table 1. Feature space.

ID	Element	Fig. 22	Fig. 21	Fig. 29	Fig. 30	Fig. 28	Fig. 27	Fig. 26
f1	Spear	No	Yes	Yes	Yes	No	Yes	Yes
f2	Horse	No	Yes	Yes	Yes	No	No	Yes
f3	Dragon	No	No	Yes	Yes	No	Yes	No
f4	Cross	No	No	Yes	Yes	Yes	Yes	No
f5	Halo	Yes	Yes	No	No	No	No	Yes
f6	Princess	No	No	Yes	Yes	No	No	No
f7	Castle	No	No	Yes	Yes	No	No	No

Table 2. Quality value space.

Quality	Fig. 22	Fig. 21	Fig. 29	Fig. 30	Fig. 28	Fig. 27	Fig. 26
Whiteness of the horse	No	Yes	Yes	Yes	No	No	Yes
Redness cloak	No	Yes	No	No	No	No	Yes
Purpleness woman dress	No	No	Yes	Yes	No	No	No

Table 3. Topological space.

Topology	Fig. 22	Fig. 21	Fig. 29	Fig. 30	Fig. 28	Fig. 27	Fig. 26
Spear - Dragon	No	No	Overlap	Overlap	No	No	Yes

Hand - spear	No	Touch	Touch	Touch	No	Touch	No

Taking into account only the features, we can easily say that "feature 1" (*f1*) is present in *n* representations, while "feature 5" (*f5*) in a smaller set.

f1 = {21, 29, 30, 27, 26}
f5 = {22, 21, 26}

This procedure, if systematically done, could easily demonstrate the evolution of the Semantic Marks used for the Cognitive Type of a specific representation, or its stabilisation into a Nuclear Content.

The above analysis focuses on the similarities from a physical perspective, but the role of situations is equivalently important. When diverse iconographical types are seen or discovered, we frame them based on recognised similarities and situations, in the form of possible relationships between elements in the visual field. What is important to underline is that the value of the possible relationships within a situation is defined by motifs, themes and other narrative-type elements. St. George is again a great ally in making this mechanism explicit. The case of the saint saving a princess is typically related to a particular motif, which is the one of the "*knight saving a princess*".

The motif/theme of the warrior which save the damsel has been used vastly during the centuries, becoming part of the canon, and that is the reason why we so easily interpret the painting. The composition of this motif is well known and involves between two or three characters: a warrior, a beast and a woman. When we perceive these elements together, we quickly provide a reading of the representations based on the CT of the situation of "*knight saving a princess*". The very proof is the easiness we have in classifying and interpreting the presence of the woman in the St. George painting not as an ancillary character, or just an external observer, but as the one to be saved from the threat of the beast. The interpretation of her role is not given by the title, or by the formal analysis of the composition, but just by her identity as a woman, and specifically, the identity of the archetypical woman in the narrative of man vs beasts.

As mentioned above, the possible relationships between the elements of the depiction are defined by this narrative. Consequently, we would have trouble understanding specific configurations such as the woman who saves the man from the dragon, or the dragon who saves the woman from the man, or vice-versa. That happens because particular values in a situation type can be considered true only in respect of the possibility of being true in the hypothetical development of the situation itself.

This framing is not limited to the visual analysis, but similar types of reading are fairly used as recognisable narrative structure in folktales, where very much work has been dedicated to their formalisation (Thompson and Leach 1957; Aarne 1928; Uther 2004) , and undoubtedly employed in all the other types of narratives we tend to construct every day.

5.4 Theoretical analysis and contextualisation

The analysis outlined in 5.2 is conceivable thanks to the human tendency to treat images as communication devices or communicative actions, thus favouring the harmonisation of their elements in order to deliver a message or merely be aesthetically comprehensible by a reference public.

The tendency is autonomous from historical development, but that does not mean that historically such standardisations have not consciously taken place, or have not been consciously fought. Speaking about the tendency towards the harmonisation of the expressions it is not equivalent to declare that we depict things in precisely the same way, but rather that we lean towards the use of the same elements/constituents to deliver the same type of significance. Hence, the illustration of these elements can be somewhat different, but they would still express the same content. These constituents of the image are exactly the same as the ones we use for the interpretation of the visual (as seen in section Semantic Marks), a process that, as we amply discussed before, relies on the re-use of visual feature to make sense of our reality. We mention before that sometimes the process of choosing specific features to deliver significance is conscious; it is the case of some historical periods in the Eastern and western artistic tradition.

In the Eastern tradition, the Byzantine Art is the period which probably is the most easily associated with a formalisation of the Christian imagery. The standardisation of the Byzantine iconography was due partially by the belief that an accurate depiction of a saint bridged time and space and connect its viewer with the prototype (the holy person depicted), as well as by the belief of the explanatory role of the images for the less literate population (Corrigan 2008).

While the latter argument is easy to grasp, an explanatory role require standardisation for the recognition and, therefore, style and themes should be carefully chosen in order to deliver the original message, the Byzantine Art image theory is a bit more complex and requires few more words to be fully comprehensible.

It was assumed that a Byzantine artist, when creating a religious image was not only driven by their artistic capabilities but inspired by divine force which allows him to establish a life-like imitation of the holy person depicted. It follows that any religious image in Byzantine art was by definition an accurate copy of his prototype. The accuracy between the prototype and the image had to be strictly kept and needed to be transferred from one image to another throughout a laborious copying mechanism. Adherence to tradition and its authority was imperative, and

innovations and new expressions had to be avoided (even if that was not always the case). A depiction had to be reduced to its essence, avoiding superfluous details which were not essential for establishing the likeness of the depiction to his prototype (Brubaker 1999).
While the modern viewers would probably have some doubts about the "true-to-life" experience of such type of bare depictions, there is no doubt that the Byzantine themselves considered them accurate portraits. The viewer position in the accurate/not-accurate argument it is only due to differences in expectations. The modern reader would, in fact, value the likeness in respect to its illusionistic nature, while the Byzantine viewer would value the ability to recognise the holy figure represented from a range of sign, such as the clothing, attribute and portrait type. The role of these features was to make a statement about the saint, because attires, age, and presence of attributes were very important for their recognition, but were also function to the class of saints. Bishops and monks, for instance, were often portrayed as old, with white or grey hair, while doctors and soldiers were shown younger. The attributes were used to define the category of saints to which an individual belonged. The focus on the category explains why Byzantine artists did not develop an extensive collection of iconographical attributes for each specific saint. The character depicted, unless part of the few Byzantine saints who had their own personal attributes, were recognised by the inscription and differentiated using variations in colour arrangements of beard, hair or facial features (Maguire 1996).
The Byzantine image theory had the consequences to confine the stylistic innovation under the rigour of the religious debate, and to consciously choose a correspondence between significance and visual, which led them to create and maintain a very specific visual vocabulary.

In the western tradition, the formalisation of the elements in visual representations had a significant impact in the Renaissance art, where, thanks mainly to a rediscovered sensibility for the Roman and Greek period, artists and patrons were feeling the need of having a standardised and understandable canon of images, an easy instrument to get inspired and follow the design and conception of new work of arts (Maffei 2012). While the need was, indeed, general, there were certain specific tasks, for instance the representation of identifiable intangible concepts such as Love or Fortune, which would benefit greatly from such formalisation. The illustration of these abstract ideas had to be done throughout the use of substitutes for the abstractions, such as symbols or personifications. The use of these visual devices as embodiment of concepts and ideas, however, would also fulfil the communicative purpose of an image, providing the viewer with a possible reading of the scene. In order to do so, these figures should be acknowledged by the highest number of persons. Achieving such goal required a figurative normalisation in accordance to specific models. It is bearing this prospect in mind that in the 16th centuries manuals like "Le imagini colla sposizione degli dei degli antichi" (Cartari 1556) and "Mythologiae sive explicationis fabularum" (Conti 1567) started to appear. A major milestone in this direction was the publication of Ripa's Iconologia (Ripa 1603) in 1593. This work covers over 1200 personifications, comprising an extensive collection of visual representation coming from both classical and contemporary works of art. Ripa's book reported on not only visual representations (added only in the 1603 edition) together with the designated meaning, but included a detailed description of how they should look and why they should be depicted in that way. The impact that Ripa's Iconologia had on his contemporaries, as well as on artists in the later centuries, was remarkable, and started to lose its importance only with the advent of realism (van Straten 1994).

The impact of Ripa's Iconologia was not only to be searched on the standardisation of types and composition, but on the influence that those standardisations had on the western-based vision of art. Art historians become used to employ a type-based thinking for their studies as well as heavily applied prescribed literary sources for their figurative reading, and "With Ripa in hand art historians—initially Émile Mâle (1932)—were able to decipher hundreds of allegorical statements in paint and stone, guided by this alphabet of personifications" (Bialostocki 1973, 530).

The method was so universal that many finally become "hunters of prototype", famously criticised for leaving matters there and not explore the matter further. The practice of searching for a prototype has built the foundation for the creation of a prototype-based framework of understanding which comes close to part of the theory outlined in chapter 4.

While the hunting of the prototype has been seen as an infatuation from which many fortunately have recovered, it also helped deliver a methodology which, even if criticised (Camille 1993), has not yet found a real challenger or an alternative (Mitchell 1994). We are talking specifically about the work of Panofsky, which help found the discipline of art history as we know it now, and it helped investigate those visual cues which we use to identify representations. In his work Panofsky (1939) outlined a method for reading a work of art which required the distinction of an artwork in three layers:

- The primary or natural subject matter, which identifies pure forms such as a configuration of lines or representations of an object, which could be called the world of artistic motifs. The collection of these motifs pertains to the pre-iconographical description of a work of art.
- The secondary or conventional subject matter is the assignment of theme and concept to the composition of artistic motifs, which are recognised to be the carrier of a conventional (how specific themes and concepts are usually depicted in the visual arts) meaning. The subject(s) of a representation are identified in this layer thanks to an iconographical analysis.

- The Intrinsic meaning or content is the interpretation of "the work of art as a symptom of something else which expresses itself in a countless variety of other symptoms, and we interpret its compositional and iconographical features as more particularized evidence of this 'something else' " (Panofsky 1939). The intrinsic meaning defined by how cultural-historical developments are reflected in a representation and such meaning it is displayed independently by the willingness of the artist, who can be completely unaware of it. In a later stage, Panofsky called this phase the iconological interpretation.

Panofsky assigned to the diverse subject matter/content different type of analysis (Table 4) that would help art historians in their interpretation and discovering. Following his methodology, the signs are identified during the pre-iconographical phase throughout the identification of a specific artistic motif and act as formalised atom of a bigger structure. This step was also identified by Barthes for the analysis of visual images. Barthes called this immediate visual impact, which defines the primary subject matter, the denoted meaning of an image, and the process where it originates, denotation (Martin and Ringham 2000; Polidoro 2008; van Leeuwen 2001).

OBJECT OF INTERPRETATION	ACT OF INTERPRETATION
Primary or *natural* subject matter — (A) factual, (B) expressional—constituting the world of artistic motifs.	Pre-iconographical description(and pseudo-formal analysis).
Secondary or *conventional* subject matter, constituting the world of images, stories and allegories.	Iconographical analysis.
Intrinsic meaning or *content*, constituting the world of 'symbolical' values.	Iconological interpretation.

Table 4. Panofsky's Scheme. Source: Studies in Iconology (1939).

The second act of interpretation is the iconographical analysis, which requires specialised knowledge, and the use, in this case, of vocabularies of forms in order to describe the content of the image. These vocabularies do not have to be external resources, but they easily can be embedded in our knowledge repositories and inherited in a social arena (see (Bourdieu 1977; Lemonnier 2012) for a theoretical treaty on the subject). The recognition of the meaning of the image is based on the identification of the diverse signs incorporated in the image usually consisting of sets of attributes and characteristics.

The combination of these attributes, such as objects, plants, animals or other icon/symbols, help identify a personification/characters in a specific situation/narrative in a work of art. Attributes can also help identify certain qualities (for instance kindness, rage) of the depicted character, or his belonging to a distinct group (such as blacksmith, noble or saint). The use and harmonisation of this combination have helped to create iconographical types and defined archetypical situations, providing the tools for the identification of diverse types of representations (Polidoro 2008; van Straten 1994).

Following the iconographical analysis, Panofsky introduces the iconological analysis which comprises the socio-historical interpretation of the symbolic value of the painting, which is part of a bigger cultural visual history and it is not a conscious process for the author. The indeterminacy of the symbolic values has been debated by some member of the art historical community because in certain instances the use of symbols was, indeed, driven by the author's intention (as frequently happened in the 16th century Dutch art for example).

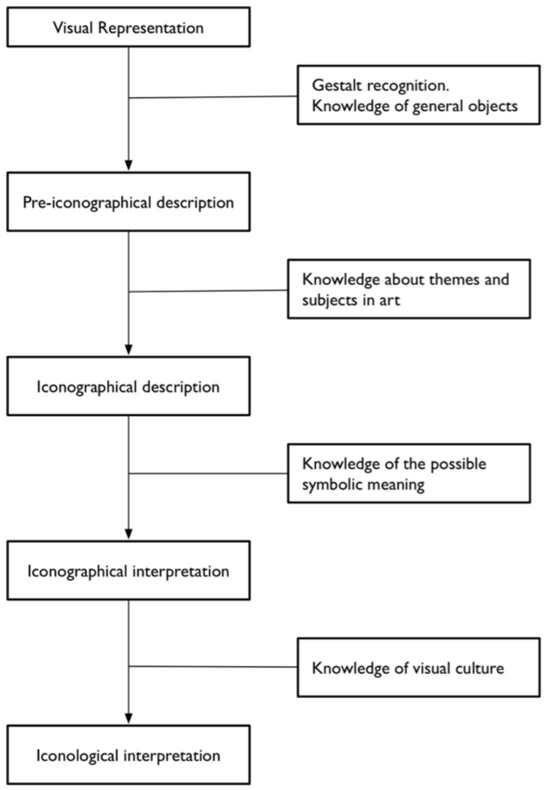

Figure 32. van Straten re-elaboration of Panofsky's schema.

In order to overcome these issue, van Straten proposed a revised schema (1986), which does not challenge the first pre-iconographical phase of analysis but re-establish the parameters for the identification of the secondary subject matter and the intrinsic meaning. van Straten proposed to divide the iconographical analysis in iconographical description (second phase) and interpretation (third phase) (Figure 32).

The iconographical description is described as the analytical phase where the subject of the representation is established (for example "St. George and the Dragon"), but not deeper meaning is searched for. In this case, we can attribute an iconographical description to all the works of art, in contrast with the analysis of Panofsky, which recognise the possibility of assignment of a secondary subject matter only to a limited set of works of art (landscape, for example, could not be iconographically analysed).

The role of the iconographical interpretation is instead to examine the explicit use of symbols by the artist, and formalises the deeper meaning of a representation. The fourth and final step of van Straten's analysis is the iconological interpretation which aims to describe the symbolic values which are not explicitly intended by the artist but are part of the visual culture of that

social and historical milieu. These unconsciously used symbolic values can be analysed historically and ethnographically and not only from an art historian perspective.
The iconographical interpretation as used by both Panofsky and van Straten adds a new meaning level to a representation, the connoted meaning. If the denoted meaning previously introduced is about the object as expressed by form, the connotation is an interpretation on the base of the socio-historical analysis of the symbols of an image (Martin and Ringham 2000; van Leeuwen 2001), making it closer to the iconographical interpretation.

5.5 Integration and connections with theoretical stances

It is paramount to harmonise the art historian interpretative theories outlined in section Formal Analysis with the one expressed in chapter 4. In doing so, we follow Eco's suggestion that iconography and iconology can be considered a fully formed chapter of semiotics (Eco 1979), as well as the thought of some other art historian who has noticed the congeniality of the analysis of Peirce and Saussure with the study of Riegl, Panofsky and Schapiro (Bal and Bryson 1991; Mitchell 1980).

Panofsky's methodology, and the revised version proposed by van Straten, can be easily integrated with our theory. The study of the phenomenology expressed in chapter 4 resulted in a framework for understanding the meaning assignment in visual representation, which is universally adaptable to the visual sign. Panofsky, on the other hand, does not propose a framework for the meaning assignment but a methodological path to follow in order to discover the meaning of an artwork. The likeness of the two methods is to be seen on the profound belief in the importance of the visual cues as well as on the significance of the viewer's knowledge during the interpretation process.
The two methods should be then seen as complementary, where the phenomenology formalise the relationships between the percepts and the formulation of the interpretation in respect to it, while Panofsky's methods provide a path for the reading of a work of art, defining the propositional assumptions of a viewer in relation to a visual representation. The division of the assumptions in layers of meaning is hypothetical and just a formal way of proposing a reading, which Panofsky uses in his attempt to eliminate subjective distortions. The various phases identified can be mapped with the JCMI (Table 5). Such mapping makes even more evident how the pre-iconographical and iconographical descriptions are nothing else than the determination of the Cognitive Type on the base of the Semantic Marks identified in the representation. The "*knowledge of themes and subjects in art*" that is required to pass from the pre-iconographical to the iconographical description is a mere analytical step which does not has any correspondence in the visual understanding of an object. The CT is going to be identified based on the SMs on a Contact. In this case, we have a set of Semantic Marks which identify an iconographical type, moreover, in a familiar Contact: a canvas. There is no possible way that, having already a fixed structure for such CT we would split the process in two and determine first some visual cues and

then others. The greatness of the visual would not allow us to make this stance, if not only the visual representation would have been shown to us only in details and not in its greatness.
The division seems to be just a residue of the diversity between formal and figurative reading in art history.

OBJECT OF INTERPRETATION	ACT OF INTERPRETATION	JCMI
Primary or natural subject matter — (A) factual, (B) expressional—constituting the world of artistic motifs.	Pre-iconographical description	Determination of Cognitive Type on the base of the Semantic Marks identified in the representation
Secondary or conventional subject matter, constituting the world of images, stories and allegories.	Iconographical description	
	Iconographical interpretation	Connotative Reference based on literary sources
Intrinsic meaning or content, constituting the world of 'symbolical' values.	Iconological interpretation	Abduction Inferencing

Table 5. Mapping between van Straten and the interpretation process according to JCMI.

The Iconographical interpretation is reflected in the construction of a denotative meaning over a denotative expression. The reason why this step is separated from the two above is that we can easily discern what is denotative and what is connotative in our daily experience, even if there is a strong tie between the two. The iconological interpretation does not find any correspondence in our theory of perception because it regards mostly the construction of a correlation network based on previously discovered results. The result, an interpretative correlation theory, do not concern us, but the domain of abductive reasoning.

5.6 Perspective

The theoretical stance above it not only aimed to clarify how we identify and interpret visual messages, but it could be used to define a set of principles that could guide the deployment of an information system able to correlate the symbolic and social nature of diverse visual representation. The denotative and connotative content could be, in fact, easily studied throughout space and time, to unveil social types and influences in the symbolisation of specific artefact or phenomena. An examination of the pair denotative-connotative would overcome the drawbacks of the current information methodology which only appears to handle an initial denotative layer of meaning and, for as much as useful as they are, they do not appear to help us discover something new about our past, but they act as descriptive algorithm and substitute for a human-based work. While this is acceptable in order to classify something, it does not help us lay the ground on further exploration of the cultural dimension, because the object of investigation is always the form and not the semiotic function.

The use of the SM theory for computation purpose would instead significantly help in this challenge. We can easily imagine, and deploy (at least with an initial human effort), systems able to link denotative and connotative content in a data-vector where for every object there a set of SMs organised as an array comprising spatiotemporal information associated with the denotative and connotative content. Such scenario would be driven by the SM theory but adapted to a computational environment. A Semantic Mark would be, therefore, replaced with a computational routine that, while reproducing the SM's characteristics, would keep intact its function in relation to the visual field. Images, for instance, comes in the form of pixel values, where each pixel as a set of coordinates (*x,y*) and carries specific information (RGB for example). The percept, in this case, would have to be identified using these kinds of elements.

The common Machine Learning pipeline tests the presence or absence of edges in images, check their arrangements in motifs and assemble them into larger representations that correspond to familiar objects. The task is achieved thanks to an initial labelled data set which act as a baseline for the final classification (Lecun et al. 2015). This methodology is flexible enough to be modified in order to associate for each vector data describing a denotative layer additional connotative and spatiotemporal information. In such a way, we can easily imagine the development of several informative layers for each of the object analysed. The result would a set of vectors such as the one in Figure 33 where to each value is associated an *object id,* an *SM*, a *place*, a *time*, a *denotative* dimension, or a *connotative* one.

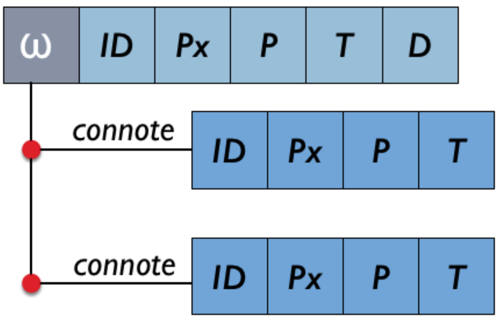

Figure 33. Possible type of connection in a data-vector.

In order to have a multi-actor perspective, we need to rely on exact grounded information. This task can be achieved only by a multidisciplinary effort taking into account the heritage scientist requirements and computer scientist capabilities. The necessary ground for further exploration of the subject should be laid down, in order to start describing and share data and information about our heritage, specifically in regards of the diverse levels of visual information which can be extracted from our current sources. The importance of the creation of grounded information should not be overlooked because is the key to such discourse. Only with this type of remarkable effort a real exchange would be achieved because without a solid foundation there would be no possibility of exploring the incredibly vast dimension which is the visual culture. To reach this result, it is essential to rely on tools and methodologies able to take into account a semantic and distributive data system relying on a shared framework for describing the diverse levels of visual interpretation.

6 On existence and models

"*Man is an animal suspended in webs of significance he himself has spun*"

— Clifford Geertz , *The Interpretation of Cultures*

6.1 Introduction

The process of identity attribution in chapter 4 and 5 shed some light on how we classify visual objects and how we link instance to type using perceptual information. However, if we want to use this theory within the digital domain for gathering and harmonising information about the diverse visual interpretations of our heritage, we need to do a step further. In order to achieve this aim, it is essential to find a way to correlate the symbolic and social nature of diverse visual expressions using a multi-agent perspective which would not only rely upon the denotative meaning of a representation but would integrate diversity in respect to the framing and the granularity of information. Such type of approach, however, raises the challenging issue of the formal integration of heterogeneous percept's descriptions.

A standard solution to this problem is the creation of a pre-established frame that specifies the way and manner of the documentation of the object, providing a unique and correct description of its object by creating language and domain-specific constraints, which, however, limits the semantic expressivity of the information. While this approach is functional with respect to the context of a field with an agreed viewpoint, it does not represent a fundamental solution within a complex domain such as the visual heritage.

In order for this integration to take place, it is necessary to develop a foundational layer that through the exploration of the conceptualisations expressed in the broad domain of discourse and divorced from linguistic and accidental can take into account the general conceptualisations common across the domain at the categorical level. It is necessary to discard the notion of a final classificatory system and, rather the attempt to deploy the new more flexible understanding of categories developed in the past years. Finally, this work would have to be expressed in a formal language separated from particular linguistic expression or closed domain expressions.

In the following sections we will see how it is possible to formalise our information in a shared and computable form, independently from its linguistic ambiguity and structure and we will present and test a solution for sharing visual information over cultural object presenting a new ontology call VIR in section VIR.

6.2 Ontology

It has been clear that the grounding of multi-actor perspectives in respect to the visual information needs an ontological layer to map statements to, and it appears that CIDOC-CRM is the perfect platform for developing such ontological extension. Before delving into the explanation of the development of a new ontology, it is paramount to tackle some problems in relation to the existential and identity commitments which should be at the base of the development itself.

We will see in section 6.2.1 and 6.2.2 how such metaphysical commitments are essential for defining the expected behaviour of the entities within a complex environment.

Finally, in section VIR, we will translate the theory in chapter 4 and 5, as well as the existential and identity commitments in section 6.2.1 and 6.2.2 in an extension of CIDOC-CRM called VIR: VIsual Representation. Additionally, in order to provide not only with an explanation of the classes of VIR, but present the reader with an example of the possibilities given by this new extension, a set of the information about the church of Asinou (section 3) have been mapped and formalised using CIDOC-CRM and VIR.

6.2.1 The clay and the statue

The process of identity attribution in chapter 4 and 5 shed some light on how we classify visual objects, and how we link instance to type using perceptual information.

What it is paramount of this theory is the clarification of the terms of the identity assignment, which is fundamental to face the material constitution problem in relation to visual objects. The material constitution problems are a series of ancient puzzles which are still debated today, and focus on the relation between matter and form, specifically questioning if constitution is an identity or not.

One of the most important puzzles, and surely the most interesting for us, is the "Puzzle of the Statue and the Clay". To illustrate: imagine a sculptor taking an unformed lump of clay, and sculpting it into the form of a statue of the biblical King David. It would seem that the sculptor has brought something new into existence: the statue. However, it also appears as the lump of clay still exists. It is tempting to say that only one entity is in the hand of the sculptor, however, temporal properties, persistence condition and kind differs. The lump existed before the statue was sculpted, and it could survive being squashed while the statue would clearly not. Moreover, the kind of the statue and the lump are very much different. The Leibniz's Law tells that, for any x and y, if x = y, then x and y have all the same properties. Thus, it seems that the sculptor is dealing with two entities, the lump and the statue, and not one.

The puzzle implies the possibility of spatially coincident objects, but it is considered a truism that two objects cannot coexist in the same space and time unless of course, they are the same. The most popular answer to this puzzle is given by the constitution view, which holds that the statue is constituted by the lump, but not identical to it. The two entities share the same matter and parts, and in virtue of this they are able to occupy the same place at the same time. Thus, constitution is not identity (Wiggins 2001).

However, following chapter 4 and 5 another perspective could be developed. We argue that two entities exist, but not in the same place and time. The lump of clay is a mass of substance, which can have many forms, but whichever the form it still retains its properties. The statue is the social object recognised by a person or a collective to reference something (the target of the reference could be unknown, but the relationship would still be valid) in respect of something else. The statue itself it is only the subject of an assignment of status. The fact that the lump of clay is recognised as coexisting with the statue is an error in placement. The object that the sculptor has in his hand is one and one only: a lump of clay. The shape of it has been the subject of an assignment of status, a recognition, which do imply that exist another entity, the statue, but it does exist only in the mind of the observer.

The assignment of status of the lump of clay is carried out on the base of its Semantic Marks, which are used to link it with a Cognitive Type. That is the reason that when a lump of clay has been destroyed, or cut in some piece, the statue ceases to exist. However, does it? Because if the statue is a social object, it will not really cease to exists unless we do not have any memory of it. If only a photo of it exists, together with a person able to recognise it, we could argue that the entity statue is still there. Therefore, social objects and material objects do coexist because social objects are an extension of the first and they exist as an extension of the physicality of material objects.

Moreover, the statue has been recognised as being the statue of David, but it would be still possible that another observer would not recognise it as such, depending on its level of knowledge over the artefact, or over the art.

Following, the lump of clay, now in pieces, could also be the subject of another assignment of status and recognised to be something else by another person. This continuous process could lead to several other status assignments, which they could even coexist socially with the first one.

6.2.2 The ship and the monastery

Another interesting puzzle of material constitution is the one of the Ship of Theseus. The original thought experiment: suppose that the ship sailed by the hero Theseus has been kept as a museum piece. Over time some of its wooden parts wore down and were replaced by new ones. After a while, all the parts had been replaced. Suppose that the planks that have been removed from the ship are preserved by a custodian and later put back together in the original arrangement. Which one is the Ship of Theseus? The copy or the original?

Following 6.2.1 we should argue that the new ship is the Ship of Theseus because it is socially recognised as such. The discourse does not change entirely with this paradox, but it does need a bit of refining.

The identity is still given by an assignment of status of the object displayed in the museum as the original. If all the parts have been replaced we can talk about a new materiality, but the identity of the Ship of Theseus was never under discussion because it is not given by the materiality, but to the social recognition of that parts as a gestalt called the Ship of Theseus. However, things become more complicated if we take into account that exist another Ship of Theseus collected by the custodian. In this case, we are faced with the concept of originals vs copy.

In this case, both the ships, if recognised as such, are the Ship of Theseus. In a society were mechanical reproducibility is a constant there is no problem into assigning the same identity to two different things which are equal. Two copies of the same edition of a novel, only printed in two different locations would still have the same identity even if the material used is coming from different batches.

The doubts could remain on the transitivity between the two objects. Although, also this one is a misguided issue because the two objects are the same only with respect to their social status, and not in respect of their materiality. Thus, the transitivity property it is still valid only in

respect to the social facts. Transitivity in respect to the materiality is impossible because the social status is grounded in two different material components.
The only remaining problem is just on the originality of the artefact. However, the originality attribute is only a social construct very much cultural dependent. The original artefact is nothing else than the one considered as original by the community of practice. It is an institutional fact and not a metaphysical problem. Chinese, for example, do follow different rules in respect of what is original and what is a copy. The latter is defined using two different concepts: Fangzhipin (仿製品) and Fuzhipin (複製品). Fangzhipin are imitations which are different from the original, while Fuzhipin are exact reproductions of the original, which, for the Chinese, are of equal value. Fuzhipin are not considered forgeries and not negative connotation is given to them (Han 2017).

Another good example of the problem original vs copy is the Grand Shrine of Ise in Japan. The shrine, thanks to a decree established by the Japanese Empress in 690 A.D., state that the shrine would be renewed every twenty years in a custom known as shikinen zotai. The practice did not stop with time, and nowadays the whole building continues to be constructed afresh every twenty years. The process follows the original plan, and each new building is a copy of the old one (Munjeri 2003). The material constitution of the shrine is not the original one. However, it is still considered the same shrine because its identity it is not given by its materiality.
Nevertheless, the sceptic could suggest that such line of reasoning would imply the possibility of the existence of several copies of an artefact not recognised to be forgeries or copies. If the only criterion for the recognition of something is to assign identity, how we can assert what it is true and what it is not?
The problem is, indeed, quite fashionable right now, because it can be easily applied to several domains. We can only suggest that the truthfulness or falsity of an information is given by its provenance and not by the fact that such information does exist. The original Ship of Theseus would only be the one recognised by an authoritative institution, which has put into practice procedure to define the scientificity of such work. In the case of memory institution, the museum would probably the one assessing the two ship and coming to an institutional decision, which in itself is a social fact.

6.2.3 A new ontology for encoding the visual: VIR

The work until now has been devoted to analyse and explain the phenomenology of visual classification, and finally in section 6.2.1 and 6.2.2 to provide answers to quite well-known metaphysical puzzles about the material constitution of an entity. The importance of this work stands in respect to the realisation of what and how things are observed as well as on what entities we make statements of. The unravelling of this process did not only aim to unveil how we develop social constructions, but it can be used to define the ontological constraints we need to assume when we computationally classify and make assertions about visual objects.
We will now translate the theoretical stance into a functional information artefact encoded as

an ontological extension of CIDOC-CRM called VIR: VIsual Representation
The name is, of course, not casual, because the scope of the ontology is the formalisation of the relationships between diverse visual representations and symbols that define our visual culture. VIR relies on the semiotic distinction between expression and content, as well as on an art-historical theoretical framework previously introduced for defining the inter-relationships between atomic elements that compose a visual item, defining, therefore, a set of criteria for the identification and clusterisation of figures in art. The objective of the initial development of the ontology was the recording of statements about a series of wall paintings present in the church of Panagia Phorbiotissa in the Troodos mountain, Cyprus.
In order to classify the statements about our use cases, we introduced eight classes (Character, Iconographical Atom, Attribute, Representation, Personification, Visual Recognition, Verso and Recto) together with twenty properties. We will introduce these classes and then use few examples to demonstrate their usefulness in the description and mappings of information about visual representations.
All the classes declared were given both a name and an identifier constructed according to the conventions used in the CIDOC CRM model. For the classes, the identifier consists of the two letters IC followed by a number. Resulting properties were also given a name and an identifier: the letter K followed by a number. Inverse properties share the same identifier, the letter K followed by a number, plus the character "i" (inverse) every time the property is mentioned "backwards", i.e., from target to domain (inverse link).
The following section will be dedicated to an explanation of the rationale behind the different classes and properties, explaining the reasoning and giving examples about their possible uses using the church of Asinou as the main case study. For each of the developed examples, we present an ontological mapping of the information using CIDOC-CRM and VIR. While initially done in RDF, the mappings have been transformed, for readability purpose, into graphical representation.
The purpose of these graphs is to provide to the reader an example of the applications of the developed ontology as well as display how the information present in just a small portion of a wall painting, if correctly described, can help create a rich-information environment that opens the doors to new ways to document a heritage object in relation to its functional and visual context. For an easy reading, we specify that the letter K and IC represent respectively the properties and the classes of the VIR ontology colour-coded in the graph in purple and orange, while the letter P and E, colour-coded in blue and green, represent the properties and classes belonging to the CIDOC-CRM ontology

The full ontology, encoded in Turtle, is available in the Annex A.

6.2.3.1 Analysis of VIR: classes and properties

6.2.3.1.1 Recognition and Representations

The very step taken while creating the ontology was the introduction of a way to sustain new relationships between the physical and visual domain declaring a new class, IC1 Iconographical Atom,

IC1 Iconographical Atom

Subclass of:	E22 Man-Man Object
Description:	A physical arrangement of forms/colours created by human activity which act as vehicle of a representation.

The substance of an Iconographical Atom is the one of a physical feature embracing an arrangement of forms/colours which are seen by an agent as a vehicle of a representation. Its identity is socially given and can comprise a part of a man-made or natural object, as much as the whole object itself. A set of Iconographical Atoms could be aggregated together, such as in an altarpiece, and be described as a unique structure. We saw before when talking about the "Puzzle of the Statue and the Clay" that the assignment of status of an object creates another entity, which is the social object we actually recognise and talk about. The recognition of an Iconographical Atom is derived by a status assigned within a specific type of observation, a Visual Recognition, that we define as:

IC12 Visual Recognition

Subclass of:	S4 Observation
Description:	The activity of assigning the iconographical status to a man-made object, or to one of its parts. It takes into account the possibility to link it to a speech act or a document where the authoritative proposition is clearly made.

A Visual Recognition is a specific type of observation which entails the assignment of status to a specific portion of reality using a fairly simple schema:

$person_a$	in	$context_z$
$person_a$	assesses	$object_x$
$person_a$	assigns	$value_y$

The above schema is the base of the interpretative act, and the only variable are the context, the classified object (Iconographical Atom) and the value assigned (Representation or Attribute). The class IC12 Visual Recognition respects and reproduces this schema, making it possible to describe, for example, the representative value assigned to an image by different art historians, thus enabling the system to keep track of the persons making the assessment over a specific object. Moreover, the use of such construct would help us record the set of features in a representation considered by a viewer more salient than others within an historical period. While we have seen that the internal knowledge for the recognition is given by the social classification of entities implied in the concept of Nuclear Content, we do want to specify, sometimes, the source used for carrying out the recognition. We re-use partially the relations (properties) that hold for S4 Observation, adding the source of outside knowledge which we used to complement our decision in respect of the recognition. We therefore declare:

K9 assigned status to (has status assigned by)

Domain	IC12 Visual Recognition
Range	E18 Physical Thing
Subproperty of:	P140 assigned attribute to
Description:	The property documents the assignment of status to a specific physical thing.

K11 assigned (was assigned by)

Domain	IC12 Visual Recognition
Range	IC9 Representation
Subproperty of:	P141 assigned attribute to
Description:	The property indicates the status assigned during the status assignment event

K10 On the base of (is basis for)

Domain	E7 Activity
Range	E89 Propositional Object
Subproperty of:	P16 used specific object (was used for)
Description:	The property describes the source used for the status

assignment.

The three properties above help us define the object under scrutiny (K9), the social object assigned to it (K11), and a source used for the assignment (K10). It is important to note that the class IC12 Visual Recognition is not intended to describe only recognitions made in a present time but could be used to model the recognition of a visual object in the past, such as the written interpretation of an art historian in the verso of a photo about the object depicted. In this way we would be able, for example, to model the diverse recognition of a painting by agents in a specific timespan and place.

We could have, therefore, an instance of IC1 Iconographical Atom acting as a hub of diverse visual interpretations carried out by different art historians which do not share the same knowledge on the subject or decide to diverge on the type of attribution (e.g. generic vs specific). As mentioned, an Iconographical Atom does not represent anything by itself but is the material container we look at when we recognise another entity. We described its essence in 6.2.1, and specifically how its properties can coexist with the one of its material containers, or how they can continue existing even without the original container. Therefore, if an Iconographical Atom is the object of an interpretation, and the conceptual understanding of what it is depicted (the Representation) is the result of an examination of the code of the representation used in the visual message, then a Representation cannot exist elsewhere than in the conceptual domain, because is the idea formed in the mind of the viewer when looking at the Iconographical Atom. Specifically, for most of the recognition events, it is an idea which is socially understood and it is part of the Nuclear Content of the object. However, there is no category for social objects in CRM, so we defined a representation as:

IC9 Representation	
Subclass of:	E36 Visual Item
Description:	A single pictorial item or a part of it. Single representations or region of the same representations are instance of this class.

The identity of the representation does not depend on a specific physical carrier and it can exist on one or more carriers simultaneously. It is possible to recognise a representation within another bigger representation, therefore, defining a representation with a part of it that is by itself a representation. We would be able to express with a partitive relation:

K20 is composed of (forms part of)

Domain	IC9 Representation

Range	IC9 Representation
Subproperty of:	P148 has component (is component of)
Description:	This property put in relation a representation with a part of itself.

Additionally, it is important to establish a further link between a physical thing and a representation, using a shortcut for the more fully developed path IC12 Visual Recognition assign (K9) to a E18 Physical Thing the status of (K11) IC9 Representation. We defined:

K1 Denotes (is denoted by)

Domain	E18 Physical Thing
Range	E36 Visual Item
Subproperty of:	P65 show visual items
Description:	The property documents the assignment of an iconographical object to a specific physical man-made object. It is a shortcut for the more fully developed path IC12 Visual Recognition assign (K9) to a E18 Physical Thing the status of (K11) IC9 Representation.

Before introducing further classes and properties it is best to provide an explanation of their possible uses. One of the best possible examples we can think of is a wall painting in the south lunette of the central bay in the Naos of the church of Asinou. The wall painting (Fig. 34) depict Mary, together with the patron of the church, Nikephoros, who’s holding in his hands a gabled church, and another character whom we can only identify as Gephyra thanks to the inscriptions.

Figure 34. Donor's portrait. Asinou church, Naos - south lunette of the central bay.

The modelling (Fig. 35) of Fig. 34 use the exact classes and properties hereby mentioned, defining the Donor's portrait as an IC9 Representation, linked to an IC1 Iconographical Atom throughout the IC12 Visual Recognition activity. The latter uses the inscription "I, Nikephoros magistros, a pitiable supplicant, erected this church with devotion, in return for which I beg to find thee my protectress" present in the E34 Inscription to assign an identity to the Donor's portrait.
Moreover, another IC9 Representation, which depicts the Asinou church is linked with a partitive property to the Donor's portrait and to the iconographical atom throughout the K1 denote relation.

6.2.3.1.1.1 Multiple Parthood

In the section 1.2 we argued over the complexity of multiple parthood representations, illustrating the argument with the case of the two Deesis presents in the Asinou church (Figure 4). At the end of the same section, we maintained that the application of a taxonomical segmentation over such complex representation was not possible. The problem was due to the diverse composition of the Deesis, the affiliation with the theme of the Last Judgment only in one of the instances as well as the diversity between the standard representations of a Deesis (Figure 4.B) and the ones present in the church.
Using the classes declared above we are finally able to define multiple categorisations of visual

elements, as well as its composition into multiple elements and themes. The modelling of this information is presented in figure 4, which demonstrate the possibility to define diverse IC1 Iconographical Atom as units of the same representations, even if are not part of a connected geometry. In this instance, the Iconographical Atoms of St. John, Christ and the Virgin denotes together the Deesis in the Narthex, which is part of a larger representation, the Last Judgment. The same representation, a Deesis, is present also in the Naos, in this case, is divided into two Iconographical Atoms. These last two figures can be described using the same pattern, composing a new IC9 Representation. The sameness link between the two described representations is modelled using an external reference source (Iconclass).
Following this schema, it is possible to differentiate the two representation, providing for each of them a single identity, but still linking them using their type, enabling the user to maintain their differences and similarity. The schema described here does not take into account a series of elements of the depiction which we can use to define sameness and similarity between representations. We will see in the sections below what these elements are and how we can use them to define diversity and similarity over visual items.

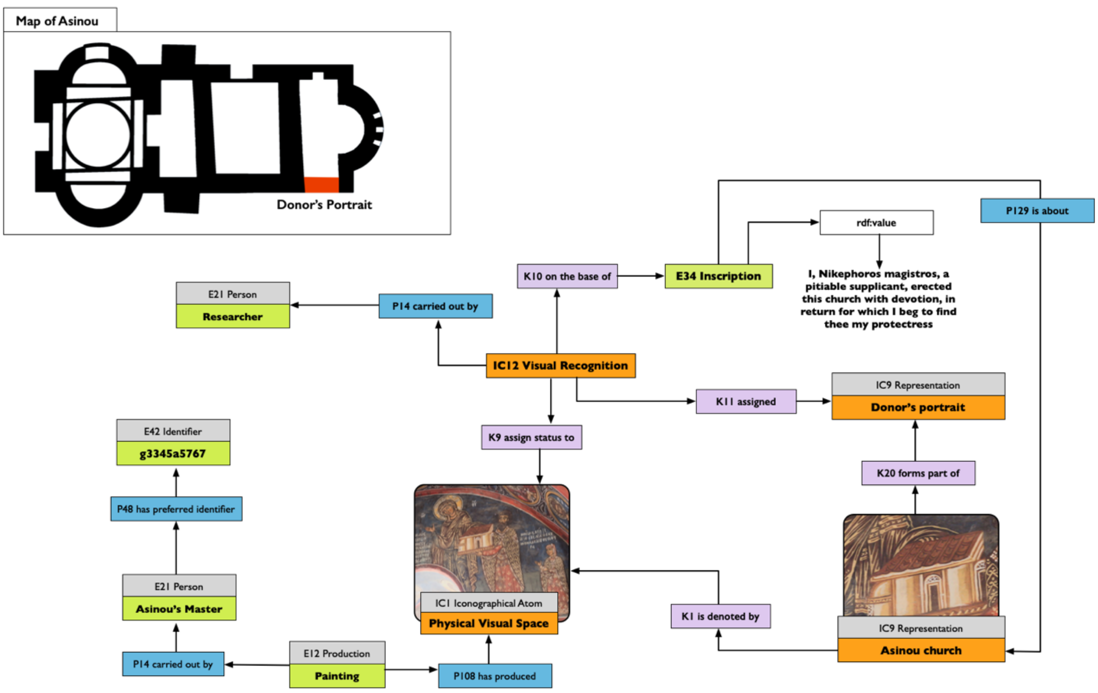

Figure 35. Modelling of the visual recognition of the Donor's portrait using VIR.

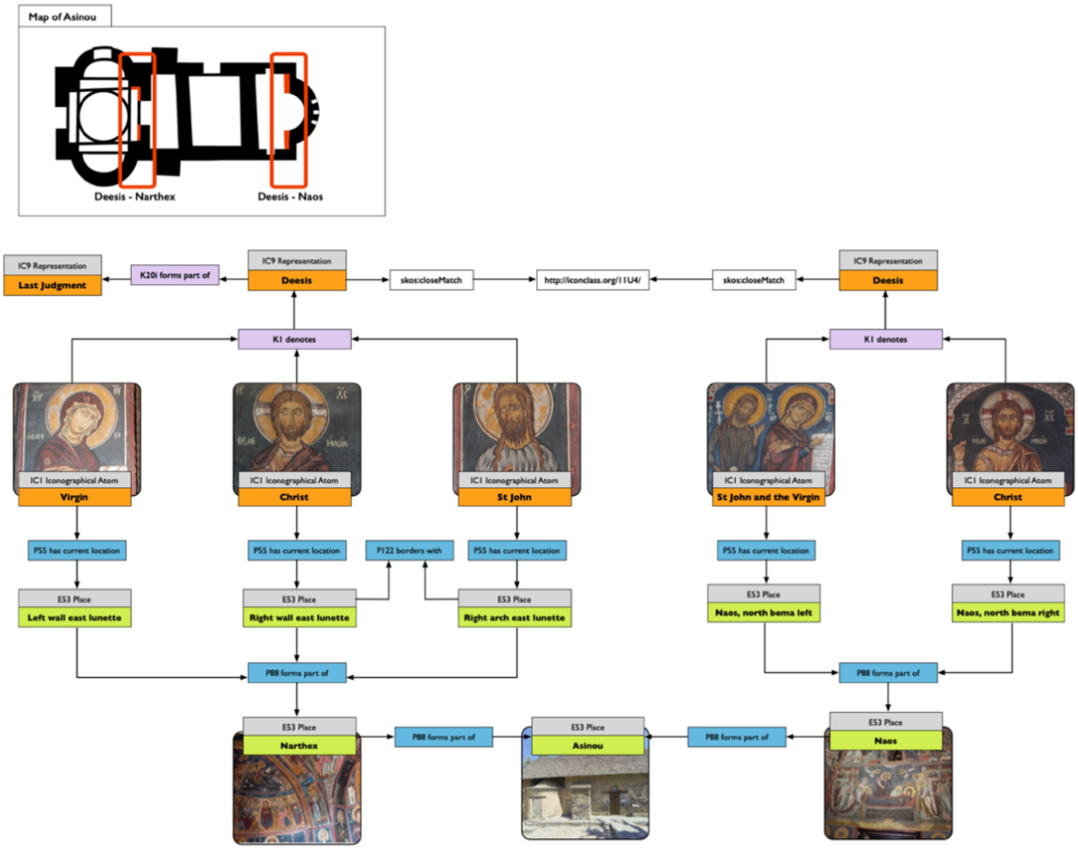

Figure 36. Modelling of the parts that compose the two Deesis in the church of Asinou, Cyprus.

6.2.3.1.2 Attributes and Symbolism

The identity of a representation is socially given and it is based on a set of features considered by the viewer more salient than others and used as a key to its identification. These features are what we called in chapter 4 Semantic Marks, and are fundamental for the recognition and classification of a visual object. While the term Semantic Mark works very well, it could be, within CRM, confused with another class, E37 Marks, which describe "symbols, signs, signatures or short texts applied to instances of E24 Physical Man-Made Thing" (Bekiari et al. 2015). In order to completely avoid such issue, we used, in the ontology, the term Attributes and define it as:

IC10 Attribute	
Subclass of:	E36 Visual Item
	E29 Design or Procedure
Description:	A set of features considered by a viewer more salient

> than others and used as a key for the identification of a Representation. The attribute could correspond to iconographical elements or simple signs which the viewer uses to provide a stable identity to a visual object.

Attributes are a very specific class because they are both visual elements and schematic objects. In fact, they are used to deliver significancy to a representation, they are socially encoded and used both in the production of a visual object as well as in its interpretation, and are key to the contextualisation of an element. During the production of an artwork, for example, one of the classic sources to be considered was the Iconologia by Ripa, which listed precisely the use of Attributive elements to deliver a narrative or a specific representation. The attributes were then used in the representation following a specific design. This same encoded design has been used for the recognition of several representations by Art Historians. Famous is the case of Émile Mâle which used extensively the iconologia by Ripa for recognis several representations, claiming that it was the "*key to the painted and sculptured allegories of the seventeen century*" (Mâle 1932) (for more details about the use of schemas for the depiction of elements and characters see Seznec (1981)).
The recognition schema <Person A recognise B in C because of D> cited just above when talking about the class IC12 Visual Recognition, it could very well comprise the case of recognition by Attributes. Such would be the case of the recognition of a depiction by an art historian who uses a set of attributes to provide identity to the depiction. However, someone would argue that the recognition it would not be based on the attribute, but on the source itself. The latter is quite a fair point, which demand an answer. We argue that the <recognition of a representation(B) in a painting (C) because of its attribute (D)> is nothing else than a compression, a term coined by Fauconnier and Turner (Fauconnier and Turner 2003) who suggested that human thinking tends to compress complex paths of relationships into simpler ones, while remaining subconsciously knowledgeable about the complete paths. Therefore, the <recognition of B in C because of D> should be translated as the <recognition that an artist used in the production of a painting a set of attributes, encoded or socially given, in order to make its depicted representation understandable as a specific subject>. We do not directly use a source which encodes the attributes, but we use that same source for understanding the code used by an artist, which will reveal the meaning of the visual message. It is an act that implies the interpretation of the visual code of production, as explained in JCMI, and not just a mere reading of an attributed listed in a book.
As mentioned above, attributes can be used in the production of a visual object. The description of their use can help us providing context to the symbolic production and better understand the normalisation of features for a representation. To describe this action we defined the property:

K15 use features (has been used by)

Domain	E12 Production
Range	IC10 Attribute
Subproperty of:	P33 used specific technique
Description:	The property indicates the specific attribute used during the production of a visual object

The clustering of the Attributes together with the Representation which they belong to, is essential for the analysis of the association between what we called Semantic Marks and the Cognitive Type they represent, showing their developments and changes over time. To conform to such objective we also declare a relation between a representation and its attribute using:

K17 is attribute of (has attribute)

Domain	IC10 Attribute
Range	IC9 Representation
Subproperty of:	P106 is composed of (forms part of)
Description:	This property associates an attribute with the representation where it is depicted.

Thanks to this relationship we can declare what is an attribute of, but nothing has been declared in relation to the nature of the attribute itself, and mostly on what it does represents. We saw in chapter 5 that the features we use to recognise representations changes in space and time, as we demonstrated using the case of St. George. It is useful to relate the identified attributes to the specific physical object they portray and represents. While this would be achievable adding a simple property to a IC9 Representation, it would not satisfy the need of diversification between a representation of an attribute in respect to a whole visual object. The lack of a class IC10 Attribute would fail in making clear the status of the attributes as identity constraints for a representation, as well as the nature and symbolism of a single attribute. In order to further model the relation between an attribute and the things it depicts, as well as with the thing it symbolises we require two additional properties

K21 depict things of type (is depiction of attribute):

Domain	IC10 Attribute

Range	E55 Type
Subproperty of:	P137 exemplifies (is exemplified by)
Description:	This property indicates the type of object depicted by an iconographical attribute.

K14 symbolize (has symbolic value)

Domain	IC10 Attribute
Range	E90 Symbolic Object
Subproperty of:	P138 represents (has representation)
Description:	The property indicates the symbolic value of the attribute presents in a representation.

The former property (K21) relates an attribute with a type of thing it depicts. The depiction value of the attribute, in fact, does not have to be searched in its relation with an instance of a physical object, but on the representation of a type of it. An attribute could depict a cross, not the cross used by a specific person. The type of object depicted could have a symbolic value, which could be expressed by K14.

It is best to explain their usage using an example. We will use a set of information about the panel of St. Anastasia with donor (Fig. 37) present in the south conch of the Narthex. The panel represents the saints with a devotee/donor Anastasia Saramalina. The saint is identified by the use of the cross of martyrdom and the bottle of medicine. Both attributes have symbolic meaning.

The modelling of the attribute information can be done in two ways, depending on the information available. We will provide the two possible ways, as an example of the methodology, however, the one really chosen on the base of our information is the second one in Fig. 38.

The first modelling (Fig. 39) foresee the use of the attribute during the production, and describe the use of a specific feature as part of the design of the wall painting. The production classifies further information such as the fuzzy time-span of the production of the wall painting as well as the coordinates, encoded in WKT, of the location where the production took place. The usage of the attributes is stated using the property K15, which allow us to specify that the "Cross of Martyrdom" and the "Bottle of Medicine" were used during the creation of the wall painting.

The modelling in Figure 38 is an alternative way to model the belonging of the attributes. In this

Figure 37. St. Anastasia with donor. Asinou church, Narthex.

case, we model the recognition of those elements in the wall painting following a IC12 Visual Recognition activity, which does identify two representations within the same IC1 Iconographical Atom, and add details about one of them (St. Anastasia). The Attributes are here linked with the object they do symbolise, as well as the type of things they depict. It has to be underlined that the relation between an attribute and their symbols or object of depiction could be easily stated in the modelling in Figure 39. The lack of such a relationship should be seen only as a choice. In the first example, in fact, using such relationship we would have implied that the artist, by design, used such symbolism on purpose. We cannot sustain the validity to such statement, therefore we did not model it as such. If the validity is proven, it could easily be stated, but this was not the case, and this is the main reason why the preferred the modelling in Figure 38. In the latter, in fact, no commitment to the artist intention has been made, but it only records the statements of a person in regards to the status of the painting.

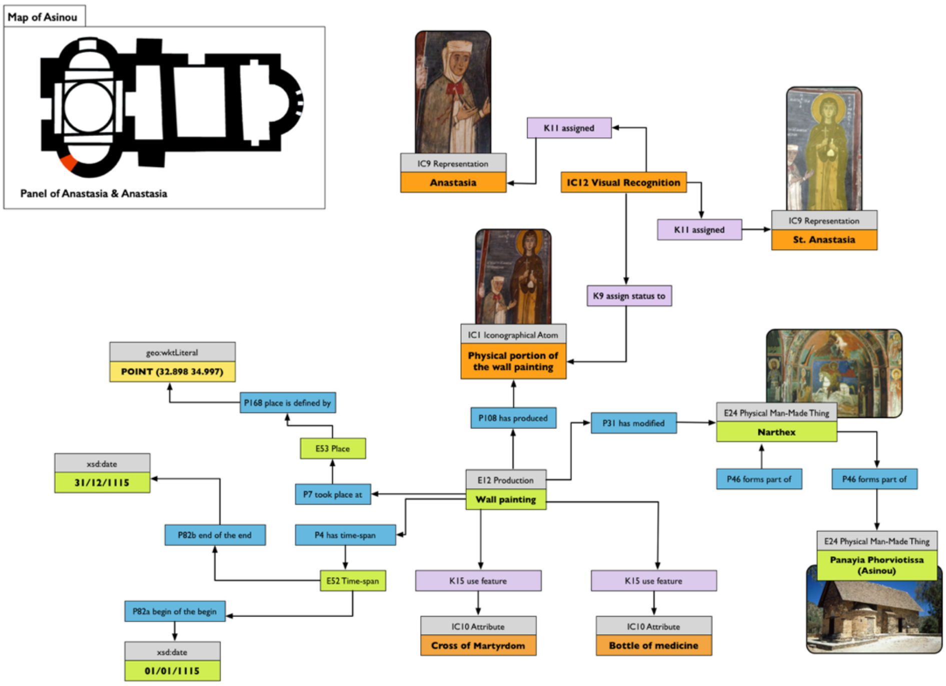

Figure 39. Modelling of the production of the panel St. Anastasia with donor

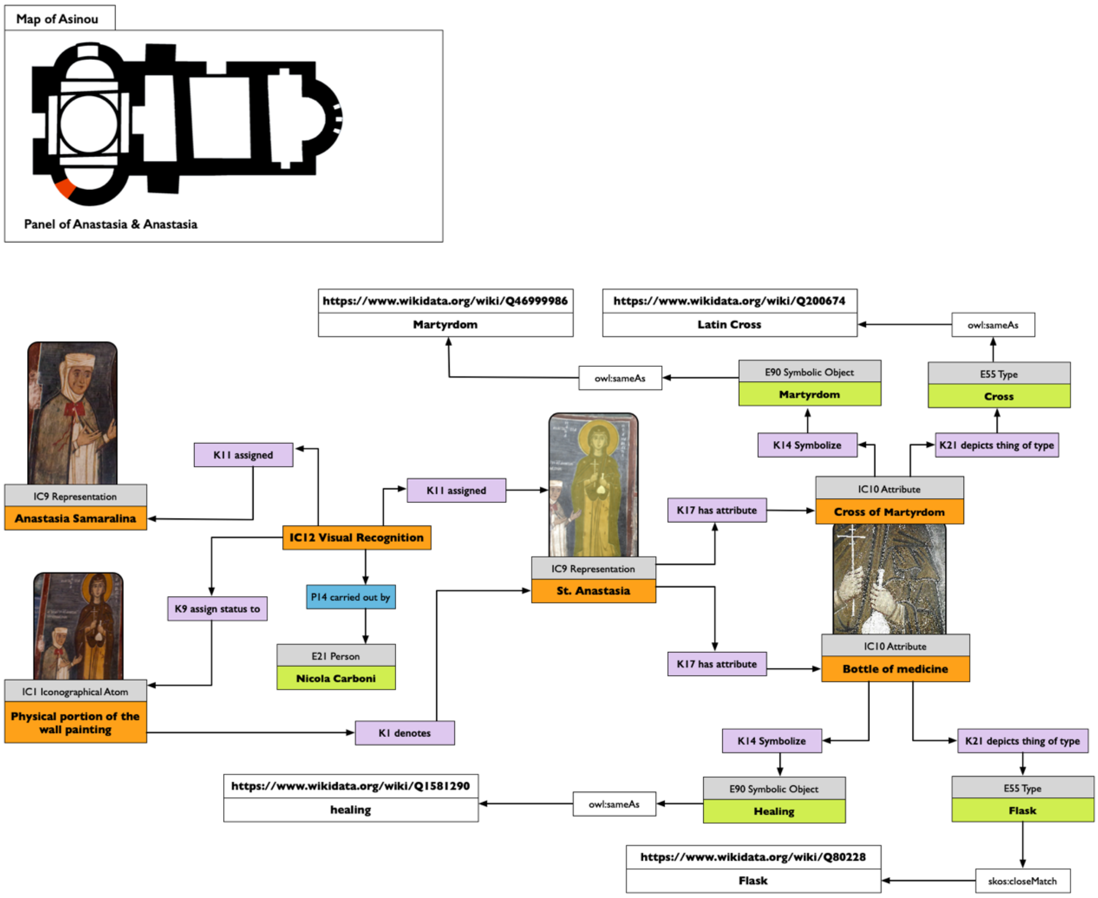

Figure 38. Modelling of the attributes recognised in the panel St. Anastasia with donor.

The modelling above is, therefore, the one we advise to use in case the information about the agency of the artist it is not historically recorded or it is difficult to prove.

6.2.3.1.3 Characters and Personification

The attributes are related to a specific character in a representation. St. George uses a mix of attributes, while St. Anastasia another set of them. It is essential to relate specific representation with the characters they depict, in order to aggregate a set of representations by spacetime, characters depicted and attributes used for it. In order to sustain such relation, we need to declare a new class:

IC16 Character

Subclass of: F38 Character

Description: This class comprises fictional individuals, or groups, appearing in a representation. Each character portrayed can have a type, for example “Saint” or "layman". Every saint portrayed is considered here as a character and not as an actor

The relation between IC16 Character and IC9 Representation has been encoded with:

K24 portray (is portrayed in)	
Domain	IC9 Representation
Range	IC16 Character
Subproperty of:	P138 Represents
Description:	This property put in relation an iconographical object with the portrayed character.

It is important to underline that unless we are modelling the Representation of a historically and critically well-documented person, a IC9 Representation is intended to portray a IC16 Character. Religious figures of the past, such as Saints, should be classified as Character and then linked to the person used as a source for that character. In the case of a representation portraying St. George, we would be able, for example, to link the character with the soldier in the reign of Diocletian who is being identified by some researcher as the possible person behind the story of the saint. For such reason we need to declare another property:

K26 Has source (is source of)	
Domain	IC16 Character
Range	E39 Actor
Subproperty of:	P138 Represents
Description:	This property associates an instance of IC16 Character with an instance of E39 Actor that the character is motivated by or is intended to represent.

Another entity which is important to declare is the one of personification. Personification do represent abstract ideas and values using anthropomorphic figures, and differently from a Representation do not portray any specific character, but only set of values. Personifications appear in various artistic traditions and are considered a typical communicative device to represent intangible concepts such as Fortune, Fate, Prudence and other allegories. The intensional and functional difference of the entity do suggest a specialisation of IC16 Character, which we declare as:

IC11 Personification

Subclass of:	IC16 Character
Description:	A subset of character which includes human, or anthropomorphic figure, that represents an abstract idea or a concept.

The relationship between a IC11 Personification and IC9 Representation do not demand for a new property, because K24 portray serve both Character and Personification quite well. However, we do need a relation to sustain the statements about types of abstraction portrayed by a personification. We declare

K25 express (is abstraction of)

Domain	IC11 Personification
Range	E90 Symbolic Object
Subproperty of:	P138 Represents
Description:	This property put in relation a symbolic object with a personification in a work of art.

The use of these two classes and their relationship is best seen with a practical example. The church of Asinou surprises us again, providing a very fitting one: the personification of the Sea. Depicted in the upper zone of the north semi-dome in the narthex, we can find the

Figure 40. Personification of the sea. Asinou church, Narthex - north semi-dome.

personification of the earth and the sea. The personification of the sea appears sitting in a sea monster holding a sailing boat and an oar (Fig. 40). The modelling of personification (Fig 41) is pretty straightforward. An iconographical Atom is recognised to depict a Representation, which is linked with a Personification. The latter figuratively express the sea.

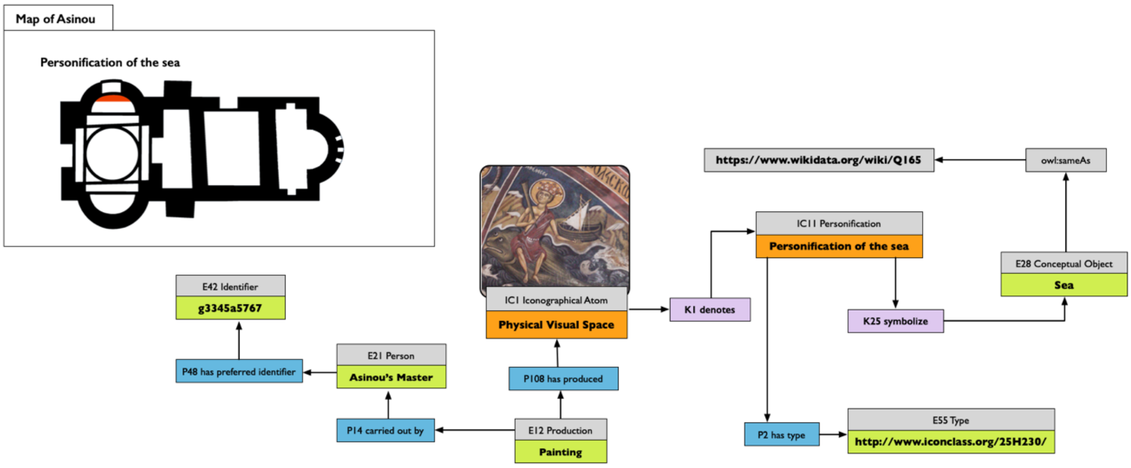

Figure 41. Modelling of the wall painting "Personification of the sea" as IC11 Personification. north apse of the narthex, Asinou church, Cyprus

The modelling of the Personification and the one of Character are very much alike. In order to show the difference, we used another subject in the Narthex, the beautiful fresco of Saint George in the south semi-dome (Fig. 21).

Figure 21. St. George panel. Asinou church, Narthex - south semi-dome.

The fresco depicts the saint in his military attire, but without the presence of any dragon or princess which usually accompany him. The visual role of the saint is, therefore, only the military one. We modelled the set of information we collected about him in Figure 42, providing a bigger context for the visual object.
We can see how the IC9 Representation is linked to the IC16 Character, as we saw in Figure 21. The main difference here is the use of the property K26 to relate the IC16 Character to a E21 Person which was used as a base for it. While this is not a rule, portrayed characters can be based on uncertain persons, which are taken as a prototype for the creation of a persona, in this case the saints. A character will be based on the symbolic version of a person, highlighting one or more of his/her feature. The documentation of the link between the Character and the person or group used as inspiration for a character can be made explicit using the property K26, as in the figure below. In this case, the character of Saint George is based on a Roman soldier working for Diocletian, and it is encoded that way.

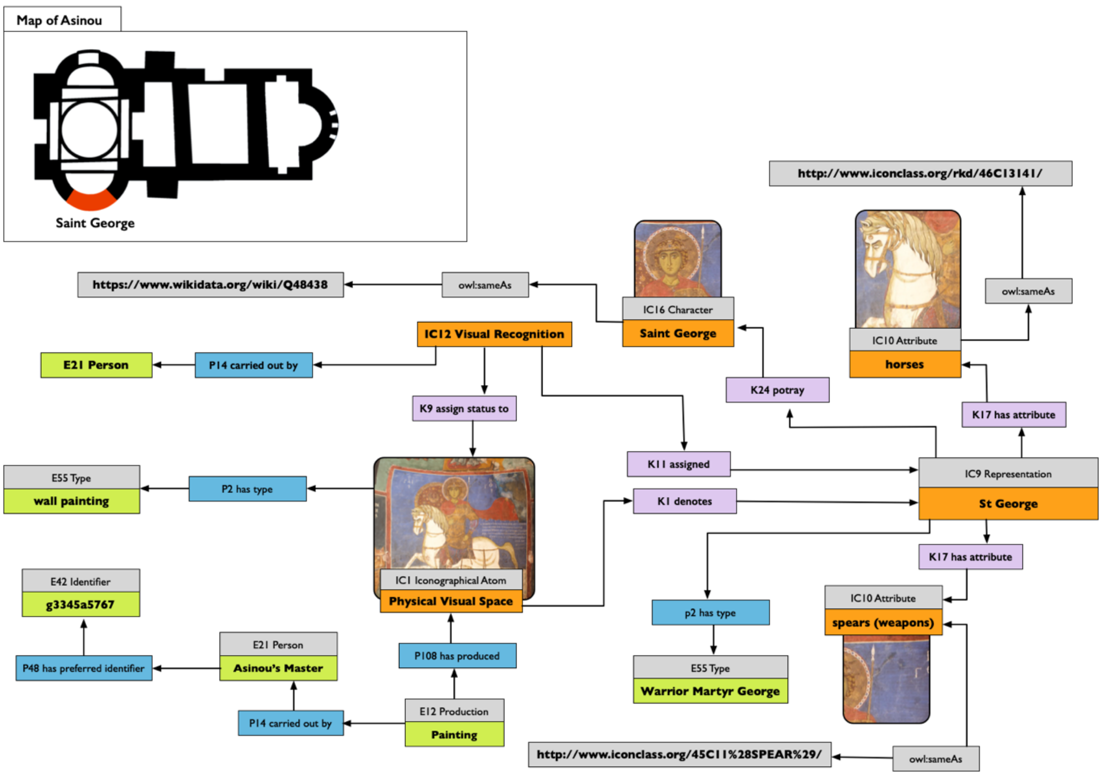

Figure 42. Modelling of a St. George as a Character.

6.2.3.1.4 Denotation and Connotation

Sometimes a Representation which has a clear denoted identity can develop a different one within the same context, such it is the case of connotation. Visual semiotics discern denotation and connotation as two layers of meaning, where denotation express what is being depicted and the connotation express the values and ideas of what is represented (van Leeuwen 2001). This view has some scholar of the likes of Barthes within its supporter. He thought, for example, that there is not any encoding/decoding function within the denotative layer because our object recognition originates from some form of "anthropological knowledge" (Barthes and Heath 1977, 36). While appealing, this description seems tip-toeing around the subject, explaining a significant feature of the perception process using a fuzzy concept which it is only grounded in itself. We stand instead with the definition given by Hjelmslev (Hjelmslev 1963, 114) of a "semiotics whose is expression plane is a semiotic", so a function that relates the content of a signification to the expression of a further content. For such reasons, we model the connotation as a further IC12 Visual Recognition which assigns (K9) to a IC9 Representation a new (K11) IC9 Representation. This modelling allows the establishment of new recognition over a previously established one. A shortcut for this relationship is provided with the relation:

K23 connote (is connotation of):

Domain	IC9 Representation
Range	IC9 Representation
Subproperty of:	P138 Represents
Description:	This property indicates the connotation relationships, formalised by Barthes, between a conceptual entity and an iconographical object. It is a shortcut for the more fully developed path IC12 Visual Recognition assign (K9) to a IC9 Representation a new (K11) IC9 Representation. It does not offer any information about when and who established the connotation relationship.

A critic would argue that connotative relationships can be repeated *ad infinitum*, creation endless representation over representation. This critic is quite valid, and has found Pierce as its primary target, but following Eco (1976) we argue that "is the only guarantee for the foundation of a semiotic system capable of checking itself entirely by its own means".

The persistence of the connotation is transitory because connotations are founded only on code convention and time-wise are less stable than denotation because their duration is influenced by the stability of the convention itself.

6.2.3.1.5 Attribution and Prototype

Few words need to be spent on another important relationship encoded in the ontology, the one of prototype. Representation, sometimes at least, have to be seen as the result of a long process

which involves preliminary studies and sketches of what, in the end, would be the final version of an artwork.
This process is being described using several types of attributes (e.g. study for, preparatory, version, prototype, studio) which can be easily grouped into one single relationship that exists between Representations, the one of K4 is visual prototype. Additionally, this relationship is being further specialised using a "relationship over relationship" construct, the one of K4.1 prototypical mode, which can be used to define the type of prototypical mode used (e.g. study for)

K4 is visual prototype of (has visual prototype)	
Domain	IC9 Representation
Range	IC9 Representation
Subproperty of:	P67 refers to
Description:	The property documents the use of a specific prototypical example for an image. The nature of the relationships helps define a map of relationships between prototypical items used in the arts.

K4.1 prototypical mode	
Domain	K4 Is visual prototype of
Range	E55 Type

This property documents the use of a specific prototypical example for an image, such as in the case of a preparatory sketch, where it is seen as a preliminary version of something else. The whole production of an artwork can be seen as continue use of diverse prototype until the final object come into being. The same relationships which connect a preparatory study and the final artwork could be easily used for relating a copy from the original. The copy is, in fact, nothing else than a new object which uses another one as an example. The type of resemblance between the two is just a perceptual judgment which does not change the process of reusing another object as a prototype for a new one. Using this relationship would be easy to track the progression from an idea to a final visual representation.
Unfortunately, we do not have any preparatory sketches from Asinou, and we need to rely upon other type of data to exemplify such relationship. We will use the Allegory of the Immaculate Conception by Vasari.

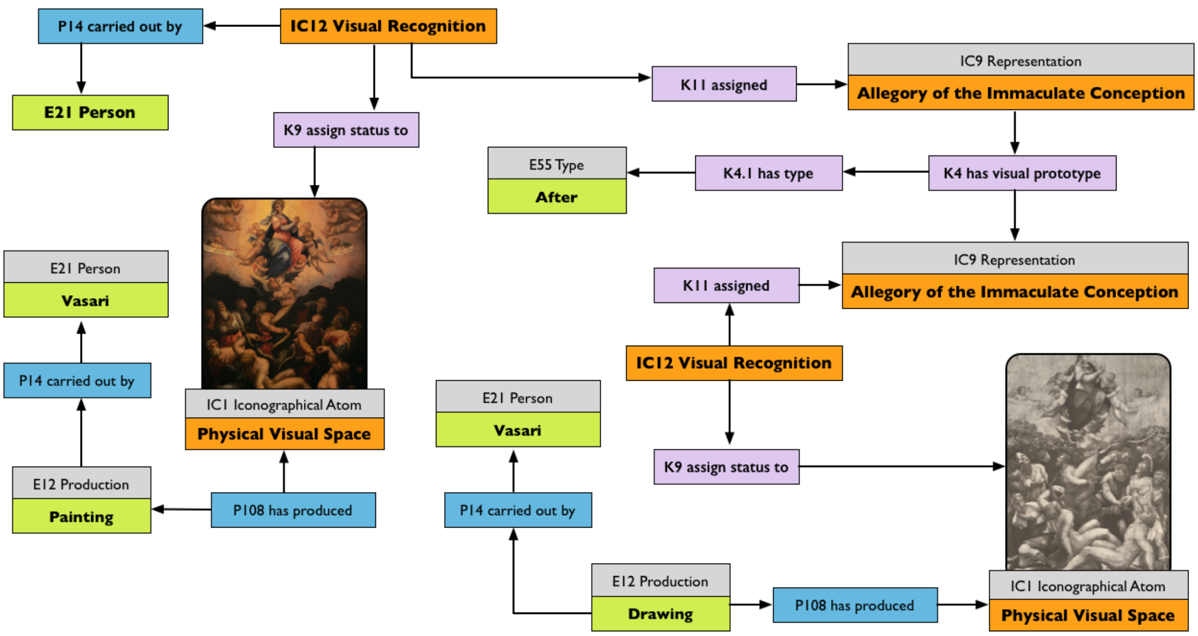

Figure 43. Modelling of a visual prototype.

The mapping in Fig. 43 displays both the Allegory of the Immaculate Conception by Vasari, as held in the church of Santi Apostoli in Florence as well as the preparatory study made by the Artist. The Representations are linked together by a type of visual prototype, in this case, a "Studio for". The choice of using a property over a property has been made in order to provide the possibility to specify the type of prototypical relationships between Representations, which could vary greatly depending on the domain.

6.2.4 Historical Grounding

The description on the ontology and the examples have been, until now, dedicate only on the description of the visual, overlooking another essential component, the historical one. In order to accurately describe a representation as a product of its time and space, and bound it to specific traditions or visual culture, it is essential to ground the visual information into a bigger historical framework. This approach enables the users to focus both on the aesthetic attributes and the development of symbolic forms or characters within a period. The church of Asinou proves to be again an excellent example for such practice. The semi-dome of the south conch in the narthex display the panel "Virgin of Mercy and Latin Donor" an iconographical type original from the West (Figure 11). This iconography, called Madonna della Misericordia, originated in Italy in the early 13th century and was promptly disseminated in the Mediterranean area by the crusaders (Bacci 2017).

In this case, it is crucial to ground the iconographical information within its history, defining the influence in the production of the painting by both the donor and the Frankish occupation of the island. Figure 44 documents the information integration of the aesthetic assertions within the historical framework of production. The creation of the painting is linked in time with the

Lusignan occupation of the island, from 1192 till 1474. The period is, moreover, linked with two other spatio-temporal gazetteers, perio.do[4] and chronontology,[5] which help in the retrieval but also in the browsing and visualisation of further documented periods.
Using this modelling we can easily cluster and browse information about representations created in a specific period or location, and thanks to the class and property defined by VIR we can explore the use of specific symbols or iconographical types within historical periods.
The link between visual representations and historical information within a formal structure that can be queried is the first step towards achieving a true digital iconology able to correlate visual culture and symbolism used. Only associating figurative expressions with their historical

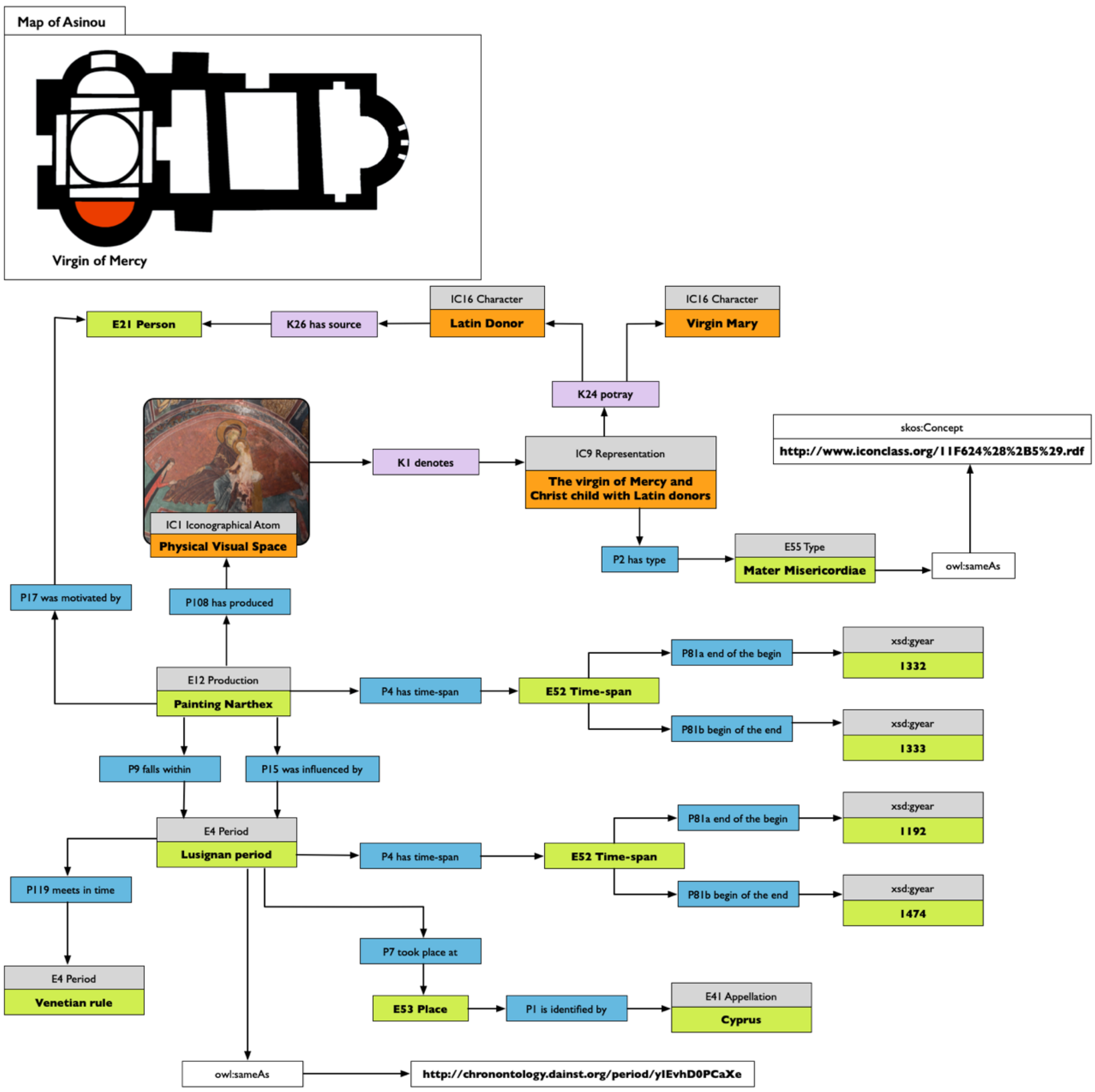

Figure 44. Modelling of the information about the historical period for the creation of the Virgin of Mercy and Latin Donor.

[4] https://test.perio.do
[5] http://chronontology.dainst.org

context we are able to accurately understand how the symbolic is derived and if some events had influenced it. In figure 44 the influence is simply associated with the production of the wall painting in relation to the Lusignan period. In order to make things clearer, we could model the type of dress worn by the Latin Donor as a type of "Cotte" a French-type of garment in fashion with the Latin women in Cyprus of the time. However, if we do that we face two great challenges. The first is the establishment of a categorical statement in CIDOC-CRM. The ontology, in fact, enables us to make statements about singular facts and not categorical truth.

We are easily able to say that an object belongs to a set of objects of the same type, but we are unable to say, that the set of those objects originates in French, because that would be a categorical statement. We could create some rules to state that all of the instances of the object have an origin in France, but that would be incorrect because the concept of origin is very ambiguous and could easily signify that all the objects with the type "Cotte" would come from France, which is clearly untrue.

The second challenge would be with the statement "in fashion with the Latin women in Cyprus" which would translate in "usually used by", a property which does not have a logic counterpart, unless we defined in probabilistic terms or in a set of fuzzy statements. The only possible solution was to rely on Wikidata[6] as an external resource (Figure 45). Wikidata, differently from CIDOC-CRM, seems to describe, as an encyclopaedia, categories of things and, therefore, we can use its flexibility to state that the garment "Cotta" present in the representation of the Latin lady has origin in the Kingdome of France.

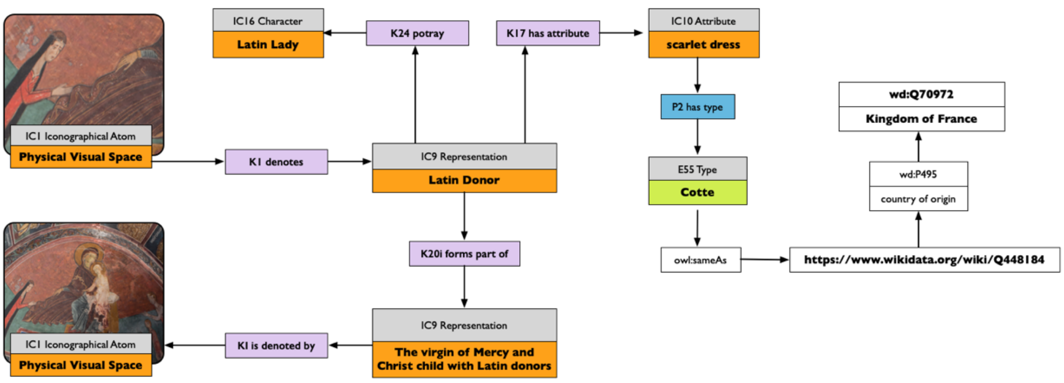

Figure 45. Modelling of the information about the clothing used by the Virgin of Mercy and Latin Donor.

While relying on Wikidata for our statements it is not the best possible outcomes, it is still a good and functional solution, because it allows us to describe how the visual elements in a

[6] https://www.wikidata.org/

representation portray historical influences, therefore shedding some lights on the visual culture of the time.

6.2.5 Performance and visual: a necessary integration

In the latest sections we have described possible information layers we may use to describe a representation. One of the proposed layers, the symbolic one (see section 6.2.3.1.2), allow us to describe the expressional value of visual content. However, as mentioned in chapter 4, the symbolic value can be tied to the viewer's context. This process become specifically compelling in a religious and communal environment like the one which animates the church of Asinou. The religious settings ascribe to the rites a significant use of symbolism and formulas to deliver emotions and sense of community. For this reasons, the intangible aspect of the wall paintings of the church deserves to be fully examined, highlighting their importance and role in shaping the community, as well as understand not only that a set of symbols exists but how we use them as a communication device.

In doing so, we focus again on the narthex of the church of Asinou. In section 3.3 we mentioned one subject common to many wall paintings in narthex: the Last Judgment. This composition is constituted by a variety of wall paintings spread all across the narthex, which together depicts Christ Last judgment and Second Coming.

Some of the imagery in this composition illustrate well-known passages of biblical sources and eschatological visions.

Well-known and typical examples are the Angel Rolling up the Scroll, the Fiery Stream and the Preparation of the Throne.

The Angel Rolling up the Scroll, painted in the soffit of the western arch of the narthex, illustrate both in Revelation 6:14 "The sky vanished like a scroll that is being rolled up, and every mountain and island was removed from its place" and Isaiah 34:4 "The skies will be rolled up like a scroll"; the Fiery Stream, in the west lunette, illustrate the Book of Daniel 7:10 "A Fiery Stream issued and came forth from before him: thousand thousands ministered unto him, and ten thousand times ten thousand stood before him: the judgment was set, and the books were opened"; Ezekiel 10:12 "the wheels were full of eyes all around" and Matthew 25:31 "When the Son of Man comes in his glory, and all the angels with him, then he will sit on his glorious throne" are illustrated by the Preparation of the Throne, also in the west lunette (Carr and Nicolaïdès 2012, 131-54).

We could continue listing more depictions, but it is clear after this very brief *excursus* that the imagery of the Last Judgment derives from its largest part from a range of diverse biblical sources, including from old and new testaments, the book of Revelation, the Gospels (especially Matthew, Isaiah and Daniel), but also apocryphal books.

The entirety of these references appear in the Narthex of Asinou, creating a clear connection between the depicted representations and the old and new testament.

In order to make clear the relationships between a literary text and a IC9 Representations that illustrate it we introduced the property:

K34 illustrate (is illustrated by):

Domain	IC9 Representation
Range	E73 Information Object
Subproperty of:	P67 refers to (is referred to by)
Description:	This property associates an information object to a representation.

This new property sustain relationship between a IC9 Representation and a CIDOC-CRM E73 Information Object, in order to link any textual resources to the representations that visually describe them. This new relation is essential to aggregate units of information with their visual counterpart (Fig. 46). The link previously mentioned between the scroll of heaven and Isaiah 34:4 can be easily encoded using the property K34 Illustrate which would associate the fragment of Isaiah to the wall painting in Asinou.

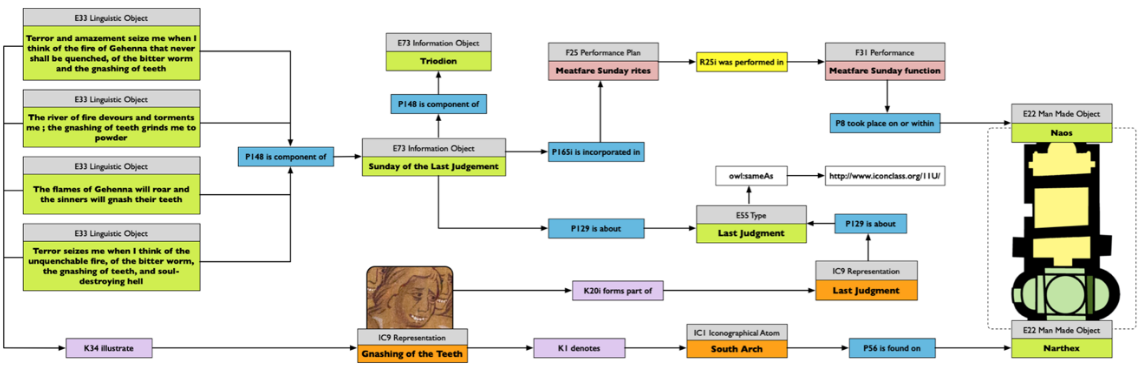

Figure 46. Modelling of the information about the iconographical representation "Scroll of Heaven". Soffit of the western arch, narthex of the church of Asinou, Cyprus.

Figure 46 describe, graphically, how we can encode such information. While could have been enough to have a binary relationship between single representation and the verse of Isaiah, we also relate the aforementioned verse with the overall subject of the Last Judgment. In such a way we can aggregate not only single representations with textual sources but also the overall Last Judgment theme per subject matter.

While associating textual resources to representations is quite an important step, because it helps frame their representational value, it is not enough for recreating the viewer's context. To achieve such objective, it is necessary to describe the representation within a framing situation, such as in the case of the Byzantine rite and the Last Judgment theme. Some of the iconographical types that compose the theme of the Last Judgment are mentioned in some of the liturgical books that prescribe the part of the liturgy of the Meatfare Sunday (the Sunday before the beginning of the lent). A prominent example is the hymn "On the Second Coming", written in the mid-sixth century by Romanos the Melodist and traditionally assigned to the Meatfare Sunday. Another example is the 10th-century lectionary from Constantinople which ascribes the reading, for the celebration of the Meatfare Sunday, of Matthew 25:31–46, the passage of the Gospel where the Second Coming is foretold (Pentcheva 2017).

However, the most important source for the 12th, 13th and 14th centuries, the period that most influenced the figurative themes in Asinou, is the Triodion, a 9th-century hymnal for the Lenten-Paschal season. The Triodion establish and prescribe the propers to be used for the functions of the Sundays and weekdays of the Lent, determining which hymn goes with which lecture. This hymnal represents and convey through the prayers the range of emotions, such as rage guilt and sorrow, fermenting in the mind of the devotees during the Lent and Easter period (Krueger 2014).

These emotions were not only shaped through the hymns and prayers recited during the Byzantine rite but also through the scenes depicted in the wall paintings adorning the church. The images, in fact, helped visually interpret a passage and communicate its sentiment to the devotee. Several of the wall paintings in the church of Asinou are linked with the subject of the Second Coming, illustrating passages from the biblical texts. Some representations, however, do not only illustrate a biblical text but are referenced within the function. According to the rules defined in the Triodion, the rites held during the Saturday of the Souls, the evening before the Meatfare Sunday, and during the Meatfare Sunday itself, speak specifically about sins and punishment painted in the church. During the ritual these words would echo across the church:

> "When Thou shalt come, O righteous Judge, to execute just judgement, seated on Thy **throne of glory**, a **river of fire** will draw all men amazed before Thy judgement-seat [..] **The books will be opened** and the acts of men will be revealed before the unbearable judgement-seat [..] **The trumpets shall sound** and the tombs shall be emptied"

The Throne of Glory, the Judgement-Seat, the Trumpets, the River of Fire are all iconographical depictions illustrated in the narthex of the church of Asinou. The presence of these representations in the narthex, the doorway to the church, the liminal space at the edge between earthly and divine, is quite significant because it makes them almost palpable to the devotee entering the naos. The latter was the space accessible only by pure of hearth, and while passing through the narthex to reach it, the representation reminded the devotees what they were leaving behind, what was waiting for them if they would not abide to the precepts of the divine (Marinis 2014). This cautionary imagery greatly helps in eliciting an emotional response from the devotees, specifically in a period, the medieval one, where the prospect of a second coming

was considered indeed very real (Patterson Ševčenko 2009).
Noteworthy, due to their extensive mention in the Triodion are the representation of collective punishments: the outer darkness, the dread worm and the gnashing of the teeth. These punishments are evoked during the function at the vesper of the Saturday of the Soul. The odes recite:

> "I lament and weep when I think of the eternal fire, **the outer darkness** and the nether world, **the dread worm** and **the gnashing of teeth**, and the unceasing anguish that shall befall those who have sinned without measure, by their wickedness arousing Thee to anger, O Supreme in love"

Furthermore, during the rite at the Meatfare Sunday we find a description of these images again:

> "Terror and amazement seize me when I think of the fire of Gehenna that never shall be quenched, of the **bitter worm** and **the gnashing of teeth**. But release me and forgive me, Christ, and set me in the ranks of Thine elect" (Canticle One)
>
> "**The river of fire** devours and torments me ; the **gnashing of teeth** grinds me to powder; **the darkness of the abyss fills my heart** with dismay" (Canticle Five)
>
> "The flames of Gehenna will roar and **the sinners will gnash their teeth**" (Canticle Six)
>
> "Terror seizes me when I think of the unquenchable fire, of **the bitter worm, the gnashing of teeth**, and soul-destroying hell" (Canticle Seven)

The Gnashing of the Teeth, the Bitter Worm and the Outer Darkness are tropes which are widely used in the Last Judgment prayers, to instil fearful emotions during such celebration. These tropes, extensively repeated during the Byzantine rite are, in their figurative form, present in the narthex of the church of Asinou (Fig 47), where their illustration complements the ritual. The representations of the collective torments in the narthex do not solely visually recall the Triodion, but their inscriptions refer to the pages of the Last Judgment. The inscription in figure 47.A "the worm that sleepeth not" recall Mark 9:48 "'where their worm does not die and the fire is not quenched", figure 47.B read "the gnashing of the teeth" reference Matthew 8:12 "while the sons of the kingdom will be thrown into the outer darkness. In that place there will be weeping and gnashing of teeth" (Carr and Nicolaïdès 2012) but also Testament of Jacob "And as to all these sinners, their punishment is the fire which will not be extinguished, and the outer darkness where there is weeping and gnashing of teeth" (Papaioannou 2004). Figure 47.C is presented with the inscription "Tartarus", a dark place of punishment for the wicked similar to the Abyss with roots in the Greek mythology but also present in Jewish literature (Somov 2017). The images of Tartarus probably refer to 2 Peter 2:4 "For if God did not spare the angels having sinned, but having cast them down to Tartarus, in chains of gloomy darkness, delivered them, being kept for judgment" (Papaioannou 2004). Figure 47.D reads "the outer darkness", referring again to Matthew 8:12 (Carr and Nicolaïdès 2012).

Figure 47. Soffit of the south arch, narthex of the church of Asinou, Cyprus. Figure A - the Worm that Sleepeth Not. Figure B - the Gnashing of the Teeth. Figure C - Tartarus. Figure D - the Outher Darkness.

It is undeniable that the existence of strong interconnections between the rituals, the figurative and the biblical texts, which seems to work as one to generate emotions between the devotees. The modelling of these sets of information can help us understand the values and the interpretations given to the wall paintings of Asinou, specifically the one acquired during the rituals which mention them. Moreover, the aggregation of these sets of information can help plot them in a historical timeline how the ritual evolves, and how such important subjects

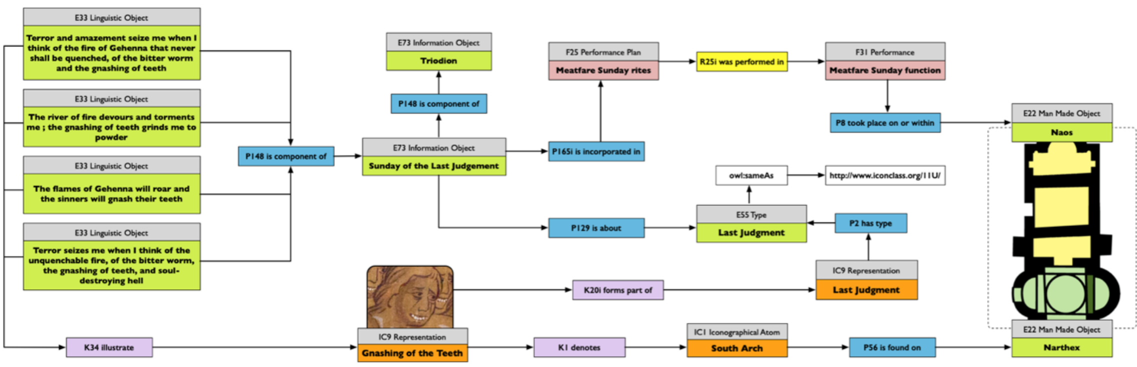

Figure 48. Modelling of the information about the iconographical representation "Gnashing of the Teeth". Soffit of the south arch, narthex of the church of Asinou, Cyprus.

differentiate across the diverse eschatological interpretations. With such aim in mind, we can use the textual reference present in the Triodion about the collective torments and link them with the Byzantine ritual performed on the Meatfare Sunday (Fig. 48). We encoded the relationship between the portions of the texts from the Triodion with the representation "Gnashing of the Teeth" using the property K34 Illustrate. Another link is established between the section of Triodion about the odes of the Last Judgment (already linked with Gnashing of the Teeth) and the function of the Meatfare Sunday. The association between function and odes is of type "incorporation", which specify that the hymns present in the section of the Triodion are going to be used in the Meatfare Sunday function. The spatialisation of the information across the church is realised linked both the performance and representation to the architectural spaces of, respectively, the naos and the narthex. Depiction and hymns are further characterised by their subject. Both are linked with the type Last Judgment, which is further related with the Iconclass entry about it. The modelling in figure 48 encodes, due to limitations in space, only the information about a single wall painting, the Gnashing of the Teeth, however, the same structure can be used to describe each representation mentioned by the Triodion or another document which describe the church rituals.

6.2.5.1 Issues

The modelling presented in figure 48 enable us to create a link between performance, figurative, architectural spaces, and textual references. However, it still presents some problems that is necessary to underline.

The very first one is the lack of documentary evidence about the performance of the ritual. On one hand there is no surviving Cypriot manuscripts of the Triodion from the period (Pentcheva 2017), thus is not clear when it was used for the first in Asinou. While the imagery in the narthex resemble the poetic of the Triodion, and in the 12th century it was an already established book in the Byzantine World, we do not have any direct proof that during the campaign of 1322/23 the Triodion was in use in the church. On the other hand, we also do not have any documentary evidence that establishes that the Meatfare Sunday was celebrated in the church of Asinou in the less recent past. We do imply so, because the Easter celebration is one of the most significant period for the Eastern Orthodox Church, and it is an annual event which is held in the church of Asinou even today. Nevertheless, we can only describe our knowledge about documented activities carried out in the church, and in this instance, a real description of a function performed in the church, leaving aside the contemporary ones, has yet to be found. Therefore, what the modelling (Figure 48) represents is a general proposition about the interconnections of performative, figurative and architectural but not a descriptive account of an episode. Modelling the process as a general proposition, however, help us underline another critical issue, the categorical one. As mentioned before in 6.2.4, CIDOC-CRM enable us to make statements about singular facts and not categorical truth. When talking about ritual, however, we tend to make statements of the like of "the Triodion hymns relatives to the Meatfare Sunday are always illustrated, during the Middle Byzantine period, by a representation present in the narthex of

the church". This statement is nothing else than a ground truth because it restrains the possible information about every performance (past, present or future) of that ritual. As a consequence, it excludes the possibility that will exist a future statements which disprove such truth. This type of statements strongly clashes with the principles of the semantic web.
It is, moreover, necessary to consider another problem, the link between figurative and ritual. Even if, in a hypothetical scenario, we do come to know through archival evidence that the celebration for the Meatfare Sunday was performed in the church of Asinou, and the Triodion was used for the hymn, we would still not be able to draw a straightforward link between performative and figurative. We would probably not have any proof that during the function the priest would directly point at the wall paintings and straightforwardly use them as a reference. The function of the image is incidental, and while the role of the visual dimension in ceremonies it is considered quite significant, they are not the centre of the function, but a tool to help the devotees focus on Christ as logos through the verbal admonitions of the priest.

6.2.6 Conclusion

The ontology proposed in this chapter covers major area for the description of figurative elements and their historical derivation, as well as use in a ritual. However, it is not exempt from limitations, specifically in respect to a contextualisation of the statements in regard to visual representation. The contextualisation of the CT in the initial analysis was supported by the use of situation and situation type. As we seen, translating this constructs in RDF is, indeed, possible, but it opens to epistemic problems in relation to the description of historical performance and rites, which are usually not studied as singular events but as group of repeating events.
A solution to the problem could be the creation of a class Situation Type, which would involve a set of physical entities in a definite configuration. A Representation would then conform/not conform to the Situation where the Visual Recognition takes place. The possibility to use Situations for differentiating between the meaning of the visual would greatly help in those performance type where the use of the visual element is strongly symbolic. Similar achievements could be done with a connotation. However, more significant effort is necessary at a community to achieve such goal, because a concept as vary as a situation type would need strong ontological agreements between parties.

7 On computation and reasoning

> "*Once the characteristic numbers of most notions are determined, the human race will have a new kind of tool, a tool that will increase the power of the mind much more than optical lenses helped our eyes, a tool that will be as far superior to microscopes or telescopes as reason is to vision*"
>
> — Gottfried Wilhelm Leibniz, *Philosophical Essays*

7.1 Introduction

In chaper 6 we formalised in an ontology called VIR a series of class and properties for the description of the representational values of the visual heritage. The ontology provides a useful methodology to track and define visual resources but it does not itself provide any relationship to link a representation with a digital asset. VIR does not include any formal relationships to link visual and digital resources, it is designed to be connected with other ontologies in use by the heritage and semantic web community that provide such type of links.

The harmonisation with other ontologies as well as the process to link digital data to structured information resources, it is not trivial and it will require further clarifications with respect to the identification of the digital object, the type of process employed and the nature of the connection used. We will delve deeper into this topics in the next sections

7.2 Digital Visual Annotation

The ontology, presented in section VIR, has been developed thinking about multi-agents classification of visual objects, and one of the best way to take advantages of such features, would be to use it within the context of a visual annotator.

Visual annotators are tools which enable a user to select a segment or the entirety of a 2D/3D representation and make a statement about it. While tools of such sort have been around for quite some time, specifically in the computer graphics community, the latest technological advancements which have introduced new programming libraries for the web, concurrently with the rise of international initiatives for viewing and connecting images, have been the catalyst for the creation of a series of toolsets for annotating 2D/3D representations.

A large number of tools have been developed for the annotation of diverse digital media over the latest years. While they have their differences, their underlying mechanism is quite similar. It is first and foremost a process driven by a user, which has as his disposal a palette of tools for selecting a segment of a media he is interested at. In case of 2D/3D representation the selection of a segment it usually results in a shape, which is then recorded. The resulting shape, depending on the system, can be further characterise using textual descriptors or links to other resources.

The use of these type of tools opened up the possibility to record, characterise and compare how human detect and define shapes in 2D/3D spaces. The annotations are, in fact, nothing else than human classification of specific segment of an area, which are recognised to be an instance of a specific type. Therefore, the use of such type of tools within a semantic system able to identify and characterise visual conceptualisations, are of crucial importance because they allow the identification of the morphological and dimensional characteristics of an object, linking such information with the conceptual understanding expressed by an agent. The collection and archiving of these types of information would enable further studies on the cultural and social diversity of the classification and perception of our heritage, overcoming the classical top-down approached that have framed the discipline.

The very first step in this direction requires the clarification and formalisation of the connection

between the digital object, which carries morphological information structured as 3D coordinates, and a conceptualisation.
Following this formalisation, it will be possible to classify user-defined spatial areas as an instance of representations, correlating these areas with their identifiable attributes appearing within the image and thus making the first step to create an organised iconographical corpus. The use of VIR to structure such type of visual statements would greatly help in the creation of an organised dataset of attributes, subjects, characters and symbols, allowing the researchers to cross and cluster together the recorded information, carrying out further research on the interconnections between the recorded elements and a specific visual culture. In order to achieve such result, it is necessary to interconnect VIR with an underlying data model for the registration of spatial annotations.

7.2.1 Standards: the Web Annotation Data Model

The creation of a shared model for recording the information about user selected areas and resources associated with them, have already begun in 2010 (Ciccarese et al. 2011), and have resulted in the release as of the Open Annotation data model (Sanderson et al. 2013). The developed model was further perfected and used as a foundation for the Web Annotation Data Model, a W3C initiative for the establishment of a shared architecture for web annotation services. The core of the model, proposed initially in 2010, has remained stable throughout the latest years and has been used by diverse projects and applications for recording and sharing linked annotation of images (IIIF), textual file (Pundit)[7] and webpages (Hypothesis[8]) making it the standard de facto for the recording of annotations.
For such reasons, in the next sections we are going to examine the structure, potential and limitations of the new Web Annotation Data Model, analysing the possible connections with VIR.
The Web Annotation data model provides a framework for expressing the relationship between a triad of connected resources: the annotation, its body and its target. The annotation is defined as an aboutness statement, a way a piece of information relates to a subject matter. The subject matter is, in this triad, the target, a digital resource subjected to the annotation. The Third part of the triad is the body, the content of the annotation, the information which is related to the target.
The resulting model (Fig 49) is a flexible three-part structure, which can be further expanded to include information about the creation, motivation and license of one of those three elements.
The work of the W3C Working Group[9] for the Web Annotation Data Model has refined the ontology, tracking and resolving some issues but keeping the original structure almost intact. The Group has focused on the annotation-media architecture working towards the definition

[7] http://thepund.it
[8] https://web.hypothes.is
[9] https://www.w3.org/TR/annotation-model

to record a shared solution for defining the selection of a segment in a media.
The selection of a portion of a text or image is done throughout the use of selector and fragment, two concept which we will analyse in more details in the next section.

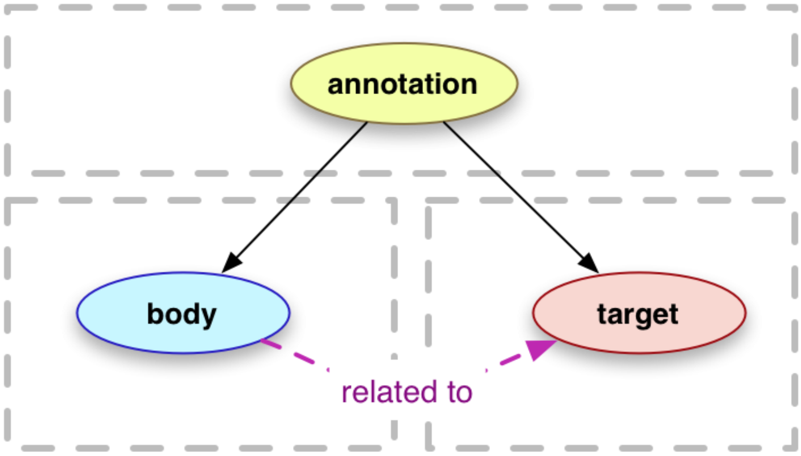

Figure 49. Core of the Web Annotation data model. Source: Web Annotation Data Model

7.2.1.1 Fragment URI

An critical obstacle that has slow down the development of annotation systems is the troublesome interconnection between annotation and resource. The construction and use of a shared architecture to define a link between the annotation and target resource has always been the most fragile part of any annotation system. For such reason we are are going to start by examining what the Web Annotation data model prescribe on the subject, specifically in relation to 3D annotations. We can start by constructing a link between an annotation and target.
As we mentioned above that the target is the digital resource subjected to the annotation. Often the target is a segment of a bigger resource (e.g. part of the text, area of an image, volume in a 3D model) which is the object of interest in the annotation. The identification of what constitute a target and its selection depends on the type of targeted object. Each media and encoding is structured differently and appropriate computational methods are required to identify its part. It is outside the scope of this work to discuss the selection and identification of a portion of a file, we will instead devote our attention to the identification and interconnection of the selected resource in an information object.
Once selected, to be used together with the Web Annotation data model, the segment have to be identified using a Fragment selector (or Fragment URI), a short string of characters which identifies something specific as a function of the document[10]. For example, the Fragment selector which identified column five, six and seven of a CSV file, created following the "URI Fragment Identifiers for the text/csv Media Type" specifications[11] is the following string:

[10] https://www.w3.org/DesignIssues/Fragment.html
[11] https://tools.ietf.org/html/rfc7111

http://example.com/data.csv#row=5-7

Fragments selector are resource-specific, and while specifications exist for many file types (HTML,[12] SVG,[13] PDF,[14] CSV,[15] ePub3[16] as well as media resources[17]) are not available for all the possible resources described in the web. The adoption of Fragment URI is in line with the specifications of the W3C and the overall web architecture, but the lack of standards fragment selectors for different media types seriously restrict the universality of the annotation method. While this is undoubtedly a problem and a limitation, it is important to underline that not that many are the cases where specifications for a fragment URI has not yet been developed.

Having outlined how, for the Web Annotation data model, a target should be defined, it is crucial to understand how it is used. Within the model, the segment of interest in a resource is encoded as value (`rdf:value`) of the class `oa:Selector` which is a container class for the different selectors defined in the ontology. The property `oa:hasSelector` sustain the relationship between an `oa:Selector` and the annotation. There is no actual class "Target" in the ontology, because the target of a `oa:Annotation` is always a web resource, identified with the property `oa:hasSource` and a specific `oa:Selector` defining the region of interest in respect to the source. The codeblock 1 below give us an overview of how it is defined. In the example it is possible to notice that the target of the annotation is nothing else than a blank node related to a selector and an image source. The selector is further described as an `oa:SvgSelector` which has the specific value `svgView(viewBox(50,50,640,480))` which identify a region of interest in the source `<https://example.org/image1>`.

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>.
@prefix oa: <http://www.w3.org/ns/oa#>.

<http://map.cnrs.fr/semantics/annotation/e8879a89d5bb4fac985b045053538847> a oa:Annotation ;
 oa:hasBody <http://map.cnrs.fr/image/3f668b0255be4e0ea8bfac80acff92f3> ;
 oa:hasTarget [
 oa:hasSource <https://example.org/image1> ;
 oa:hasSelector [
 a oa:SvgSelector ;
 rdf:value "svgView(viewBox(50,50,640,480))" ] ].
```

Codeblock 1. Encoding of an image annotation using the Web annotation Data Model.

RDF graph, encoded in Turtle syntax, of a user-selected portion of an image. The RDF encoding use the Web Annotation data model for ontologically define the structure of the selection. The

[12] https://tools.ietf.org/html/rfc3236
[13] https://www.w3.org/TR/SVG11/
[14] https://tools.ietf.org/html/rfc3778
[15] https://tools.ietf.org/html/rfc7111
[16] http://www.idpf.org/epub/linking/cfi/epub-cfi-20140628.html
[17] https://www.w3.org/TR/media-frags/

result is three nodes-structure formed by an annotation (identified by the URI http://map.cnrs.fr/semantics/annotation/e8879a89d5bb4fac985b045053538847), linked with a body (identified by the URI http://map.cnrs.fr/image/3f668b0255be4e0ea8bfac80acff92f3 but not specified here) and a Target, a node which contains the user-selected area encoded in the SVG, a graphical encoding for vector images (`svgView(viewBox(50,50,640,480))`).

It is important to stress that the target has to be considered just a pointer segmenting the region of a resource. The content of the annotated area, as well as its dimension, have to be extracted and recorded using other properties (e.g. `rdf:value`).

The W3C Fragment URI specifications can be used in order to define the attributes of an application interface for selecting and constructing URI which identified a segmented part of a resource. This operation has been performed by the IIIF (International Image Interoperability Framework) consortium[18] which has developed an API for serving 2D images. The IIIF consortium has agreed to use this shared framework for interconnecting image databases between each other and deliver full or segmented images over the web using the schema:

```
{scheme}://{server}{/prefix}/{identifier}/{region}/{size}/{rotation}/{quality}.{for
mat}
```

Using the above schema, it is possible to identify a specific region defined using a percentage of the image dimensions (or alternatively in absolute pixel values). A specific region can be requested in respect to its horizontal and vertical axis as well as its width and height, specifying in the URI the percentage (using pct:x,y,w,h) or the absolute value (x,y,w,h).

Following this schema, the selector of an annotation can easily points to the specific segment of an image as in codeblock 2 below.

```
oa:hasTarget [
 oa:hasSource <https://example.org/iiif/image1> ;
 oa:hasSelector [
 a iiif:ImageApiSelector;
 rdf:value "pct:0,0,10,10" ] ].
```

Codeblock 2. Encoding of a region of an image using the IIIF selector

RDF graph, encoded in Turtle syntax, of a user-selected portion of an image. The resulting RDF use the Web Annotation data model for ontologically define the structure of the selection. In respect to the Codebox 1 (see above) the target node does not identify a SVG value, but it uses the IIIF standard API selector, which encode the visual selected area using pct coordinates.

[18] https://iiif.io

7.2.1.1.1 Current solutions

Currently, no standard solution similar to the one developed for IIIF is available for 3D objects, however, some of the attempts for creating web annotations over 3D objects are worth a closer examination, specifically to understand how they connect 3D fragments to an annotation.

The 3D Heritage Online Presenter (3DHOP) (Potenziani et al. 2015) is by far the most popular solution in the Digital Heritage area for displaying 3D objects in the browser.
3DHop support a specific kind of annotation mechanism named "hotspot". Defined as "clickable geometries", the hotspots are added as transparent elements to the scene, positioned to overlap the element they annotate. The hotspots are loaded, as the overall model itself, as distinct PLY files to a web server and declared within the HTML document under the section "meshes".
The declaration of the meshes within the HTML follows the codeblock below

```
presenter.setScene({
 meshes: {
  "Gargoyle": {
   url: "models/multires/gargo.nxs"
  },
  "Cube": {
   url: "models/singleres/cube.ply"
  },
  "Sphere": {
   url: "models/singleres/sphere.ply"
  },
  "Wing" : {
   url: "models/singleres/wing.ply"
  }
 }
```

Codeblock 3. Relative meshes location in 3DHop.

Declaration, present in the HTML page displaying a 3DHop viewer, of the relative meshes location ("url") in the server.

Such structure within the HTML page makes each defined hotspot retrievable from the webserver. Thus, it is possible (however, not ideal) to use the URI of an hotspot as Fragments selector and link it to the target defined by the Web Annotation data model. Once this link it is established, it is possible to encode statements, in the form of annotations, linked to the hotspot. One important drawback of this approach is that the fragment selector does not identify really a fragment, therefore it cannot make explicit the relation between 3D model and hotspot. It is not a structural connection but only a visual one.
Another important limitation regards the creation of the hotspot, which need to prepared by the user beforehand, making the process of annotating a model with 3DHop a bit clucky.
Three-dimensional coordinates can be encoded as WKT (well-known text) object, an RDF serialisation created by the OGC (Open Geographical Consortium). WKT is mainly used for

recording 2D geographical coordinates or 2D polygonal shapes. However, WKT it is flexible enough to be used for the definition of 3D object. If the three-dimensional measurements are recorded as WKT literal in RDF and assigned to a corresponding class (`geo:Geometry`), they can be easily queried through a SPARQL endpoint.
Using this method, we would be able to encode 3D elements as WKT coordinates, assigning them an identity and linking them with other statements in the graph. Additionally, this solution enables the recording, querying and analysis of three-dimensional polygons in a graph using the GeoSPARQL extension developed by the OGC. Eventually, the 3D coordinates can be extracted with a SPARQL query and automatically plotted in a map (Beek et al. 2018). Additionally, the WKT coordinates could be double instantiated as `geo:Geometry` and as the `oa:Selector` and be used as target of an annotation. This system has many advantages but two main limitations: the encoding of the 3D measurements and the presence of texture. The encoding of elaborate 3D structure would necessitate the extraction from a model of the measurement of each surfaces, curves and angles and their conversion into WKT. Such process can be daunting and the result could be poor in comparison with the current 3D visualisation possibilities. The second limitation regards the texture. No texture information is possible to encode or visualise with this method.
Three-dimensional annotations can be encoded also in another important platform: Sketchfab.[19] Sketchfab provides a 3D viewer based on WebGL with work across several devices (e.g. mobile/desktop/VR headset). Annotations can be added to it, but it is not possible to export them as area or point and, therefore, it is not possible to use them for performing any type of analysis. They are aimed to aid to the comprehension of the digitised object, and not a scholarly tool.

A novel tool for annotating three-dimensional model within a web-interface has been recently introduce: Aioli[20]. This new system, developed by the CNRS MAP laboratory, provides a pipeline for the creation, annotation and sharing of 3D models. The user is able to upload the result of an acquisition campaign and the system automatically creates, using micmac in the backend, a point cloud of the digitised object. Once the point cloud is computed, it can be annotated using the initial 2D images. The annotations created over one image are automatically projected over the 3D structure (Figure 50) and, if they covered the annotated area, propagated in the rest of the image set. This unusual approach appears to be very functional and usable because it relies of a common medium, the photo, instead of forcing users to cope with the heaviness and complications of a 3D model.
Furthermore, the annotations are aggregated separately from the object and preserving the geometrical link between 2D and 3D. Starting from these premises, Aioli appears to be potentially the bridge between 2D and 3D, enabling an IIIF-based approach to 3D objects. We will delve further (in section Aioli) on the detail of how this software can help us interconnect

[19] http://sketchfab.com
[20] http://www.aioli.cloud

conceptual, physical and digital domain.

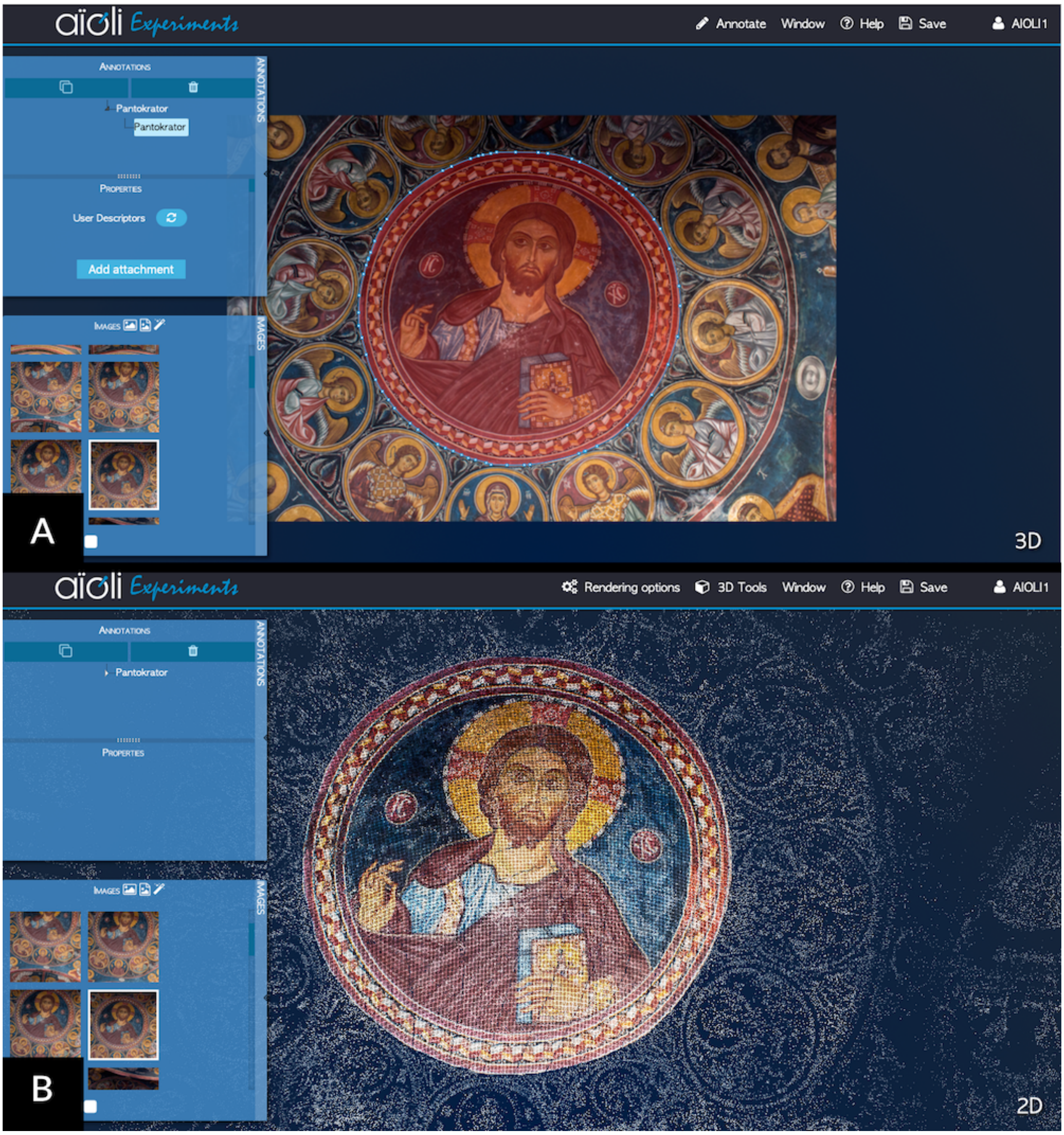

Figure 50. Workflow for the transformation of a record in RDF.

Another break in the field could also come while using a different encoding for 3D Objects. The new format developed by the Khronos Group, glTF, offer a JSON based encoding which could significantly help to define the correspondence of an annotation in respect to a 3D area. A specific segment of a glTF file could be defined using a JSON pointer, and afterwards would be possible to use it as a target for an `oa:Annotation`. If the matrix of a 3D object is defined in a format compatible with a URI fragmentation, such as JSON, CSV or SVG, it would always be possible to use current fragment URI standards to identify a specific segment of the resource and classify it as an instance of a `oa:Selector`.

An example of the use of a mod of glTF is the new Smithsonian Voyager,[21] an open-source 3D web visualiser and annotator. The Voyager can visualise diverse 3D objects (obj, ply, gltf, glb) and uses its own document format, SVX (Smithsonian Voyager eXperience), a JSON file very similar to glTF in structure, for displaying them on the web. Voyager describes 3D scenes using JSON nodes, where each node can describe with one of this components: camera, light, model, metadata, setup. An authoring interface is present where it is possible to add annotations over a model. The annotations are, at the time of writing, simple points in the model that can have titles, tags and text. The Voyager appears to be quite an interesting projects, specifically for its aim to be IIIF compatible, however it seems focus only on the general audience, providing tools for visualising and exploring the object modelled, leaving aside features that could be more useful to researchers (e.g. 3D surfaces, area measurements).

7.2.1.1.2 Possible agreements

As seen in the section above, a standard connection between a segment of a 3D model and an annotation it is no yet resolved. It is necessary to define a standard fragment URI, or a common framework, that can be used to point to a specific spatial region in a 3D representation. In this section we outline a proposal for the fragment information that should be included in a 3D Fragment URI.
A fragment selector should provide information about these dimensions:

- Typological dimension. Specifies the type of model to load.
- Spatial dimension. Denotes the position specific ranges of points/triangles covered by the annotation.
- Camera dimension. Denotes the viewpoint in respect of the annotation.
- Annotation dimension. Specifies visual characteristics of the annotation.

The Typological dimension should be a required value and should be used to specify between the different types of model visualisations to load. Options, encoded as identifiers, can include (but are not limited to) textured mesh, point cloud, coloured point cloud.

The spatial dimension should be another required value and should be used to specify the type of annotation:

- 3D point. A single point in the 3D space.
- 3D surfaces. A closed region within the surface of the 3D model. A selected group of triangles in case of a mesh or a subset of points in case of a point cloud.

[21] https://smithsonian.github.io/dpo-voyager/

- 3D volumes. A frustum

The camera dimension should not be a required value and should be used to specify three attributes, the camera position, the rotation of the model, and (if present) the position of the label. All the attributes have to be encoded using the necessary coordinate system. The value “0” could be used to denote the lack of information about the attributes of this dimension. In such case, the default parameters are going to be used.

The annotation dimension should not be a required value and should be used to specify two attributes, transparency and colour for each annotation. The transparency attribute should use a percentage value to request the level of transparency for the annotations. The colour attributes should use HTML colour names or an equivalent system to specify the colour of the point/surface/volume of the annotation. The “0” could be used to denote the lack of information about the attributes of this dimension. In such case, the default parameters are going to be used.

The above specifications could be used to construct a shared method to define the selection of 3D annotation resources.

7.2.2 Digital Visual Annotation: integration with VIR

In the previous sections we focused on the object-ontology interconnections and limitations, examining methods to link an object fragment from a 3D model with an ontology. In this section, we face another challenge, the ontological integration. Linking two ontologies together is not an automatic task, but it is necessary to analyse conceptual and formal constraints encoded in the ontologies. In our case, we are interested in defining the interconnections between a representation and the body of an annotation, defined as its aboutness. What we would like to state is that a specific annotation is about an attribute, a representation, a personification or a character defined by VIR.

For such reasons it is essential to analyse from the range and domain constraints of the body of a `oa:Annotation`. According to the Web Annotation data model, a `oa:Annotation` can be linked to other RDF classes using the property `oa:hasBody`. The latter does not constrain the range, thus allowing classes from other ontologies to be used as the body of the annotation. Following this logic, we could be able to state that the annotation of a specific area of an image is about a `vir:IC9_Representation`. Both VIR and the Web Annotation Vocabulary are, in fact, flexible enough to allow such interconnections without the need of any workaround.

The interconnections with the Web Annotation data model are not limited to the class of representation but can be expanded re-using all the classes defined in VIR and creating a graph comprising attributes, characters and personifications (Figure 51).

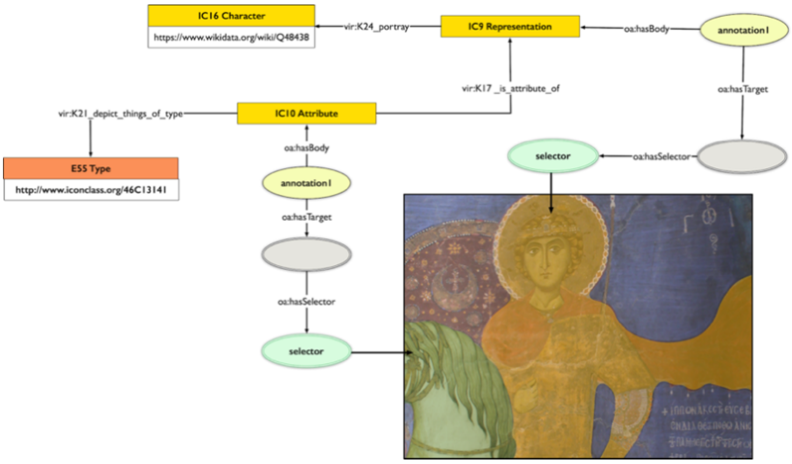

Figure 51. Visual representation of the integration between the Web Annotation data model and VIR.

For each visual statement it would be also possible to record its provenance in respect to the recognition of the visual features, using the class IC12 Visual Recognition, which allows us to define the subject assignment act, recording who did it as well as the information source he used. An example, showcasing the possible connections between the two ontologies, is available in codeblock 4. As it is possible to see from the code below, the fragment URI is related to both an IC9 Representation and an IC10 Attributes, relating the visual feature together, and linking them with shared reference sources (in this case Wikidata and Iconclass).

```
<https://map.cnrs.fr/sm/oa/ddc7d3f514784> a oa:Annotation ;
       oa:hasTarget [
       oa:hasSelector [
 a oa:SvgSelector ;
 rdf:value "<svg:svg>... </svg:svg>" ] ].
       oa:hasBody <https://map.cnrs.fr/sm/representation/d461e97396064> ;
       dcterm:creator <https://map.cnrs.fr/sm/persons/92f25dd306a54>.

<https://map.cnrs.fr/sm/persons/92f25dd306a54> a crm:E21_Person, dcterms:Agent, foaf:Person ;
       foaf:nick “nicola”@fr ;
       foaf:mbox "mailto:nicola@mail.fr".

<https://map.cnrs.fr/sm/representation/d461e97396064> a vir:IC9_Representation ;
       crm:P1_is_identified_by <https://map.cnrs.fr/sm/name/281b7bd49ce14>
       vir:K1_denotes <https://map.cnrs.fr/sm/physical/157fb87e3c6d4> ;
       crm:P2_has_type <http://Iconclass.org/11H%28GEORGE%2934> ;
       vir:K24_portray <https://www.wikidata.org/wiki/Q48438>.

<https://map.cnrs.fr/sm/event/db6caf7653c14f6cac4e6573df610a1b> a vir:IC12_Visual_Recognition
;
       vir:K9_assigned_status_to <https://map.cnrs.fr/sm/physical/157fb87e3c6d4> ;
       vir:K11_assigned <https://map.cnrs.fr/sm/representation/d461e97396064> ;
       crm:P14_carried_out_by <https://map.cnrs.fr/sm/persons/92f25dd306a54>.

<https://map.cnrs.fr/sm/name/281b7bd49ce14> a crm:E41_Appellation ;
       rdfs:label “Saint “George
```

```
<https://map.cnrs.fr/sm/physical/157fb87e3c6d4> a vir:IC1_Iconographical_Atom ;
        crm:P1_is_identified_by <https://map.cnrs.fr/sm/281b7bd49ce14>.

<https://map.cnrs.fr/sm/oa/ef04630eb366470aa23366e48b887c8b> a oa:Annotation ;
        oa:hasTarget [
        oa:hasSelector [
 a oa:SvgSelector ;
 rdf:value "<svg:svg>... </svg:svg>" ] ].
        oa:hasBody <https://map.cnrs.fr/sm/representation/294ac4b6a57e4> ;
        dcterm:creator <https://map.cnrs.fr/sm/persons/68f511d373d64>.

<https://map.cnrs.fr/sm/persons/68f511d373d64> a crm:E21_Person, dcterms:Agent, foaf:Person ;
        foaf:nick "nicola"@fr ;
        foaf:mbox "mailto:nico@mail.fr".

<https://map.cnrs.fr/sm/representation/294ac4b6a57e4> a vir:IC10_Attribute ;
        crm:P1_is_identified_by <https://map.cnrs.fr/sm/name/deaa075687a84> ;
        vir:K17_is_attrribute_of <https://map.cnrs.fr/sm/representation/d461e97396064> ;
        vir:K1_denotes <https://map.cnrs.fr/sm/physical/157fb87e3c6d4> ;
        vir:K21_depict_things_of_type <https://map.cnrs.fr/sm/type/5f69cb80b3314> ;
        vir:K25_express <https://map.cnrs.fr/sm/symbolic/e68ad353661e4> ;

<https://map.cnrs.fr/sm/symbolic/e68ad353661e4> a crm:E90_Symbolic_Object ;
        rdfs:label "Martyrdom"
        owl:exactMatch <http://vocab.getty.edu/page/aat/300379937>.

<https://map.cnrs.fr/sm/type/5f69cb80b3314> a crm:E55_Type ;
        rdfs:label "cross"@en
        owl:sameAs <http://www.Iconclass.org/11D123>.

<https://map.cnrs.fr/sm/physical/157fb87e3c6d4> a vir:IC1_Iconographical_Atom ;
        crm:P1_is_identified_by
                <https://map.cnrs.fr/sm/name/deaa075687a84>.

<https://map.cnrs.fr/sm/name/deaa075687a84> a crm:E41_Appellation ;
        rdfs:label "Cross "of Martyrdom@en.
```

Codeblock 4. Encoding of annotation using the Web Annotation Data model and VIR.

RDF Graph, encoded in Turtle syntax The RDF describes the selection and annotation of two separate areas in an image, and the corresponding classification by an user. The resulting RDF use the Web Annotation data model for ontologically define the structure of the selection and VIR to describe the visual constituents of the image. The first annotated area (identified by the URI https://map.cnrs.fr/sm/oa/ddc7d3f514784) identify a representation which portray Saint George. The identity of the Saint is further linked with other datasets where it is possible to retrieve more information on the saint (Iconclass and Wikidata). The second annotated area (identified by the URI https://map.cnrs.fr/sm/oa/ef04630eb366470aa23366e48b887c8b). identify an Attribute of the representation, a cross which is classified in the RDF graph to represent the Martyrdom. Both annotations present, moreover, information about the annotator responsible for them, in form of name and contact.

7.2.3 A new way: Aioli

Aioli is a platform developed within the CNRS MAP laboratory and focused on the creation of annotations over 3D digital objects. In respect to other approaches, Aioli is built as a photogrammetric pipeline that enable the users to upload the result of a data acquisition campaign and automatically obtain an annotable three-dimensional geometry. An important feature of this web application is the combination and interconnections between 2D and 3D, creating links between the initial data acquisition and three-dimensional result. This interconnection is crucial, not only because it allows the user annotate the initial photos and have the resulting projection in the 3D surface, but because it clearly display the propagation and spatialisation of information.

Aioli appears to be the perfect case to present and display the possibilities given by VIR to assign meaning to shapes, making transparent the process of classification and interpretation. In order to fulfil such objective it is, however, necessary to model and integrate Aioli within a semantic framework description able to integrate dimensional and conceptual data, formally integrating the annotated data within a semantic graph of information starting from one simple concept: the annotation.

Aioli, in fact, is a system creating around the annotation itself, and its dimensional interconnections.

For the encoding of the annotation we will follow the W3C Web Annotation model explained in the sections above, while the heritage information will be encoded using the CIDOC-CRM Ontology (see section 2.3.2.2).

In order to define the aboutness of an annotation it is necessary to define first and foremost what is the object of the annotation. Aioli annotate 2D images and then re-project the annotation over other 2D images and a 3D Object, resulting in a single identifiable annotation which exists across multiple images and models. We define it using a double instantiation of `oa:Annotation` from the Web Annotation Data Model and a `D29_Annotation_Object` from CRMdig. The use of the double instantiation is due by the decision to rely on the Web Annotation Data Model for the modelling of the computational part of the process, while using the more flexible and complete CIDOC-CRM for the modelling of the agency of the annotation.

The annotation (`oa:annotation`) is linked with the diverse annotated digital resources, connected by the property `oa:hasTarget`, and modelled as double instances of CRMdig `D35_Area` and the Web Annotation `oa:specificResource`. The `D35_Area/oa:specificResource` is identified in respect of a source (a specific image) and a selector (in this case a `oa:SvgSelector` a subclass of `oa:Selector`) which is responsible to identify the annotated area in each single image. This method enables the recording of a single identifiable annotation which cover diverse areas across a set of photos.

A particular type of resource that deserve our attention is the 3D Model. As mentioned above, once an annotation is created in a 2D image, it is projected over the 3D object. To represent such connection, and link it with the annotation act that is responsible for the creation of the first 2D annotation, we will categorise the 3D Object as a `oa:specificResource`, linked with the annotations presents in the 2D images. In this way, the 3D object will also appear as the target of the initial annotation. The initial annotation will, moreover, act as a wrapper element linking all the annotated resources together with the annotated areas.

In order to differentiate between the initial annotation act, performed by a user, and the reprojection of the annotation, performed automatically, the `oa:annotation/crmdig:D29_Annotation_Object` is linked with each of the `oa:specificResource/crmdig:D35_Area` using other two CRMdig properties `L49_has_primary_area` and `L50_has_propagated_area` which identify the initial user-created (L49) and the reprojected (L50) annotations. Each `oa:specificResource/crmdig:D35_Area` can be, moreover, linked with a dimension (`crm:D54_Dimension`) which can be used to identify the dimension of the annotation in the physical domain, reflecting the actual area of the object in the physical realm (specifically useful when photogrammetric computation use scaled value).

Using this construct, we are able to identify the source of the annotation across a large corpus of images and tracks its reliability and the agency of its creator. Moreover, the registration of the selectors can help us track the dimensionality of the annotated area across a dataset.

A better perspective over the model is given in Figure 52, which display on its left part the diverse 2D Annotations and on its right part the 3D one, both linked together by an annotation construct.

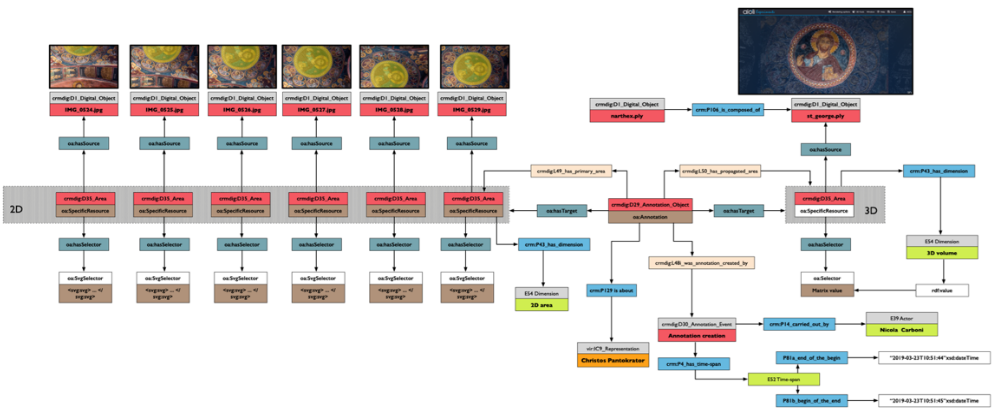

Figure 52. Modelling of the annotation in Aioli using the Web Annotation Data Model and CRMdig. A larger version is available in Annex C.

While the modelling of the computational part of the process is covered by the Web Annotation Data Model, the agency, act and interconnections with heritage information is completely left to CIDOC-CRM.

CIDOC has developed over the years a similar model for recording information about Digital Objects, CRMdig , which does also partially overlap with Web Annotation Data Model. Such functional and conceptual overlap allows us to easily interconnect the two models using the Web

Annotation Data Model for recording machine-based information and rely on the robustness of CIDOC-CRM for recording information about the creation of the annotation. Using CIDOC-CRM, in fact, we can link the Annotation Object (`crmdig:D29_Annotation_Object`) with the Annotation act (`crmdig:D30_Annotation_Event`), specifying the creator of the annotation as well as other important information such as the source used, the time of the annotation, the motivation and further contextual information around the researcher's annotation act.

Until now we focused on the creation of the annotation, but another important feature needs to be addressed, the one of aboutness. An Annotation can be, and in most of the time is, about something. It can refer, report some words or just plainly specify that the area covered by an annotation is a representation of something. In order to construct such complex relationship, we rely on the CIDOC-CRM property `P129_is_about` which help us state that the annotation of a specific area of an image is about a CIDOC-CRM entity (an object, visual item or others). In the example proposed in Figure 52 we link the annotation of the dome of a church with a representation of the iconographical figure, and using further annotations we would be able to define its attributes, the characters depicted and the relationship to a specific text it illustrates, moreover relating the visual feature together, and linking them with shared reference sources (in this case Wikidata and Iconclass).

7.3 Sources and data Integration

While surely a visual annotator is the best use case to examine the behaviour of VIR, the ontology can be also used for recording, integrating and sharing visual information using the semantic web stack. The result presented here are the result of an ETL (Extract, Transform, Load) process which transformed tabular data into enriched and linked RDF using VIR. In the next sections we will describe the ETL process, together with its limitation, and the role of VIR for the recording and integration of data with other sources.

7.3.1 Data transformation

A considerable amount of information system in use today relies on a relational database for storing their data. This solution is by far the most robust and documented one between the diverse products in the market. While relational databases suffer from a series of issues (e.g. federation, flexibility, integration, transparency) which are overcome by current graph technologies they still represent the most prominent product in the market for storing information. Moreover, the presence of a large numbers of libraries and methodologies for retrieving and storing data from/in a database within the web, together with the presence of countless tutorial and other types of documents describing methods and tools, have been the key to establish relational databases as the technology for the construction of an information system.

For the above reason, the initial data entry has been performed using a database, with three simple tables where to record information about the representation and the place where it is located. After the recording of the necessary data, the content of the table has been transformed using a series of steps (Figure 53). Initially, the data were extracted from the database as three separated CSV (Comma Separated Value), an open format for the registration of tabular data. The CSV had been enriched prior to their transformation, in order to connect them to useful linked data resources such as Wikidata, Iconclass[22], Getty Art and Architecture Thesaurus[23], and others. The enrichment has been carried out done using OpenRefine,[24] a software for data cleaning and enrichment, which allow to execute API calls to external services and parse the result in a cell.

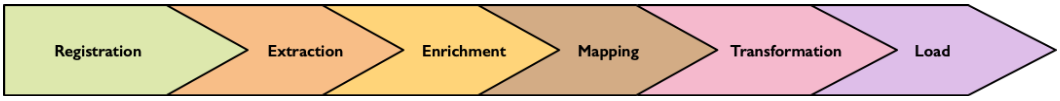

Figure 53. Workflow for the transformation of a record in RDF.

Once the data have been enriched, the mapping process began. This step is a critical one, and it necessitates the help of a knowledge engineer able to conceptually pair each information set to its specific class. A sample of a record extracted from the database is visible in the codeblock 5 below.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<rows>
 <iconography>
 <id>5f69cb80b3314652b9beb65de3c2c323</id>
 <Appellation>Saint George</Appellation>
 <Subject>Saint George Martyr</Subject>
 <sameAs>http://www.Iconclass.org/11H%28GEORGE%2934</sameAs>
 <Attributes_1>Horse</Attributes_1>
 <sameAsAttribute_1>http://www.Iconclass.org/46C13141/</sameAsAttribute_1>
 <Attributes_2>Spear</Attributes_2>
 <sameAttribute2/>
 <Character>Saint George</Character>
 <sameAsCharacter>https://www.wikidata.org/wiki/Q48438</sameAsCharacter>
 <partOf>300379937</partOf>
 </iconography>
 <feature>
 <id>300379937</id>
 <Appellation>South Lunette</Appellation>
 <Type>http://vocab.getty.edu/aat/300177433</Type>
 <PartOf>3f668b0255be4e0ea8bfac80acff92f3</PartOf>
 <Date_production_start>01/01/1180</Date_production_start>
 <Date_production_end>31/12/1180</Date_production_end>
 </feature>
 <physical>
```

[22] http://www.Iconclass.org
[23] http://www.getty.edu/research/tools/vocabularies/aat/
[24] http://openrefine.org

```
 <id>3f668b0255be4e0ea8bfac80acff92f3</id>
 <Appellation>Panagia Phorbiotissa</Appellation>
 <AppellationAlternative1>Asinou</AppellationAlternative1>
 <AppellationAlternative2>Mother of god Phorbiotissa</AppellationAlternative2>
 <AppellationAlternative3>Panagia ton Phorbion</AppellationAlternative3>
 <Type>http://vocab.getty.edu/aat/300004624</Type>
 <hasFeature>300379937</hasFeature>
 <Place>POINT(32.973431 35.0460829)</Place>
 <sameAs>https://www.wikidata.org/wiki/Q30773293</sameAs>
 <Date_production_start>1105</Date_production_start>
 <Date_production_end>1106</Date_production_end>
 <Founder>Nikephoros</Founder>
 </physical>
</rows>
```

Codeblock 5. XML extract of a recording documenting the fresco of Saint George, Asinou.

An XML extract of a database record documenting the fresco of Saint George in the narthex of the Asinou church, Cyprus. The record presents three main sections: iconographical description, image feature and physical information. Each line in the record represents a pair of element and value, where the element is the descriptor encompassing the value.

As it is possible to notice, the record presents information about the iconographical representation of St. George in the narthex of Asinou, as well as a list of some of the characteristic of the representation. Moreover, it documents the creation of the artwork and its current location. In order to transform the XML record to RDF we used the X3ML Language engine, an application which takes in input an XML file and, on the base of an X3ML file definition, transform the original XML to an RDF.
The mapping from these two formats is achieved thanks to the use of a declarative language called X3ML which enable the classification of each element in the XML as an instance of a chosen class present in the ontology. The transformation engine reads the X3ML mapping and, on the base of the written instructions, it creates an RDF file.
One the greatest benefit of X3ML in respect to other mapping languages is its flexibility, which allows the user to define long paths for describing each element of the XML, instead of relying on the classic key-value pair. Codeblock 6, a sample of an X3ML file, is the perfect example to illustrate the process. An initial domain node, called source nodes, is initially identified. The source node is going to be used across the mappings as the main subject of all the declared statements. Each one of the elements linked with the source node is regarded as possible nodes which can be instantiated as an element of a class.

```
<domain>
 <source_node>/rows/iconography</source_node>
 <target_node>
 <entity>
  <type>vir:IC9_Representation</type>
```

```
<instance_generator name="iconURI">
<arg name="id" type="xpath">ID/text()</arg>
</instance_generator>
</entity>
</target_node>
</domain>
<link>
<path>
<source_relation>
<relation>Appellation</relation>
</source_relation>
<target_relation>
<relationship>crm:P1_is_identified_by</relationship>
<entity>
<type>crm:E41_Appellation</type>
<instance_generator name="appellationURI">
<arg name="id" type="xpath">../ID/text()</arg>
</instance_generator>
</entity>
<relationship>http://www.w3.org/2000/01/rdf-schema#label</relationship>
</target_relation>
</path>
<range>
<source_node>Appellation</source_node>
<target_node>
<entity>
<type>http://www.w3.org/2000/01/rdf-schema#Literal</type>
<instance_generator name="Literal">
<arg name="text" type="xpath">text()</arg>
</instance_generator>
</entity>
</target_node>
</range>
</link>
```

Codeblock 6. X3ML mapping in CIDOC-CRM of the content of an XML element.

X3ML mapping file. The file displays an element to element declarative mapping from the content of a XML element (see Codeblock 4) to CIDOC-CRM. Each XML node is identified using the XPATH protocol and mapped as the subject of an RDF statement. The URI identifying each elements are generated on base of instructions and argument (e.g. `<instance_generator name="Literal"> <arg name="text" type="xpath">text()</arg>`).

In the example in codeblock 6, the domain node represents an IC9 Representation, and the link is the set of steps necessary to define the content of the element Appellation in the XML as an instance of the class `crm:E41_Appellation` containing a `rdfs:Literal`.
Codeblock 6 present only a small mapping of the XML present in codeblock 5. Once each of the element has been mapped and specified, the engine would process the files and generate a new RDF (codeblock 7).

```
@prefix owl: <http://www.w3.org/2002/07/owl#>.
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
@prefix skos: <http://www.w3.org/2004/02/skos/core#>.
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>.
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix xml: <http://www.w3.org/XML/1998/namespace>.
@prefix vir: <http://w3id.org/vir#>.
@prefix crm: <http://www.cidoc-crm.org/cidoc-crm/>.
@prefix geo: <http://www.opengis.net/ont/geosparql#>.

<https://map.cnrs.fr/sm/id/5f69cb80b3314652b9beb65de3c2c323> a crm:E42_Identifier ;
 rdfs:label "5f69cb80b3314".

<https://map.cnrs.fr/sm/name/5f69cb80b3314652b9beb65de3c2c323/> a crm:E41_Appellation ;
 rdfs:label "Saint George".

<https://map.cnrs.fr/sm/icon/5f69cb80b3314652b9beb65de3c2c323> a vir:IC9_Representation ;
 crm:P1_is_identified_by
 <https://map.cnrs.fr/sm/name/5f69cb80b3314652b9beb65de3c2c323/> ,
 <https://map.cnrs.fr/sm/id/5f69cb80b3314652b9beb65de3c2c323> ;
 vir:K24_portray <https://map.cnrs.fr/sm/character/b028048361574> ;
 vir:K17_has_attribute
 <https://map.cnrs.fr/sm/attribute/fc5c826ad9ec40> ,
 <https://map.cnrs.fr/sm/attribute/a31fd4d2acd94> ;
 crm:P65_is_shown_by <https://map.cnrs.fr/sm/feature/6f197b3ef1d84>.

<https://map.cnrs.fr/sm/attribute/fc5c826ad9ec40> a vir:IC10_Attribute ;
 crm:P1_is_identified_by <https://map.cnrs.fr/sm/name/38438dbd1bc94> ;
       owl:sameAs <http://www.Iconclass.org/46C13141/>.

<https://map.cnrs.fr/sm/name/38438dbd1bc94> a crm:E41_Appellation ;
 rdfs:label "Horse".

<https://map.cnrs.fr/sm/attribute/a31fd4d2acd94> a vir:IC10_Attribute ;
       crm:P1_is_identified_by <https://map.cnrs.fr/sm/name/5a793c973d994>.

<https://map.cnrs.fr/sm/name/5a793c973d994> a crm:E41_Appellation ;
 rdfs:label "Spear".

<https://map.cnrs.fr/sm/character/b028048361574> a vir:IC16_Character ;
               crm:P1_is_identified_by <https://map.cnrs.fr/sm/name/0fa3c66effd14> ;
               owl:sameAs <https://www.wikidata.org/wiki/Q48438>.

<https://map.cnrs.fr/sm/name/0fa3c66effd14> a crm:E41_Appellation ;
 rdfs:label "Saint George".

<https://map.cnrs.fr/sm/feature/6f197b3ef1d84> a crm:IC1_Iconographical_Atom ;
               crm:P1_is_identified_by
               <https://map.cnrs.fr/sm/name/0225323770dd4> ,
               <https://map.cnrs.fr/sm/id/8998a73f2bca4> ;
               crm:P2_has_type <http://vocab.getty.edu/aat/300177433> ;
               crm:P56_is_found_on
<https://map.cnrs.fr/sm/physical/3f668b0255be4e0ea8bfac80acff92f3> ;
               crm:P108_was_produced_by <https://map.cnrs.fr/sm/event/fea8eb2480ef4>.

<https://map.cnrs.fr/sm/id/8998a73f2bca4> a crm:E42_Identifier ;
               rdfs:label "300379937".
```

```
<https://map.cnrs.fr/sm/event/fea8eb2480ef4> a crm:E12_Production ;
               crm:P4_has_time-span <https://map.cnrs.fr/sm/time/a3985ddaf9db4>.

<https://map.cnrs.fr/sm/name/0225323770dd4> a crm:E41_Appellation ;
 rdfs:label "South Lunette".

<https://map.cnrs.fr/sm/time/a3985ddaf9db4> a crm:E52_time-span ;
               crm:P81a_end_of_the_begin "01/01/1180"^^xsd:dateTime ;
               crm:P81b_begin_of_the_end "31/12/1180"^^xsd:dateTime.

<https://map.cnrs.fr/sm/physical/3f668b0255be4e0ea8bfac80acff92f3> a crm:E25_Physical_Man-
Made_Thing ;
               crm:P1_is_identified_by
                       <https://map.cnrs.fr/sm/name/7a54bb6c4b064>,
                       <https://map.cnrs.fr/sm/name/fc10841a55784>,
                       <https://map.cnrs.fr/sm/name/1455f5de98624>,
                       <https://map.cnrs.fr/sm/name/c044600e3f0b4> ;
               crm:P2_has_type <http://vocab.getty.edu/aat/300004624> ;
               owl:sameAs <https://www.wikidata.org/wiki/Q30773293> ;
               crm:P108_was_produced_by <https://map.cnrs.fr/sm/event/6db0c9d86e304> ;
               crm:P55_has_current_locaton <https://map.cnrs.fr/sm/place/0dd517c24b134>.

<https://map.cnrs.fr/sm/event/6db0c9d86e304> a crm:E12_Production ;
               crm:P4_has_time-span <https://map.cnrs.fr/sm/time/f26d523ad3f64> ;
               crm:P14_carried_out_by <https://map.cnrs.fr/sm/person/1eaee2410f474>.

<https://map.cnrs.fr/sm/time/f26d523ad3f64> a crm:E52_time-span ;
               crm:P81a_end_of_the_begin "1105"^^xsd:gYear ;
               crm:P81b_begin_of_the_end "1106"^^xsd:gYear.

<https://map.cnrs.fr/sm/person/1eaee2410f474> a crm:E21_Person ;
               crm:P1_is_identified_by <https://map.cnrs.fr/sm/name/3f779a5581414>.

<https://map.cnrs.fr/sm/place/0dd517c24b134> a crm:E53_Place ;
               crm:P168_place_is_defined_by "POINT(32.973431 35.0460829)"^^geo:wktLiteral.

<https://map.cnrs.fr/sm/name/3f779a5581414> a crm:E41_Appellation ;
 rdfs:label "Nikephoros".

<https://map.cnrs.fr/sm/name/7a54bb6c4b064> a crm:E41_Appellation ;
 rdfs:label "Panagia Phorbiotissa" ;
 crm:P2_has_type <http://vocab.getty.edu/aat/300404670>.

<https://map.cnrs.fr/sm/name/fc10841a55784> a crm:E41_Appellation ;
 rdfs:label "Asinou".

<https://map.cnrs.fr/sm/name/1455f5de98624> a crm:E41_Appellation ;
 rdfs:label "Mother of god Phorbiotissa".

<https://map.cnrs.fr/sm/name/c044600e3f0b4> a crm:E41_Appellation ;
 rdfs:label "Panagia ton Phorbion".
```

Codeblock 7. Turtle file resulting from the transformation of the XML in Codeblock 5.

RDF Graph, encoded as Turtle file, resulting from the transformation of the XML in Codeblock

5 using the mapping provided in Codeblock 6. The elements containing identifiers in Codeblock 5 were reused to create new elements and, when absent, automatically randomly computed.

The process of data transformation can be used to harmonise data from diverse sources. In this instance, the integration and querying of information coming from two sources is almost impossible without the use of an ontological layer. The issue resides on the diverse ways to describe the same type of information. In order to illustrate such complexity, we will use as an example a record extracted from the Photo Archive of the Harvard University centre for Italian Renaissance Studies which describe the artwork by Vittore Carpaccio titled "Saint George killing a dragon". The record (codeblock 8), extracted from SharedShelf, the digital collection manager from ArtStore, give us an idea on the diversity in classification and description, specifically in relation to the several attributes we usually associate with one artwork. In the record, everything appears to be smashed together as Subject. However, it is easy to see how some of these elements, for example the armour or the skull, are not a subject of the painting at all, but just recurring attribute elements of the iconography of Saint George.

```
<Titles xmlns="">
 <Display>St. George killing the dragon</Display>
 <Title pref="true" term="St. George killing the dragon"/>
 </Titles>
 <WorkTypes tempered="true" xmlns="">
 <Display>paintings</Display>
 <WorkType id="11316996" term="paintings" uri="MFCL/11316996" vocab="MFCL"/>
 </WorkTypes>

[…]

<Subjects xmlns="">
 <Display>castles ; lakes ; dragons ; princesses ; armor ; vessels ; skulls ; spears
(weapons) ; horses ; saints ; George, Saint (d.303)</Display>
 <Subject id="11298800" term="castles" uri="MFCL/11298800" vocab="MFCL"/>
 <Subject id="11298620" term="lakes" uri="MFCL/11298620" vocab="MFCL"/>
 <Subject id="11299515" term="dragons" uri="MFCL/11299515" vocab="MFCL"/>
 <Subject id="11301919" term="princesses" uri="MFCL/11301919" vocab="MFCL"/>
 <Subject id="11301398" term="armor" uri="MFCL/11301398" vocab="MFCL"/>
 <Subject id="11302888" term="vessels" uri="MFCL/11302888" vocab="MFCL"/>
 <Subject id="11299050" term="skulls" uri="MFCL/11299050" vocab="MFCL"/>
 <Subject id="11300206" term="spears (weapons)" uri="MFCL/11300206" vocab="MFCL"/>
 <Subject id="11298670" term="horses" uri="MFCL/11298670" vocab="MFCL"/>
 <Subject id="11300744" term="saints" uri="MFCL/11300744" vocab="MFCL"/>
 <Subject id="9000370425" refid="N18337" term="George, Saint" type_lkup="associated names"
type_lkup_id="11309059" uri="SSN/9000370425" vocab="SSN"/>
</Subjects>
```

Codeblock 8. XML sample of the record "Saint George killing a dragon" by Vittore Carpaccio, part of the Digital Photo Archive of Harvard University centre for Italian Renaissance Studies.

Extracted XML sample. The XML is part of the database of "Saint George killing a dragon" by Vittore Carpaccio, part of the Digital Photo Archive of Harvard University centre for Italian Renaissance Studies. The record presents a series of interconnected identifiers and a list of subject terms and associated names used to describe the artwork of Carpaccio.

The mapping of the data in Codeblock 8 as a simple subject of a representation would hinder the possible integration with other iconographical data, for example preventing the harmonisation of the information present in Codeblock 5. It is necessary to use VIR to discriminate the elements which do represent attributes, from the ones that represent the character depicted, as well from the ones which only describe the iconographical type. VIR has been developed precisely for tackling such cases.

7.4 Integration with other techniques

7.4.1 Logic and computation

VIR it is not only functional to the data annotation, recording and integration, but can be used to enhance and augment our current information if combined with the potentiality of a notational language able to express logical rules.

The purpose is to automatically create instances of a class if the original data respect a set of parameters. Specifically, the presence of a set of attributes should trigger a reasoner and automatise the assignment of a type.

For such objective to be achieved, it is necessary to write a set of rules for each iconographical type, assigning a number of features to each type using a logic notation.

While the structure of an ontology is always expressed in a logical dialect, the logical reasoner is able to automatically infer new facts only on the bases of the premises in the data, and in our case, such constrains are not, and should not, be written within the ontology. It is paramount, in fact, to separate the operational rules, from the constraints rules, in order to offer a structure able to accommodate diverse needs and use cases.

In order to achieve our purpose and still keep VIR a lightweight ontology flexible enough to be used by diverse projects, it is essential to use a rule language.

We chose Notation 3 (N3) as such format because of its simplicity, the maintenance efforts carried out by the W3C community and the presence of easy-to-use reasoning engines.

Notation 3 was developed as a compact and readable alternative to the RDF/XML syntax capable of integrating logical rules and built-in calculated functions within the language. N3 offers the possibility to use variables and construct rules with them.

```
@prefix log: <http://www.w3.org/2000/10/swap/log#>.
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>.
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix : <http://www.agfa.com/w3c/euler/socrates#>.
```

```
@prefix crm: <http://www.cidoc-crm.org/cidoc-crm/>.
@prefix gnd: <http://d-nb.info/standards/elementset/gnd#>.

:John crm:P14_performed <http://map.cnrs.fr/semantics/x>.

<http://map.cnrs.fr/semantics/x> a crm:E7_activity ; crm:p2_has_type "exhibition".
```

Codeblock 9. RDF encoding of a performing an exhibition activity.

RDF graph encoded in Notation 3. The RDF describe, using CIDOC-CRM as ontology, a Person perform an activity, further defined as of type exhibition.

For example, given the statement in codeblock 9, we can declare that if a person (?X) carried out an exhibition (?Y), that person is an artist. This is expressed with the following formula:

```
{       ?X crm:P14_performed ?Y.
        ?Y crm:p2_has_type "exhibition". }

=>

{       ?X crm:p2_has_type <http://map.cnrs.fr/semantics/type/artist>.
        ?X a gnd:Artist.}.
```

Codeblock 10. Example of rule in Notation 3.

RDF graph encoded in Notation 3 which formalise a rule stating that if a person (?X) carried out an exhibition (?Y), that person is an artist. While the attribute person was never explicitly made clear in the rule, the ontological axiom explicitly encoded in CIDOC-CRM requires the subject of the property `crm:P14_performed` to be a Person.

Which defined a material condition of the sort p → q where if p is true, then q is also true. The N3 file is then passed to a reasoner, in our case the EYE (Euler Yet another proof Engine) reasoner[25], which use our rules to enhance the initial statements (results in Codeblock 11).

```
PREFIX : <http://www.agfa.com/w3c/euler/socrates#>
PREFIX crm: <http://www.cidoc-crm.org/cidoc-crm/>
PREFIX gnd: <http://d-nb.info/standards/elementset/gnd#>

:John crm:P14_performed <http://map.cnrs.fr/semantics/x>.
<http://map.cnrs.fr/semantics/x> a crm:E7_activity.
:John a gnd:Artist.
<http://map.cnrs.fr/semantics/x> crm:p2_has_type "exhibition".
:John crm:p2_has_type <http://map.cnrs.fr/semantics/type/artist>.
```

[25] http://eulersharp.sourceforge.net

Codeblock 11. Example of a result from the RDF EYE reasoner.

RDF Graph, expressed in Notation 3. The graph above is the result of the computation using the EYE reasoner of the Codeblock 9 and the formula stating that if a person (?X) carried out an exhibition (?Y), that person is an artist formalised in in Codeblock 10.

Following the same logic, we can define a set of rules for automatically assigning types to representation on the base of their attributes and character depicted. In codeblock 12 we have defined rules for the automatic assignment of types on the base of the character depicted and the attribute of the scene. In the example, we assign four different iconographical types depicting "*the warrior Martyr Saint George*", "*St. George is ripped up by iron nails*", "*St. George is sawn in two*" and "*St. George is put in a cauldron of boiling oil*". These four iconographical types present different scenes from the martyrdom of Saint George, as well as from the golden legend. Their automatic classification is based on the attributes they portray, classifying a depiction having as iconographical subject "*the warrior Martyr Saint George*" on the base of the presence of a princess together with a dragon and a character named Saint George. The presence of nails together with the character Saint George would instead trigger the classification of the depiction as having the subject "*St. George is ripped up by iron nails*". Following the same logic, the subject "*St. George is sawn in two*" and "*St. George is put in a cauldron of boiling oil*" are classified for the presence of the character Saint George and respectively the attribute saw and cauldron.

```
# Warrior Martyr St. George

{       ?X vir:K17_has_attribute <http://www.Iconclass.org/44B15122>,
<http://www.Iconclass.org/25FF411>.
        ?X vir:K24_portray <https://www.wikidata.org/wiki/Q48438>. }

=>

 {      ?X crm:p2_has_type <http://www.Iconclass.org/11H%28GEORGE%2934>. }.

# St. George is ripped up by iron nails

 {      ?X vir:K17_has_attribute <http://www.Iconclass.org/47D8%28NAIL%29>.
        ?X vir:K24_portray <https://www.wikidata.org/wiki/Q48438>.}

=>

 {      ?X crm:p2_has_type <http://www.Iconclass.org/11H%28GEORGE%2966>. }.

# St. George is sawn in two

 {      ?X vir:K17_has_attribute <http://www.Iconclass.org/47D8%28SAW%29>.
        ?X vir:K24_portray <https://www.wikidata.org/wiki/Q48438>. }

=>
```

```
{       ?X crm:p2_has_type <http://www.Iconclass.org/11H%28GEORGE%2964>. }.

# St. George is put in a cauldron of boiling oil

{       ?X vir:K17_has_attribute <http://www.Iconclass.org/41C27%28CAULDRON%29>.
        ?X vir:K24_portray <https://www.wikidata.org/wiki/Q48438>. }

=>

{       ?X crm:p2_has_type <http://www.Iconclass.org/11H%28GEORGE%2962>. }.
```

Codeblock 12. Diverse rules for Iconclass expressed in Notation 3.

Set of rules, expressed in Notation 3, to classify specific picture. Each rule determines at least one characteristics (e.g. the presence of an attribute) which would trigger the rule and automatically assign to the described picture presenting the aforementioned characteristic a new attribute (e.g. a specific type).

While the approach adopted has targeted the automatic assignment of types it can also work, with slight modifications, backwards, and define the presence of a specific character on the base of the assignment of a type.
It is also important to underline that the methodology outlined here has some limitations, specifically in respect to iconographical types which share many attributes. In that case, a proper set of rules cannot be formalised, and the classification needs to rely on the visual closeness of a scene in respect to another, using Machine Learning (ML) techniques to classify a representation as belonging to its proper type.

7.4.2 Machine Learning

While data conversion and integration or visual annotations are undoubtedly the most common use-cases, the ontology could also be used in correlation with machine learning (ML) algorithms. This type of algorithms excels in detecting differences and similarity between images, as well as, if a good corpus of training data exists, to assign labels to them. Several experiments (Arnold et al. 2017; Impett and Moretti 2017; Seguin 2018; Wevers and Smits 2019) have been carried out in the latest years, showing the potential to identify and differentiate visual works using ML. However, the same experiments that demonstrate the potential for the identification of a visual work show also the lack of structuralisation. Identifying the exact correlation between attributes and representation, as well as characters and symbolic depictions, is fundamental to understand the relationship between symbolic and visual. Making these correlations searchable within a large dataset is, therefore, paramount for understanding and studying the cultural context of the depictions and its change over time.

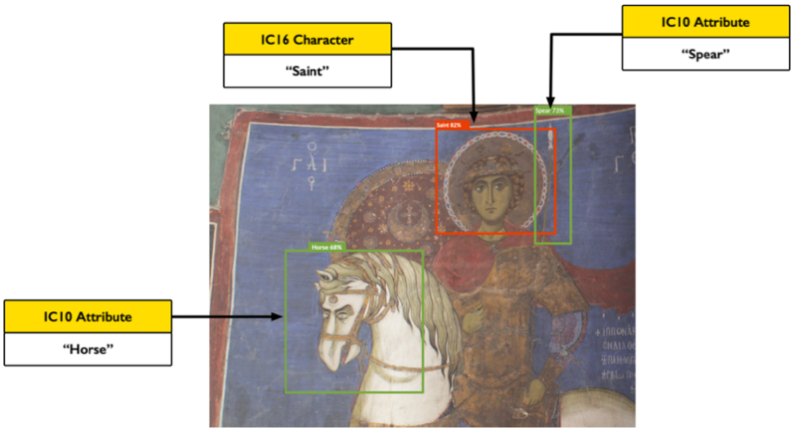

Figure 54. Possible integration between ML and VIR.

It is conceivable that ML algorithms would be used to define a series of attributes for each representation (Fig 54), using the ontology for recording them in a database. Some initial step towards the creation of an integrated framework combining ML and linked data has been done (Porello et al. 2013), but more research is necessary to develop a combined system which tackles the similarly in respect to the four elements outlined in section Semantic Marks: Topological, Feature, Alignment and Value information. These elements are necessary to define the identity of an image, but without an approach grounded on a shared information framework such as VIR, would not be possible to make any of these values searchable and usable within a system.

7.5 Conclusion

The different applications identified and explained in this section have the purpose of creating a digital environment which enables further research and automatically relates visual information. The role of VIR for the development of this environment is crucial because it allows us to explore a new dimension, which has not been tackled yet and deserves our full attention: the symbolic one. The implementation of the ontology within the listed methods, enable the comparison between different visual culture, highlighting the interpretative role over the image given by a social context in respect to another, and unveiling the meaning-assignment. Questions about the variations of the elements of depictions of Saint George across the Mediterranean basin during the middle age would be way harder to achieve without the use of the ontology because no exact correlation and structure could be given to the image. Furthermore, the possibility to understand which symbols are associated with a specific representation over a diverse geographical area (middle east vs continental Europe) can help us cluster and analyse examples which would reveal where the symbolic elements come from and how they are used to classify and make something recognisable. We could easily calculate novelty in respect to previous symbolism and examine their relation to historical data, or even more understand how much a specific event influence the imagery of the time, and therefore, how much people know and understand the reference to such event. Many are the question that can be answered by implementing VIR, and many more would be open by its use. While the work behind a mapping could seem tedious at first, it is only opening the archive of information we do create as a community that we can help each other understand our shared past.

8 On provenance and validation

"The acquisition of
knowledge is always of use to the intellect,
because it may thus drive out useless things
and retain the good. For nothing can be
loved or hated unless it is first known."

— Leonardo da Vinci, *XIX—Philosophical Maxims. Morals. Polemics and Speculations*

8.1 Introduction

We discussed in section 1.2 how we create and use digital representations as simulacra of the object, using them to collect proposition about their physical counterpart. We also stressed that, if that is the case, it is crucial to scholarly document the process of construction of this digital objects, in order to assess their truthfulness in respect to reality.

Digital replicas, in the form of three and four dimensional digital hyper-realistic images of reconstructions, are indeed used to convey the original meanings to a public that cannot access the original visual works. In such cases, the knowledge provenance is paramount to distinguish the realistic against the hyper-real, as well as to discern the intentionality of the representation versus the machine-based reconstruction.

Digital images in all their forms do appear to be exact reproductions, however, as much as for the analogue one, they are representations of a specific physical object in a specific setting and time. A digital picture, a digital scan or a digital 3D object would always represent an instance of an object on the base of a grammar and a set of choices. The nature of the digital image implies such underlying grammar, which is part of the medium itself.

An object, in fact, can be framed using diverse dimensionalities; a digital picture portrays only a set of these dimensions with the purpose of creating a depiction of the object which appears as close as it can be to our common understanding of it.

Therefore, what the machine record in a digital image is only a selection of the available spectrum of information. The decision to capture only a set of data is due by both the manufacturer and the user.

The manufacture consciously builds an acquisition device, such as a digital camera, using specific hardware which limits the recorded data to only a set of information (e.g. a part of the Electromagnetic Spectrum). Digital camera sensors are, for example, able to record both the near infrared and near ultraviolet ranges of the spectrum (360-1000 nm). However, commercial digital cameras are designed to reflect or block infrared transmission using IR cut-off filter, therefore, pre-selecting the representative information to be recorded in a photo (Cosentino 2016).

Nevertheless, digital cameras can be modified in order to capture the 360-1000 nm spectral range, and with the help of specific techniques (UVf, UVr, IR, IRf, IRfc, RAK) (Pamart et al. 2017) we are able to record sets of information which do highlight specific dimensions of the visual space (Fig. 55).

Additionally, manufacturers do not only influence the size and type of data recorded, but they heavily affect, using specific hardware and solutions what is being recorded. A manufacturer decides on an image sensor (CDD or CMOS) and on specific solutions for capturing the colours present in the visual space (e.g. three sensor device, X3 device, single sensor device). The choice between the sensor devices deeply influences the recording of the colour value, the light sensitivity and the registration of information. For example, single sensor devices use a single-chip sensor covered with a Color Filter Array (CFA) to capture, using specific patterns, for each

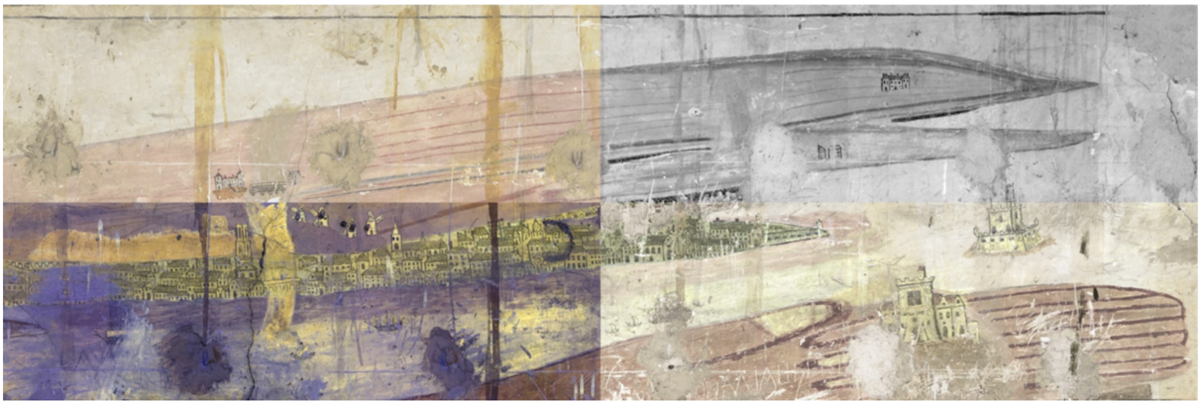

Figure 55. Multi-spectral Orthophoto combining Visible Spectrum, Infrared, Ultraviolet induced fluorescence, Composite. Source Pamart, A., et al. (2017). Multispectral photogrammetric data acquisition and processing for wall paintings studies.

pixel one of the three primary colours (RGB or CMY) (Lukac et al. 2007). The missing colours are calculated using demosaicking algorithms which use pixel neighbourhood information to compute the possible values. Many are the demosaicking algorithms, and they all provide slightly different results which can influence the colour quality of the picture (Li et al. 2011). Being the most computationally-intensive step in the processing of digital images and a key to the success of a specific camera, they are usually proprietary or covered by patents. Demosaicking algorithms heavily depend on the CFA pattern. Bayer array is the most popular pattern, but many others are available (e.g. Yamanaka pattern, diagonal stripe pattern, vertical stripe pattern, diagonal Bayer pattern, pseudo-random patterns, HVS-based pattern). Each combination of CFA pattern and demosaicking algorithms can provide diverse results (Ramanath et al. 2005).

Hence, the quality and validity of the captured and pre-processed data is primarily driven by the technological choices that a manufacturer made when producing an acquisition device.

While the responsibility of the manufacturer significantly impacts the capturing and pre-processing phase, the responsibility of the user is pivotal with respect to the settings he uses to record the visual space. Changing the aperture, the exposure, the white balance, the colour calibration, as well as the perspective, angle, and shooting condition users are able to accentuate and record diverse features, highlighting some parts or minimising others (Fig. 56 and 57).
The nuances and differences that a combination of diverse devices with their various settings can produce are a strong enough argument to stress the importance of tracing the origin of digital visual items. Additionally, those same images can be the subject of further elaborations which produce new digital objects. Set of 2D digital images can, in fact, be used by imaging techniques (see section 2.2) for the virtual reconstruction of 3D objects. Structure from Motion (SfM) algorithms compute the object's structure through the changes in the camera pose in 2D images, producing a sparse point cloud as well as calculating the camera parameters. The use of

Figure 56. Four consecutive shots of the Dormition with four diverse exposure time: 1/15, 1/8, 1/4, 1. Asinou Church, Cyprus.

Multi-view Stereo (MVS) algorithm use these parameters and enable the production of a densified version of the initial point cloud. Surfacing algorithms and texture mapping allow the transformation of the produced point cloud into a textured 3D model (Georgopoulos and Stathopoulou 2017).

The production of the point cloud, as well as the textured 3D models, use an initial set of 2D images processing them throughout a pipeline which, in most cases, it is not open and verifiable. The results are, therefore, visual products difficult to replicate and puzzling in respect to their representativeness of the original object. A visual product constructed in such way fails in important ways in its explanatory purpose.

We stressed, making the case of digital images, how tracing the origin of the knowledge is essential because it helps distinguish the realistic against the hyper-real. In a framework which aims to distinguish the percept as well as the type of reasoning we use to classify it as an object of a kind, making a distinction between the realistic and the hyper-real is essential. A comprehensive account of the interpretative reasoning would, in fact, be substantially weakened by the lack of understanding of the nature of the object of interpretation, which could easily be digital. As we stressed above, the nature of the digital object does not provide us with the overarching visual cues and dimensionalities which are common when we physically encounter an object. The visual understanding when looking at a digital object is based on a mediation, such as a photo, which is a summary or the object's dimensionalities based on a series of pre-chosen settings. The lack of provenance information about such digital mediation would create serious fallacies in our reasoning because we would equalise the interpretative behaviour over the physical and digital, not considering that the digital is in itself already an interpretation which could drive further visual reasoning over the object. As a consequence, it is essential to provide frameworks for the recording and documentation of the provenance information over digital visual objects.

With such aim in mind, in the following section (8.2) we will examine the concept of knowledge provenance and what it entails. Additionally, in section Data provenance in photogrammetric protocols we will propose a framework for documenting the provenance of digital visual reconstruction using a process-based pipeline.

8.2 Knowledge Provenance

The tracing of the origin of digital sources of information has grown in importance with the exploding body of digital information (Marins et al. 2007). While common best practices were adopted early as the XIX century in the archival community (Sweeney 2008), the investigation of the knowledge provenance and the validity of information has been a subject of discussion by many disciplines. In the computer science domain researchers focused on the information retrieval rationale, and specifically the reasons for the appearance of a specific information as the result of a query (Khanna et al. 2001). Within the GIS community researchers were more interested with the ongoing transformations happening within the data creation pipeline (Simmhan et al. 2005). In the cultural heritage domain, researchers were given more attention to the origin of an information-bearing artefact (Sweeney 2008).
These diverse approaches only recently started to converge towards a broad definition (Missier et al. 2013), which decomposes the problem of knowledge provenance into three different branches:

- Agent-centred provenance
- Object-centred provenance
- Process-centred provenance

The term agent-centred provenance covers the information about individuals who participated

in the process of creation of a particular document, or set of documents. The primary function is to help traces responsibilities, copyright holders as well as and the person/group to contact in case more information are needed.
For object-centred provenance we understand the documentation of the relationships between parts and whole of an information set, making explicit where the data comes from. It is highly recommended to preserve and make explicit such type of provenance information, specifically in the case of digital datasets which mesh-up several kinds of diverse data types (e.g. different CSV from different sources).
While agent-centred and object-centred provenance information do focus on, respectively, the agency and the composition of a dataset, the process-centred provenance record the information about the arguments, rationale and steps used for developing a digital object.

The recording of these three kinds of information helps clarify the legal and scientific value, as well as the validity, of the analysed object, improving its chance to be re-used. Moreover, the formalisation of such type of information significantly helps in depicting the context of production.

8.2.1 Charters

The documentation of agent-centred, object-centred and process-centred provenance information helps to frame digital objects as scholarly reconstructions capable of enabling an intelligible level over mere visual products. Such need is not uniquely formalised by the author, but starting in 2006 a group of scientists have been actively trying to pursue such goal, creating the London charter and, afterwards, the Seville Principles.

The London Charter is an international charter dedicated to computer-based visualisation of cultural heritage (Bentkowska-Kafel et al. 2012). Directly in the preamble, it lays out the most basic goal: to "*ensure that digital heritage visualisation is, and is seen to be, at least as intellectually and technically rigorous as longer established cultural heritage research and communication methods"*. The Charter uses as a foundational premise that "*the outcomes of research (…) should accurately convey to users the status of the knowledge that they represent, such as distinctions between evidence and hypothesis, and between different levels of probability*" (Beacham et al. 2009). Later, in the section concerning documentation, the Charter highlights the necessity that, "*computer-based visualisation outcomes should be disseminated in such a way that the nature and importance of significant, hypothetical dependency relationships between elements can be clearly identified by users and the reasoning underlying such hypotheses understood*" (Beacham et al. 2009). These three short quotations show the critical challenge of documenting the arguments and evidence deployed in the process of cultural heritage study.
While the London Charter points out the generic need of transparency in the relevant fields of cultural heritage, the Seville Principles take up these reflections and examine their implementation in the field of virtual archaeology. The Seville Principles propose a definition

of virtual reconstruction as "*using a virtual model to visually recover a building or object made by humans at a given moment in the past from available physical evidence of these buildings or objects, scientifically- reasonable comparative inferences and in general all studies carried out by archaeologists and other experts in relation to archaeological and historical science*" (Lopez-Menchero and Grande 2011). Such a definition is a clear encouragement to more formally document the process of reconstruction activities in order to make explicit their meaning.

8.3 A proposal for recording data provenance in photogrammetric protocols

As mentioned in section 8.1, in contemporary visual heritage studies, digital replicas of physical artefacts, in the form of three and four dimensions digital hyper-realistic images of reconstructions, are used to convey the original meanings to a public that cannot access the original visual works. Techniques such as photogrammetry, laser scanning and similar, plays an important role in the documentation process.

The resulting 3D models, orthophotos or 2D plans can be used for various purposes, from geometric analysis of structures and features, to the creation of interactive visualisations in education, for providing support for management decision-making and information tracking. CH specialists increasingly rely on photogrammetric products for geometric documentation of an object and as a means to link and communicate knowledge across disciplines. Despite its increasing importance, recognised standards and protocols for the collection of the appropriate metadata and paradata that would support the effective long-term use of the photogrammetric output as a documentation resource are not broadly available. Image-based data and products should ideally stand as referenceable documents in their own right with a known provenance. This would allow another actor in the scientific research community to reuse them with reliable knowledge of the essential parameters that have gone into the creation and delivery of that resource. Appropriate documentation of such data objects' provenance would effectively put them on par with traditional bibliographic resources and thus open them up fully for academic and commercial re-use.

Several factors make this goal difficult to achieve. One of the most laborious tasks is organising and relating the different steps of a digitisation workflow. Proper organisation of the workflow has both important long and short-term effects on the data. The long-term effects concern the accessibility and reliability of the data that will be produced over time. Digitisation is considered to be an important mean of preserving artefacts by capturing important information from the original object. Yet, without preserving information about how the digitisation was generated, this aim is severely undermined, as the accuracy and reliability of the digitisation cannot be assessed. The workflow as a tool for day-to-day planning, meanwhile, focuses on the management of shared resources and their proper interpretation by the different members of a digitisation team. The continuous research into new applications of photogrammetric techniques using new technological tools means that novel ways of applying it to CH research are continuously being discovered, and this further complicates the goal of selecting the relevant metadata to record in the process. Finally, the task of defining protocols for digitisation workflow is made even more difficult by the multidisciplinary uses it is put to, requiring a dialogue among all the professionals involved to ensure that the protocol meets the minimum technical and analytic needs of each one to ensure its usefulness. Nevertheless, keeping a record of the digitisation process not only contributes to the sustainability of the produced data object, but also supports the long-term evaluation of techniques and methodologies, allowing the comparison of projected methods against results and the eventual refinement of techniques for various aims and relative to different types of objects.

Our proposed approach describes the essential processes to be carried out and the metadata to be gathered in digital photogrammetry survey projects, from image acquisition to the delivery of final products.

In the following sections, we introduce the methodology and aspects of the case study are presented and discussed in order to illustrate how they were handled with regards to the workflow and protocols.

8.3.1 Methodology

Reality-based 3D modelling is a well-established and low-cost process that can typically be divided into the following steps: project planning (equipment, staff, budget, time, etc), data acquisition (image and reference system observations) and data processing (from images to point clouds and photorealistic 3D models) (Remondino and El-Hakim 2006; Remondino et al. 2013). The photogrammetric process - especially when dealing with cultural heritage objects - requires the coordinated efforts of different actors as well as the integration of different kinds of data. We propose a typical workflow for a complete digitisation, breaking it up into seven iterative and repeatable steps: (i) project planning, (ii) preliminary studies, (iii) data acquisition, (iv) data processing, (v) result analyses and acceptance testing (vi) creation of dissemination products and (vii) delivery. For each step, we propose an information workflow methodology and metadata schema for capturing the data relevant to each step. The complete collection of registers, as well as a sample of control lists developed during the project, is available online at http://itndch.map.archi.fr/pacs.

Each of the individual steps of the overall workflow is the result of an extensive process of analysis of the implicit and explicit information relied upon and the general action/decision events that occur during the production and exchange of data in a digitisation process using photogrammetry. The workflow are represented using the Business Process Modeling Notation 2.0 (BPMN) (White 2004; Chinosi and Trombetta 2012) and the seven steps mentioned above are encoded into seven Business Process Diagrams (BPD). BPD were chosen because they are a well-known tool to create a formal analysis of relevant events, allowing us to show how the different participants interact and to indicate at what point data and metadata should be captured to document essential information with regards to the creation of digital products. It is especially useful in this latter process of helping visualise and define when, within the workflow, documentation should be created and updated, as well as who is in charge of doing

so, providing a well-defined information pipeline within the digitisation team that can be used as a guide for the organisation of the overall process (Fig.58, 59 and 60).
Each of the BPD we propose is accompanied by a set of metadata registers that indicate a schema of fields to be used for the description of the relevant information called for in each step. These registers together form a conceptual schema which can easily be encoded in various languages such as XML (eXtensible Markup Language) or DDL (Data Definition Language) according to the individual project needs. An example of encoding this data into a database schema is also provided in the additional documentation available on the website noted above.

8.3.2 Photogrammetric documentation workflow

The steps of the documentation protocol (Fig. 58) are described in the following sections. Their development and evaluation, both in the office and then in the field with a real case study, allowed us to immediately test and progressively adjust the proposed model, deciding on the key information to be recorded and preserved. At the same time, we were able to discover which data were not important, allowing us to streamline the metadata recording process as much as possible. The final proposal is the fruit of interdisciplinary research between 3D surveying experts, technicians, CH analysts and dissemination professionals.
We present a selection of the workflow diagrams and metadata forms that we created. For each step of the protocol, we will understand the rationale of the step, and give an example of how following the workflow and recording the relevant metadata aided in the management of data production and exchange amongst the digitisation team in our case study. For the completed metadata registers reference the complete documentation set in the Annex B.

8.3.2.1 Project planning

We argue that the central logical element of the photogrammetric workflow, and digitisation more generally, is the project itself, to which all intersecting and related activities, physical objects, digital documents, actors and equipment can be referenced. Further, each digitisation project should be defined in relation to a goal, or is initiated in order to answer one or more research questions. This goal-oriented nature of the digitisation process is a natural part of any scientific activity, but is often documented only in narrative form or, in the worst cases, remains implicit in the minds of the actors initiating the project. Therefore, in addition to recommending the recording of the originating project of the digital object, we make the proposal to record also the questions/goals that spurred the project. These questions are to be referenced later in the workflow in order to link questions to types of solutions as well as their success or failure at resolving the questions posed. In this way, the digitisation process contributes to its own progressive amelioration through long term recording of successful and unsuccessful strategies relative to different types of goals.
In our case study, the Project Register was useful for recording the actors involved (engineers and cultural heritage specialists) and the artefacts under consideration. The equipment register

allowed for the recording of the available equipment which, in this instance, included one DSLR cameras with multiple focal length lenses and a tripod. Explicitly recording the research question of the case study proved to be one of the biggest challenges because it is not part of the usual digitisation practice. In fact, rendering the research questions explicit and available to all members of the team in the Question Register generated useful and interesting dialogue. While in our case the value of the acquisition was purely aesthetical and simply aimed to create the three-dimensional representation of the Pantokrator and the south and north lunettes, the Question Register could be useful to define aims such as the testing of three different photogrammetry software applications (Photoscan, SURE, and aspect3D) or the exploration of High Dynamic Range (HDR) imaging in photogrammetry as compared to standard images. For each of these aims it is possible to documented the projected acquisition, processing, and dissemination methods which would be required in order to organise the overall workflow.

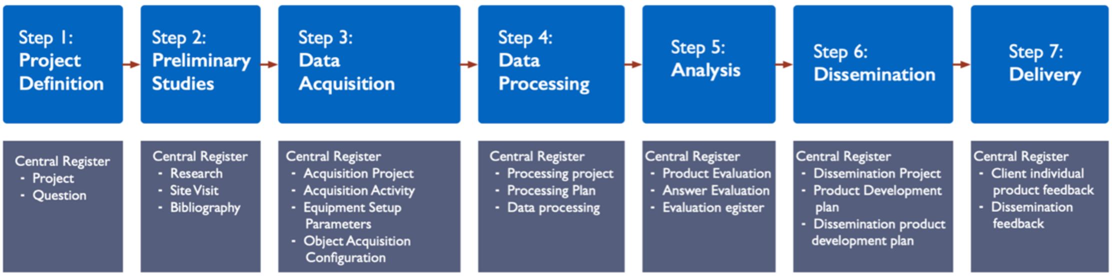

Figure 58. Overview of the general documentation pipeline and its related registers.

8.3.2.2 Preliminary studies

Any kind of digitisation project, using photogrammetry or other surveying methods must take into account previous and parallel work regarding not only the geometric documentation of the object but the relevant literature and information from contemporary site visits as well. The data collected in the preliminary study step serves to inform all the following processes, both as a reference and as potential input to the planning and processing stages.

We therefore proposed the preparation of a Research Register to explicitly document this background research and to stand as a base resource in the project. This Research Register can be linked to Bibliographic Register, previous geometric documentation in the Digital Assets Register and the Site Visit Register.

In the case study, the site and objects had previously been geometrically recorded (Sofocleous et al. 2006) and several related articles were collected in the Bibliographic Register. A site visits where local experts explained the context of the artefacts was organised. The presentation document was appended to the Site Visit Register. Taking this additional research step and documenting it explicitly was of use both to the acquisition team in planning its acquisition strategies and to the dissemination team in preparing the application for presenting the finished models in their full context. This step is represented in the figure below (Fig. 59).

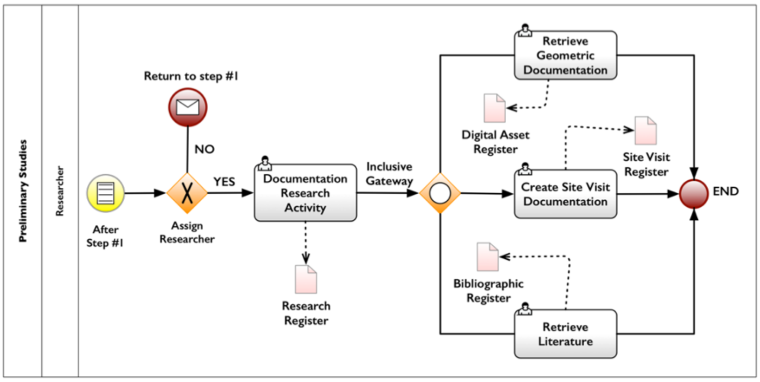

Figure 59. BPD: Step 2.

8.3.2.3 Acquisition

The acquisition phase attempts to follow the plan established during the initial setup of the project, taking into account the projected output requirements to answer the research questions and goals posed. This phase requires careful and detailed documentation in order to fully contextualise the data acquired, and overall, to make them reusable for the different current and future actors engaged with the data. The central documentation tool for this phase is the Acquisition Project Register, understood as a container activity for documenting multiple acquisition activities. The aim of each object's acquisition should therefore be registered separately, documenting the object of analysis, the level of accuracy required, the agents involved and the relevant time limits.

The individual acquisition activities should be documented separately in the Acquisition Activity Register, using an activity-based metadata log linked to the overall acquisition project. Each data object produced during an acquisition event is the result of the activity of some actor(s) in a certain environment at a certain time, and involves the use of specific equipment, set to particular parameters. Recording these parameters correctly is of paramount importance to allow its interpretation and derive the desired results. The acquisition activity itself should be recorded with regards to: its object (e.g. the artefact or the site under study), acquisition time and environmental factors, actors involved, equipment employed (linked to its technical details) and setup parameters during the capture. These parameters involve the shooting methodology, overlap, calibration and other decision factors which affect the overall outcome of the final digital product (GSD, DoF, distance to the object etc.). As an example, the acquisition parameters for an individual object (more detail below) of the case study are recorded in Tables 6 and 7.

Finally, each acquisition activity is linked to its products, which are recorded in the comprehensive Digital Asset Register.

Documenting the acquisition and its relevant parameters proved one of the most challenging processes to discretise into its basic components.

Table 6. Form filled for Equipment Setup Parameters Register - Camera.

Equipment Setup Parameters Register - Camera	
Camera Body	Canon EOS 650D
Lens	EF-S18-55mm f/3.5-5.6 IS II
Lens type	Tele
Platform	Tripod
ISO	400
Shutter Mode	Manual
Shutter Speed (sec)	0.8
Aperture (f-stop)	8
Focus	Automatic
Focus fixed	No
Focus distance	1 m
Depth of field	12 cm
Near focus	28 cm
Far focus	40 cm
Focal lenght	18.0 mm
White balance	No
Lightmeter used	No
Camera pre-calibrated (geometrical calibration)	No
Colour calibration	No
HDR	No

Table 7. Form filled for Object Acquisition Configuration Register.

Object Acquisition Configuration Register	
Camera configuration type	Parallel
Camera configuration type	Convergent
Average GSD (Ground Sampling Distance)	0.024 mm
Percentage of object covered (%)	80
Average distance from the object	1 m
Forward/Longitudinal overlap (%)	-
Side Overlap (%)	80%
Markers	No
GCP	No
On-site camera calibration	No
Obstacles	Lamps

In the tables above we described the setup which was used for the photogrammetric data acquisition, which in this instance included a APS-C camera, Canon 650D, with a 18-55mm focal lens, mounted on a tripod for increasing the shooting stability. The camera resolution was set to the maximum (5184x3456), and automatic exposure and automatic focus were used. Both the camera and the tripod were previously entered in the general Equipment Register, so as not to repeat the information in the acquisition step and to better relate the equipment with the products of the acquisition and the actors involved.

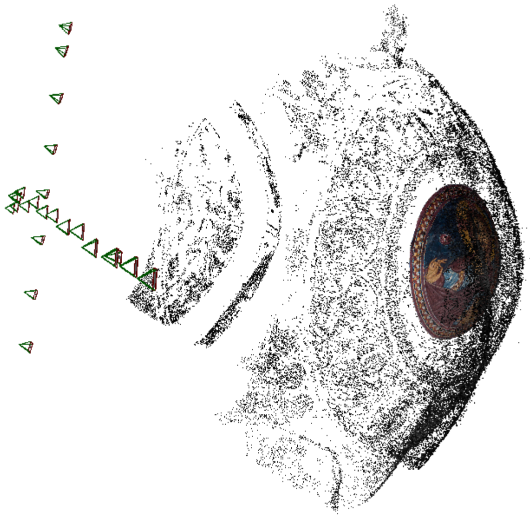

Figure 61. Camera positions related to the acquisition of the figure of the dome of the Christ Pantocrator. Colored dense cloud

In this case, the object was acquired using a parallel acquisition (Fig. 62). Within the model, we take into account the input of n images for the photogrammetric reconstruction in order to link the original file to the final outcome of the reconstruction. We do not explicitly document the spatial position of the camera in relation to the object plane because such parameters are later automatically calculated by the software.
Recording the time used for the acquisition allows us to evaluate the speed of the digitisation in comparison to other setups and rate their efficiency. While the protocol was tested in this occasion only in relation to one objects, there is no issue for the scalability of the approach to large or multiple objects (Calles et al. 2016). We use chains of activities as units of documentation, therefore, it is irrelevant, methodologically speaking at least, whether the object to be digitised is large or small because in the former case it can be still documented into its smaller processing units registered together during the processing phase (Fig. 63).

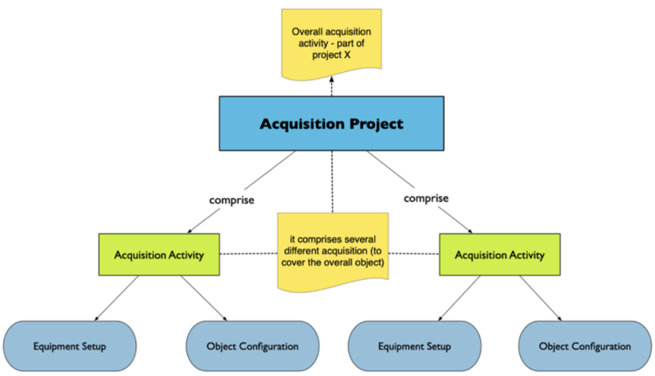

Figure 63. Schema followed for the documentation of the different agencies and subjects during the acquisition events.

In addition to the setup information shown in Table 6 and 7, the protocol includes descriptors for specifying the environmental light control, as well as the presence of markers during the acquisition event.

Through the use of the documentation registers, we were able to record the individual photogrammetric data acquisition activities and their input parameters, notably equipment and acquisition methodology, and link these to the digital outputs. This allows us not only to contextualise the data acquired but also to provide more general information on field-tested setups for future scenarios with similar conditions.

It is important to underline that the recording of certain types of parameters does not have to be carried out manually, but can easily be partially automated using efix metadata. While this interest in automated metadata collection does not concern only the acquisition phase, we noticed these kinds of requirements and requests come out specifically in relation to this specific phase.

8.3.2.4 Processing

The processing step takes the results of data acquisition activities and plans for their transformation using automatic or semi-automatic software operations. The results are data products aiming to meet the specifications set out during the initial evaluation of the research question as established in the project planning step. Since processing can be a complex operation, requiring continuous iterative 'results versus goals' validation, we propose a three-tier documentation scheme to track these tasks: (i) Processing Project Register, (ii) Processing Plan Register, and (iii) Data Processing Register.

The overall documentation unit is the Processing Project Register, which acts as a wrapper for a sequence of processing actions that will take place according to a documented plan held in the Processing Plan Register. Moreover, the Processing Project Register, outlines the products and its accuracy expected, and by whom the processing will be organised, controlled and performed. The processing action links to the original question to which the processing plan should respond, as illustrated in Fig. 60.

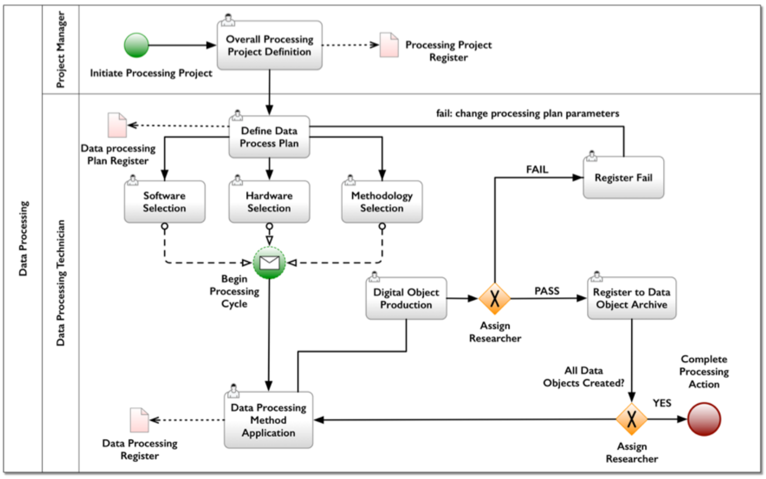

Figure 60. BPD: Step 4.

The actual execution of a processing project that will result in the intended end product will require several processing steps with individual processing plans and iterative processing actions checking for data accuracy and acceptability.

For each discrete step, we envision a separate documentation of a data processing plan, which would lay out the software, hardware and methodology to be employed to achieve the desired end. Each data processing action that is carried out under a plan is then documented in its own right in the Data Processing Register with the relevant input, output and indicated parameters used and obtained.

As an example, a type of data processing project is the overall creation of a coloured point cloud, while the processing action is the discrete operation taken for achieving a goal. These actions used different parameters that need to be recorded in order to register the provenance of the data as well as comply with the need for reproducibility of results in the future.

Furthermore, the differentiation of processing plan and processing action is useful to establish the similarity or dissimilarity between the original plan and the real results of the processing. The execution of the processing action can result in different outcomes than the original expectations and therefore need to be adjusted. The recording of different approaches allows the documentation of not only success but also errors, useful as a foundation of the knowledge organisation of a research group. The documentation of the obtained accuracy is essential, as it determines the success or failure of the process. Success validates the data processing plan and allows the articulation of the next step of the processing project. Failure indicates that the data processing actor/engineer should return to the processing plan, adjust relevant parameters, and then run the processing actions again until a satisfactory result can be obtained, or a negation of one of the relevant factors can be obtained (e.g. software, hardware, methodology or input variables).

The three-step approach to documenting data processing allowed us to capture the array of different algorithms and software platforms that were tested to obtain optimal results. In our case the images were processed using micmac (Rupnik et al. 2017). Tie points were calculated using Tapioca, while the calibration was carried out using Tapas FraserBasic, a restricted version of Fraser with only 10 parameters (in respect to the 12 of Fraser).

Three different processing projects were created in order to discretise the complexity of the operations and achieve a better understanding and record of the distinct operations performed and the resulting data.

After dense image matching, a final coloured point cloud was generated. Information about the different processing units used are recorded in Table 8, which formalised parameters used and accuracy value obtained.

The recording of each of these steps as different processing units comply with the provenance principles of the documentation, establishing a better accountability for the steps taken, influencing factors and the algorithms used.

Table 8. Form filled for the Data Processing Register

Data Processing Register	
Processing type	Feature detection
Data processing technician	Nicola Carboni
Software used	Micmac
Algorithm used	SIFT
Used parameters	Tapioca All ".*jpg" 1200

Data Processing Register	
Processing type	Calibration
Data processing technician	Nicola Carboni
Software used	Micmac
Used parameters	Tapas FraserBasic ".*jpg" Out=All
Accuracy type	Residual value
Accuracu value	1.10411216960864222

Data Processing Register

Processing type	Compute dense points cloud
Data processing technician	Nicola Carboni
Software used	MicMac
Used parameters	mm3d C3DC QuickMac ".*jpg" All

8.3.2.5 Analysis and acceptance testing

After the completion of a cycle of acquisition and processing, we introduce in the protocol an analytical phase in which the resultant products are tested for their potential usefulness in regards to the initial research questions posed. Here, we envision specialists in a team or even clients, engaging in a review process of the raw acquisition products and/or processed data. We break up the evaluation and analysis stage into two principal components: (i) a general Product Evaluation Register documented on a per question basis, and (ii) a specific Answer Evaluation Register for each question in which the individual data objects generated to answer that question are evaluated.

For each stated research question, an analysis form can be filled out giving an overview of the digital objects produced and an overall rating of the methodology adopted and the usefulness of the data generated. Here, we have in mind a comparison of the objects against broader and less technical criteria than those envisioned in the self-testing aspects of the acquisition and processing steps of the digitisation project. The question is to understand whether or not the outputs were able to support an interpretation relevant to the original research questions. Regardless of the result, a documentation of the evaluation of the methods employed and the method of evaluation helps to improve the process of answering future questions.

In the second, more specific step, the individual data products related to the question are accepted or rejected, with a documented justification. This step, therefore, can potentially result in restarting the processing project or even the acquisition, depending on the outcome. This review phase was conceived to create a formal space for documenting the analysis and testing of the processed models as digital assets and link their evaluation to the initial research questions.

8.3.2.6 Dissemination

Dissemination plays an ever more prominent role in cultural heritage research and in some cases it may even be the raison d'être for the entire project. A careful balance is therefore required; while a project must ensure from its inception that it will produce results that can be used for the desired dissemination, data reusability means that information that may not directly affect the dissemination must also be recorded to ensure its reliability and usefulness in the future. Which products are requested and required for the dissemination aspect of digitisation can vary widely, depending on the intended audience, budget, space constraints and other factors. From a model for simple visualisations for the general public to full-scale, 4D interactive environments, the dissemination of the results of a digital documentation project could be the subject of an entire workflow control process of its own. However, we propose to treat dissemination activities as an integral part of the total digitisation workflow. Considered from this perspective, the dissemination control process can be modelled using a framework similar to the processing structure, differing mostly in its consideration of goal variables. While processing must consider its base questions of accuracy, dissemination must consider questions of suitability for an audience.

Therefore, we propose a parallel tripartite structure to the processing control activity. This consists of the basic documentation units of the Dissemination Project Register, Product Development Plan Register and Dissemination Product Development Activity Register.

The overall Dissemination Project Register records the target audience, the planned medium, the aim of the dissemination product and the projected dates of production. Each dissemination project will entail a number of internal development cycles that will require their own planning. In the dissemination cycle, the developers can take full advantage of all generated products within the digitisation pipeline to this point. They may therefore import assets from the research, acquisition and processing phases as part of the base materials from which to construct their final product. This provides a map of provenance of the inputs to the end product, while not imposing overly onerous metadata entry requirements on the user.

Each individual product of the dissemination cycle should be subject to at least one planning event. These serve as the control base from which to execute processing for the development of dissemination products. As in the acquisition phase, we suggest that each significant processing event for the creation of a digital asset related to dissemination purposes should be documented and related to its relevant Product Development Plan and the activities initiated to achieve that plan recorded in a Dissemination Product Development Activity Register.

8.3.2.7 Project conclusion

The completion of a digital documentation project is signalled by the handing over of the requested final products to the client, be it an internal researcher or external contracting actor, who should provide an evaluation, whose acceptance or rejection of the end products should be recorded, and may trigger the development of a new process for acquisition, processing and dissemination product creation. The evaluation of the dissemination products should be recorded in the Client Individual Product Feedback and Dissemination Feedback Register and should follow the same model as that of the analysis and evaluation step for acquisition and processing steps, only now with regards to final dissemination products and the overall project goals. The recording of such information is to be considered vital, because it will enhance the quality control with regards to the digitisation steps needed.

8.3.3 Recording process, results and interpretation: an ontological grounding

The proposal allows for the tracking of the digitisation process that leads to and makes possible the digital product through the complete photogrammetric workflow from planning through acquisition, processing and analysis all the way to dissemination. We outline the complete workflow and relate some of the key metadata registers we propose to capture the main framework of data interactions, from the functional requirements to the scientific analysis of a digital documentation project. The framework proposed has been also mapped to CIDOC-CRM and CRMdig, in order to create a semantic pipeline that tracks the data acquisition phase, the processing and the annotation. Such pipeline can help us understand the analysis and use of digital information and its truthfulness in respect to the physical artefact they represent. Following the example outline in section 8.3.2 the information in the table 7 and 6 were mapped to CIDOC-CRM. The graph in Figure 64 and 65 presents a semantic mapping of the information about the acquisition and processing of a series of photos taken in the narthex of the church of Asinou.

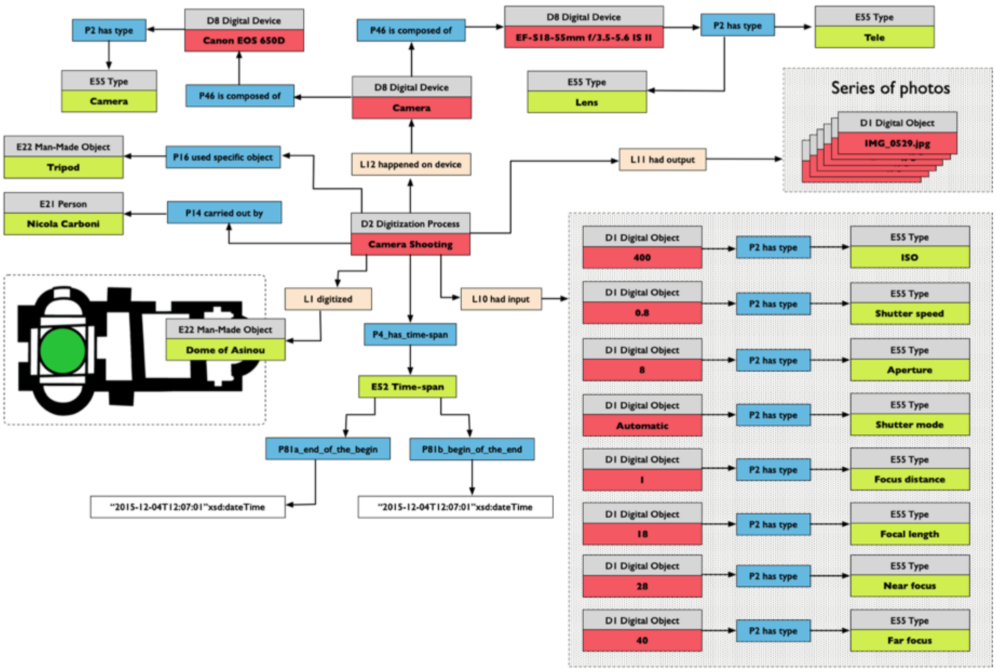

Figure 64. Diagram representing the provenance information encoded in CRM about the data acquisition phase used for the documentation of the church of Asinou.

The diagram in Figure 64 makes clear the connection between the physical domain and the digital one. The diagram describes the digitisation of the dome of the church of Asinou and what kind of set of devices has been used for it specifying, moreover, the set of parameters used. The results are a series of photos which are then processed using MicMac. The processing (Figure 65) describe three steps and track the digital object throughout the various changes until the production of a final 3D model.

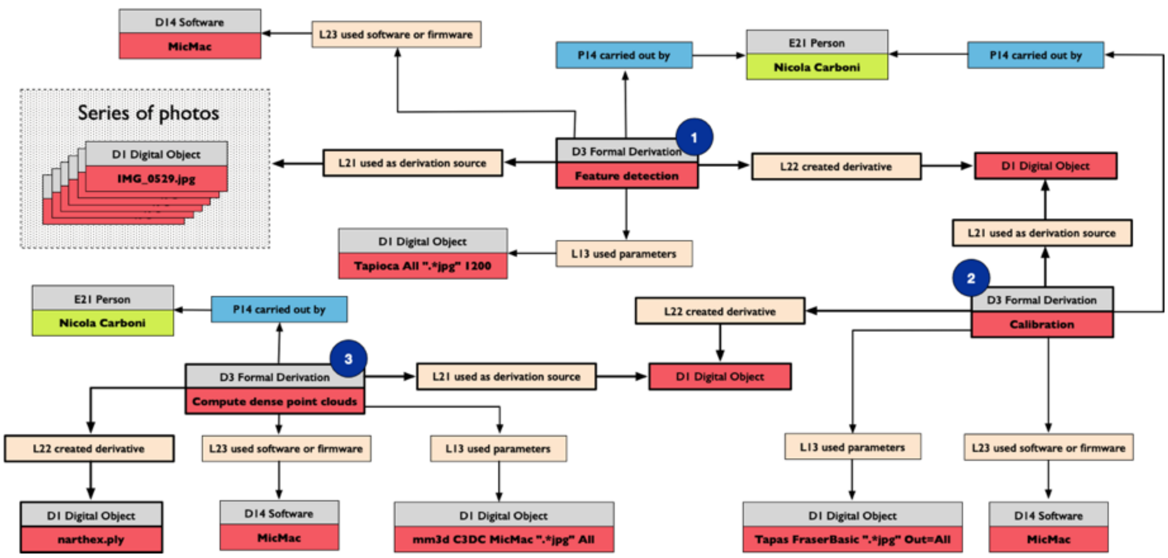

Figure 65. Diagram representing the information encoded in CRM about the processing phase used for the creation of the final three-dimensional model.

This same set of photos and the final 3D model can be further described in respect to the annotations created. Section Aioli, and specifically Figure 52 describe exactly this passage. The photos in this diagram are the same set described and documented above. We have, therefore, a complete pipeline describing the acquisition of the physical, the creation of the digital, and its classifications throughout annotation, making evident the link between digital act, physical world and conceptualisation (using VIR).
This type of process is the necessary step to create a digital environment able to display the diverse classification given to the same object and escape from the top-down characterisation of cultural object that has plagued for too many years the digital heritage studies. Using this methodology, in fact, we are able to retrieve and compare diverse conceptualisation and digitalisation of the same artefact, analysing not only how the diversity create different digital products, but how a conceptual diversity can define differently the same digital resource.

8.4 Conclusion

In the last sections we understood how complex is the documentation of the provenance of our information, but we also highlight the importance that such conceptual tool has in our interpretation of the real.

Section 1.2 introduces the major issues with our current use of the digital representation, stressing the importance of tracing the origin of the knowledge for these data objects. At this point, before running the risk to slip into a relativistic foundation, it is important to stress that, for as much as the complexity of a digital representation does not capture the granularity of information a physical encounter would provide, digital objects are in themselves usually quite capable of representing the visual space. Therefore, the importance of tracing the origin of the knowledge of a digital object, rest in respect to its usage for scholarly practice, where its inherent biases need to be clearly stated.

The usage of provenance-free digital objects as mediation in the visual interpretation discourse it is quite acceptable if the premises are not academic. Once, however, such discourse needs to be a citable piece of evidence it is essential to frame it under a scientific light, which does not automatically provide an answer to the truth or falsity of its propositions, but it makes the argument transparent, helping the community understand if there are fallacies.

On account of the above reasons, a framework was elaborated

In section Data provenance in photogrammetric protocols we presented a solution for the problem of recording the data provenance. In this section, we outlined a framework for the recording of the digitisation process using photogrammetry as the primary example. Driven by the use case requirements, the framework split the acquisition into several steps, which are then linked with information sources and registers. Each step is constituted by a set of documentation units which are related to each other. The interconnections between these units create a final graph of linked information which represents the information about the pipeline used to produce the digital object.

The usage of these framework help creates intelligible and scholarly acceptable reconstruction, which can be assessed and compared between each other, making them usable for further investigation, and diverse from other hyper-real products which surround us.

9 Conclusion

"Like all walls it was ambiguous, two-faced. What was inside it and what was outside it depended upon which side of it you were on."

— Ursula K. Le Guin, *The Dispossessed*

9.1 Conclusion

This work has examined the process of meaning-assignment and defines a computational model able to reproduce the elements of that process using a formal method. The study of the meaning has been initially explored from a semiotic perspective defining the nuclear operational components responsible for such a complex process. Once theorised, it has been discussed in relation to art-historical theoretical models and then formalised as a semantic artefact called VIR.

VIR has been harmonised with the ISO standard ontology for cultural heritage, CIDOC-CRM, and tested across various scenarios. It has been employed to define iconographical characteristics of an image, the use of pictorial elements in a performative event, the connection between image and textual sources, and it has also been used to define the historical influence for the selection of specific elements of the image.

The ontology has been further harmonised with an annotation model able to link 2D/3D structure with iconographical representations. The resulting model has been assessed with a provenance-based framework able to document the creation of digital 2D/3D resources. The result is an information pipeline that interconnects the meaning assigned to a visual resource with spatial and morphological information as well as with the digitisation process where this information has been encoded. Moreover, we further linked the visual artefact with its historical and physical settings. These elements have been all harmonised together, and the result is a graph able to provide a meaningful understanding of the construction, use and comprehension of a visual item.

While the results have been promising, and the work answers the objectives presented in section 1.3, the overall work requires further analysis and research with respect of two important trends in the discipline: crowdsourcing and machine learning.

9.2 Limitation

9.2.1 Crowdsourcing

The first challenge that the study of the interpretation of digital cultural objects has to face is the one of crowdsourcing. Crowdsourcing is the name of a distributive model that entail the division of the work in micro-tasks, assigned to an evolving group of employee/participants which access the work over the internet (Howe 2006). Crowdsourcing can be used as a process of knowledge graph refinement (Paulheim 2017) in order to increase the quality of the stored information, specifically with respect to the addition of new knowledge or with the correction of existing ones. While this is already a reality, and many applications in the form of Human Computation (Quinn and Bederson 2011) based games or crowdsourcing activities have been presented (Guéret et al. 2012; Hees et al. 2011; Simperl et al. 2011; Re Calegari et al. 2018) some issues remain open. The major problem concerns the crowd-agreement. Dealing with complex subjects, such as the identification of iconographic subject and motifs, requires advanced knowledge of the topic at hand. While this has been taken into account in the ontology, specifically introducing a construct able to define the interpretation over an image (and not simply an assignment of a status) the use of crowdsourcing to refine visual information could still lead, if major differences arise, to some issues at a query level. Agreements between annotators is usually seen as a quality measure, however, as we specified plenty of time across this work, there is some implicit fuzziness and ambiguity in the visual data, derived from cultural or knowledge differences. It is necessary to continue working on a framework such as the one proposed by Crowdtruth (Anca et al. 2018), for defining metrics such as "Annotation Quality Score" or "Worker Quality Score" able to quantify the possibility of errors in the newly added data. The rise of this metrics would help the community further specialise their data not only through interlinking or definition of equivalences, but using quality crowdsource power.

9.2.2 Machine Learning

Part of this work focus on the harmonisation between the created ontology VIR and the annotation model, envisioning visual annotation systems, such as the one discussed in section Visual Annotation, which enable the users to create visual annotations and store this information in a graph database. While this method is surely important, it does not scale at the same speed that a machine learning based system would. While this is not an issue per se, it is important to highlight that an interconnection between an ontology and a machine learning based system could provide faster results. The quality of the annotation would not be, however, as good as with a user-driven approach. A possible solution to this problem could be the use of a semi-automatic system which suggests possible values to a user created annotation, helping him classify a heritage object. The major drawback of this approach is that machine learning algorithms require a training set to train the model. This training sets are manually created by domain experts. Therefore, if the information we are after are specific enough, the creation of a training set would be quite a complicated affair, because of the level of art historical knowledge required for the definition of the set. In order to represent a truthful reflection of the field would be necessary to gather many minds around the project, minds who could have very diverse thoughts and reflection on the classification of one object. Moreover, as underlined at length in this work, social and cultural diversity can easily create diverse classifications of the visual, therefore the creation of the initial training set could result in a flattening work, which would not be able to take into account the same differences that made the discipline of visual study thrive.

However, machine learning approaches could be combined with manual annotations, creating grids of comparisons and using 2D/3D quantitative metrics to propose similar objects to a user. In this instance, the agreement problem mentioned before would be easily overcome by the principles embedded in the knowledge representation discipline, which recognise diversity and do not try to frame specific views. Using the annotation models, as demonstrate in section Visual Annotation, we are able to accommodate and visualise diverse perspectives over the object.

If automatic and semi-automatic methods have to be employed, it is of the utmost importance to classify the results accordingly, dividing the information gather by experts from the one of dubious validity obtained automatically. It could be, however, envisioned an information sandbox that would require human confirmation before releasing or interconnecting the automatically computed information.

As it is possible to guess from this last section, many are the possibilities which have not found space in this work and need to be further analysed in order to creates a large repository of organised visual items, able to provide to the community the instruments for new digital iconological studies.

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11 Annex A

Entities

E1	CRM Entity								
E7	-	-	-	-	Activity				
E13	-	-	-	-	-	Attribute Assignment			
E14	-	-	-	-	-	-	Condition Assessment		
E15	-	-	-	-	-	-	Identifier Assignment		
E16	-	-	-	-	-	-	Measurement		
IC12	-	-	-	-	-	-	**Visual Recognition**		
E17	-	-	-	-	-	-	Type Assignment		
E18	-	-	-	-	Physical Thing				
E26	-	-	-	-	-	Physical Feature			
IC19	-	-	-	-	-	-	**Recto**		
IC20	-	-	-	-	-	-	**Verso**		
E24	-	-	-	-	-	Physical Man-Made Thing			
E22	-	-	-	-	-	-	Man-Made Object		
E25	-	-	-	-	-	-	Man-Made Feature		
IC1	-	-	-	-	-	-	-	**Iconographical Atom**	
E28	-	-	-	-	Conceptual Object				
IC16	-	-	-	-	-	**Character**			
IC11	-	-	-	-	-	-	**Personification**		
E90	-	-	-	-	-	Symbolic Object			
E73	-	-	-	-	-	-	Information Object		
E27	-	-	-	-	-	-	-	Design or Procedure	
IC10	-	-	-	-	-	-	-	-	**Attribute**
E31	-	-	-	-	-	-	-	Document	

E33 - - - - - - - Linguistic Object

E36 - - - - - - - Visual item

IC9 - - - - - - - **Representation**

IC10 - - - - - - - **Attribute**

E38 - - - - - - - Image

E41 - - - - - - Appellation

E89 - - - - - Propositional Object

E55 - - - - - Type

Classes

IC1 Iconographical Atom

Subclass of: **E25 Man-Made Feature**

An iconographical atom is a physical arrangement of forms/colours created by human activity

> **Proprieties**:
>
> K1 denotes (is denoted by): E36 Visual Item

IC9 Representation

Subclass of: **E36 Visual Item**

The nuclear characteristics which are recognized to belong to the same type

Example:

The painting "La primavera" in Botticelli
The last judgment wall painting in Asinou
The impresa of Bernardo Cles in the Buonconsiglio castle in Trento
The Maria Maddalena statue by Donatello.
The Bayeux Tapestry.

> **Proprieties:**
>
> K20 is composed of (forms part of): IC9 Representation
> K22 has personification (is present in): IC11 Personification
> K23 connote (is connotation of): IC9 Representation
> K17 has attribute (is attribute of): IC10 Attribute
> K24 portray (is portrayed in): IC16 Character
> K34 illustrate (is illustrated by): E73 Information Object
> K4 is visual prototype of (has visual prototype): IC9 Representation

IC10 Attribute

Subclass of: **E36 Visual Item**
E29 Design or Procedure

A set of features considered by a viewer more salient than others and used as a key for the identification of a Representation. The attribute could correspond to iconographical elements or simple signs which the viewer uses to provide a stable identity to a visual object.

Example:
The cross in the Anastasia Samaralina painting in Asinou that symbolize the Martyrdom.
The dragon in "Saint George and the Dragon" by Tintoretto.

Proprieties:
K17 is attribute of (has attribute): IC9 Representation
K21 depict things of type (is depiction of attribute): E55 Type
K14 symbolize (has symbolic value): E90 Symbolic Object
K15 has been used by (use feature): E12 Production

IC11 Personification
Subclass of: **IC16 Character**
A human, or anthropomorphic figure, that represents an abstract idea or a concept.
Example:
Marianne in "La Liberté guidant le people" of Delacroix.

Proprieties:
K25 express (is abstraction of): E90 Symbolic Object

IC12 Visual Recognition
Subclass of: **S4 Observation**
The activity of assigning the iconographical status to a man-made object, or to one of its parts. It takes into account the possibility to link it to a speech act or a document where the authoritative proposition is clearly made.
Example:
An expert saying that object A is a IC9 Representation
The recognition that a simple drawing represents a type of animal

Proprieties:
K9 assigned status to (has status assigned by): E18 Physical Thing
K11 assigned (was assigned by): IC9 Representation
K10 on the base of (is basis for): E89 Propositional Object

IC16 Character

Subclass of: **F38 Character**

This class comprises fictional individuals, or groups, appearing in a representation. Each character portrayed can have a type, for example “Saint” or “layman”. Every saint portrayed is considered here as a character and not as an actor.

Example:

St. Anastasia in the Panel “Anastasia & Anastasia” in Asinou.

Proprieties:

K26 has source (is source of): E39 Actor

K24 is portrayed in (portray): IC9 Representation

IC19 Recto

Subclass of: **E19 Physical Feature**

The front or face of a single sheet or the right-hand page of an open book. The feature is presents in object such as codex, books, pamphlets, documents, photographs and painting.

Example:

The recto of the drawing 57 E r “Busto di giovane donna di profile” by Raphael, preserved in the Department of Prints and Drawings, Uffizi.

The recto of the photograph of St. John the Baptist by Vicino da Ferrara

Proprieties:

K6 has back (has front): IC20 Verso

K7 is recto of (has recto): E22 Man-Made Object

IC20 Verso

Subclass of: **E19 Physical Feature**

The back or underside of a single sheet of paper, or the left-hand page of an open book. The feature is presents in object such as codex, books, pamphlets, documents, photographs and painting.

Example:

The verso of the drawing 57 E v “Testa di donna di profile” by Anonymous XVI century, preserved in the Department of Prints and Drawings, Uffizi

The photographer's stamp in the verso of the photograph of St. John the Baptist by Vicino da Ferrara

Proprieties:
K6 has front (has back) IC19 Recto
K8 is verso of (has verso) E22 Man-Made Object

Properties

K1 Denotes (is denoted by)
Domain: E18 Physical Thing
Range: E36 Visual Item
Subproperty: P65 show visual items
The property documents the assignment of an iconographical object to a specific physical man-made object. It is a shortcut for the more fully developed path IC12 Visual Recognition assign (K9) to a E18 Physical Thing the status of (K11) IC9 Representation.

K4 is visual prototype of (has visual prototype)
Domain: IC9 Representation
Range: IC9 Representation
Subproperty: P67 refers to
The property documents the use of a specific prototypical example for an image. The nature of the relationships helps define a map of relationships between prototypical items used in the arts.

K4.1 prototypical mode
Domain: K4 Is visual prototype of
Range: E55 Type

K6 has back (has front)
Domain: IC19 Recto
Range: IC20 Verso
Subproperty: P46 is composed of
The property documents the presence of a Verso or a Recto, respectively in the back or in the

front of an object.

K7 is recto of (has recto)
Domain: IC19 Recto
Range: E22 Man-Made Object
Subproperty: P46 is composed of
The property indicates the presence of a recto in the described object.

K8 is verso of (has verso)
Domain: IC20 Verso
Range: E22 Man-Made Object
Subproperty: P56 bears feature
The property indicates the presence of a verso in the described object.

K9 Assigned status to (has status assigned by)
Domain: IC12 Visual Recognition
Range: E18 Physical Thing
Subproperty: P140 assigned attribute to (was attributed by)
The property documents the assignment of status to a specific physical thing.

K10 On the base of (is basis for)
Domain: E7 Activity
Range: E89 Propositional Object
Subproperty: P16 used specific object (was used for)
The property describes the source used for the status assignment.

K11 Assigned (was assigned by)
Domain: IC12 Visual Recognition
Range: IC9 Representation
Subproperty: P141 assigned attribute to
The property indicates the status assigned during the status assignment event.

K14 symbolize (has symbolic value)
Domain: IC10 Attribute
Range: E90 Symbolic Object
Subproperty: P138 Represents
The property indicates the symbolic value of the attribute presents in a representation.

K15 use features (has been used by)
Domain: E12 Production
Range: IC10 Attribute
Subproperty: P33 used specific technique
The property indicates the specific attribute used during the production of a visual object

K17 Has attribute (is attribute of)
Domain: IC9 Representation
Range: IC10 Attribute
Subproperty: P106 is composed of (forms part of)
This property associates an attribute with the representation where it is depicted.

K20 is composed of (forms part of)
Domain: IC9 Representation
Range: IC9 Representation
Subproperty: P148 has component (is component of)
This property put in relation an iconographical object with a part of itself.

K21 depict things of type (is depiction of attribute):
Domain: IC10 Attribute
Range: E55 Type
Subproperty: P137 exemplifies (is exemplified by)
This property indicates the type of object depicted by an iconographical attribute.

K22 has personification (is present in)
Domain: IC9 Representation
Range: IC11 Personification
Subproperty: P138 Represents
This property indicates the membership of a personification in an iconographical object.

K23 Connote (is connotation of)
Domain: IC9 Representation
Range: IC9 Representation
Subproperty: P138 Represents
This property indicates the connotation relationships, formalized by Barthes, between a

conceptual entity and an iconographical object. It is a shortcut for the more fully developed path IC12 Visual Recognition assign (K9) to a IC9 Representation a new (K11) IC9 Representation. It doesn't offer any information about when and whom established the connotation relationship.

K24 Portray (is portrayed in)
Domain: IC9 Representation
Range: IC16 Character
Subproperty: P138 Represents
This property put in relation an iconographical object with the portrayed character.

K25 express (is abstraction of):
Domain: IC11 Personification
Range: E90 Symbolic Object
Subproperty: P138 Represents
This property put in relation a symbolic object with a personification in a work of art.

K26 Has source (is source of)
Domain: IC16 Character
Range: E39 Actor
Shortcut: E57 is based on
This property associates an instance of IC16 Character with an instance of E39 Actor that the character is motivated by or is intended to represent.

K34 Illustrate (is illustrated by)
Domain: IC9 Representation
Range: E73 Information Object
Subproperty: P67 Refers to
This property associates an information object to a iconographical representation

K36 Anchors (was anchored by)
Domain: IC17 Anchorage
Range: E90 Symbolic Object
Subproperty: P141 assigned (was assigned by)
The property documents the symbolic object which has been used in the anchoring activity.

K37 anchors to (is anchored by)

Domain: IC17 Anchorage

Range: E36 Visual Item

Subproperty: P140 assigned attribute to (was attributed by)

The property documents the image used within the anchoring activity

Turtle Encoding of the Ontology presented in section Ontology.

```
@prefix vir: <http://w3id.org/vir#>.
@prefix crm: <http://www.cidoc-crm.org/cidoc-crm/>.
@prefix crmsci: <http://www.ics.forth.gr/isl/CRMsci/>.
@prefix frbroo: <http://iflastandards.info/ns/fr/frbr/frbroo/>.
@prefix owl: <http://www.w3.org/2002/07/owl#>.
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix xml: <http://www.w3.org/XML/1998/namespace>.
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>.
@prefix dc: <http://purl.org/dc/elements/1.1/>.
@prefix vann: <http://purl.org/vocab/vann/>.
@prefix skos: <http://www.w3.org/2004/02/skos/core#>.
@prefix lio: <https://w3id.org/lio/v1>.


<http://w3id.org/vir#> rdf:type owl:Ontology ;
 dc:creator "Nicola Carboni" ;
 dc:date "2019-02-26" ;
 dc:description "This ontology, called VIR, is an extension of CIDOC-CRM created to sustain
propositions on the nature of visual elements and permit these descriptions to be published
on the Web.With the term visual element, we refer to those signs identified in the visual
space as distinct and documentable units, and subject to an analytical interpretation. The
scope of this ontology is to s to provide a framework to support the identification,
annotation and interconnections between diverse visual elements and presents and assist their
documentation and retrieval. Specifically, the model aims to clarify the identity and the
relation of these visual signs, providing the necessary classes to characterise their
constituent elements, reference, symbolic content and source of interpretation. VIR expands
on key entities and properties from CIDOC-CRM, introducing new classes and relationships
responding to the visual and art historical community, specifically building up on the
iconographical tradition. The result is a model which differentiates between interpretation
and element identified, providing a clear distinction between denotation and signification of
an element. As a consequence of such distinction, the ontology allows for the definition of
diverse denotative criteria for the same representation, which could change based on
traditions and perspective. Visual objects can be, in fact, polysemic and ambiguous, and it
is not so easy to pin down a denotative or connotative meaning because they are very much
context-dependent." ;
 dc:right "This work is distributed under a Creative Commons Attribution License
(http://creativecommons.org/licenses/by/3.0/)."@en ;
 dc:title "VIR - Visual Representation ontology"@en ;
 vann:preferredNamespacePrefix "vir" ;
 vann:preferredNamespaceUri "http://w3id.org/vir#" ;
 rdfs:comment "On 03/03/2019 change the range of K11 to E36_Visual_Item in order to
accommodate the description of the recognition of Attributes" ;
 owl:versionInfo "1.1".
```

```
### CLASSES

 vir:IC10_Attribute a rdf:Class ;
 rdfs:subClassOf crm:E36_Visual_Item, crm:E29_Design_or_Procedure ;
 rdfs:comment "A set of features considered by a viewer more salient than others and used as
a key for the identification of a Representation. The attribute could correspond to
iconographical elements or simple signs which the viewer uses to provide a stable identity to
a visual object." ;
 rdfs:label "Iconographical Attribute" ;
 skos:closeMatch <http://dbpedia.org/ontology/iconographicAttributes> ;
 skos:closeMatch <https://www.wikidata.org/wiki/Q204231>.

 vir:IC16_Character a rdf:Class ;
 rdfs:subClassOf frbroo:F38_Character ;
 rdfs:comment "This class comprises fictional individuals, or groups, appearing in a
representation. Each character portrayed can have a type, for example 'Saint' or 'layman'.
Every saint portrayed is considered here as a character and not as an actor." ;
 rdfs:label "Character".

 vir:IC11_Personification a rdf:Class ;
 rdfs:subClassOf vir:IC16_Character ;
 rdfs:comment "A human, or anthropomorphic figure, that represents an abstract idea or a
concept" ;
 rdfs:label "Personification" ;
 skos:closeMatch <https://www.wikidata.org/wiki/Q207174>.

 vir:IC12_Visual_Recognition a rdf:Class ;
 rdfs:subClassOf crmsci:S4_Observation ;
 rdfs:comment "The activity of assigning the iconographical status to a man-made object, or
to one of its parts. It takes into account the possibility to link it to a speech act or a
document where the authoritative proposition is clearly made" ;
 rdfs:label "Visual Recognition".

 vir:IC19_Recto a rdf:Class ;
 rdfs:subClassOf crm:E26_Physical_Feature ;
 rdfs:comment "The front or face of a single sheet or the right-hand page of an open book.
The feature is presents in object such as codex, books, pamphlets, documents, photographs and
painting." ;
 rdfs:label "Recto" ;
 skos:exactMatch <https://www.wikidata.org/wiki/Q9305022>.

 vir:IC1_Iconographical_Atom a rdf:Class ;
 rdfs:subClassOf crm:E25_Man-Made_Feature ;
 rdfs:comment "An Iconographical Atom is a physical arrangement of forms and colours created
by human activity" ;
 rdfs:label "Iconographical Atom".

 vir:IC20_Verso a rdf:Class ;
 rdfs:subClassOf crm:E26_Physical_Feature ;
 rdfs:comment "The back or underside of a single sheet of paper, or the left-hand page of an
open book. The feature is presents in object such as codex, books, pamphlets, documents,
photographs and painting." ;
 rdfs:label "Verso" ;
 skos:exactMatch <https://www.wikidata.org/wiki/Q9368452>.

 vir:IC9_Representation a rdf:Class ;
 rdfs:subClassOf crm:E36_Visual_Item ;
 rdfs:comment "A visual item that represent the nuclear characteristic of a particular set of
```

```
symbols associate with a cognitive type of a person, animal or concept" ;
 rdfs:label "Iconographical Object" ;
 skos:exactMatch lio:PictorialElement.

 vir:PCK4_is_visual_prototype_of a rdf:Class ;
 rdfs:subClassOf crm:PC0_Typed_CRM_Property ;
 rdfs:comment "n-ary construct to document the use of a specific prototypical example for an
image. The nature of the relationships helps define a map of relationships between
prototypical items used in the arts. To be used together with 'K4.1_prototypical_model'".


### PROPERTIES


 vir:K4.1_prototypical_model a rdf:Property ;
 rdfs:domain vir:PCK4_is_visual_prototype_of ;
 rdfs:range crm:E55_Type.


 vir:K10_on_the_base_of a rdf:Property ;
 rdfs:comment "The property describes the source used for the status assignment" ;
 rdfs:label "On the base of" ;
 rdfs:range crm:E89_Propositional_Object ;
 rdfs:subPropertyOf crm:P16_used_specific_object.

 vir:K10i_is_basis_for a rdf:Property ;
 rdfs:domain crm:E89_Propositional_Object ;
 rdfs:comment "The property describes the source used for the status assignment" ;
 rdfs:label "is based on" ;
 rdfs:subPropertyOf crm:P16i_was_used_for.

 vir:K11_assigned a rdf:Property ;
 rdfs:domain vir:IC12_Visual_Recognition ;
 rdfs:comment "The property indicates the status assigned during the visual recognition
event" ;
 rdfs:label "assigned" ;
 rdfs:range crm:E36_Visual_Item ;
 rdfs:subPropertyOf crm:P141_assigned.

 vir:K11i_was_assigned_by a rdf:Property ;
 rdfs:domain crm:E36_Visual_Item ;
 rdfs:comment "The property indicates the status assigned during the visual recognition
event" ;
 rdfs:label "was assigned by" ;
 rdfs:range vir:IC12_Visual_Recognition ;
 rdfs:subPropertyOf crm:P141i_was_assigned_by.

 vir:K14_symbolize a rdf:Property ;
 rdfs:domain vir:IC10_Attribute ;
 rdfs:comment "The property indicates the symbolic value of the attribute presents in a
representation" ;
 rdfs:label "symbolize" ;
 rdfs:range crm:E90_Symbolic_Object ;
 rdfs:subPropertyOf crm:P138_represents.

 vir:K14i_has_symbolic_value a rdf:Property ;
 rdfs:domain crm:E90_Symbolic_Object ;
 rdfs:comment "The property indicates the symbolic value of the attribute presents in a
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representation" ;
 rdfs:label "has symbolic value" ;
 rdfs:range vir:IC10_Attribute ;
 rdfs:subPropertyOf crm:P138i_has_representation.

 vir:K15_use_feature a rdf:Property ;
 rdfs:domain crm:E12_Production ;
 rdfs:comment "The property indicates the specific attribute used during the production of a
visual object" ;
 rdfs:label "use feature" ;
 rdfs:range vir:IC10_Attribute ;
 rdfs:subPropertyOf crm:P33_used_specific_technique.

 vir:K15i_has_been_used_by a rdf:Property ;
 rdfs:domain vir:IC10_Attribute ;
 rdfs:comment "The property indicates the specific attribute used during the production of a
visual object" ;
 rdfs:label "has been used by" ;
 rdfs:range crm:E12_Production ;
 rdfs:subPropertyOf crm:P33i_was_used_by.

 vir:K17_has_attribute a rdf:Property ;
 rdfs:domain vir:IC9_Representation ;
 rdfs:comment "This property associates an attribute with the iconographical object where it
is depicted" ;
 rdfs:label "has attribute" ;
 rdfs:range vir:IC10_Attribute ;
 rdfs:subPropertyOf crm:P106_is_composed_of.

 vir:K17i_is_attribute_of a rdf:Property ;
 rdfs:domain vir:IC10_Attribute ;
 rdfs:comment "This property associates an attribute with the iconographical object where it
is depicted" ;
 rdfs:label "is attribute of" ;
 rdfs:range vir:IC9_Representation ;
 rdfs:subPropertyOf crm:P106i_forms_part_of.

 vir:K1_denotes a rdf:Property ;
 rdfs:domain crm:E18_Physical_Thing ;
 rdfs:comment "The property documents the assignment of an iconographical object to a
specific physical man-made object. It is a shortcut for the more fully developed path IC12
Visual Recognition assign (K9) to a E18 Physical Thing the status of (K11) IC9
Representation" ;
 rdfs:label "Denote" ;
 rdfs:range crm:E36_Visual_Item ;
 rdfs:subPropertyOf crm:P65_shows_visual_item.

 vir:K1i_is_denoted_by a rdf:Property ;
 rdfs:comment "The property documents the assignment of an iconographical object to a
specific physical man-made object. It is a shortcut for the more fully developed path IC12
Visual Recognition assign (K9) to a E18 Physical Thing the status of (K11) IC9
Representation." ;
 rdfs:label "is denoted by" ;
 rdfs:range crm:E18_Physical_Thing ;
 rdfs:subPropertyOf crm:P65i_is_shown_by.

 vir:K20_forms_part_of a rdf:Property ;
 rdfs:domain vir:IC9_Representation ;
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 rdfs:comment "This property put in relation an iconographical object with a part of itself."
;
 rdfs:label "forms part of" ;
 rdfs:range vir:IC9_Representation ;
 rdfs:subPropertyOf crm:P148_has_component.

 vir:K20i_is_composed_of a rdf:Property ;
 rdfs:domain vir:IC9_Representation ;
 rdfs:comment "This property put in relation an iconographical object with a part of itself."
;
 rdfs:label "is composed of" ;
 rdfs:range vir:IC9_Representation ;
 rdfs:subPropertyOf crm:P148i_is_component_of.

 vir:K21_depict_things_of_type a rdf:Property ;
 rdfs:domain vir:IC10_Attribute ;
 rdfs:comment "This property indicates the type of object depicted by an iconographical
attribute" ;
 rdfs:label "depict things of type" ;
 rdfs:range crm:E55_Type ;
 rdfs:subPropertyOf crm:P137_exemplifies.

 vir:K21i_is_depiction_of_attribute a rdf:Property ;
 rdfs:domain crm:E55_Type ;
 rdfs:comment "This property indicates the type of object depicted by an iconographical
attribute" ;
 rdfs:label "is depiction of attribute" ;
 rdfs:range vir:IC10_Attribute ;
 rdfs:subPropertyOf crm:P137i_is_exemplified_by.

 vir:K22_has_personification a rdf:Property ;
 rdfs:domain vir:IC9_Representation ;
 rdfs:comment "This property indicates the membership of a personification in an
iconographical object" ;
 rdfs:label "has personification" ;
 rdfs:range vir:IC11_Personification ;
 rdfs:subPropertyOf crm:P138_represents.

 vir:K22i_is_present_in a rdf:Property ;
 rdfs:domain vir:IC16_Character ;
 rdfs:comment "This property indicates the membership of a personification in an
iconographical object" ;
 rdfs:label "is present in" ;
 rdfs:range vir:IC9_Representation ;
 rdfs:subPropertyOf crm:P138i_has_representation.

 vir:K23_connote a rdf:Property ;
 rdfs:domain vir:IC9_Representation ;
 rdfs:comment "This property indicates the connotation relationships, formalised by Barthes,
between a conceptual entity and an iconographical object. It is a shortcut for the more fully
developed path IC12 Visual Recognition assign (K9) to a IC9 Representation a new (K11) IC9
Representation. It doesn&#8217;t offer any information about when and whom established the
connotation relationship" ;
 rdfs:label "connote" ;
 rdfs:range vir:IC9_Representation ;
 rdfs:subPropertyOf crm:P138_represents.

 vir:K23i_is_connotation_of a rdf:Property ;
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 rdfs:domain vir:IC9_Representation ;
 rdfs:comment "This property indicates the connotation relationships, formalised by Barthes, 
between a conceptual entity and an iconographical object. It is a shortcut for the more fully 
developed path IC12 Visual Recognition assign (K9) to a IC9 Representation a new (K11) IC9 
Representation. It doesn&#8217;t offer any information about when and whom established the 
connotation relationship" ;
 rdfs:label "is connoted by" ;
 rdfs:range vir:IC9_Representation ;
 rdfs:subPropertyOf crm:P138i_has_representation.

 vir:K24_portray a rdf:Property ;
 rdfs:domain vir:IC9_Representation ;
 rdfs:comment "This property put in relation an iconographical object with the portrayed 
character." ;
 rdfs:label "portray" ;
 rdfs:range vir:IC16_Character ;
 rdfs:subPropertyOf crm:P138_represents.

 vir:K24i_is_portrayed_in a rdf:Property ;
 rdfs:domain vir:IC16_Character ;
 rdfs:comment "This property put in relation an iconographical object with the portrayed 
character." ;
 rdfs:label "is portrayed by" ;
 rdfs:range vir:IC9_Representation ;
 rdfs:subPropertyOf crm:P138i_has_representation.

 vir:K25_express a rdf:Property ;
 rdfs:domain vir:IC10_Attribute ;
 rdfs:comment "This property put in relation a symbolic object with a personification in a 
work of art" ;
 rdfs:label "express" ;
 rdfs:range crm:E90_Symbolic_Object ;
 rdfs:subPropertyOf crm:P138_represents.

 vir:K25i_is_abstraction_of a rdf:Property ;
 rdfs:domain crm:E90_Symbolic_Object ;
 rdfs:comment "This property put in relation a symbolic object with a personification in a 
work of art." ;
 rdfs:label "is abstraction of" ;
 rdfs:range vir:IC10_Attribute ;
 rdfs:subPropertyOf crm:P138i_has_representation.

 vir:K26_has_source a rdf:Property ;
 rdfs:domain vir:IC16_Character ;
 rdfs:comment "This property associates an instance of IC16 Character with an instance of E39 
Actor that the character is motivated by or is intended to represent" ;
 rdfs:label "has source" ;
 rdfs:subPropertyOf frbroo:R57_is_based_on.

 vir:K26i_is_source_of a rdf:Property ;
 rdfs:comment "This property associates an instance of IC16 Character with an instance of E39 
Actor that the character is motivated by or is intended to represent" ;
 rdfs:label "is source of" ;
 rdfs:range vir:IC16_Character ;
 rdfs:subPropertyOf frbroo:R57i_is_basis_for.

 vir:K34_illustrate a rdf:Property ;
 rdfs:domain vir:IC9_Representation ;
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 rdfs:comment "This property associate an information object to a iconographical
representation" ;
 rdfs:label "illustrate" ;
 rdfs:range crm:E73_Information_Object ;
 rdfs:subPropertyOf crm:P138_represents.

 vir:K34i_is_illustrated_by a rdf:Property ;
 rdfs:domain crm:E73_Information_Object ;
 rdfs:comment "This property associate an information object to a iconographical
representation" ;
 rdfs:label "is illustrated by" ;
 rdfs:range vir:IC9_Representation ;
 rdfs:subPropertyOf crm:P138i_has_representation.

 vir:K4_is_visual_prototype_of a rdf:Property ;
 rdfs:domain vir:IC9_Representation ;
 rdfs:comment "The property documents the use of a specific prototypical example for an
image. The nature of the relationships helps define a map of relationships between
prototypical items used in the arts." ;
 rdfs:label "is visual prototype of" ;
 rdfs:range vir:IC9_Representation ;
 rdfs:subPropertyOf crm:P67_refers_to.

 vir:K4i_has_visual_prototype a rdf:Property ;
 rdfs:domain vir:IC9_Representation ;
 rdfs:comment "The property documents the use of a specific prototypical example for an
image. The nature of the relationships helps define a map of relationships between
prototypical items used in the arts." ;
 rdfs:label "has visual prototype" ;
 rdfs:range vir:IC9_Representation ;
 rdfs:subPropertyOf crm:P67i_is_referred_to_by.

 vir:K6_has_back a rdf:Property ;
 rdfs:domain vir:IC19_Recto ;
 rdfs:comment "The property documents the presence of a Verso or a Recto, respectively in the
back or in the front of an object" ;
 rdfs:label "has back" ;
 rdfs:range vir:IC20_Verso ;
 rdfs:subPropertyOf crm:P46_is_composed_of.

 vir:K6i_has_front a rdf:Property ;
 rdfs:domain vir:IC20_Verso ;
 rdfs:range vir:IC19_Recto ;
 rdfs:comment "The property documents the presence of a Verso or a Recto, respectively in the
back or in the front of an object." ;
 rdfs:label "has front" ;
 rdfs:subPropertyOf crm:P46i_forms_part_of.

 vir:K7_is_recto_of a rdf:Property ;
 rdfs:domain vir:IC19_Recto ;
 rdfs:comment "The property indicates the presence of a recto in the described object" ;
 rdfs:label "is recto of" ;
 rdfs:range crm:E22_Man-Made_Object ;
 rdfs:subPropertyOf crm:P56_bears_feature.

 vir:K7i_has_recto a rdf:Property ;
 rdfs:domain crm:E22_Man-Made_Object ;
 rdfs:comment "The property indicates the presence of a recto in the described object" ;
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rdfs:label "has recto" ;
rdfs:range vir:IC19_Recto ;
rdfs:subPropertyOf crm:P56i_is_found_on.

vir:K8_is_verso_of a rdf:Property ;
rdfs:domain vir:IC20_Verso ;
rdfs:comment "The property indicates the presence of a verso in the described object" ;
rdfs:label "is verso of" ;
rdfs:range crm:E22_Man-Made_Object ;
rdfs:subPropertyOf crm:P56_bears_feature.

vir:K8i_has_verso a rdf:Property ;
rdfs:domain crm:E22_Man-Made_Object ;
rdfs:comment "The property indicates the presence of a verso in the described object" ;
rdfs:label "has verso" ;
rdfs:range vir:IC20_Verso ;
rdfs:subPropertyOf crm:P56i_is_found_on.

vir:K9_Assigned_status_to a rdf:Property ;
rdfs:domain vir:IC12_Visual_Recognition ;
rdfs:comment "The property documents the assignment of status to a specific physical thing"
;
rdfs:label "Assigned status to" ;
rdfs:range crm:E18_Physical_Thing ;
rdfs:subPropertyOf crm:P140_assigned_attribute_to.

vir:K9i_has_status_assigned_by a rdf:Property ;
rdfs:domain crm:E18_Physical_Thing ;
rdfs:comment "The property documents the assignment of status to a specific physical thing."
;
rdfs:label "has status assigned by" ;
rdfs:range vir:IC12_Visual_Recognition ;
rdfs:subPropertyOf crm:P140i_was_attributed_by.
```

12 Annex B

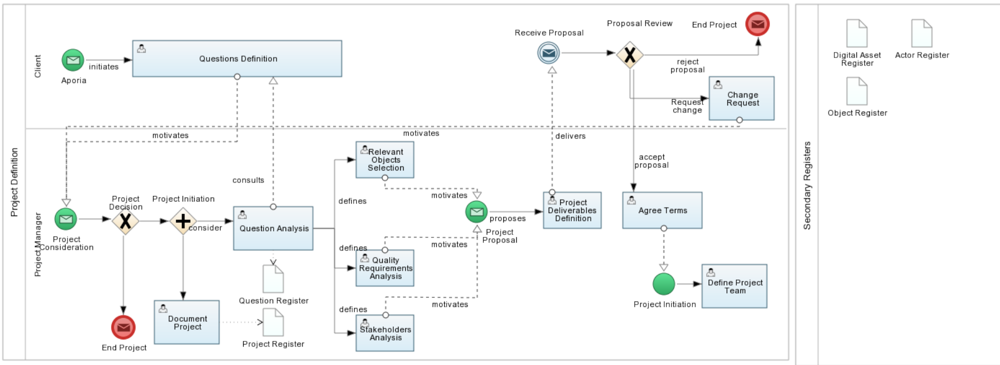


Figure 66. BDP. Project Definition.

For the stable documentation of a complex and multi-actor process, a central register must be developed to serve as the point of reference for all involved stakeholders. The logical unit of documentation for the central element of the digital survey process is a register of the project to reference all intersecting and related activities, objects, documents, actors, etc. We would argue that each digital survey project is initiated in order to answer one or more research questions. The initiation of a digital survey project necessitates the registration and understanding of this series of research questions and projective planning of the kinds of activities in terms of acquisition, processing and dissemination product creation that would be necessary to meet these aims. Such a process of analysis, we argue, forms a natural part of any scientific activity, but is often documented only in narrative form or, in the worst cases, even remains implicit in the minds of the actors initiating the project. As digital surveys grow in complexity and increasingly employ intensive interdisciplinary collaborations between different actors, the need for explicit documentation of these steps becomes more urgent. Such externalisation of project details and, particularly, the recording of an explicit register of questions, projective techniques and solutions to apply to the question not only offer a reference support during the project but contributes to the sustainability of the project data as well as to the long term evaluation of techniques and methodologies related to questions of a given type, moreover aiding in the comparison of projected methods against the methods that were actually used and led to effective solutions. The compilation of the project register co-entails the beginning of the compilation of a series of associated registers which will be added to and referenced throughout the rest of the digital survey project. In particular registers for objects of study, actors involved and digital documents receives an initial compilation.

Table 9. Project Definition

Name	Element
Central Register	Project, Question
Supporting Register	Object, Actors, Digital Assets
Related Control Lists	Project Type, Actor Role, Acquisition Type, Processing Type, Visualization Type

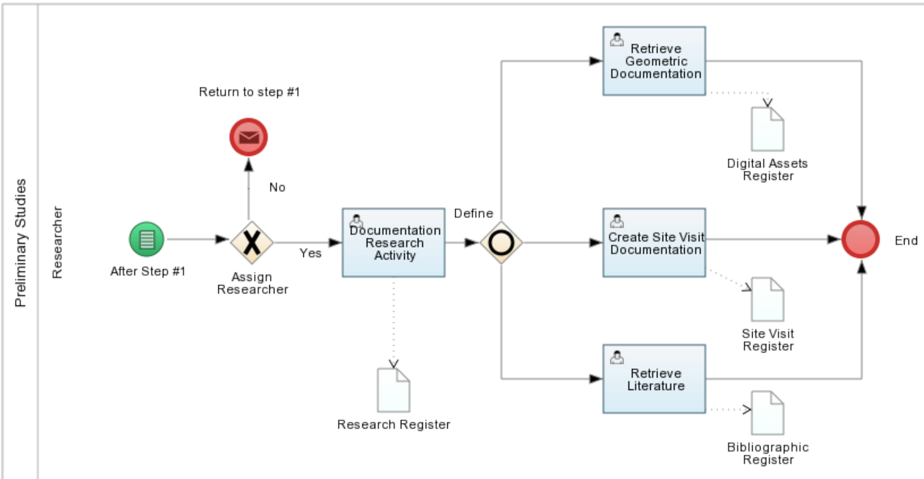


Figure 67. BDP. Preliminary studies.

While the research domain and profession of digital survey involves constantly changing technology and the application of novel techniques according to the latest progress in research methodology, it is a process deeply embedded in academic and professional traditions. A complete digital survey process must position itself with regards to the existing research and understanding of the objects of which it undertakes to provide an analysis and ought to avail itself of the existing resource basis of research outputs while examining both previous geometric documentation and bibliography. Furthermore, as a study of objects susceptible to processes of generation, modification and decay, both with regards to the object itself and the surrounding space to which it is related, a site-visit to study the latest state of the object is required. This research step serves to inform all the following steps as reference and potential input to the planning and processing stages. Each research activity is envisioned as related to at least a project and potentially to a particular research question raised during the project. We therefore propose the preparation of a research register to explicitly document different research questions undertaken. These can be linked to registers documenting bibliography, previous geometric documentation and site visit data.

Table 10. Preliminary Studies

Name	Element
Central Register	Research, Site Visit, Bibliographic
Supporting Register	Question, Actors, Digital Assets, Project
Related Control Lists	Publication Type

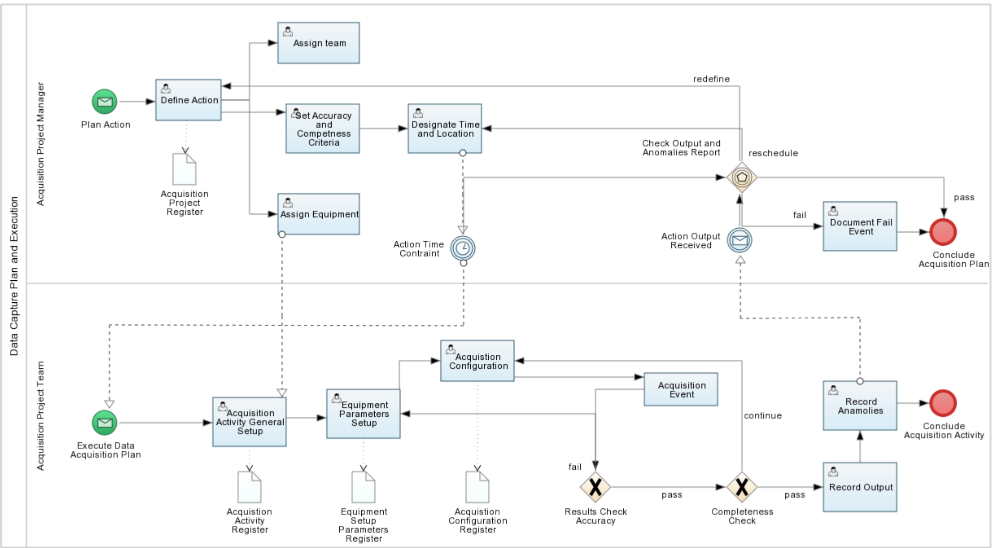


Figure 68. BDP. Acquisition.

Following the plan established during the initial setup of the project and the projected acquisition requirements in response to the research questions identified, the acquisition phase requires careful and detailed documentation in order to fully contextualise the data acquired and make it reusable and understandable for the different actors engaged in the project. The central unit of documentation for this phase is the acquisition project, understood as a container activity for the multiple acquisition events. Each overall acquisition project with a singular acquisition aim should therefore be registered separately, documenting its object of analysis, the level of accuracy required, the agents involved and the relevant dates. To this acquisition project, the documentation of the various acquisition activities from the actual process events will be attached.

It is on the level of the individual acquisition activity that the highest level of detail of documentation is required, in order to support the understanding of the data objects produced. The correct breakdown of the relevant factors that need to be recorded and the nature of these factors is of paramount importance in order to support interpretation and correction of results. Each data object acquired from an acquisition activity event is the result of the presence of some actors in a certain environment at a certain time, and involves the use of particular equipment, set to particular parameters and which engaged a particular methodology of setting up the overall acquisition parameters. We, therefore, argue that each acquisition event contributing to the overall acquisition project planned must be documented separately, entailing an activity-based metadata log.

The acquisition activity itself should be recorded with regards to its object, time and the environmental factors at time of capture. For this activity, the actors involved in carrying out the acquisition and the equipment they deployed is documented. A separate register for documenting equipment can allow quick reference to its technical details. Each session may be subject to a different equipment parameter setup, therefore, for each piece of equipment used and according to the type of device, the parameters used in that session should be logged. Additionally, and separately to the equipment parameters, the parameters of the methodology employed during the acquisition should be logged. These parameters involve the methodology of distance, overlap, calibration and other decision factors which affect the overall outcome of the final digital product. Finally, each acquisition activity is linked to its products which are recorded into the comprehensive digital object register.

Due to the large number of files generated by any given acquisition activity and the already large number of variables to document, the likely documentation unit for the files generated would be a bulk register of the collective objects (when they are of the same type). We therefore propose the saving of digital object results into a container format such as a zip file in order to facilitate the quick and efficient documentation of the acquisition product.

Table 11. Table Acquisition

Name	Element
Central Register	Acquisition Project, Acquisition Activity, Equipment Setup Parameters, Object Acquisition Configuration
Supporting Register	Equipment, Project, Object, Actors, Digital Assets

Related Control Lists	Object Scale Type, Output Type, Accuracy Level Type,Evaluation Criteria, Acquisition Method, Digitization Scale Type, Shutter Mode Type, White Balance, White balance Preset, Camera Configuration Type, Marker Type, Evaluation Criteria, Environment Type, Weather Type, Light Type, Role Type

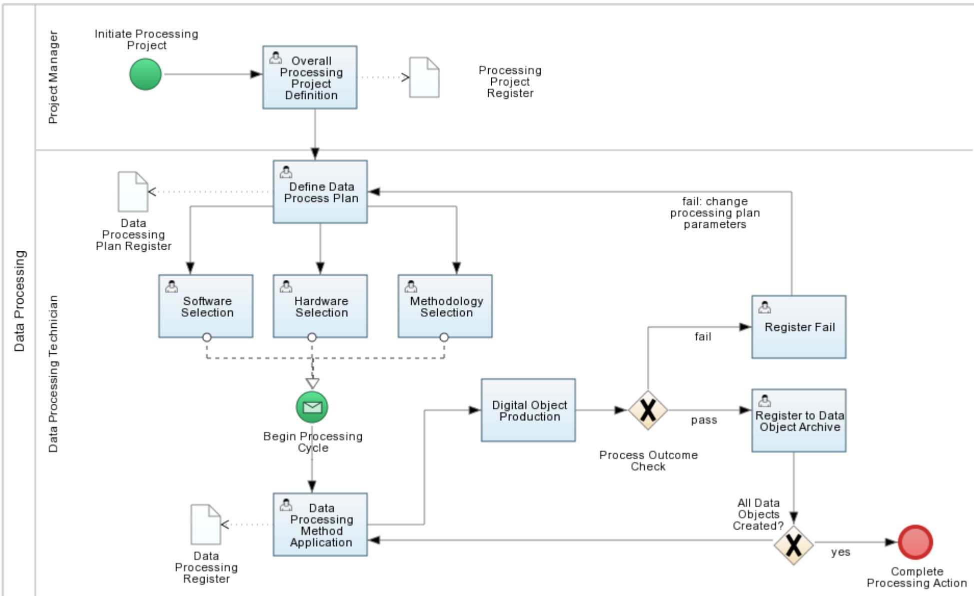


Figure 69. BDP. Processing.

The processing step of a digital survey project takes the results of data acquisition activities and plans for their transformation through various steps using semi-automatic software operations.The results are data products meeting the specifications set out in relation to the initial evaluation of the research question as established in the project initiation step. Since processing can be a complex action with many stages as well as the need for continuous iterative results versus goals validation, we propose a three-tier documentation scheme to track this process: data processing project, data processing plan, data processing action.

The overall documentation unit is a processing project. The processing project is the documentation unit for outlining a sequence of processing actions that will take place according to a controlled data process plan. The processing action indicates the original question to which the processing plan should respond, the products and accuracy it will aim to obtain, and by whom the processing will be organised and controlled. Particularly, the appropriate data objects from the data acquisition activities are selected and documented relative to the objects of study in question. The actual execution of a processing project that will result in the intended end product will require several steps of processing with individual processing plans and iterative processing actions checking for data accuracy and acceptability.

For each distinctive processing step, then, we envision a separate documentation of a data processing plan. The data processing plan lays out the software, hardware and methodology to be employed to achieve the desired effect. Therefore, this data processing plan is attached to the data processing action which has been planned.

Each actual action of processing data under a plan is documented in its own right with the relevant input, output and indicated parameters. What is markedly important is the documentation of the accuracy obtained and therefore, the explicit and documented evaluation by the data processing engineer of the success or failure of the process. Success validates the data processing plan and allows the articulation of the next step of the overall processing project. Failure indicates that the data processing technician should return to the data processing plan and adjust relevant failures and then run the processing actions again until a satisfactory result can be obtained or a negation of one of the relevant factors can be obtained (e.g. software, hardware, methodology or input variables).

Table 12. Table Processing

Name	Element
Central Register	Processing Project, Processing Plan, Data Processing
Supporting Register	Question, Actors, Object, Digital Assets, Equipment
Related Control Lists	Processing Type, Algorithm, Accuracy Type, Software, Methodology

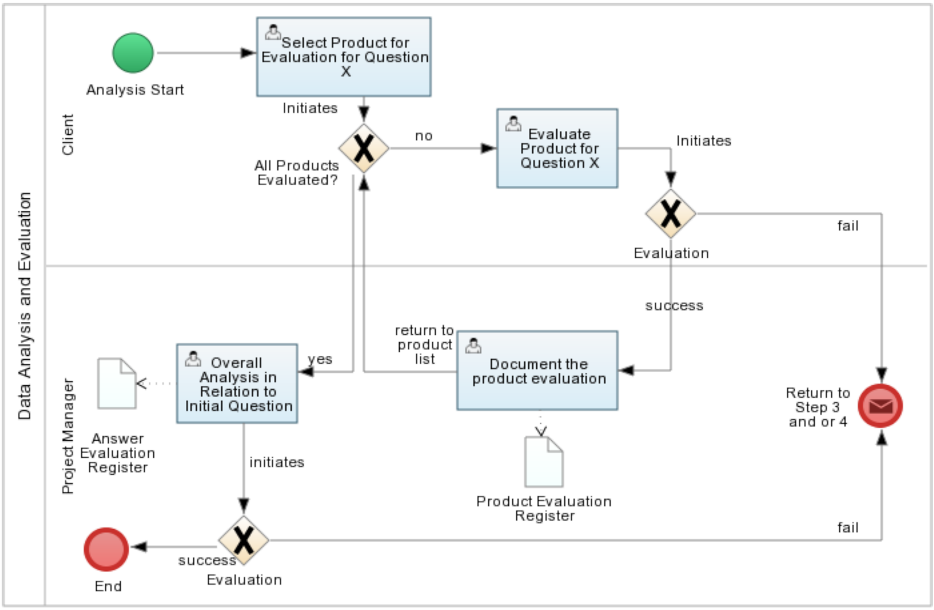


Figure 70. BDP. Analysis.

The completion of a cycle of acquisition and processing allows the ability to proceed to an analysis phase in which the resulting products of these phases can go through a testing process in order to understand if they support a possible responsible to the initial research questions posed. Here we can envision specialists in a team or even clients, if the specialists are not part of the acquisition team, engaging in a review process of the raw acquisition products and/or the processed data. We break up the evaluation and analysis stage into main parts: a general part, broken up by questions and a particular part, for each question in which individual data objects are evaluated.

For each question posed at the beginning of the project an analysis form is to be filled out indicating the products produced and giving an overall rating of the methodology adopted and the answers generated from the data objects generated. Here we have in mind a comparison of the objects against a broader and less technical criteria than those envisioned in the self testing aspects of the acquisition and processing steps of the digital survey. The question is not test for levels of accuracy in the technical execution of the digital products. Rather the question is to understand whether or not the products produced were able to support an interpretation which would lead to some negative or positive conclusion in relation to the original question. Regardless of the result, a documentation of the evaluation of the methods employed and the method of evaluation provides the possibility of ameliorating future efforts to answer questions in a similar direction. Wherever possible links to published data are encouraged.

In the second, more specific step, an evaluation of the individual data products related to the question is given in terms of an overall acceptance or rejection of the product. This step therefore has the ability to restart an acquisition or data processing project depending on the outcome of the product evaluation.

Table 13. Table Analysis

Name	Element
Central Register	Product Evaluation, Answer Evaluation Register
Supporting Register	Question, Actors, Object, Digital Assets, Bibliographic
Related Control Lists	Evaluation Criteria

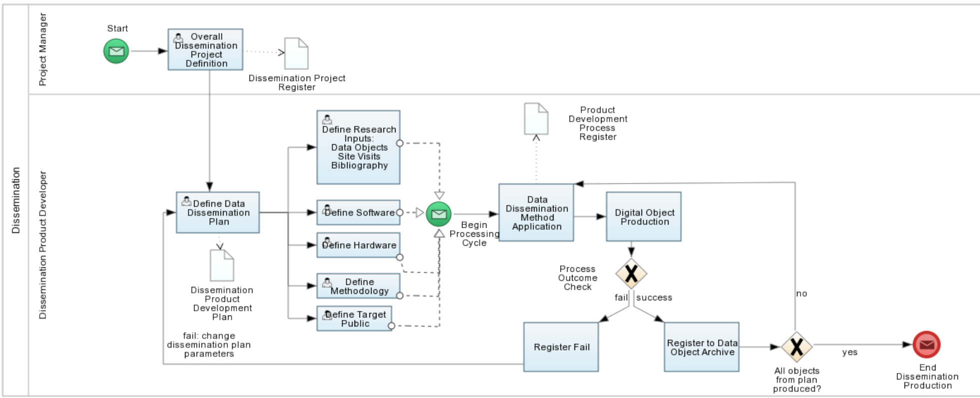


Figure 71. BDP. Dissemination.

The dissemination aspect of the digital survey process can range widely in the requested products. From a model for simple visualisations by the public to full scale interactive and 4 dimensional environments, the production of the dissemination products of a digital survey project could be the subject of an entire workflow control process of its own. However, for small and medium interdisciplinary teams, one can consider it as the completing cycle of the production of results from a digital survey process. It is therefore desirable to model the minimum control mechanism for managing this process and connecting it to the previous steps. Indeed, considering dissemination as an integrated and controlled process within the scientific production stream, allows one to more closely correlate dissemination material with the scientific results obtained from controlled acquisition and data processing events. In fact, we can consider the dissemination control process under a similar structure to the processing structure, changing largely the consideration of goal variables. While processing must consider at its base questions of accuracy, dissemination must consider questions of suitability for an audience. We therefore propose a parallel tripartite structure to the processing control activity.

The structure consists then of the basic documentation unit of the dissemination project that has as its goal one or more related dissemination products. The overall project has documentation fields especially for the targeted audience, the aim of the dissemination product and the aimed for dates of production.

Each dissemination project will entail a number of internal development cycles that will require their own planning. In the dissemination cycle, the developers can take full advantage of all products produced within the digital survey pipeline to this point. They may therefore import assets from the research, acquisition and processing phases as part of the base materials from which to construct their final product. This provides a map of provenance of the inputs to the end product, while not providing overly onerous metadata entry requirements on the data creator. Each individual product of a the dissemination cycle should be subject to at least one if not more planning events. These serve as the control base from which to execute processing for the development of dissemination products.

Parallel to the proposed production control processes, we suggest that each significant processing event for the production of a dissemination product be documented and related to its relevant production plan. The inputs and outputs of the process and an evaluation help to track whether the processing achieved its end and determine whether or not the processing can be considered as accepted or must be run again with a reconfigured processing plan.

Table 14. Table Dissemination

Name	Element
Central Register	Dissemination Project, Product Development Plan, Dissemination Product Development Activity
Supporting Register	Actors, Object, Digital Assets, Bibliographic, Equipment, Site Visit
Related Control Lists	Dissemination Goal, Target Public, Language, Digital Product Type, Acquisition Product Type, Processed Product Type, Software, Methodology, Product Development Activity Type, Algorithm, Parameters

	Type

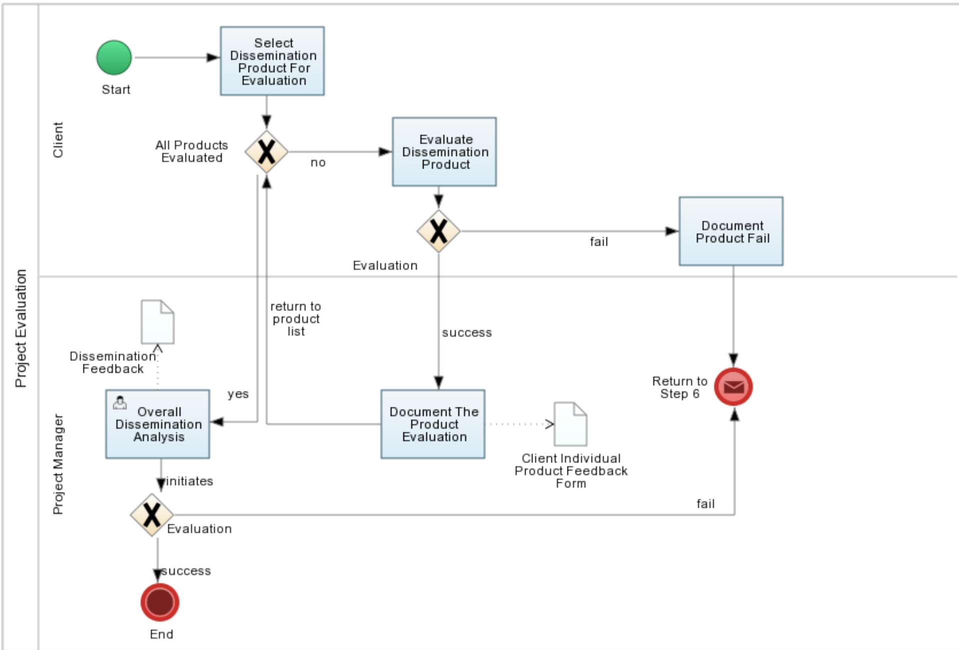


Figure 72. BDP. Conclusion.

The completion of a digital survey project is signalled by the handing over of the requested final products. The project then should be concluded on a checking step, in which the final products are delivered to the client (be it internal researcher or external contracting actor) and their acceptance or rejection of the end products should be recorded. Where rejection of a product in part of in total is a result, new processes of acquisition, processing and dissemination production creation can be triggered. Again, the evaluation of the dissemination products can be considered as a parallel to the evaluation of the processing and acquisition outputs. The ability to evaluate both on a global scale with regards to fitness to purpose, this time with regards to audience and dissemination goal, and with regards to the individual products within the overall dissemination product should be made available and recorded in order to manage quality control both in the short term and as a long term research resource.

Table 15. Table Conclusion

Name	Element
Central Register	Client Individual Product Feedback, Dissemination Feedback

Supporting Register	Question, Dissemination Project, Bibliographic
Related Control Lists	Evaluation Criteria

Descriptors of the object of analysis

Object Name

A standard name for the object in question

Type: Text

Required: YES

Repeatable: YES

Object ID

The commonly recognisable ID of the object in questions

Type: Text

Required: YES

Repeatable: YES

Object ID Institution

The name of the institution providing the ID

Type: Link - (Actors Register)

Required: NO

Repeatable: YES

Part Of

Link to the main object that this object forms a part of.

Type: Link - (Object Register)

Required: NO

Repeatable: YES

Object Type

A field to indicate the kind of object. Should make use of some sort of standard relevant to the object type

Type: Text from Controlled List

Required: YES

Repeatable: YES

Institution responsible for

A field to indicate who is the usual custodian of this object

Type: Link - (Actors Register)

Required: YES

Repeatable: YES

Found at

Place where object is found (Country, City, Building, Drawer... as you known)

Type: Text

Required: NO

Repeatable: NO

Location / Storage Place

Place where object is currently located (Country, City, Building, Drawer... as you known)

Type: Text

Required: NO

Repeatable: NO

Material

Actual object's surface materials

Type: Text from Controlled List

Required: NO

Repeatable: YES

Reflectance Qualities

Surface reflectance characteristics of the object eg. diffuse, specular, reflective

Type: Text from Controlled List

Required: NO

Repeatable: YES

Dimension

Records the size of the object

Type: Numeric

Required: NO

Repeatable: NO

Conservation Status

The conservation status of the object

Type: Text from Controlled List

Required: NO

Repeatable: YES

Handling Constraints

Type of constraints in handling the object

Type: Text from Controlled List

Required: NO

Repeatable: YES

Constraint Notes

Notes regarding the handling constraints.

e.g. reasons, how to handle etc

Type: Long Text

Required: NO

Repeatable: YES

Metadata regarding the main actors of the process

Name

The name of the actor be it a person or institution or group

Type: Text

Required: YES

Repeatable: YES

Actor ID

The commonly recognizable ID of the actor in questions

Type: Text

Required: YES

Repeatable: YES

Actor Type

The kind of actor this is.

E.g. Person, institution, group

Type: Text from Controlled List
Required: NO
Repeatable: NO

Role

This is the person's general role in life as we know them as an institution. For each different action in the project they may take on a different role. So this could be the CEO, but in the acquisition action, he could be the cameraman
Type: Text from Controlled List
Required: NO
Repeatable: YES

Affiliation

An affiliation of an actor to an other actor and the kind of affiliation
Type: Link - (Actors Register)
Required: NO
Repeatable: YES

Contact point

Data on how to contact the individual
Type: Text
Required: NO
Repeatable: YES

Metadata regarding the digital assets used

Digital Asset Name

Indicate the name of the assets
Type: Text
Required: YES
Repeatable: YES

ID

A unique ID assigned to the document
Type: Text
Required: YES

Repeatable: NO

Digital Asset Type

Indicate the digital asset type

Type: Text from Controlled List

Required: NO

Repeatable: YES

Number of Files

If this is a multi object file, such as a zip, indicate total content of file.

Type: Numeric

Required: NO

Repeatable: NO

Digital Asset Creator

Link to person or organisation who created asset

Type: Link - (Actors Register)

Required: YES

Repeatable: YES

Digital Asset Creation Date

Date of creation of asset

Type: Date

Required: NO

Repeatable: NO

Refers to

Here you put any object that this asset is related to

Type: Link - (Object Register)

Required: NO

Repeatable: YES

Document Storage

Place of storage of document

Type: Text

Required: YES

Repeatable: NO

Format
The encoding of the file
Type: Text
Required: YES
Repeatable: NO

Subject
Topics/Themes of the document. Preferably from a controlled vocabulary
Type: Text from Controlled List
Required: NO
Repeatable: YES

Descriptors for the equipment used during the process

Name
Indicate the name of the documented item
Type: Text
Required: YES
Repeatable: YES

ID
A unique ID assigned to the item
Type: Text
Required: YES
Repeatable: NO

Sensor Type
Type of sensor
Type: Text
Required: YES
Repeatable: NO

Sensor Dimensions
Sensor width and height expressed in mm
Type: Number

Required: YES

Repeatable: NO

Maximum sensor resolution

Maximum sensor width and height in pixels

Type: Number

Required: YES

Repeatable: NO

Pixel Pitch

The size of each pixel, considering it square

e.g. 6 µm

Type: Number

Required: NO

Repeatable: NO

Principal Point

Intersection point of the optical axis and the image plane (Kraus, 2000). Here we need coordinates x0,y0

Type: Number

Required: NO

Repeatable: NO

Documents

Documents associated with this particular piece of equipment

Type: Link

Required: NO

Repeatable: YES

Shutter Modes

Register the shutter modes available at the camera body

Type: Text from Controlled List

Required: NO

Repeatable: NO

Metadata for documenting the overall project

Project ID

A unique ID given by the institution to allow this project to be unambiguously identified into the future

Type: Text

Required: YES

Repeatable: NO

Project Title

A title given for the project to help identify it in the future.

Type: Text

Required: YES

Repeatable: YES

Type

A value indicating the kind of project to be undertaken.

Type: Text from Controlled List

Required: NO

Repeatable: YES

Digitisation to be produced for

The institution or person for which/whom the project is undertaken.

Type: Link - (Actors Register)

Required: NO

Repeatable: YES

Institution responsible

The institution or person undertaking the responsibility for the execution of the project.

Type: Link - (Actors Register)

Required: YES

Repeatable: YES

Project Members

List of individuals assigned to the project and the general role assigned to them.

Type: Link - (Actors Register) + Control List

Required: NO

Repeatable: YES

Object/s in consideration

A list of the object or objects that are the focus of the project

Type: Link - (Object Register)

Required: YES

Repeatable: YES

Project Start Date

Indicates the start date of the project.

Type: Date

Required: YES

Repeatable: NO

Project End Date

Indicates the end date of the project.

Type: Date

Required: YES

Repeatable: NO

Project Evaluation Details

Project Accepted

Here the acceptance or rejection of the project is indicated.

Type: Boolean

Required: NO

Repeatable: NO

Date Acceptance

The date on which the approval for the project was given

Type: Date

Required: NO

Repeatable: NO

Project Approved by

The individual(s) or institution(s) responsible for approving the project.

Type: Link - (Actors Register)

Required: NO
Repeatable: YES

Project Acceptance/Rejection Reason
Reason for accepting or rejecting project
Type: Long Text
Required: NO
Repeatable: YES

Related Documentation

Project Documents
List of Project Documents
e.g. Requirements Documents, Contract, Overall Permissions, Risk Management Study Docs, Quality Certificates of Company
Type: Link - (Digital Assets Register)
Required: NO
Repeatable: YES

Descriptors for the scientific questions which drive the process.

Question
A plain language, concise description of the scientific problem or dissemination goal that the digitisation would help to answer/achieve
Type: Long Text
Required: YES
Repeatable: YES

Question Of
Relation from the question to the relevant project.
Type: Link - (Project Register)
Required: YES
Repeatable: NO

Notes

Where one can write a free description of the requirement for answering this question
Type: Long Text
Required: NO
Repeatable: NO

Pipeline Planning
A planning list of the objects relevant to answering this question and the potential acquisition, processing and visualization activities needed to move towards answering the proposed question. This is a projective planning list, it can include different projective plans. It is meant for the internal use of the digitisation team.
e.g. Castle + Photogrammetry + SURE + Web Model + a note goes here
Type: Link - (Object Register) + Control List + Control List + Control List + Note
Required: No
Repeatable: Yes

Collection of previously compiled information on the object of analysis

---

Researcher Name
Here we indicate the researcher(s) assigned to carry out background research on the objects that will be digitized and their general context.
Type: Link - (Actors Register)
Required: YES
Repeatable: YES

Project
Link to Project of which this research is a part.
Type: Link - (Project Register)
Required: YES
Repeatable: YES

Question
Link to project research question, that research aims to help elaborate at a first stage.
Type: Link - (Question Register)
Required: NO
Repeatable: YES

Site Visit Data

Link to site visit data, used to obtain contemporary information about the object.

Type: Link - (Site Visit Register)

Required: NO

Repeatable: YES

Previous Digital Data

Link to previous geometric data files available with regards to the objects in question.

Type: Link - (Digital Assets Register)

Required: NO

Repeatable: YES

Bibliography

Link to bibliographic data available with regards to the objects in question.

Type: Link - (Bibliographic Register)

Required: NO

Repeatable: YES

Start Date

Indicates the start date of the research.

Type: Date

Required: NO

Repeatable: NO

End Date

Indicates the end date of the research.

Type: Date

Required: NO

Repeatable: NO

Documentation regarding the pre-acquisition visit of the site

---

Researcher Name

Indicate the researchers who carried out the site visit.

Type: Link - (Actors Register)

Required: YES

Repeatable: YES

Start Date
Indicates the initial date of the site visit
Type: Date
Required: YES
Repeatable: NO

End Date
Indicates the end date of the site visit if multi-day.
Type: Date
Required: NO
Repeatable: NO

Site Visit Documents
A list of documents any documents relevant to the site visit.
Type: Link - (Digital Assets Register)
Required: NO
Repeatable: YES

Site Visit Documents Generated
A list of documents generated by the site visit. This field is especially envisioned to allow linking of site visit photos.
Type: Link - (Digital Assets Register)
Required: NO
Repeatable: YES

Bibliographic resource concerning the cultural object or its context

---

Publication type
Type of publication described.
e.g. article, book etc.
Type: Text from Controlled List
Required: NO
Repeatable: YES

Title

Title of the resource

Type: Text

Required: YES

Repeatable: YES

Author

Creator of the described resource.

Type: Link - (Actors Register)

Required: YES

Repeatable: YES

Title of the container

Title of the overall container of the bibliographic work.

e.g. in case of article the title of the journal

Type: Link - (Bibliographic Register)

Required: NO

Repeatable: YES

Publication date

Date that the document was published.

Type: Date

Required: NO

Repeatable: NO

Edition

Version of the resource took in consideration.

Type: Text

Required: NO

Repeatable: NO

Digital Representation

Digital file associated with the resource

Type: Link - (Digital Assets Register)

Required: NO

Repeatable: YES

Wrapper of the information regarding the overall acquisition.

Project Acquisition ID

ID of the project acquisition

Type: Text

Required: YES

Repeatable: NO

Project Acquisition Name

Here the name of the overall acquisition project is entered in order to make reference to it in the future.

Type: Text

Required: YES

Repeatable: YES

Part Of Project

Specify part of which overall project

Type: Link - (Project Register)

Required: YES

Repeatable: YES

Object and Acquisition Feature

Here a list of the objects to be scanned within the overall acquisition project is made. The objects are linked to from the overall project object register table. Additionally, a control term is added in order to indicate an overall estimation of the size of the object, the expected output, and the accuracy level aimed for in order to facilitate planning and execution of acquisition.

Expected output of the acquisition project. For photogrammetry e.g.:

DEM, Orthophoto, 3D points (and 3D model), maps, measurements, other (photogrammetric products)

e.g. Castle + Large + Orthophoto + 1:50, GSD=0.0 1 cm

Type: Link - (Object Register)+ Text from Controlled List

Required: YES

Repeatable: YES

Responsible

Here a link to the overall project actor register is made in order to indicate the individual

person or institution who is responsible for organizing and carrying out the overall acquisition project
Type: Link - (Actors Register)
Required: NO
Repeatable: YES

Starting time
Here the starting date of the overall acquisition project is entered.
Type: Date
Required: YES
Repeatable: NO

Ending time
Here the ending date of the overall acquisition project is entered.
Type: Date
Required: YES
Repeatable: NO

Related Documents
Here a list of all related documents to the overall acquisition project are entered. These document are assumed to be in digital format and are thus to be entered in the associated digital assets register
Type: Link - (Digital Assets Register)
Required: NO
Repeatable: YES

Related Results Evaluation

Acquisition Conformed to Plan
Here the actor responsible for the overall acquisition project indicates the overall accomplishment of the project relative to its goals.
Type: Boolean
Required: NO
Repeatable: NO

Acquisition Satisfactoriness
Here the actor responsible for the overall acquisition project can indicate a series of criteria by

which they have evaluated the conformity of the acquisition project to its overall aims and the value they associate to it.
Type: Text from Controlled List + Value
Required: NO
Repeatable: NO

Results Analysis
Here the actor responsible for the overall acquisition project can indicate in long text format an evaluation of the project, success, failure, further steps etc.
Type: Long Text
Required: NO
Repeatable: NO

Methodology used and conditions used in each acquisitions step.

Acquisition ID
ID of the specific acquisition.
Type: Text
Required: YES
Repeatable: NO

Acquisition Name
Here the name of the acquisition activity is entered in order to make reference to it in the future.
Type: Text
Required: YES
Repeatable: YES

Part Of Acquisition
Define the link between the acquisition activity and the overall acquisition plan
Type: Link - (Acquisition Project Register)
Required: YES
Repeatable: NO

Acquisition Method
Here the method used in this particular acquisition activity is indicated.

Type: Text from Controlled List
Required: YES
Repeatable: NO

Object Digitized & Area
Here a link to the particular object(s) being acquired in this particular acquisition activity is made. The list of objects is connected to the overall digital survey project object register (see step 0). Additionally, a text can be added in order to indicate the particular part of the object that was scanned. This is particularly useful is the object is of large scale.
Type: Link - (Object Register) + Text
Required: YES
Repeatable: YES

Digitization Area Scale
Here the scale of the object to be digitised is given according to a predetermined list. It is used in order to help understanding the size of the section of the object that is to be or was digitised.
Type: Text from Controlled List
Required: NO
Repeatable: NO

Starting time
Here the starting date of the specific acquisition project is entered.
Type: Date
Required: YES
Repeatable: NO

Ending time
Here the ending date of the specific acquisition project is entered.
Type: Date
Required: YES
Repeatable: NO

Environmental Conditions

Environment
Here the overall environment in which the acquisition took place is indicated from an enumerated list.

Type: Control List
Required: NO
Repeatable: NO

Weather
Here, if the overall environment is indicated to be outdoor, overall weather conditions for the outdoor environment during the acquisition activity are indicated.
Type: Control List
Required: NO
Repeatable: NO

Light Temperature
Here the light temperature in Kelvin relevant to the time of acquisition is recorded.
Type: Number
Required: NO
Repeatable: NO

Light Type
Here the light type is indicated.
Type: Control List
Required: NO
Repeatable: NO

Temperature
Here the prevailing temperature in the environment of the acquisition activity for the time of the activity is indicated in degrees celsius.
Type: Number
Required: NO
Repeatable: NO

Altitude
Here the altitude in metres from sea level for the location at which the acquisition activity took place is indicated.
Type: Number
Required: NO
Repeatable: NO

Air Pressure

Here the air pressure for the location at which the acquisition activity took place is indicated.

Type: Number

Required: NO

Repeatable: NO

Acquisition Sketch/Digital Assets Related

Here a link can be made to the digital objects register of the overall digital survey project (see Step 0). For acquisition that include acquisition sketches, the acquisition sketch would be attached here. Additionally, other relevant digital documents can be added in supporting the documentation of this particular acquisition activity.

Type: Link - (Digital Assets Register)

Required: NO

Repeatable: YES

Actor Operators

Here the individuals who carried out the particular acquisition activity are listed along with what role they played in action and what equipment they operated

Type: Type: Link - (Actors Register) + Control List + Link - (Equipment)

Required: YES

Repeatable: YES

Created Digital Assets

Here the digital objects that were created by the acquisition activity are listed. Each digital object should be added as a new entry to the overall Digital Survey project's Digital Asset Register (see step 0). In the case of photogrammetry or other processes resulting in many files, it may be preferable to save all files in a zip file or tarball in order to lessen the documentation burden in practical terms.

Type: Link - (Digital Assets Register)

Required: NO

Repeatable: YES

Note

Here any additional commentary on the acquisition activity can be added.

Type: Long Text

Required: NO

Repeatable: NO

Description of the equipment parameters employed

Camera Body

Here a link to the camera body actually used is made.

Type: Link - (Equipment Register)

Required: YES

Repeatable: NO

Setup Of

Indicate the setup of which acquisition activity.

Type: Link - (Acquisition Activity Register)

Required: YES

Repeatable: NO

Lens

Name of the lense.

Type: Link - (Equipment Register)

Required: YES

Repeatable: NO

Platform

Platform from which the pictures were taken and its stability.

Type: Link - (Equipment Register)

Required: NO

Repeatable: NO

Orientation

X, Y, Z, roll, yaw, pitch (if known). If the camera is mounted on any platform with a IMU/GNSS sensor, this parameters can be used as initial parameters of the orientation.

Type: Number

Required: NO

Repeatable: NO

ISO

Light sensibility value selected if manual or automatic

Type: Number
Required: NO
Repeatable: NO

Shutter mode
Automatic/Fully Manual/Aperture priority/Shutter speed priority
Type: Text from Controlled List
Required: YES
Repeatable: NO

Shutter speed
Length of time expressed in seconds when the digital sensor in the camera is exposed to light through the shutter mechanism
Type: Number
Required: NO
Repeatable: NO

Aperture / f-stops
The amount of light to which the sensor is exposed (f-stops), regulates the brightness of the image
Type: Number
Required: YES
Repeatable: NO

Focus
Automatic or manual focus
Type: Boolean
Required: YES
Repeatable: NO

Focus Fixed
Fixed or variable focus
Type: Boolean
Required: YES
Repeatable: NO

Focus distance

Medium focus distance from the camera to the focus point.
Type: Number
Required: NO
Repeatable: NO

Depth of field
Distance between the nearest and farthest objects of the scene that appear sharp in the image.
Type: Number
Required: NO
Repeatable: NO

Focal Length
Distance from the principal point of the camera to the image plane. If it is blocked at minimum or maximum, otherwise leave as unknown.
Type: Number
Required: NO
Repeatable: NO

White balance
Here the white balance employed: Automatic, pre-set or manual.
Type: Text from Controlled List
Required: YES
Repeatable: NO

White balance preset
White balance preset used (tungsten, sunlight)
Type: Text from Controlled List
Required: NO
Repeatable: NO

White balance manual methodology used
Reference to the method used for defining the white balance.
Type: Text
Required: NO
Repeatable: NO

Digital Image for Calibration

The digital used for calibrating the white balance.
Type: Link - (Digital Assets Register)
Required: NO
Repeatable: NO

Lightmeter used
The Lightmeter used for the light calculation.
Type: Link - (Equipment Register)
Required: NO
Repeatable: NO

Lightmeter value
The value found by the Lightmeter.
Type: Number
Required: NO
Repeatable: NO

Camera Calibrated - geometric calibration
Yes if camera internal orientation calibration parameters calculated before the acquisition, no if otherwise
Type: Boolean
Required: NO
Repeatable: NO

Color calibration
Yes if the color calibration are calculated, no if otherwise
Type: Boolean
Required: YES
Repeatable: NO

HDR
Yes if HDR capturing was performed
Type: Boolean
Required: NO
Repeatable: NO

HDR technique

HDR technique used (Bracketing vs actual HDR camera).
Type: Text
Required: NO
Repeatable: NO

HDR Bracketed series
Number of images taken for exposure bracketing.
Type: Number
Required: NO
Repeatable: NO

HDR exposure values
The exposure value chosen for the HDR.
ex: -2EV, 0EV, 2EV
Type: Text
Required: NO
Repeatable: NO

Documents
Documents related to equipment e.g. manuals, technical specifications etc
Type: Link - (Digital Assets Register)
Required: NO
Repeatable: YES

Documentation on the object configuration in relation to the acquisition

---

Camera Configuration Type
Relative geometry of the image plane with respect to the object plane. Normal is when these two planes are parallel. e.g. Convergent/normal.
Type: Text from Controlled List
Required: NO
Repeatable: NO

Part Of
Indicate the relationships between the below field and the Acquisition Activity
Type: Link - (Acquisition Activity Register)

Required: YES

Repeatable: NO

Average GSD

Average Ground Sample Distance, average size of a pixel projected on the 3D object space.

Type: Number

Required: YES

Repeatable: NO

Percentage of Object Covered

Percentage of object which can be covered by a single picture at the average distance from the object selected

Type: Number

Required: NO

Repeatable: NO

Average Distance From The Object

The distance between the acquisition point and the average object surface

Type: Number

Required: NO

Repeatable: NO

Forward/longitudinal Overlap

Percentage of overlap between the images over the main acquisition direction (stripe)

Type: Number

Required: NO

Repeatable: NO

Side Overlap

Percentage of overlap between the images in the orthogonal direction to the main acquisition one

Type: Number

Required: NO

Repeatable: NO

Markers

Indicate the presence of markers.

Type: Boolean
Required: YES
Repeatable: NO

Markers type/codification
Type of markers which have been placed or identified at the object itself or its environment. Eg. natural marks, codified marks, crosses, balls...
Type: Text from Controlled List
Required: NO
Repeatable: YES

Markers Number
Total number of markers either placed or identified at the object or its environment
Type: Number
Required: NO
Repeatable: NO

Markers Digital File
Digital file relative to the marker acquired for the acquisition
Type: Link - (Digital Assets Register)
Required: NO
Repeatable: YES

GCP
Indicate the presence of Ground Control Points
Type: Boolean
Required: YES
Repeatable: NO

GCP Number
Total number of GCP measured in the object or its environment.
Type: Number
Required: NO
Repeatable: NO

GCP Digital File
Digital file relative to the coordinates acquired for the GCP

Type: Link - (Digital Assets Register)
Required: NO
Repeatable: YES

On-site Camera Calibration
Define if a calibration process was performed on site before the actual camera acquisition.
eg. use of calibrated grid or board
Type: Boolean
Required: NO
Repeatable: NO

Image base/baseline
Distance between two sequential image acquisition points (projection centre s).
Type: Number
Required: NO
Repeatable: NO

Obstacles
Indicate the presence or absence of obstacles and, in case it is necessary, add the necessary notes.
Type: Boolean + Text
Required: NO
Repeatable: YES

Documents
Documents created during the acquisition that serve for better understanding of the setup or the acquisition process
e.g. sketches.
Type: Link - (Digital Assets Register)
Required: NO
Repeatable: YES

Wrapper for the overall processing project

Processing Project Name
Here the name of the processing action is indicated for future reference.

Type: Text
Required: YES
Repeatable: YES

Processing Project ID

Here a unique ID for the processing action is given in order to unique find the action in the future.
Type: Number
Required: YES
Repeatable: NO

Question Relation

Here the researcher in charge of the processing action indicates the question as originally documented in the project initiation to which the processing action aims to provide data in order to allow for an answer.
Type: Link - (Question Register)
Required: NO
Repeatable: YES

Researcher Name

Here a link to the actor register indicates the researcher who is responsible for planning this processing action.
Type: Link - (Actor Register)
Required: YES
Repeatable: YES

Object of Study

Here a link to the object register is used in order to indicate the object of which the processed data object will be a representation/study/metric model etc.
Type: Link - (Object Register)
Required: YES
Repeatable: YES

Digital Asset Inputs

Here the researcher lists the data objects from the acquisitions processes that they intend to use in the processing plan in order to reach their processing aims.
Type: Text from Controlled List

Required: NO

Repeatable: YES

Products and Accuracy Required

This step is a reiteration of the original step which takes into consideration the original question evaluation but now is able to give a better estimate of what will need to be done within the context of the project (where aspects may change)

Type: Text from Controlled List

Required: NO

Repeatable: NO

Products and Accuracy Change Description

If products and accuracy expectation differs substantially from the description originally envisioned at project initiation, the researcher can provide a free text description for the reasons for the change in direction.

Type: Text Long

Required: NO

Repeatable: NO

Processing Action Dates

Here the time frame of the overall processing action is indicated.

Type: Date

Required: NO

Repeatable: NO

Documentation of the plan to be followed during the processing phase

---

Process Plan Title

Here the name of the data processing plan is indicated for future reference.

Type: Text

Required: YES

Repeatable: YES

Process Plan ID

Here the id of the data processing plan is indicated for future reference.

Type: Text

Required: YES
Repeatable: NO

Part of Processing Project
Indicate the relationships between this steps and the overall Processing Project
Type: Link - (Processing Project Register)
Required: YES
Repeatable: NO

Processing type
Here we indicate the type of data processing planned.
Type: Text from Controlled List
Required: NO
Repeatable: NO

Description
Here a free text description of the processing plan is provided in order to give a sense of the overall strategy adopted.
Type: Text
Required: NO
Repeatable: NO

Software to be used
Here a list of software programmes to be used the particular processing loop are listed in order to provide provenance of software input in the process. The terms are selected from a control list enumerated at the end of this document and should include the version number.
Type: Text from Controlled List
Required: NO
Repeatable: NO

Hardware to be used
Here a link to the hardware devices to be used in the carrying out of the processing planned in this step is made. The hardware devices can be entered once in the equipment register and can thereafter simply be linked to.
Type: Link - (Equipment Register)
Required: NO
Repeatable: NO

Methodology to be Used

Here the methodology to be employed in executing this processing loop is specified by picking from a controlled list of methodologies. This list is enumerated at the end of this document.

Type: Text from Controlled List

Required: YES

Repeatable: NO

Documentation of the parameters of the actual processing step

---

Processing Action ID

For each processing round that occurs, a unique ID is assigned to this event in order to be able to retrieve it again in the future.

Type: Number

Required: YES

Repeatable: NO

Part of Processing Plan

This field allows the indication of which processing plan, the data processing action was a part.

Type: Link - (Processing Plan Register)

Required: YES

Repeatable: NO

Part of Processing Project

Type: Link - (Processing Project Register)

Required: YES

Repeatable: NO

Processing Type

Here the researcher indicates the data processing type they used in this loop, choosing from a control list. This will, in general, be the same as the processing type planned for in the previous step.

Type: Text from Controlled List

Required: NO

Repeatable: YES

Methodology Used

Here the methodology employed in executing this processing loop is specified by picking from a controlled list of methodologies. This list is enumerated at the end of this document.

Type: Text from Controlled List

Required: YES

Repeatable: YES

Data Processing Technician

Here the researcher who initiated and was responsible for this particular data processing action is indicated by linking to the actor register.

Type: Link - (Actors Register)

Required: YES

Repeatable: YES

Software Used

Here the software programme used in this processing action is listed.

Type: Text from Controlled List

Required: YES

Repeatable: NO

Hardware Used

Here a link to the hardware devices used in the carrying out of the process.

Type: Link - (Equipment Register)

Required: NO

Repeatable: NO

Algorithm Used

Here the algorithm used in this processing action is listed.

Type: Text from Controlled List

Required: NO

Repeatable: NO

Used Input Files

Here we link to the particular input files used in this process. We link to the digital asset register and generally would take from the files generated in acquisition events. For a control step, link to the control measurement object.

Type: Link - (Digital Assets Register)

Required: YES
Repeatable: YES

Used Parameters
Here we list the parameters invoked in the process. We indicate the parameter and the value. This is a multivalue field.
Type: Text + Value
Required: YES
Repeatable: YES

Had Output Files
Here we indicate the files that were generated by the process. They will in fact form part of the overall digital assets register of the project.
Type: Link - (Digital Assets Register)
Required: YES
Repeatable: YES

Accuracy Type
Here we indicate the accuracy type obtained.
Type: Text from Controlled List
Required: NO
Repeatable: NO

Accuracy Value
Here we indicate the value of the accuracy type obtained.
Type: Number
Required: NO
Repeatable: NO

Processing Outcome Acceptable
Here the researcher indicates if the processing outcome is acceptable and meets the criteria set out in the processing plan step. If the answer is no, the data and this metadata are still kept but the data processing plan is reevaluated and another round of processing is iterated.
Type: Boolean
Required: NO
Repeatable: NO

Processing Outcome Evaluation Note

This field is used for a free text analysis of the processing outcome. It can be used by the processor in order to indicate features including elements of success and failure of the process.

Type: Long Text

Required: NO

Repeatable: NO

Processing Date

Here the date on which the processing occurred is indicated.

Type: Date

Required: YES

Repeatable: NO

Evaluation of a single output in relation to established criteria

---

Relevant Question

Here the initial question which triggered the creation of this digital product is referenced.

Type: Link - (Question Register)

Required: YES

Repeatable: YES

Product Evaluated

Here the digital product that was created and linked to and evaluated. Each object can be evaluated according to multiple criteria. For each product this form should be filled out once.

Type: Link - (Digital Assets Register)

Required: YES

Repeatable: YES

Evaluation Criteria

Here the criterion by which the object was evaluated are listed, along with the evaluation itself.

Type: Text from Controlled List + Long Text

Required: NO

Repeatable: YES

Accept/Reject

Here an indication of the overall acceptance or rejection of the product is indicated.

Type: Boolean
Required: YES
Repeatable: NO

Evaluator Name
Here the actor accepting or rejecting the product is listed.
Type: Link - (Actors Register)
Required: YES
Repeatable: YES

Date of Evaluation
Here the date on which the evaluation took place is listed.
Type: Date
Required: NO
Repeatable: NO

Overall assessment of the set of resource produced

Relevant Question
Here the initial question which was meant to be answered by the digital acquisition is referenced.
Type: Link - (Question Register)
Required: YES
Repeatable: YES

Product Evaluation

Product Evaluation
Link to Product Evaluation Register above. Lists all products generated in order to respond to the initial research question.
Type: Link - (Product Evaluation Register)
Required: YES
Repeatable: YES*

Overall Evaluation

Was Question Answered?

Here the Analyst/Evaluator indicates whether or not the digitised objects provided sufficient information to provide an answer to the question posed. They also indicate in a free form text, the reason for this evaluation.

Type: Boolean + Long Text

Required: NO

Repeatable: NO

Answer Documented In

Here a reference is provided to any published material in which the full evaluation of the question is provided.

Type: Link - (Bibliographic Register)

Required: NO

Repeatable: YES

Wrapper for the overall dissemination project

Dissemination Project Name

Here the name of the planned dissemination project is indicated.

Type: Text

Required: YES

Repeatable: YES

Dissemination Action ID

Here a unique id is given to the dissemination action in order to uniquely refer to it.

Type: Text

Required: YES

Repeatable: NO

Dissemination Responsible Name

Here the individual or institution responsible for planning the dissemination is indicated.

Type: Link - (Actors Register)

Required: YES

Repeatable: YES

CH Object to be Disseminated

Here the list of CH objects which are relevant to the particular dissemination project are linked.
Type: Link - (Object Register)
Required: YES
Repeatable: YES

Dissemination Goal
Here the overall aim(s) of the dissemination project are listed.
Type: Text from Controlled List
Required: NO
Repeatable: YES

Dissemination target public
Here the target audience(s) for the dissemination product are entered.
Type: Text from Controlled List
Required: NO
Repeatable: YES

Target language
Here the languages in which the dissemination product are to be produced are indicated.
Type: Text from Controlled List
Required: NO
Repeatable: YES

Products Expected
Here the dissemination project planner indicates the kind of products expected. They are also able to indicate in a long text form, specific product specifications that need to be met.
Type: Text from Controlled List + Text
Required: NO
Repeatable: YES

Acquisition Product Dependency
Here the dissemination project manager indicates the acquisition product types that this project will depend on, the date required and the date received.
Type: Text from Controlled List + Date (projected) + Date (delivered)
Required: NO
Repeatable: YES

Processing Product Dependency
Here the dissemination project manager indicates the processing product types that this project will depend on, the date required and the date received.
Type: Text from Controlled List + Date (projected) + Date (delivered)
Required: NO
Repeatable: YES

Dissemination Target Dates
Here the dissemination project manager indicates the target date for completion of the dissemination product.
Type: Date
Required: NO
Repeatable: NO

Dissemination Actual Dates
Here the dissemination project manager indicates the actual date of completion of the dissemination product.
Type: Date
Required: NO
Repeatable: NO

Related Documents
Here the data project can be linked to the various supporting documents related to the dissemination project.
Type: Link - (Digital Assets Register)
Required: NO
Repeatable: YES

Documentation of the plan to be followed during the dissemination phase

---

Dissemination Product Plan Title
Here a name is given to the dissemination project product development plan.
Type: Text
Required: YES
Repeatable: YES

Part of Dissemination Project

Indicate the relationships between this steps and the Dissemination Project.

Type: Link - (Dissemination Project Register)

Required: YES

Repeatable: NO*

Description

Here the overall plan is described in a free text form.

Type: Text

Required: NO

Repeatable: NO

Software to be Used

Here a list of software programmes to be used the particular processing loop are listed in order to provide provenance of software input in the process. The terms are selected from a control list enumerated at the end of this document.

Type: Text from Controlled List

Required: NO

Repeatable: YES

Hardware to be used

Here a link to the hardware devices to be used in the carrying out of the processing planned in this step is made. The hardware devices can be entered once in the equipment register and can thereafter simply be linked to.

Type: Link - (Equipment Register)

Required: NO

Repeatable: YES

Methodology to be Used

Here the methodology to be employed in executing this processing loop is specified by picking from a controlled list of methodologies. This list is enumerated at the end of this document.

Type: Text from Controlled List

Required: NO

Repeatable: NO

Site Visit Assets Used

Here relevant site visit data collected during preliminary studies can be linked to the dissemination project plan to serve as a resource for executing the plan.
Type: Link - (Site Visit Register)
Required: NO
Repeatable: YES

Digital Objects Used
Here relevant digital objects from the overall digital object register can be linked to the dissemination project plan to serve as a resource for executing the plan.
Type: Link - (Digital Assets Register)
Required: YES
Repeatable: YES

Bibliographic Data Used
Here relevant bibliographic data gathered during the preliminary studies phase can be linked to the dissemination project plan to serve as a resource for executing the plan.
Type: Link - (Bibliographic Register)
Required: NO
Repeatable: YES

Documentation of the parameters used during the dissemination step

---

Product Development ID
Here a unique identifier is given for the product development activity.
Type: Number
Required: YES
Repeatable: NO

Part of Dissemination Project
Indicate the relationships between this steps and the Dissemination Project.
Type: Link - (Dissemination Project Register)
Required: YES
Repeatable: NO
*

Part of Product Development Plan
Here the product development plan to which the product development activity belongs is

indicated.
Type: Link - (Product Development Plan)
Required: YES
Repeatable: NO
*

Product Development Activity Type
Here the kind of product development activity that is being undertaken is indicated.
Type: Text from Controlled List
Required: NO
Repeatable: YES

Actor
Here the actor or actors responsible for carrying out this activity are indicated.
Type: Link - (Actors Register)
Required: YES
Repeatable: YES

Software Used
Here the software actually used in executing the product development activity is indicated, along with version and other relevant details.
Type: Text from Controlled List
Required: YES
Repeatable: NO

Hardware Used
Here a link to the hardware devices used in the carrying out of the process.
Type: Link - (Equipment Register)
Required: NO
Repeatable: YES

Algorithm Used
Here the algorithm employed by the software to execute the product development activity is indicated.
Type: Text from Controlled List
Required: NO
Repeatable: YES

Methodology Used

Here the methodology employed in executing this processing loop is specified by picking from a controlled list of methodologies. This list is enumerated at the end of this document.

Type: Text from Controlled List

Required: NO

Repeatable: YES

Used Input Files

Here we link to the input files for executing this action.

Type: Link - (Digital Assets Register)

Required: YES

Repeatable: YES

Used Parameters

Here we indicate the parameter types that were used in carrying out this action.

Type: Text from Controlled List

Required: NO

Repeatable: YES

Had Output Files

Here we indicate the output files from running this action.

Type: Link - (Digital Assets Register)

Required: YES

Repeatable: YES

Processing Date

Here we indicate the date on which the action was undertaken.

Type: Date

Required: YES

Repeatable: NO

Documentation on the client reaction of a single product

Relevant Question

Here the initial question which triggered the creation of this digital product is referenced.

Type: Link - (Question Register)
Required: YES
Repeatable: YES

Dissemination Project Evaluated
Indicate the relationships between this steps and the Dissemination Project.
Type: Link - (Dissemination Project Register)
Required: YES
Repeatable: NO*

Delivered to Client
Here whether the product was delivered to client or not is indicated.
Type: Boolean
Required: NO
Repeatable: NO

Date of Delivery
Here the date on which the product was delivered to the client is indicated.
Type: Date
Required: NO
Repeatable: NO

Accepted by Client
Here whether or not the client accepted the product is indicated.
Type: Boolean
Required: NO
Repeatable: NO

Date of Acceptance
Here the date on which the product was accepted is indicated.
Type: Date
Required: NO
Repeatable: NO

Was the client satisfied?
Here the satisfaction of the client is indicated in boolean format.
Type: Boolean

Required: NO

Repeatable: NO

Client comment

Here a text field is provided to allow for explanation of client response.

Type: Text

Required: NO

Repeatable: NO

Date of Comment

Here the date of the client's response is indicated.

Type: Date

Required: NO

Repeatable: NO

Overall assessment of the set of resource produced

Relevant Question

Here the initial question which was meant to be answered by the digital acquisition is referenced.

Type: Link - (Question Register)

Required: YES

Repeatable: YES

Product Evaluation

Product Delivered

Link to Client Individual Product Feedback above. Lists all products generated in order to respond to the initial research question.

Type: Link - (Client Individual Product Feedback Register)

Required: YES

Repeatable: YES*

Overall Evaluation

Was Dissemination Appropriate?

Here appropriateness of of dissemination evaluated.

Type: Boolean

Required: NO

Repeatable: NO

Evaluation Criteria

Here the multiple criteria and evaluations supporting the evaluation of appropriateness are indicated.

Type: Text from Controlled List + Text

Required: NO

Repeatable: YES

Was targeted public satisfied?

Here the satisfaction of the public is indicated.

Type: Scale

Required: NO

Repeatable: NO

Dissemination Evaluation Criteria

Here the criterion for the satisfaction of the public is indicated along with the actual value attributed.

Type: Text from Controlled List + Text

Required: NO

Repeatable: NO

Dissemination Documented In

Here any place where the dissemination was documented is indicated.

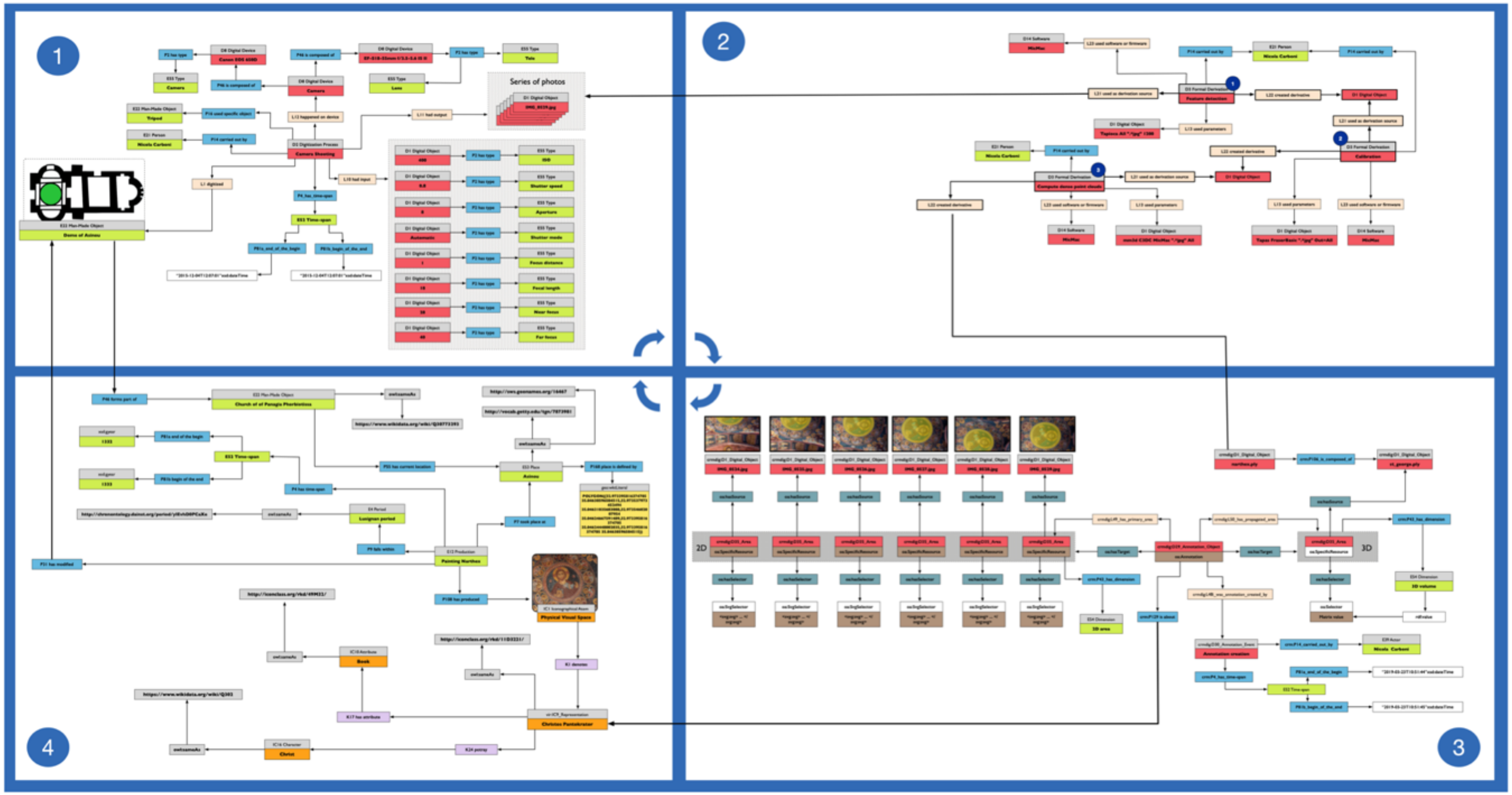
Type: Link - (Bibliographic Register)

Required: NO

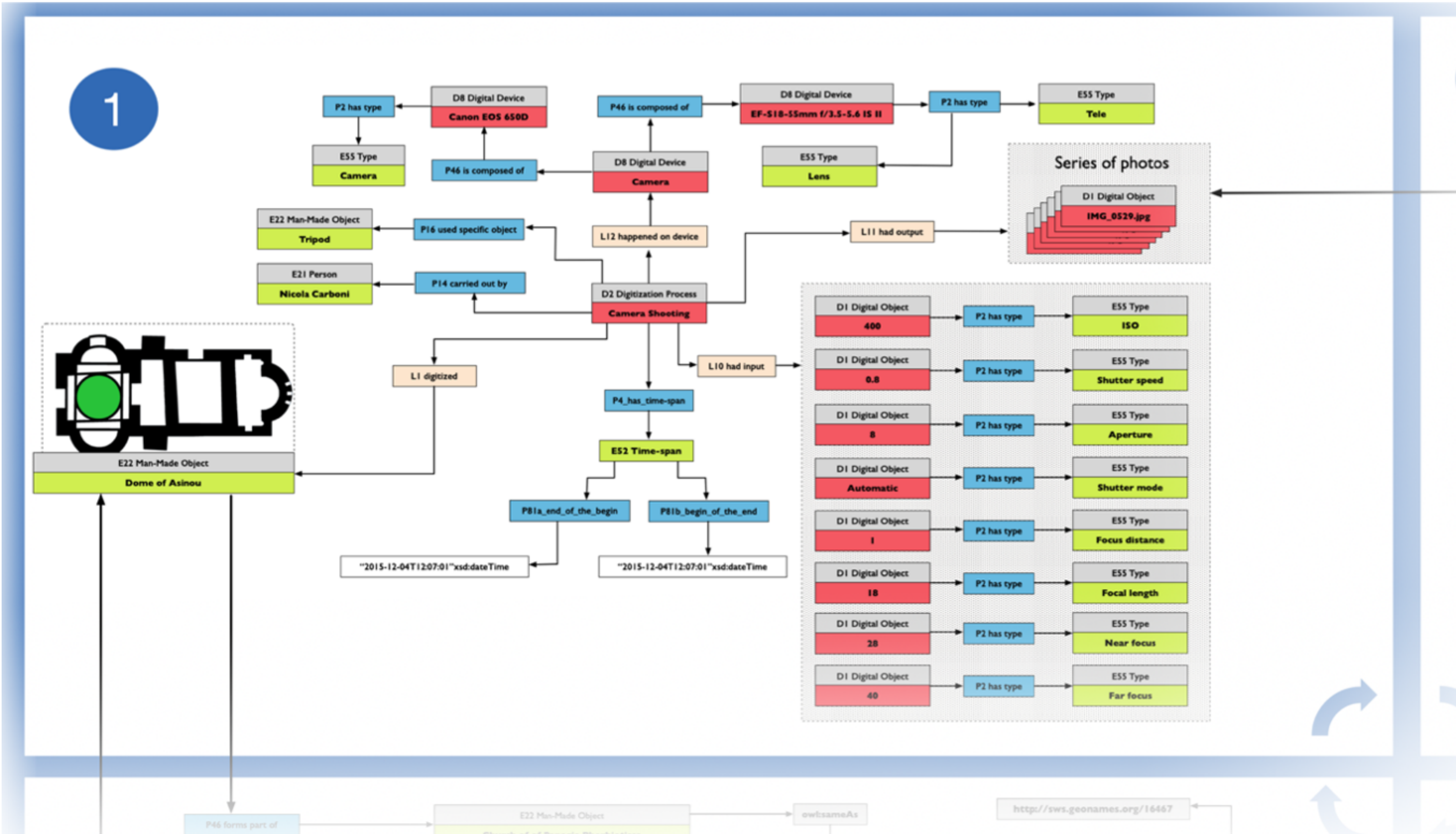
Repeatable: YES

13 Annex C

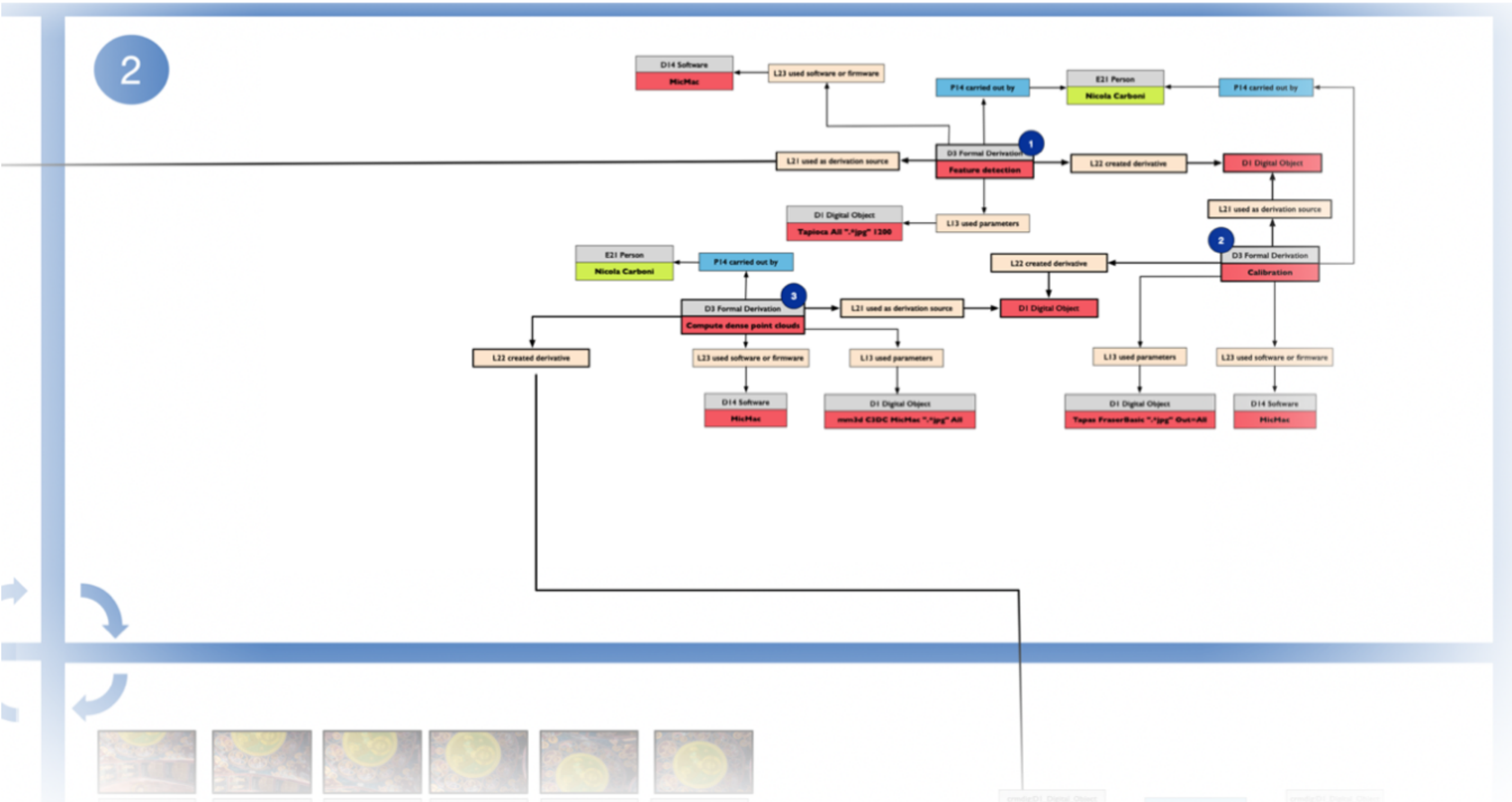
Mapping complete



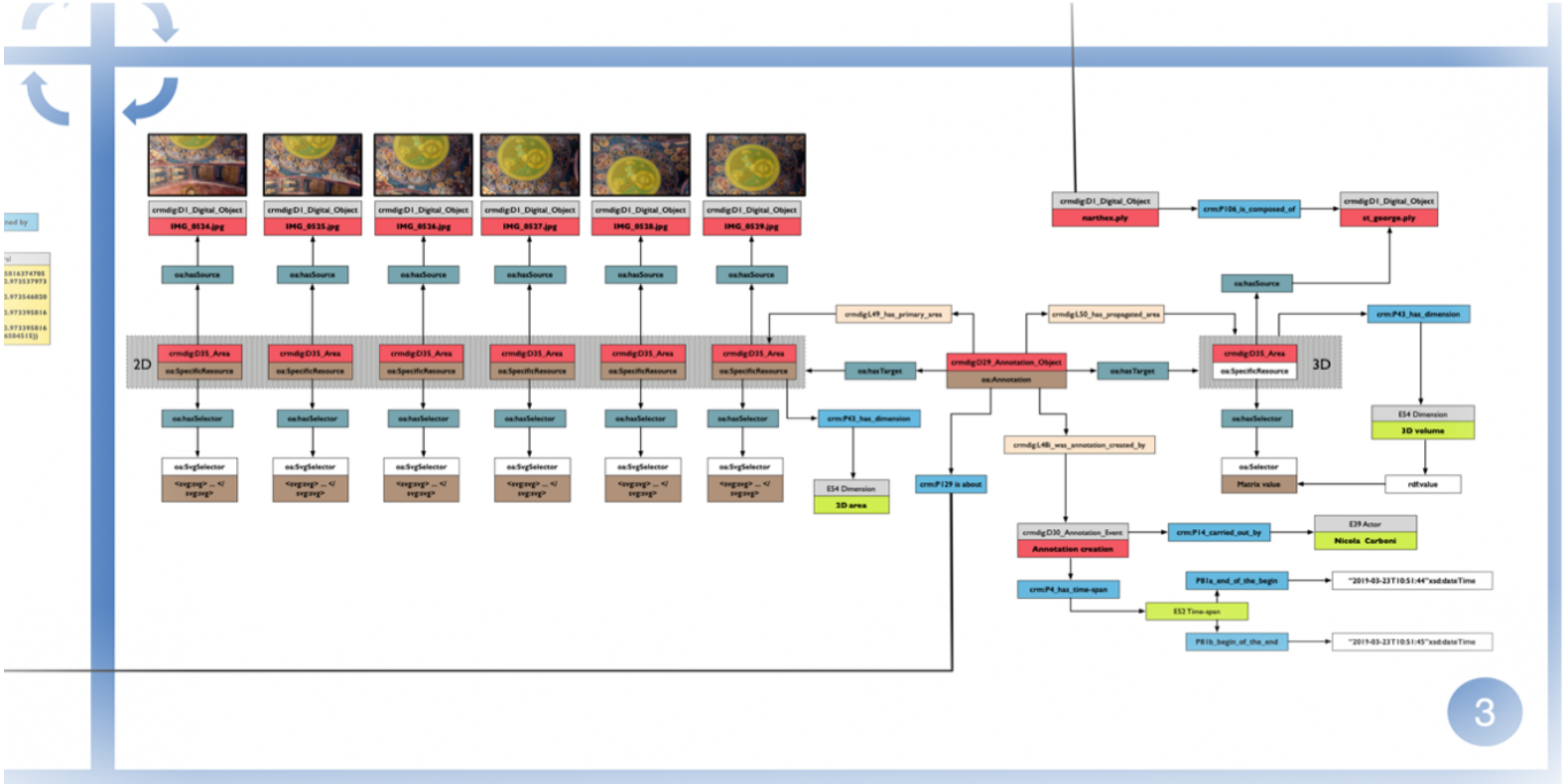
Mapping Part 1



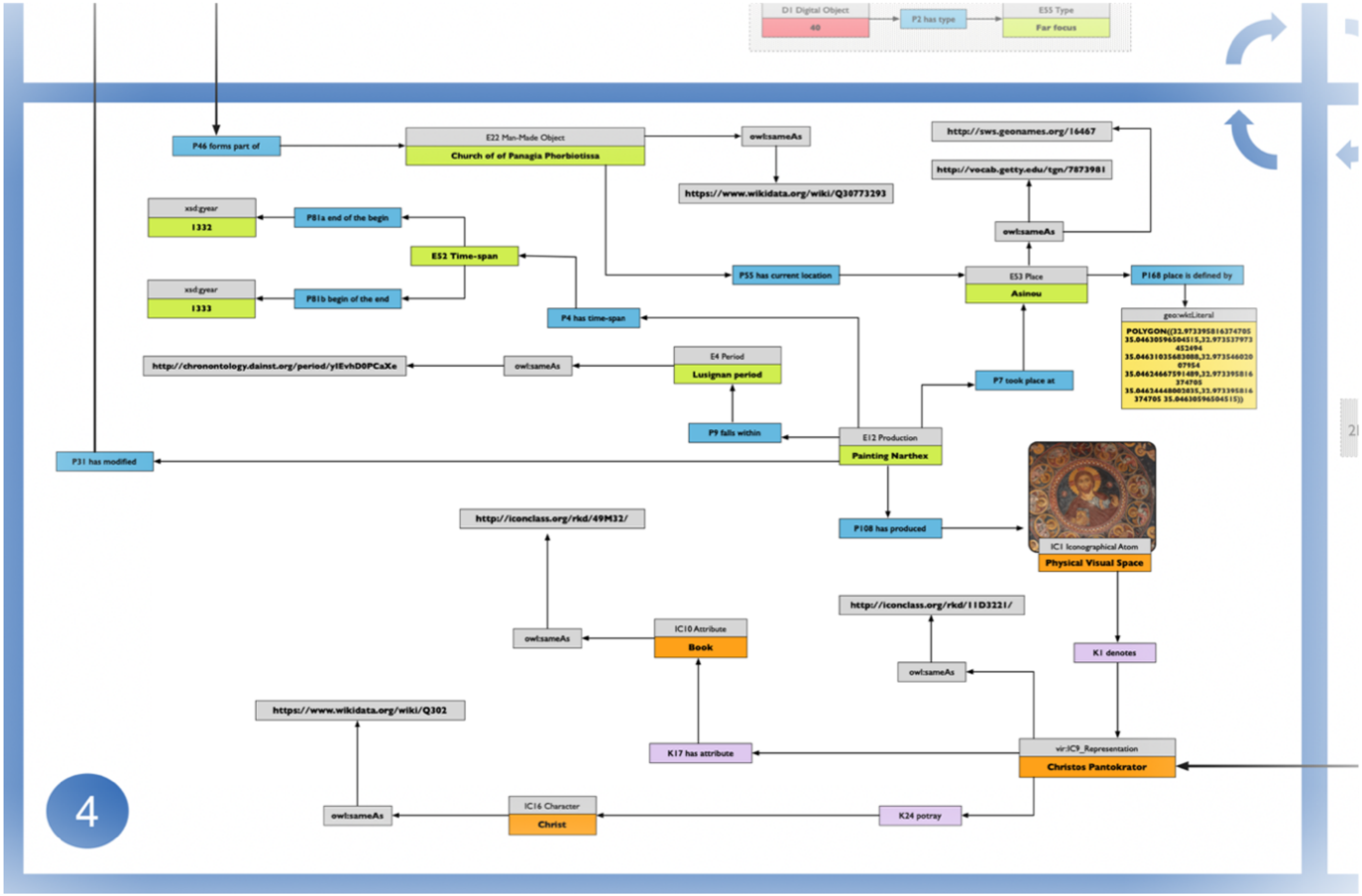
Mapping Part 2



Mapping Part 3



Mapping Part 4



14 CV

Nicola Carboni

Curriculum Vitae

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https://nicola.carboni.me

Research and Professional Experience

Jan. 2019 - August 2019 **Semantic Data Architecture**, *IUAV University*, Venice, Burckhardtsource.org.
- Develop a semantic model for the correspondence of Jacob Burckhardt.

July 2018 - **Research Fellow**, *University of Zurich*, Zurich, Art History.
- Framework for a distributed system of reference resource: conflict of information and vagueness.
- Semantic features aggregation for visual heritage.
- Semantic Architect for Swiss Art Research Infrastructure.

Feb. 2018 - June 2018 **Digital Humanities Fellow**, *Harvard University*, Florence, Harvard Center for Italian Renaissance Studies.
- Modeling of Iconographic & Symbolic items in visual heritage.
- Data modelling (CIDOC-CRM) of a 19th Century Epistolarium.

June 2014 - July 2017 **EU Marie Curie Early Stage Researcher**, *CNRS*, Marseille, MAP Laboratory.
- ITN-DCH project: **Initial Training Network for Digital Cultural Heritage**.
- Create a framework for the description of tangible and intangible cultural objects.
- Develop a CIDOC-CRM extension for iconographic & symbolic meaning of cultural objects.
- Analysis and development of a metadata set for the registration of provenance information in 3D processing.

Visiting

Researcher, *FORTH ICS*, Heraklion, Greece.
- Ontology engineering and data integration with CIDOC-CRM.

Researcher, *KAAK, German Archeological Institute (DAI)*, Stuttgart, Germany.
- Data management and modelling. From Filemaker to CIDOC-CRM: MAyaArch3D project.

Researcher, *3DOM, Fontazione Bruno Kessler (FBK)*, Trento, Italy.
- data acquisition and processing for image-based modeling and web visualisation of 3D point clouds. Data enrichment and provenance information.

Researcher, *NTUA, National Technical University of Athens*, Athens, Greece.
- Testing of OpenCV for ontology-based semantic tagging of elements in 2D images.

Conference & Workshop

- **Organiser** *ITN-DCH - Digital Heritage 2017 Final Conference*, Olimje, Slovenia.
- **Presenter** Workshop *Workflow for the Integration of Heritage Digital Resources* - ITN-DCH Digital Heritage 2017 Final Conference, Olimje, Slovenia.

Nov. 2013 - May. 2014 **Data Curator and Modeler**, *Informatica Trentina*, Trento, Italy, Open Data project.

- Development a bottom-up ontology for describing public data.
- Data cleaning, refinement mapping and enrichment.
- In charge, from a technical standpoint, of the release of the data. Responsible for developing guidelines for the providers.
- Coordinating the information architecture and workflow of of the catalog & collaborating in the EU FP7 Fusepool project.

Oct 2012 - Dec 2012 **Research internership**, *CVCE - Digital Humanities Lab*, Salem, Luxembourg.

- image-based modeling of underwater cultural heritage assets.
- Developing an entity-relationship model for the EU FP7 project CUbRIK.
- Creating guidelines and workflows for the model.
- Defining the rules of an authority file for non-authors (EU politicians)

Education

jun 2014 - present **PhD, Engineering**, *NTUA*, Athens, Greece.

- *Objective 1*: How visual information relate to reality.
- *Objective 2*: What kind of method could be used for recording, enriching and retrieving information about visual items.
- *Objective 3*: How their semantic description help us understand the visual culture.

2011 - 2013 **International MA in Digital Library Learning**, *DILL*, Oslo, Tallinn, Parma, Erasmus Mundus.

- *Major:* Digital library.
- *Thesis title:* Digital preservation network: a case study about CLOCKSS.
- *Thesis content:* Interviews, document and workflow analysis about the usage, the governance, and the trends of CLOCKSS as main distributed network for the digital preservation of e-journals.

Universities

Oslo Metropolitan University, *OsloMet*, Oslo, Norway.

- *Courses include:* Ontology creation, Linked Open Data, RDF, Metadata, Usability studies.

Tallinn University, *TLU*, Tallinn, Estonia.

- *Courses include:* Knowledge management and business oriented information management.

Università di Parma, *UNIPR*, Parma, Italy.

- *Courses include:* UX, project management, KPI and evaluation methods, digital library management.

2007 - 2010 **Bachelor in Cultural Heritage Science**, *UNIPI*, Pisa, Italy.

- *Major:* Cultural Heritage Science.
- *Courses include:* Information science, knowledge organisation, textual bibliography, cataloguing, history of art, literature, ethnography, history.

Teaching

Course *Integrating Human Science Data using CIDOC-CRM as Formal Ontology: a practical approach* at the European Summer University in Digital Humanities held in *Leipzig, Germany*

Lesson *Digital Art History* at the Summer school *Stucchi E Stuccatori Ticinesi a Roma - Dalla riscoperta cinquecentesca alla grande tradizione barocca* held in *Rome, Italy*

Lesson Lesson on *Digital Heritage* within the Digital Library Learning MA — *Online*

Organization

Conference ITN-DCH - Digital Heritage 2017 Final Conference — *Olimje, Slovenia*

Workshop Workflow for the Integration of Heritage Digital Resources — *Olimje, Slovenia*

Languages

Italian Native

English Fluent

French Intermediary

Computer Skills and Technologies

Data UML, XML, RDF, Protege, OpenRefine, Silk, X3ML/3M, Ontop.

Web HTML, CSS, Drupal, KirbyCMS, Wordpress.

3D MicMac, Photoscan, Potree, 3DHOP, Faro Scene, MeshLab.

Server Apache, SQL, TemaTres, iQvoc, Skosmos.

Other QGIS, CLI, Markdown, GIT, Microsoft/Libre Office, Adobe Lightroom/Photoshop, Omnigraffle & Wireframing.

Platforms Mac OS, Linux, Windows.

Publications

2019 Nicola Carboni, Susanne Muller, and Maurizio Ghelardi. Towards a Foundation for Documenting Digital Textual Resources with CIDOC-CRM, Conference proceedings of the workshop *Scholarly Digital Editions, Graph Data-Models and Semantic Web Technologies*, in press.

Nicola Carboni and Livio De Luca. An Ontological Approach to the Description of Visual and Iconographical Representations, *Heritage*, 2(2)1191–1210.

2017 George Bruseker, Nicola Carboni, and Anaïïs Guillem. The Role of Formal Ontology and CIDOC CRM. In M. L. Vincent, V. M. Lopez-Menchero, M. Ioannides and T. E. Levy (Eds.), *Heritage and Archaeology in the DigitalAge*, pages 93-131. Springer, 2017.

Nicola Carboni and Livio De Luca. Towards a Semantic Documentation of Heritage Objects through Visual and Iconographical Representations, *International Information Library Review*, 49(3).

2016 M.M. Ramos, D. Bellido, N. Carboni, M. Domajnko, E. K. Stathopoulou, G. Stavropoulou, D. Morabito, and F. Remondino. Complex 3d heritage architectures accessible on the web. In *Proc. 8th Arqueologica 2.0*, pages 426–429, 2016.

Nicola Carboni and Livio De Luca, Towards a conceptual foundation for documenting tangible and intangible elements of a cultural object, *Digital Applications in Archaeology and Cultural Heritage*, 3(4):108–116.

Nicola Carboni, G Bruseker, A Guillem, Diego Castañeda Bellido, Chance Coughenour, M Domajnko, Marleen de Kramer, Magda Calles Ramos, E K Stathopoulou, and Rossella Suma, Data Provenance in Photogrammetry Through Documentation Protocols, *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences*, pages 57–64.

2015 G Bruseker, A Guillem, and N Carboni, Semantically Documenting Virtual Reconstruction: Building a Path to Knowledge Provenance, *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences*, II-5/W3:33–40.

Scholarships, Awards and Grants

2018 Digital Humanities Fellowship. Harvard University.

2014-2017 Marie Curie Early-Stage Researcher Fellowship. European Commission (FP7).

2011-2013 EU - Erasmus Mundus Master Programme Scholarship.

Miscellaneous

May 2017 Chair of of the session *"Ontologies and Metadata in Digital CH"* - ITN-DCH Digital Heritage 2017 Final Conference, Olimje, Slovenia.

Nov 2016 Chair of the session *"3D Reconstruction and Modeling"* - Euromed 2016, Nicosia, Cyprus.