



NATIONAL TECHNICAL UNIVERSITY OF ATHENS
SCHOOL OF RURAL AND SURVEYING ENGINEERING
POSTGRADUATE PROGRAMME GEOINFORMATICS
LABORATORY OF PHOTOGRAMMETRY

MASTER OF SCIENCE THESIS

THE CONTRIBUTION OF 3D MODELS TO SERIOUS GAMES APPLICATIONS

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Abstract

Digital technologies have affected many fields of computer graphics such as Games and especially the Serious Games field. This kind of games is usually used for educational purposes in many scientific fields such as Health Care, Military, Education etc. Digital Cultural Heritage is a scientific field in which Serious Games are gradually applied and many applications have been developed according to the literature.

Realistic 3D models which have been produced using different photogrammetric methods could be a useful tool for the creation of Serious Games applications in order to make the final result more realistic and closer to the reality.

The basic goal of this thesis is the development of a Serious Game for the Ancient Agora of Athens by using different kind of 3D documentation data created in previous projects. These models vary not only as far as their production methods (Time of Flight Laser scanner, Structure from Motion, Virtual Historical reconstruction etc.) is concerned, but also as far as their era, because some of them are illustrated according to the existing situation and some others according to how these monuments would have looked like in the past.

The Unity 3D Game development engine was used for the game development in which all these models were inserted in the same file format. The scenario of the game includes two virtual tours of the area in different eras and a quiz game. In this quiz game questions are posed to the user for each monument with three possible answers of which the player should select the correct one. In case that the answer is right he will continue with the next question. In case that the answer is wrong the player will be presented with the correct answer and an explanation about his mistake. Furthermore a preliminary stage about ancient Greek temples and their orders is created in order to help the players to acquire more knowledge and facts about Ancient Greek architecture.

The evaluation of the game was carried out by a group of people, experienced and non-experienced in Cultural Heritage field, who played and evaluated the game by filling in a carefully prepared online questionnaire. The game was improved according to these evaluations for a better result. Finally some concluding remarks and the future evolution of this game is presented.

Keywords: Serious Games, 3D models, Cultural Heritage.

**Η Συμβολή των Τρισδιάστατων Μοντέλων στα Παιχνίδια Σοβαρού
Σκοπού**

Γεωργία Κοντογιάννη

Μεταπτυχιακή Εργασία

Οκτώβριος 2015

Περίληψη

Οι νέες τεχνολογίες έχουν επηρεάσει σημαντικά πολλούς τομείς στον κλάδο των γραφικών υπολογιστών όπως είναι τα παιχνίδια και πιο συγκεκριμένα το πεδίο των Παιχνιδιών Σοβαρού Σκοπού. Το συγκεκριμένο είδος παιχνιδιών χρησιμοποιείται για εκπαιδευτικούς σκοπούς σε πολλά επιστημονικά πεδία όπως είναι η Υγεία, οι Στρατιωτικές Εφαρμογές, η Εκπαίδευση κλπ. Τα παιχνίδια Σοβαρού Σκοπού έχουν εφαρμογή στο πεδίο της Ψηφιακής Πολιτιστικής Κληρονομιάς όπου έχουν αναπτυχθεί πολλές εφαρμογές σύμφωνα με την διεθνή βιβλιογραφία.

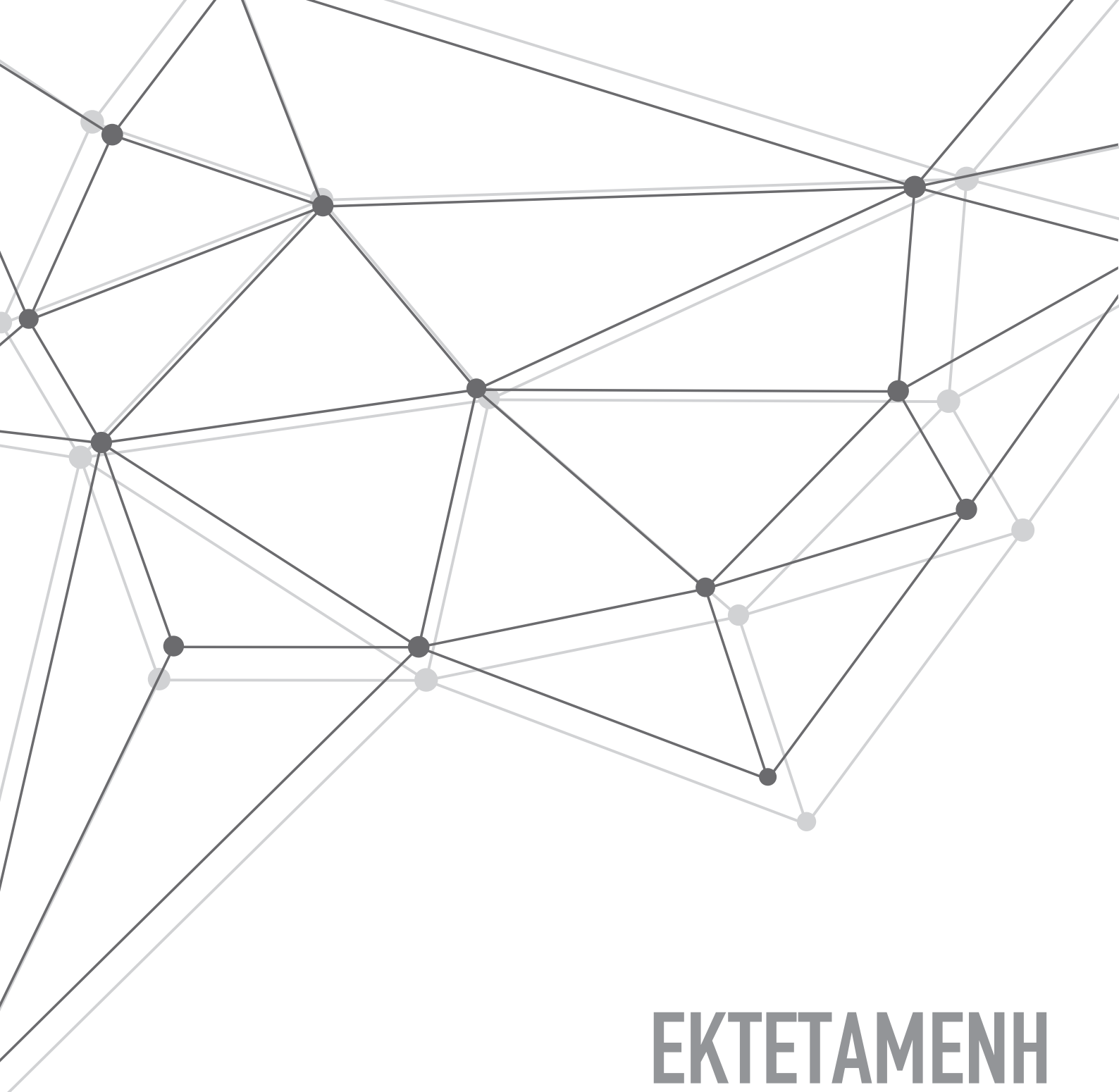
Τα ρεαλιστικά τρισδιάστατα μοντέλα τα οποία έχουν παραχθεί με διαφορετικές φωτογραμμετρικές μεθόδους θα μπορούσαν να είναι ένα πολύ χρήσιμο εργαλείο για τη δημιουργία τέτοιων εφαρμογών προκειμένου το τελικό προϊόν/αποτέλεσμα να είναι πιο ρεαλιστικό και πιο κοντά στην πραγματικότητα.

Ο βασικός στόχος της παρούσας εργασίας είναι η δημιουργία ενός παιχνιδιού Σοβαρού Σκοπού για την Αρχαία Αγορά της Αθήνας χρησιμοποιώντας διαφορετικών ειδών τρισδιάστατα δεδομένα τεκμηρίωσης των μνημείων τα οποία δημιουργήθηκαν σε προηγούμενες εργασίες. Τα συγκεκριμένα μοντέλα διαφέρουν όχι μόνο ως προς τη μέθοδο την οποία παρήχθησαν (σαρωτές Time of Flight, λογισμικά Structure from Motion, Τρισδιάστατη Εικονική Ανακατασκευή κλπ.) αλλά και ως προς τη χρονολογία αφού ορισμένα απεικονίζουν την υπάρχουσα κατάσταση και κάποια άλλα απεικονίζουν τα μνημεία όπως ήταν κατά το παρελθόν.

Το λογισμικό ανάπτυξης παιχνιδιών Unity 3D χρησιμοποιήθηκε για τη δημιουργία του παιχνιδιού όπου όλα τα μοντέλα εισήχθησαν με τον ίδιο μορφότυπο αρχείου. Το σενάριο του παιχνιδιού περιλαμβάνει δύο εικονικές περιήγησεις της περιοχής σε διαφορετικές χρονικές στιγμές και ένα παιχνίδι ερωτήσεων. Στο παιχνίδι ερωτήσεων υπάρχουν ερωτήσεις για κάθε μνημείο με τρεις πιθανές απαντήσεις από τις οποίες

η μία είναι σωστή και οι παίκτες θα πρέπει να την επιλέξουν. Στη περίπτωση που η απάντηση είναι σωστή ο παίκτης συνεχίζει παρακάτω. Σε αντίθετη περίπτωση ο παίκτης βλέπει τη σωστή απάντηση μαζί με την εξήγηση της. Ακόμα έχει δημιουργηθεί ένα αρχικό στάδιο το οποίο περιλαμβάνει γενικές πληροφορίες γύρω από τους Αρχαίους Ελληνικούς ναούς και τους ρυθμούς προκειμένου οι παίκτες να μάθουν κάποια επιπλέον πράγματα γύρω από την Αρχαία Ελληνική Αρχιτεκτονική. Ακόμα πραγματοποιήθηκε η αξιολόγηση του παιχνιδιού από ομάδα ανθρώπων στην οποία ανήκουν άνθρωποι οι οποίοι έχουν εμπειρία στο πεδίο της Πολιτιστικής κληρονομιάς και άνθρωποι οι οποίοι δεν έχουν εμπειρία στο συγκεκριμένο πεδίο. Το συγκεκριμένο γκρουπ έπαιξε το παιχνίδι και το αξιολόγησε συμπληρώνοντας ένα ερωτηματολόγιο το οποίο ήταν αναρτημένο στο διαδίκτυο. Η εφαρμογή βελτιώθηκε σύμφωνα με τις συγκεκριμένες αξιολογήσεις. Τέλος παρουσιάζονται κάποια συμπερασματικά σχόλια και η μελλοντική εξέλιξη της συγκεκριμένης εφαρμογής.

Λέξεις Κλειδιά: Παιχνίδια Σοβαρού Σκοπού, 3D Μοντέλα, Πολιτιστική Κληρονομιά



**ΕΚΤΕΤΑΜΕΝΗ
ΠΕΡΙΛΗΨΗ**

Οι νέες τεχνολογίες έχουν επηρεάσει σημαντικά πολλούς τομείς στον κλάδο των γραφικών υπολογιστών όπως είναι τα παιχνίδια και πιο συγκεκριμένα το πεδίο των Παιχνιδιών Σοβαρού Σκοπού. Σύμφωνα με τη βιβλιογραφία (Michael κ.α. 2005, Zyda 2006, Laamarti κ.α 2014) υπάρχουν αρκετοί ορισμοί σχετικά με τα συγκεκριμένα παιχνίδια ενώ το πεδίο εφαρμογής του εκτείνεται σε πολλούς τομείς. Ο πιο πρόσφατος από αυτούς (Laamarti κ.α 2014) τα ορίζει ως παιχνίδια τα οποία έχουν τρία βασικά χαρακτηριστικά τα οποία είναι τα πολυμέσα, η διασκέδαση και εμπειρία. Οι τομείς στους οποίους εφαρμόζονται τα παιχνίδια σοβαρού σκοπού είναι: η Υγεία, ο Στρατός, όλες οι βαθμίδες της εκπαίδευσης, η Δημόσια Διοίκηση, Διαφήμιση, Πολιτιστική κληρονομιά και σε πολλούς άλλους τομείς. Στο πεδίο της πολιτιστικής κληρονομιάς έχουν γίνει προσπάθειες σχετικά με τον διαχωρισμό των συγκεκριμένων παιχνιδιών σε κάποιες κατηγορίες (Anderson κ.α 2010, Mortara κ.α 2014). Η πρώτη κατηγοριοποίηση (Anderson κ.α 2010) τα διαχωρίζει σε: Prototypes & Demonstrations, Εικονικά Μουσεία και σε Εμπορικά παιχνίδια. Η δεύτερη κατηγοριοποίηση (Mortara κ.α 2014) τα διαχωρίζει σε Cultural Awareness, Εικονική ανακατασκευή και Heritage Awareness. Ακόμα έχουν αναπτυχθεί πολλές εφαρμογές παιχνιδιών σοβαρού σκοπού όπως: Rome Reborn, ICURA, THIATRO, Ancient Olympic Games, The Battle of Thermopylae κλπ.

Σκοπός της παρούσας εργασίας είναι η δημιουργία ενός παιχνιδιού Σοβαρού Σκοπού για την Αρχαία Αγορά της Αθήνας. Τα δεδομένα τα οποία χρησιμοποιήθηκαν για τη δημιουργία του παιχνιδιού ποικίλλουν. Αρχικά χρησιμοποιήθηκε η εικόνα του ΨΜΕ και η αντίστοιχη ορθοεικόνα για τη δημιουργία του μοντέλου του εδάφους πάνω στο οποίο θα τοποθετηθούν τα τρισδιάστατα μοντέλα. Τα συγκεκριμένα μοντέλα έχουν δημιουργηθεί με διαφορετικές μεθόδους σε προηγούμενες εργασίες του εργαστηρίου. Η πρώτη κατηγορία αφορά τα μοντέλα τα οποία δημιουργήθηκαν με τη χρήση σαρωτή Time of Flight (ToF) και ορθοεικόνων για την απόδοση υψής στα μοντέλα. Στη κατηγορία αυτή ανήκουν ο Γίγαντας από το ωδείο του Αγρίππα και η νοτιοδυτική γωνία των θεμελίων της Μεσαίας Στοάς. Το μοντέλο του Ναού του Ηφαίστου ανήκει στη κατηγορία των μοντέλων όπου δημιουργήθηκαν με τη χρήση σαρωτή ToF οποίος όμως δίνει πληροφορία χρώματος για κάθε σημείο που σαρώνει. Η νοτιοδυτική γωνία της Μεσαίας Στοάς ανακατασκευάστηκε εικονικά χρησιμοποιώντας παλιά σχέδια, εικόνες, τη διαθέσιμη βιβλιογραφία αλλά και υποθέσεις οι οποίες έγιναν από τις επιστημονικές υπεύθυνους που εργάζονται στην Αρχαία Αγορά. Τα μοντέλα της εκκλησίας των Δώδεκα Αποστόλων, ο διάκοσμος της σίμης στη Μεσαία Στοά καθώς και η οροφή του εσωτερικού του Ναού του Ηφαίστου δημιουργήθηκε με τη μέθοδο Structure from Motion όπου με τη χρήση ψηφιακών εικόνων μεγάλης επικάλυψης μεταξύ τους δημιουργείται το τρισδιάστατο μοντέλο των αντικειμένων. Στην επόμενη κατηγορία ανήκουν τα μοντέλα τα οποία λήφθηκαν από το διαδίκτυο και πιο συγκεκριμένα από το 3D Warehouse library. Στην τελευταία κατηγορία ανήκει το εσωτερικό του Ναού του Ηφαίστου το οποίο δημιουργήθηκε από συνδυασμό

μεθόδων. Πιο συγκεκριμένα το εσωτερικό πάρθηκε από το συνολικό μοντέλο, όμως η υφή αποδόθηκε με τη χρήση ορθοεικόνων αλλά και κανονικών εικόνων λόγω έλλειψης ορθοεικόνων και στη συνέχεια ενώθηκε με το μοντέλο της οροφής.

Το σενάριο του παιχνιδιού περιλαμβάνει δύο εικονικές περιηγήσεις στην Αρχαία Αγορά μία σήμερα και μία κατά τον 2^ο αιώνα μ.Χ και ένα παιχνίδι γνώσεων. Στο παιχνίδι γνώσεων υπάρχει ένα στάδιο εκπαίδευσης όπου ο χρήστης μπορεί να μάθει εφόσον το επιθυμεί κάποια στοιχεία σχετικά με την Αρχαία Ελληνική αρχιτεκτονική και πιο συγκεκριμένα για τους αρχαίους ναούς και ρυθμούς. Στη συνέχεια μπορεί να ξεκινήσει με το παιχνίδι όπου επιλέγοντας το πρώτο μνημείο μπορεί να περιηγηθεί εικονικά για να δει πως ήταν ή πως είναι το μνημείο να μάθει κάποιες πληροφορίες για αυτό ενώ στη συνέχεια να συνεχίσει με τις ερωτήσεις. Στη περίπτωση που απαντήσει σωστά τότε προχωράει στην επόμενη ερώτηση. Ενώ αν απαντήσει λάθος δε χάνει βλέπει ποια είναι η σωστή ερώτηση και προχωράει στη συνέχεια με την επόμενη ερώτηση.

Η δημιουργία του παιχνιδιού πραγματοποιήθηκε στο λογισμικό Unity 3D Personal Edition η οποία είναι ελεύθερη και έχει παρέχει πολλές λειτουργίες για τη δημιουργία ενός παιχνιδιού. Σε πρώτη φάση δημιουργήθηκε το μοντέλο του εδάφους από το ΨΜΕ και την ορθοεικόνα. Πιο συγκεκριμένα στο λογισμικό Photoshop πραγματοποιήθηκε η μετατροπή της εικόνας από 32bit σε 16bit μορφότυπου raw καθώς και η τροποποίηση των διαστάσεων της εικόνας με σκοπό το άδειο terrain που έχει δημιουργηθεί στο Unity να είναι ίδιας ανάλυσης με την εικόνα του ΨΜΕ. Ακόμα στο Photoshop πραγματοποιήθηκε αναστροφή της εικόνας κατακόρυφα έτσι ώστε όταν εισαχθεί στο Unity και εφαρμοστεί στο άδειο μοντέλο του εδάφους αυτό να είναι σωστό και όχι το είδωλό του. Μετά την εφαρμογή του ΨΜΕ πάνω στο terrain πραγματοποιήθηκε η εξομάλυνση του με εργαλεία που παρέχει το πρόγραμμα με σκοπό την εξάλειψη των αποτόμων εναλλαγών του υψομέτρου λόγω των δέντρων και των κτηρίων που υπάρχουν στην περιοχή. Η απόδοση της υφής στο μοντέλο του εδάφους έγινε με τη χρήση της ορθοεικόνας της περιοχής.

Στη συνέχεια πραγματοποιήθηκε η εισαγωγή των τρισδιάστατων μοντέλων των μνημείων και τα οποία εισήχθησαν με τον ίδιο μορφότυπο αρχείου (fbx). Τα προβλήματα τα οποία προέκυψαν κατά την εισαγωγή των μοντέλων αφορούσαν τη μη απόδοση υφής η οποία αποδόθηκε στο Unity απλά ξαναισιάζοντας τις υφες. Το δευτερο πρόβλημα αφορούσε τη σκούρα υφή η οποία παρατηρήθηκε στα μοντέλα της εκκλησίας των Δώδεκα Αποστόλων, του Ναού του Ηφαίστου και του Γίγαντα του Ωδείου του Αγρίππα. Στις δύο πρώτες περιπτώσεις το πρόβλημα οφειλόταν στο ότι το Unity αποδίδει και χρώμα στις υφές. Το πρόβλημα διορθώθηκε αλλάζοντας το χρώμα από γκρι σε άσπρο. Στην περίπτωση του γίγαντα το πρόβλημα οφειλόταν στο φωτισμό του περιβάλλοντος και διορθώθηκε αλλάζοντας κάποιες παραμέτρους. Τα μοντέλα από το 3D Warehouse Library είχαν κάποια προβληματάκια τα οποία διορθώθηκαν είτε πριν την εισαγωγή τους το Unity όπως η μία κιονοστοιχεία στο

Ναό του Άρεως η οποία διαπερνούσε το έδαφος, είτε μετά όπως ο χρωματισμός των μοντέλων όπου αποφασίστηκε να είναι ίδιος με εκείνον της Μεσαίας Στοάς.

Μετά την εισαγωγή όλων των διαθέσιμων δεδομένων πραγματοποιήθηκε η διαδικασία της δημιουργίας του παιχνιδιού όπου σε πρώτη φάση δημιουργήθηκε ο φωτισμός του περιβάλλοντος του παιχνιδιού με σκοπό ένα πιο ρεαλιστικό αποτέλεσμα. Επόμενο βήμα είναι η δημιουργία των διαχρονικών εικονικών περιηγήσεων οι οποίες είναι δύο όπως αναφέρθηκε και προηγουμένως. Η πρώτη αφορά την Αρχαία Αγορά όπως είναι σήμερα και η άλλη όπως ήταν την περίοδο ακμής της κατά τον 2^ο αιώνα μ.Χ. Η πραγματοποίηση των εικονικών περιηγήσεων πραγματοποιείται με τη χρήση του εργαλείου First Person Controller όπου ο χρήστης χρησιμοποιώντας τα βελάκια και το ποντίκι μπορεί να περιηγηθεί εικονικά στο χώρο. Ακόμα δίπλα, πάνω ή μπροστά από κάθε μνημείο αναγράφεται το όνομα του με σκοπό ο παίκτης να βλέπει ποιο μνημείο βλέπει. Ακόμα η δημιουργία ενός GUI παραθύρου δίνει τη δυνατότητα στο χρήστη είτε να προχωρήσει στην επόμενη περιήγηση είτε να γυρίσει πίσω στο αρχικό μενού.

Πρώτο βήμα για τη δημιουργία του παιχνιδιού ήταν η δημιουργία ενός αρχικού μενού έτσι ο παίκτης να μπορεί να περιηγηθεί. Με λίγα λόγια ο χρήστης έχει την επιλογή είτε να πραγματοποιήσει τις περιηγήσεις είτε να ξεκινήσει να παίζει το παιχνίδι γνώσεων. Ακόμα υπάρχει και ένα πλήκτρο βοήθειας με σκοπό ο χρήστης να δει κάποιες οδηγίες σχετικά με το πως παίζεται το παιχνίδι. Η χρήση των κουμπιών πραγματοποιήθηκε με τη χρήση ενός script που δημιουργήθηκε στη γλώσσα προγραμματισμού C#.

Όταν ο χρήστης επιλέξει το «Play» για να ξεκινήσει το παιχνίδι τότε έχει την επιλογή για το αν θέλει να συμμετέχει σε ένα στάδιο εκπαίδευσης και να μάθει κάποια πράγματα σχετικά με την Αρχαία Ελληνική Αρχιτεκτονική. Αν επιλέξει ότι θέλει να μάθει τότε θα δει και θα μάθει κάποια σημαντικά στοιχεία σχετικά με του Αρχαίους Ελληνικούς ρυθμούς και ναούς. Το στάδιο αυτό είναι προαιρετικό επομένως είτε το επιλέξει είτε όχι στη συνέχεια μπορεί να ξεκινήσει με το παιχνίδι. Ο παίκτης βλέπει έναν χάρτη με όλα τα μνημεία τα οποία συμμετέχουν στο παιχνίδι από τα οποία μόνο ένα είναι ξεκλειδωμένο και μπορεί να το επιλέξει. Όταν το επιλέξει στη συνέχεια περιηγείται εικονικά μέσα στο χώρο όπου βλέπει πως ήταν το μνημείο στις περιπτώσεις που το μνημείο δεν υφίστανται και πως είναι αν το μνημείο σώζεται σήμερα. Ακόμα μπορεί να δει κάποιες πληροφορίες σχετικά με το μνημείο πάνω στις οποίες βασίζονται ως επι το πλείστον οι ερωτήσεις που πρέπει να απαντήσει. Επιλέγοντας το «Continue» τότε συνεχίζει με το στάδιο των ερωτήσεων. Οι ερωτήσεις αφορούν είτε το κείμενο είτε τη θέση του μνημείου στην Αγορά είτε σε κάποιες περιπτώσεις τη μορφή που είχε το κτήριο. Στη περίπτωση που ο παίκτης απαντήσει σωστά στην ερώτηση τότε συνεχίζει με την επόμενη ερώτηση. Στην περίπτωση που απαντήσει λάθος τότε ο παίκτης δε χάνει αλλά βλέπει ποια είναι η σωστή απάντηση με κάποια εικόνα ή σχήμα σε κάποιες περιπτώσεις και στη συνέχεια μπορεί να συνεχίσει με την επόμενη ερώτηση. Το

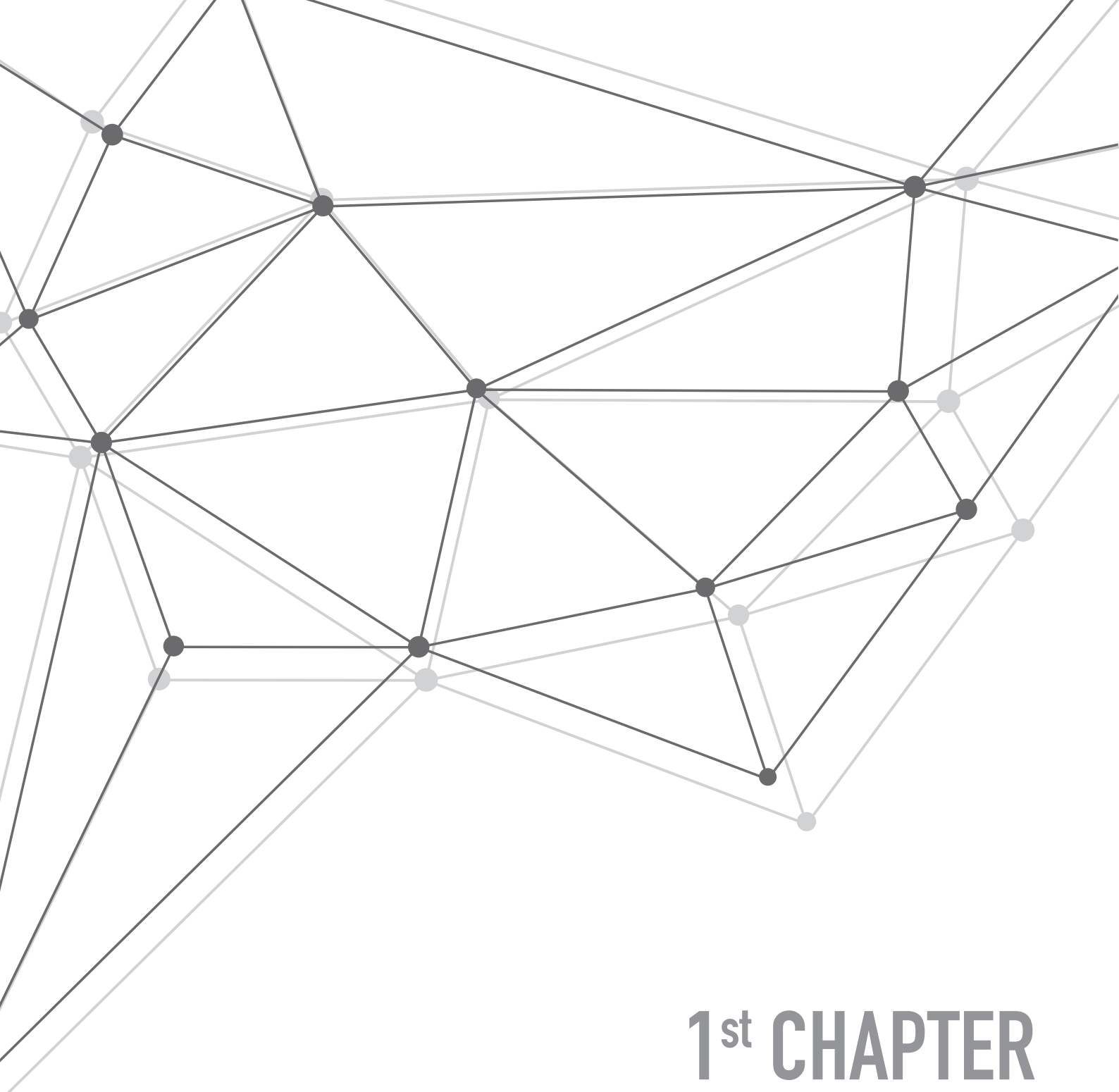
παιχνίδι ολοκληρώνεται όταν ο χρήστης απαντήσει όλες τις ερωτήσεις για όλα τα μνημεία τα οποία συμμετέχουν στην εφαρμογή.

Μετά το τέλος της δημιουργίας η εφαρμογή στάλθηκε σε ομάδα ατόμων αποτελούμε από 200 άτομα περίπου με σκοπό την αξιολόγησή της και στη συνέχεια τη βελτίωση της. Εκτός από την εφαρμογή στάλθηκε και ένα online ερωτηματολόγιο με σκοπό όσοι παίζουν το παιχνίδι να το αξιολογήσουν μέσω αυτού του ερωτηματολογίου το οποίο δημιουργήθηκε στο Google forms. Αξίζει να σημειωθεί εδώ ότι καλό είναι να χρησιμοποιούνται έτοιμα ή τροποποιημένα ερωτηματολόγια. Στη περίπτωση του ερωτηματολογίου για το παιχνίδι της Αρχαίας Αγοράς το ερωτηματολόγιο πάρθηκε από το διαδίκτυο και τροποποιήθηκε για τις ανάγκες του εξεταζόμενου παιχνιδιού. Το ερωτηματολόγιο περιείχε γενικές ερωτήσεις, ερωτήσεις για τη χρήση ηλεκτρονικών συσκευών, παιχνιδιών, ερωτήσεις σχετικά με το εξεταζόμενο παιχνίδι, το αντίκτυπο που είχε ενώ οι παίκτες είχαν την επιλογή να αφήσουν και κάποια ελεύθερα σχόλια σχετικά με την εφαρμογή που έπαιξαν. Στη συνέχεια πραγματοποιήθηκε επεξεργασία των απαντήσεων των ερωτηματολογίων για την εξαγωγή κάποιων στατιστικών στοιχείων. Συνοπτικά η πλειονότητα των χρηστών βρήκε το παιχνίδι και πιο συγκεκριμένα τις ερωτήσεις, τα μοντέλα και το σενάριο του παιχνιδιού ρεαλιστικά. Ακόμα ανέφεραν ότι έμαθαν στοιχεία σχετικά με τα μνημεία της αρχαίας αγοράς ενώ θεώρησαν ότι έμαθαν πολλά παίζοντας το παιχνίδι.

Στη συνέχεια πραγματοποιήθηκαν κάποιες βελτιώσεις οι οποίες έγιναν με βάση τα ελεύθερα σχόλια που έκανα οι παίκτες κατά τη διάρκεια της αξιολόγησης. Αρχικά προστέθηκε ένας μινιχάρτης στις περιηγήσεις με σκοπό ο χρήστης να βλέπει που βρίσκεται σε μια πιο ευρύτερη περιοχή. Ακόμα προστέθηκε μουσική στις περιηγήσεις για ένα πιο ρεαλιστικό αποτέλεσμα. Κάποιες πιο δευτερευουσες διορθώσεις αφορούν ενός κουμπιού εξόδου στις περιηγήσεις και η μετακίνηση του κουμπιού συνέχειας. Τελος μια ακόμα μικροδιόρθωση αφορά τη μείωση της ταχύτητας του ποντικιού το οποίο έφευγε πολύ κατά τη διάρκεια των περιηγήσεων.

Στο τέλος αναφέρονται κάποια συμπερασματικά σχόλια όπου αναφέρονται ότι τα παιχνίδια σοβαρού σκοπού είναι εκπαιδευτικά παιχνίδια και αυτό φάνηκε και από την αξιολόγηση του παιχνιδιού για την Αρχαία Αγορά της Αθήνας. Ακόμα είναι διεπιστημονικό αντικείμενο και χρειάζονται πολλές ειδικότητες για να πιο ολοκληρωμένο και σωστό αποτέλεσμα. Τα μοντέλα από τους σαρωτές δεν ήταν τόσο διαχειρίσιμα λόγω του όγκου τους σε σχέση με τα μοντέλα τα οποία προέκυψαν από τη μέθοδο Structure from Motion (SfM) τα οποία όμως δεν χάνουν σε ποιότητα. Τα μοντέλα από το 3D warehouse library δεν ήταν τόσο ακριβή και ρεαλιστικά ενώ σε κάποιες περιπτώσεις είχαν και λάθη (π.χ Ναός του Άρεως). Το μοντέλο του Θησαυρίου λόγω της μεθόδου που δημιουργήθηκε δε βγήκε τόσο καλό. Μια καλή λύση θα ήταν η δημιουργία του τρισδιάστατου μοντέλου μέσω της μεθόδου SfM.

Τέλος οι προοπτικές εξέλιξης του παιχνιδιού αφορούντη προσθήκη ενός συστήματος βαθμολόγησης όπου ο χρήστης θα χάνει αν απαντάσει λάθος σε περισσότερες από δύο ερωτήσεις. Ακόμα οι ερωτήσεις ανάλογα με τη δυσκολία τους θα μπορούν να έχουν περισσότερους βαθμούς ενώ ακόμα ο χρήστης να χάνει πόντους αναπαντάει λάθος σε μία ερώτηση. Ακόμα θα υπάρχει η δυνατότητα αποθήκευσης του παιχνιδιού όπου ο χρήστης με το που θα ξεκινάει το παιχνίδι θα δίνει το όνομα του και οποιαδήποτε στιγμή το επιθυμεί να βγαίνει από το παιχνίδι και όταν θέλει να το ξαναπαίξει να ξεκινάει από εκεί που το είχε αφήσει την τελευταία φορά. Ακόμα ο χρήστης θα μπορεί να ξεκινάει με το μνημείο της επιλογής του.



1st CHAPTER

INTRODUCTION

1.1 MOTIVATION

The evolution of new technologies in computer graphics during the recent years has helped significantly the gaming industry and especially the field of Serious Games. This kind of Games is spreading rapidly in the field of academic research and is used not only for entertainment but also for educational purposes (Michael et al. 2005, Susi et al. 2007).

In the field of Cultural Heritage, Serious Games can significantly help people who are not oriented or specialized in this field such as tourists, school children, college students, museum visitors and others to gain experience and expand their knowledge through these games. This kind of games can be interactive through the use of virtual tour facilities, through posing questions about heritage objects and the monuments and many other similar operations. Textured 3D models that have been developed from different methods such as Laser scanning, Structure from Motion, Procedural Modeling etc. can be a useful tool for developing Serious Games applications because they present a higher reliability, they are more realistic and the player will be able to interact with these models by visiting and answering some questions about them.

This thesis aims firstly on how 3D textured detailed and realistic models can be used for creating a Serious Game application in the Ancient Agora of Athens. Furthermore it is attempted to investigate the use of these 3D realistic models, which were produced for geometric documentation purposes and hence they are more realistic, have undeniable metric value and thus may enable the user to understand better the game environment and the era concerned. This game includes virtual tours of the area and a game quiz that includes few questions of each monument. Through questions the user will be able to learn many interesting details about the history and the architecture of each monument. Finally an evaluation of this game will be done at the end of this project which helps significantly towards the improvement of the game.

1.2 OUTLINE

In this master thesis the development of a Serious Game application for the Ancient Agora of Athens is presented. It is composed of six chapters and one appendix.

Chapter 1 presents the motivation for this thesis and the outline of this project.

Chapter 2 describes the scientific field of Serious Games through an historical overview of the field, the taxonomy and the application areas which are applied. Moreover the field of Serious Games in cultural heritage is described in this chapter

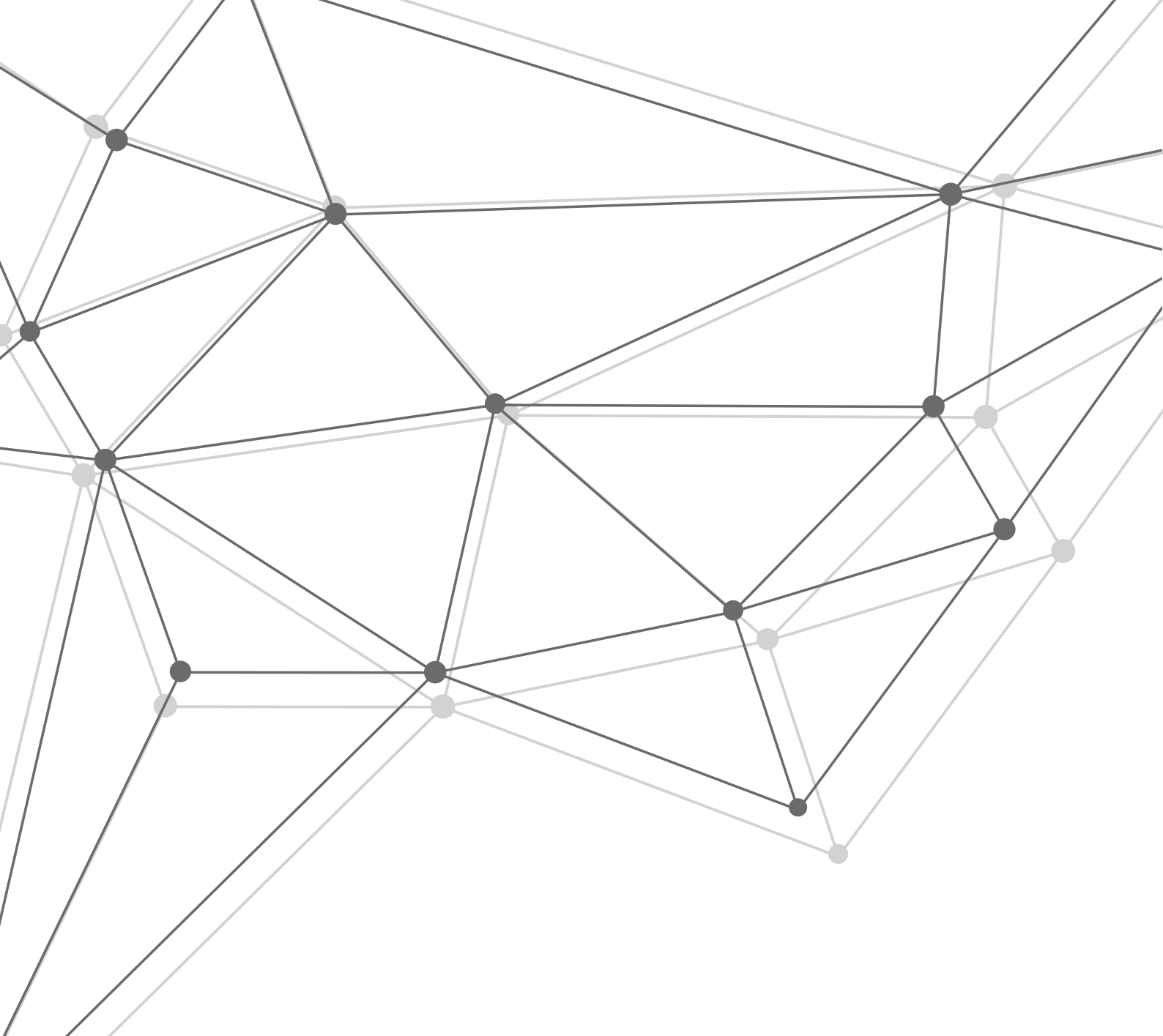
and especially the categorizations of this field and the application that have been developed.

Chapter 3 presents the available data used for the game development and how they were produced. Furthermore some elements about the Ancient Agora and the monuments that take part in the game are presented.

Chapter 4 describes the procedure about the development of the Serious Game.

In **Chapter 5** the procedure for the evaluation and the improvement of the game is described.

Finally in **Chapter 6** the conclusions of this project are presented.



2nd CHAPTER

SERIOUS GAMES

2.1 STATE OF THE ART OF SERIOUS GAMES

2.1.1 Definition

There are several perspectives of defining serious games as seen from the academia and the industry. For example, some industry persons believe that a serious game must include a genuine entertainment element combined seemingly with a practical dimension (Alvarez et al. 2008). Some researchers argue that all games have a serious purpose such as gambling, fortune telling (Laamarti et al. 2014) or politics. In this case the term may be used to refer to any application produced using development software from the gaming industry, which means a majority of simulations would be considered serious games (Sawyer et al. 2002). Other researchers believe that a serious game is simply a computer game, and that the classification is nothing more than a marketing technique (Sawyer 2009).

Probably the most common definition of serious games is the one according to Michael et al. (2005) and defines the Serious Games as “games that do not have entertainment, enjoyment, or fun as their primary purpose”. Another definition of serious games is that it is a mental contest, played with a computer in accordance to specific rules that use entertainment to further abilities in government or corporate training, education, health, public policy and strategic communication objectives (Zyda 2005). Laamarti et al. (2014) also define serious games as an application with three components: experience, entertainment and multimedia (Fig. 1). Also Figure 1 demonstrates the differences between serious games and several terminologies such as training simulation, computer game and sports.

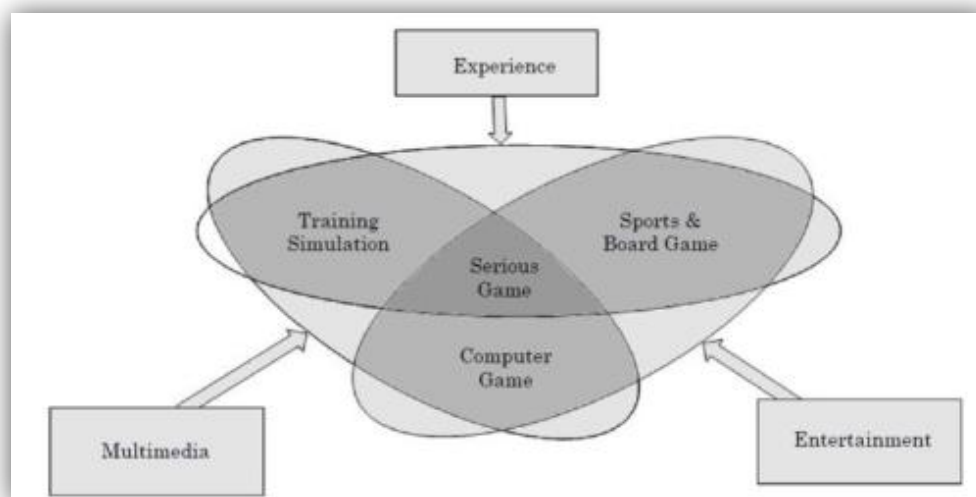


Figure 2.1: Definition of Serious Games
(Laamarti et al. 2014)

Furthermore Gamification is a new notion in gaming industry and especially in Serious Games. Gamification is an expression of the pervasiveness of gaming in

every day (De Freitas et al. 2011). Serious Games, education gaming and games and virtual worlds are one of the best examples of Gamification which are developed for educational purposes reveal the potential of these technologies to engage and motivate beyond leisure time activities.

2.1.2 History of Serious Games

The idea of playing games dates to back the ancient past and is considered an integral part of all societies. Also there are evidences for playing Serious Games in the antiquity, an example being the Mancala Game designed around 1400 B.C. and which was used as an accounting tool for trading animals and food (<https://en.wikipedia.org/wiki/Mancala#History>). The concept of Serious Games was first coined by Abt (1970) and it was described as “We are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement.” He also used innovative gaming approaches to improve education for the physical and social sciences, occupational choice and training, planning and problem solving in government and industry (Laamarti et al. 2014). Furthermore during World War II, the U.S. army general staff were the first to use the term “war games” and employed them to improve their image with the population. The Odyssey by Magnavox, launched in USA in 1972, was the one of the world’s first commercial home video game console. Also it is considered that was one of the first serious video games. Later, in 1973 the Minnesota Education Computing Consortium (MECC) produced the educational games “The Oregon Train” and “Lemonade Stand”. In 1981 a simulation also known as “The Bradley Trainer” was developed for the American army in order to train new recruits in how to operate a Bradley tank. The release of several arcade games such as Pole Position as well as games for the Atari VCS 2600 console, such as Pepsi invaders, which included elements of advertising, happened in 1982 and 1983. In 1996 the Marine Doom game was used for training the members of the US Marine Cops. America’s Army is a first-person shooter game developed by the U.S. army and distributed free-of-charge over the Internet in 2002. Sawyer considered that America’s Army game as the first successful and well-executed serious game that gained total public awareness. Other breakthrough games were DARWARS introduced in 2003 and VBS1 in 2005. In the last decade Serious Gaming grew exponentially. In 2006 BiLAT was introduced and it is an immersive learning environment that teaches the preparation, execution and understanding of bilateral meeting in a cultural context. The second edition of VBS1 was released in 2009 and in 2012 a new version of the flight simulator game X-Plane for supporting various mobile platforms (Laamarti et al. 2014).

2.2 TAXONOMY OF SERIOUS GAMES

Since Serious Games have already been developed significantly and they will continue on in the future, it is necessary to define a fundamental taxonomy in order to classify and characterize the considerable work dedicated to this domain. Laamarti et al (2014) tried to define the characteristics that are important in the game's design and that have the potential to make a significant difference in the success of a serious game. These criteria are based on information derived from the study of different articles and applications related to Serious Games. These criteria are Activity, Modality, Interaction Style, Environment, and Application Area.

2.2.1 Activity

The first characteristic is the type of activity which is performed by the player and required accordingly for the game. Activity is the function performed by the player as a response and/or input to the game. Activity types can be physical exertion, for example in games for well-being or games for health and for fighting childhood obesity (Scarle et al. 2011). Also activity type can be physiological such as in rehabilitation games or for detection of some health conditions. It can also be mental such as educational, training or interpersonal communication games.

2.2.2 Modality

Modality is a criterion which characterizes the sensory modalities that the player experiences in the game. The most common are visual, auditory and haptic. Also there are some smell attempts for examples application which use the sense of smell in therapy. Modalities are very useful and must be used to the advantage of the game's purpose. It is important to include the right modalities for enhancing the user's experience and thus to increase the successfulness of the game. Music incorporation in the game is one of the most important properties and helps the players to increase motivation to exercise using the game in question. Also integrating haptic feedback in serious games has the potential to enhance the learning experience through a tactile perception of objects and to provide more realism in rehabilitation games for stroke patients.

2.2.3 Interaction style

The interaction style defines with which means the interaction of the players are realized. These means are traditional interfaces such as keyboard, mouse or joystick or using some intelligent interfaces such as brain interface, eye gaze, movement tracking, tangible interfaces etc. Choosing the right interface for the

serious game design may have an impact on the success of the game. For instance, for some games it is important to use intelligent interfaces instead of traditional ones. In games which include player movement tracking such as the one provided by the Microsoft Kinect or the use of a remote such as the Nintendo Wii which allows the player to feel more freedom and realism while playing the game. Additionally, for some games it would not be useful to use traditional interfaces, in cases that a game needs as input a kind of biological data such as heart beat rate, which is collected from the player's body by means of bio-sensors and sent directly to the game without the user's interference. In other domains it is actually critical to integrate the right interface in the game.

2.2.4 Environment

This criterion defines the environment of the digital game and can be a combination of several criteria which are:

- 2D/3D environment: The environment which a serious game was applied can be either two dimensional (2D) or three dimensional (3D) or a combination of the two.
- Virtual or mixed reality environment: Virtual reality is a computer generated immersive environment that can either represent the real world or can be purely imaginative and is widely used in serious games. A mixed reality includes both augmented reality and augmented virtuality and refers to an environment that merges real and digital worlds, allowing objects from each world to interact in real time.
- Location awareness: Depending on whether the game allows the determination of the player's current location.
- Mobility: Determines whether the game is mobile or not.
- Online: Determines if the game can be played over a computer network, usually internet.
- Social presence: Depending on whether the game is single or multi-player. This can be an important criterion to be taken into consideration

2.2.5 Application Area

The application area refers to the different application domains relevant to Serious Games. There are many possible application areas which are: Educational, healthcare, well-being, cultural heritage, interpersonal communication, military, Corporative, Political and religious games, Government. In the next chapter these application areas will be presented with some examples for each one.

2.3 APPLICATION AREAS

Serious Games have been applied in many scientific fields which will be described below.

2.3.1 Educational Games

Educational Games is an effective teaching tool and many examples can be found in literature. The *Sea Game* is an application for high school students designed to promote best practices in sea-related behaviours such as sailing or doing surveillance (Belloti et al. 2009). *Wu's castle* is another serious game in which students interactively construct a C++ code in order to solve game-problems (Eagle 2009). The game *Power Agent* (Gustafsson et al. 2008) is a game which teaches teenagers and their parents how to reduce energy consumption at home. A big amount of Serious Games can be found online to reach a wide audience. *Skills Arena* (Shin et al. 2012) is a game designed specifically for classroom use. It uses Nintendo Gameboy and teaches students arithmetic skills at varying levels of difficulty. *Making History* (Watson et al. 2011) is an educational game too used in the classroom for teaching high school students about World War II. *Lost in the Middle Kingdom* (Shepherd et al. 2011) is a serious game that helps players to learn a second language. *3rd World Farmer* (Hermund et al. 2005) is a simulation and management game whose main goal is to sensitize players to the hardships of maintaining a farm in developing countries. *IBM CityOne* or *IMB INNOV8* (<http://www-01.ibm.com/software/solutions/soa/innov8/cityone/>) is a city-building simulation game which educates players on facing today's cities related to transportation, energy infrastructure, water management in order to design smarter cities. Another game that educates about today's environment challenges is the *Clean World* (Barbosa et al. 2014).

2.3.2 Corporative Games

This kind of games deals with industrial applications for training, simulation, further education and skill enhancement in general. *CyberCIEGE* (Greitzer et al. 2007) is a security training game that users spend virtual money to operate and defend their networks. The Serious Game *World of Subways Vol. 1* was presented in 2009 in which the player slips into the role of a train conductor and learns the complex procedure of operating a subway train within a realistic training environment.

2.3.3 Political and Religious Games

Political and Religious Games often intend to spread a message than to teach the player. There are many publications about these areas and a collection of games can be found on internet (www.socialimpactgames.com). A game which is a very good example is the *Dafur is Dying*. This game was released in 2006 and demonstrated what it is like for more than 2.5 million people who have been displaced by the crisis in Sudan.

2.3.4 Healthcare Games

In healthcare many serious games are used for treatment, recovery and rehabilitation. *2020 Classroom* (Marsh et al. 2005; Wong et al. 2007) is a project to develop a 3D learning environment through a game called *Metalloman* which teaches bioscience concepts to undergraduate students. In this game students travel and perform virtually vital functions to complete mission objectives and interact with the human body in a playful way. A similar game is the *Immune Attack* (Kelly et al. 2007) which combines a realistic 3D depiction of biological structures and functions with educational technologies for teaching immunology to high school students and college freshmen. *SMILE* (Science and Math in an Immersive learning Environment) is a game that employs a fantasy 3D Virtual Environment to engage deaf and hearing children in Maths and science-based educational tasks. This game is the first bilingual immersive learning environment for deaf and hearing children (Adamo-Villani et al. 2007).

2.3.5 Government Games

A Government Game simulates politics of a nation such as the creation of domestic political policies or political campaigns. *FloodSim* is a such Serious Game created to raise awareness of flooding, flood policy and flood related to government expenditure in the UK. In this game which is online the players takes on the role of a flood policy strategic employed to implement a selection of strategies for addressing the risk of flooding based on a pre-defined budget (Rebolledo-Mendez et al. 2009).

2.3.6 Military Games

Serious Games were firstly applied in the area of the military (Michael et al. 2005). The first version of *America's Army* (Zyda 2005) was released in 2002 and started a revolution in thinking about the potential role of video games for non-entertainment purposes. The game was successfully used as a soldier training and recruiting tool. Other examples of military games are *Tactical Iraqi* and *Virtual Iraq*.

Tactical Iraqi was developed in order to accelerate a learner's acquisition of spoken Arabic to assist soldiers in unpredictable tactical situations. *Virtual Iraq* is a virtual reality simulation intended to reduce the effects of Post-Traumatic Stress Disorder (Johnson et al. 2007; Losh 2006). *Tactical Iraqi* is a pedagogical game and *Virtual Iraq* is therapeutic. The *3D Asymmetric Domain Analysis and Training* (3D ADAT) is a platform for the development and visualization of dynamic sociocultural models and provides a possibility to learn culture in a safe and realistic 3D environment (Zielke et al. 2009). This game lets the players increase their cultural expertise in simulated Afghan rural and urban environment.

2.3.7 Well-Being

This kind of games motivates players to be physically active by means of an entertaining and engaging game play (Laamarti et al. 2014). Chen et al. (2014) explore how the intention element of players can affect how they will benefit from the exercise game. *Heartlands* or *Ere Be Dragons* is another example of an exercise game where the players walk around an area of their choice, wearing a heart-rate monitor and carrying a pocket PC with GPS. A landscape is built on the pocket PC screen as the player moves around. The result is a representation of the player's heart performance as well as his location (Davis et al. 2006). A similar game is the *Monster and Gold* (Battussi et al. 2010) which includes a set of rules in order to motivate players to jog outdoors at their optimal heart rate level. *Fish'n'Steps* is another game in which players wear a pedometer, which provides the account of their daily footsteps. *Sensor network for Active Play* (SNAP) is an exercise game in which players have sensors attached to different parts in their body to make sure that their whole body is moving. This kind of game is used in order to reproduce a set of dance positions and their performance is evaluated by the sensor network (Laamarti et al. 2014).

2.3.8 Advertisement

Serious Games designed for advertising aim at promoting a particular brand or product or a service while they play the game. They are commonly known as advergames (Laamarti et al. 2014). In literature there are many examples about advergames many of them are *Pepsi*, *7 Up*, *NFL*, *Formula One* and *Burger King* (Edery et al. 2008). Also *America's Army* can be considered as an advergame because this game intends to boost recruitment for the United States Army (Alvarez et al. 2008).

2.4 SERIOUS GAMES IN CULTURAL HERITAGE

2.4.1 General

So far the implementation of Serious Games in Cultural Heritage has been explored in several projects and many initiatives have already been realized. The field of cultural heritage is extended in many areas. One of them is the tangible cultural heritage such as historic places and buildings, monuments, documents, works of arts, machines and other artifacts that are considered worthy of presentation in the future. Physical environment is an important factor of the cultural heritage and includes: landscapes, flora, fauna as well geological paleontological and morphological elements. Nevertheless there are many further factors which characterize a culture but they have a non-physical nature, this is the intangible cultural heritage. This area includes social values and traditions, customs and practices, philosophical values, religious beliefs, artistic expressions, language and folklore. Intangible heritage is very difficult to preserve compared to tangible heritage (Mortara et al. 2014). Serious games are a very powerful tool for the preservation and learning of Cultural heritage both Tangible and Intangible.

In the following section the attempts of the taxonomy/categorization of Serious Games in the field of cultural Heritage is presented.

2.4.2 Categorization

Many categorization attempts have been realized about this field according to the literature (Anderson et al. 2010; Mortara et al. 2014). A first categorization of this domain is according to Anderson et al. (2010) and divides the field in the three following areas.

- Prototypes & Demonstrations: In this domain there are projects that were developed with the use of visualization and virtual reconstruction. These methods are used in order to train and educate the user. These systems are used for academic studies and they have never been released to the wider public. In this field many applications have been developed that are presented below.
- Virtual museums: This kind uses games' technologies (Jones et al. 2002; Lepouras et al. 2004) in order to provide a means for the presentation of digital representations for cultural heritage sites (El-hakim et al. 2006) that entertain and educate visitors (Hall et al. 2001). Sylaiou et al. (2009) examine all the technologies and tools which are used in museums.
- Commercial games: this kind of games has a cultural heritage theme which are usually of the "Documentary game" genre (Burton 2005) that depict real historical events like wars and battles which the human player can partake in.

These games are primarily created for entertainment purpose but their historical accuracy allows them to be used and for educational purposes as well (Anderson et al. 2010).

Mortara et al. (2014) proposed a new classification of the domain which includes three categories as the previous categorization.

- Cultural Awareness: This kind is particularly focused on intangible or especially immaterial heritage including the language, customs, traditions, spiritual beliefs, folklore and rules of behaviour in a society without forgetting the influence of past events on that society.
- Historical Reconstruction: These games have history as their primary educational goal and focus on the faithful reconstruction of a specific historical period, event or process which happened in the past; notions of archaeology, art sociology and politics are also involved.
- Heritage Awareness: This kind of games offer an immersive, realistic reconstruction of a real location to appreciate and learn the architectural, artistic and natural values of a site or simply offer engaging mechanisms in order to motivate users into a real experience. In this case the term of virtual/augmented cultural tourism games is used and includes many kinds of games.

Furthermore Mortara et al. (2014) propose the game genres in field of Serious Games in Cultural Heritage. These genres are: Strategy games, Simulation Games, Trivia games, Puzzle games and Adventure games.

2.4.3 Case studies

In this chapter the Serious Games developed in the field of the Cultural Heritage are presented. Applications for Tangible and Intangible Cultural Heritage are presented.

One of the most known projects is the *Rome Reborn* which is running for about 15 years. The main goal of the *Rome Reborn* project is to produce a high resolution version of Rome at 320 A.D. (Fig.2.2), a lower resolution model is used in order to create an application with Google Earth (<http://earth.google.com/rome/>) and finally the collaborative mode of the model for use with virtual world applications and aimed primarily at education (Frischer 2008).



Figure 2.2 :View of Rome Reborn model from the Palatine across the valley of the Circus Maximus to the Aventine (Frischer 2008)

In order to investigate how efficient is the *Rome Reborn* project for learning, exploration, re-enactment and research of cultural and architectural aspects of Ancient Rome the Serious Game of *Roma Nova* has been developed. The *Roma Nova* is taking place in a replica of the antique city of Rome and its main aim is to teach history by means of an original and engaging experience where the player is immersed in a crowd of virtual Romans (<http://www.seriousgamesinstitute.co.uk/applied-research/Roma-Nova.aspx>).

Another project is the *Ancient Pompeii* in which a model of this ancient city was constructed using procedural modeling techniques (Muller et al. 2005) and populated with avatars in order to simulate the life in Ancient Pompeii in real time (Fig. 2.3). The main goal of this project is to simulate a crowd of Virtual Romans exhibiting realistic behaviours in a reconstructed distinct of Pompeii (Maim et al. 2007). Furthermore the virtual entities can navigate freely in several buildings in Pompeii's model and interact with the entire environment (Arnold et al. 2008).



Figure 2.3 Crowds of Virtual Romans in a street in Ancient Pompeii (Maim et al. 2007)

The *Parthenon project* is a short computer animation which reunited the Parthenon and its sculptural decorations (Debevec 2005). The main goal of this project is to create a virtual version of the Parthenon and its separated sculptural elements so that they could be reunited in a virtual representation.

Virtual Egyptian Temple is a Serious Game application that depicts an hypothetical Egyptian Temple (Jacobson et al. 2005; Troche et al. 2010) and has no real-world equivalent. The Temple represents a typical New Kingdom period Egyptian Temple that an untrained audience can understand. This temple is divided into four areas; each of one housed an instance of the High Priest. Furthermore each area represents a different feature from the architecture of the era of representation. The game "*Gate of Horus*" (Jacobson et al. 2009) explores this Virtual Temple and its main goal is to explore the model and collect enough information in order to answer the questions asked by the High Priest.

The *Ancient Olympic Games* is a number of gaming applications associated with the Olympic Games in Ancient Greece (Gaitatzes et al. 2004) and has produced by the Foundation of the Hellenic World. One of the game applications which is included in the Ancient Olympic Games is the "*Olympic Pottery Puzzle*" (Fig. 2.4a). In this game the user must re-assemble a number of ancient vases putting together pot shards. To the users a colour coded skeleton of these vases with different colours showing the correct position of the pieces is presented. The player tries to select one piece at a time and place it in the correct position. Another mini game of this project is the *Feidias Workshop* (Fig. 2.4b) which is an interactive virtual experience and takes place during the construction of a tall golden ivory statue of Zeus, one of the seven wonders of the ancient world. The visitors enter into the workshop and they are able to see a sight of an accurate reconstruction of unfinished versions of the statue of Zeus. They can take part in the construction as the sculptor's assistants and help finish the creation of the statue, by using virtual tools in order to apply the necessary material onto the statue.



Figure 2.4a Olympic Pottery Puzzle
(Gaitatzes et al. 2004)



Figure 2.4b Feidias Workshop
(<http://www.virtuality.gr>)

The last mini game is the “*Walk through Ancient Olympia*” within which the user can virtually visit the site and furthermore learn about the ancient games in Olympia by interacting with athletes of the ancient game of pentathlon (Fig. 2.4c). Also he can take part to the games as player. Moreover in this game the user can visit and learn more things about the ancient buildings of the Olympia such as Heraion, the temple of Zeus, the Gymnasium, the Palestra, the Leonidaion, the Bouleuterion, the Philippeion.



Figure 2.4c Walk through Ancient Olympia
(Gaitatzes et al. 2004)

PLAYHIST is an attempt of developing a Serious Game that will allow players to act and interact as a historical character in a 3D environment recreating one of the historical moments depicted in the Foundation of the Hellenic World (FHW) and he will achieve a better knowledge about history (Perez-Valle et al. 2014).

The *Virtual Priory Undercroft* game (Anderson et al. 2010; Doulamis et al. 2012) is located in the heart of Coventry UK. The Priory Undercrofts are the remains of Coventry’s original Benedictine monastery which was demolished by Henry VIII. The application offers a virtual exploration of the site. Furthermore the basic aim of the game is to solve a treasure hunt scenario by collecting medieval objects that were used to be located in and around the Priory Undercroft. Each time that the player finds a new object then he is motivated to answer a question related to the history of the site. The questions may have the following structure: “What did St George slay? -Hint: It is a mythical creature- Answer: The Dragon”. The previous answer means that the player has to find the Dragon.

The *Battle of Thermopylae* Serious Game application (Christopoulos et al. 2011) has as main goal to deliver the historical context and importance and many other significant details of this Battle (Fig. 2.5a). The application combines 3D computer generated imagery (CGI) and interactive games and divides the experience in two parts. The first one consists of a short 10-minutes high resolution, stereoscopic, CGI movie which employs a documentary style approach and

introduces the historical context of the battle. The representation of the Battle was divided into three parts one of each day, showing all the important facts. The second one is the interactive game which travels the players back in time especially in the beginning of the battle the first day. Players, in this phase of the game, learn about the culture, battle preparations, tactics and weapons of the warriors which happened in the antiquity. Furthermore the user has to find and apply weapons or equipment in order to complete the final goal. When a task is finished the user is rewarded with a narration about its usage and other relevant historical information. When all the tasks have been completed the interactive game zooms out and focuses the camera onto the rendering of an old book with which the battle is narrated. The pages of this book are browsed showing pictures of what narrated. Another similar SG application is “*The Siege of Syracuse*” (Christopoulos et al. 2009) in which the battlefield of the siege by Romans in 212 B.C. is recreated. In this game two players can take the role of the two rival historical generals (Fig. 2.5b).



Figure 2.5a : Screenshots of the Battle of Thermopylae (Christopoulos et al. 2011)



Figure 2.5b : The Siege of Syracuse (Christopoulos et al. 2009)

ICURA is a Serious Game application for intangible cultural heritage and provides an opportunity to learn more about Japanese culture and etiquette (Froschauer et al. 2010). In this application the player who is an Austrian tourist in Japan and wants to learn about Japanese culture, habits and some language basics has to investigate the 3D environment, collect items, combine them and talk to persons in order to complete the game. Moreover the player is a member of the Couchsurfing network (www.couchsurfing.org) and he has planned to meet another member in the imaginary city of Kuya in order to stay at his place for some time. Unfortunately both forgot to communicate the exact address of the meeting point. Shoji, the host that players must find, describe typical rules of behaviour for tourists.

THIATRO (Froschauer et al. 2012; Froschauer et al. 2013) is an art history Serious Game in which player can slip into the role of a museum curator. There are four museums in a fictive town which looks like the inner districts in Vienna. In these museums there are exhibitions of different paintings and each museum focuses on a specific era or subject. In each level player has to search for paintings in four museums in order to carry out the task of arranging an exhibition of an art-historical

concept. At the end of each level, the player can examine his own collection, with the metadata about the collecting paintings. The player learns from level to level genres in art history, iconography, famous topics in art, composition and perspective, eras of art history, facts about lighting and shading and finally how to use the information that he had learned in previous levels so as to identify a specific painter or artistic era.

MuseUs (Coenen et al. 2013) is another Serious Game application carried out in a museum environment which is running as a smartphone application. The basic goal is the player learning about the exhibits of the museum. The concept of the game is to enable the player to create his own exposition when he visits the museum in reality. Also the application motivates the visitor/player to look at the cultural heritage elements in a different way, allowing the construction of personal narrative while create a personal exposition.

The *MedieEvo* game is a didactic game about the history of the Middle Ages and aims to meet the needs of teachers and students. The project, takes place in the city of Otranto, develops a multi-channel and multi-sensory platform in Cultural Heritage and tests new data processing technologies for the realization of a digital didactic game oriented to the knowledge of medieval history and society (De Paolis et al. 2011).

The *Via Appia* application (Fig. 2.6) is an indirect augmented reality system in which 1km of the Via Appia Antica was reconstructed in three time periods and the user can explore the notion of narrative movement and travel across space and time in a cultural heritage context, which includes a quiz game with questions related to the information provided in the virtual environments (Liestol 2014).



Figure 2.6 Screenshots of the Via Appia application (Liestol 2014)

Another Serious Game application is the *"Your stone to the building"* (Lecllet-Groux et al. 2013) in which 11-13 year old teenagers are able to construct the south portal of the cathedral. The application is composed of six passages in which the one is explained by the authors (2013). The first passage allows explaining how the portal is built. First level allows to know the portal structure in terms of architecture keywords and in second level a puzzle game is available in order to build the portal.

These levels give the opportunity to the players to recognize the architectural forms and assembly parts.

Touch BIM (Lee et al. 2014) is a serious game application which includes a touch screen kiosk designed for showing digital heritage contents intuitively and its main goal is to archive and educate about the Korean architectural heritage and their construction techniques. Firstly the user can see a virtual building which has Korean architectural elements on a view point that he wants. Furthermore he can change the rendering style with options that game gives to him. The user has option to choose which building of the two he wants to build. In this phase he can see an empty space where he builds the selected building. Moreover he can see three parts which are: 1. Upper class, 2. Middle class and 3. View methods on the screen. If the player selects one of upper classes, he can see the middle class components which belong to the upper class (Fig. 2.7).



Figure 2.7 TouchBIM application
(Lee et al. 2014)

Another Serious Game application developed is about the Fort Ross a Russian fur trading outpost and multi-cultural colony located in the Northern California coast (Lercari et al. 2013; Lercari et al. 2014). The main aim of the *Fort Ross Warehouse* application (Fig. 2.8) is to explore novel ways for archiving, disseminating and teaching cultural and historical information and creating an interactive tool able to educate elementary school students and park visitors about California history. In project Fort Ross historical landscape was produced through a multimodal approach in which different kind of data were incorporated. These data are: Lidar, terrestrial laser scanning, image-based 3D reconstruction and 3D models created from historical and iconographical sources.



Figure 2.8 Screenshot of Fort Ross Warehouse application
(Lercari et al. 2013)

MyMuseum (Goins 2010) is a Serious Game application developed for playing in Facebook. In this application players are able to create their own gallery space by buying furniture and digitizing objects from the Smithsonian Museum of American Art's collection. No scoring is available in this game and players enjoyed setting up the rooms as they want.

Mosaic is a mobile game prototype for IOS platform, not available to the general public and designed for the J. Paul Getty Trust to engage player with the museum and teach them something about Ancient Roman Mosaics. The concept of this application is the creating of a hybrid space for the players between museum and game worlds. The idea was to create a strong fictional game narrative and space that could project, from the players mind into real gallery space (Goins et al. 2013).

The *Travel in Europe* (Tie) is a serious game in which the player has to visit a certain number of cities across Europe and completing a mission in each one of them. Each mission is contained by a number of general questions that the player should try to answer while exploring the city. The player's avatar explored the faithfully reconstructed urban environment in search of target places in order to answer the questions. These places are referred as PIs and are important palaces and churches. At each target place the player looks for an icon that triggers the task related to that PI via a user interface. During the mission the player can move freely in the city. The mission finishes at the end of the exploration of the city. In the final there is a city-level test with quizzes that are related to the mission's questions. Every mission is rewarded with a city prize such as a picture, a symbol that is stored in the player's repository (Belloti et al. 2012).

Another EU funded project is the *i-Treasures* in which 3D game-like applications were designed and developed with the aim of providing innovating tools for Intangible Cultural Heritage (ICH) education (Dimitropoulos et al. 2014; Maria Dagnino et al. 2015). The first phase of this project includes four novel game-like

educational applications which are: i) *Human Beat Box* (HBB) for rare traditional singing; ii) the popular *Greek Tsamiko* dance for rare dances (Fig. 2.9) iii) the art of making pottery and iv) the contemporary music composition.



Figure 2.9 i-Treasures project Greek Tsamiko dance (Maria Dagnino et al. 2015)

Shih et al. (2015) presented two applications which are in form of augmented reality (AR). The first application is the “3D AR of Hukou Old” (Fig. 2.10) in which the player is helped to grasp a concept of cultural treasures and to absorb the educational information on Hukou history. This game brings the beauty of Hukou local culture and traditional architecture to the palms of players. However the purpose of this game is to stimulate players’ motivation to pay a visit to nowadays Hukou Old Street and to taste the cultural atmosphere. The second application is “Hsinchu County History Museum AR Tour” (Fig. 2.10) in which AR technology was applied in order to create a value added virtual exhibition. It is an innovative exhibition which seeks to bring an outdoor tour application into the museum exhibition space. There are 27 artifacts in the exhibition room designed as AR tracking objects of the application.



Figure 2.10 3D AR of Hukou Old (left) and Hsinchu County History Museum AR Tour(right) (Shih et al. 2015)

History Line 1914-1918 is a commercial historical game and an early turn-based strategy game in which are presented the events of the First World War. The historical context of this game was introduced by a long animated introduction, depicting the geopolitical situation of the period and the events leading up to the outbreak of war in 1914). Furthermore the player is provided with additional information on concurrent events that shape the course of the conflict illustrated with animation and newspaper clipping from the period (Anderson et al. 2010).



Figure 2.11 Great Battle of Rome
(Anderson et al. 2010)

Another historical game is the *Great Battle of Rome* which was used by the History channel (Slitherine Strategies 2007). In this documentary game there are mixes of interactive 3D real-time tactical simulation of actual battles with documentary information (Fig. 2.10) including footage produced for TV documentaries which placed the battles in their historical context.

The Total war series is the most representative of historical games and provide a gameplay combination of turn-based strategy and real-time tactics. The historical setting is enriched with information about important events and developments that occurred during the timeframe experienced by the player. Furthermore games from the Total War series have been used to great effect in the visualization of armed conflicts in historical programs which are produced for TV (Anderson et al. 2010).

Another Serious Game application is about the *Medieval Craftsmen at Castle Waldenfels in Austria* (Giang et al. 2015). This game's approach (Fig. 2.12) is trying to provide education on historical construction techniques and foster motivation for preservation of built heritage. The content of the game is the intangible heritage of medieval construction work. The target groups of this game are local people, tourists with an interest in castles, students in architecture as well as craftsmen and conservators. The virtual reconstruction of the castle was used for setting the application. The game is divided into four levels which include recruitment of construction workers, collection and processing materials, operating construction devices and completing the medieval castle.



Figure 2.12 Screenshots of the Medieval Craftsmen at castle Waldenfels Serious Game (Giang et al. 2015)

The *Play Design!* (Ceconello et al. 2015) is a project whose basic aim is to create a location-based serious game for mobile devices with the purpose of promoting and spreading the culture of design. It consists of two games, the *Design Hunt* and the *Design Learn*. *Design Hunt* (Fig. 2.13) is an urban mobile treasure hunt which allows the players to discover some of the most relevant places and icons of Milanese design by following the trail of the Zizi monkey which is the award winning toy design by Bruno Munari. The second mini mobile game is the *Design Learn* which is a role-play game which involves four teams of three players each. This application is a role-play game on which the participants divided into four teams corresponding to the four degree courses offered by the School of Design at the Politecnico di Milano, confront each other on specific paths throughout the streets of downtown Milan, answering questions, challenging and trying to prevail one on the other reaching the highest score.



Figure 2.13 Screenshots of the Design Hunt game (Ceconello et al. 2015)

The *Second World War Holocaust* is the basic subject of a Serious Game application proposed by Moffat et al. (2015). The main character of the application is Marion, an elderly lady today who is recounting her experience when she was a young girl of a Jewish family exiled in Siberia. The game shows Marion as a young girl, travelling across the map of central Eurasia. Her vocal descriptions are recorded as audio files and they were used in the game in order for the players to hear the authenticity of Marion's own voice via describing the events. Players are asked to make key decisions for Marion and the family when Marion is travelling across Europe in order to continue to the next location. This Serious Game application consists of three minigames which illustrate dramatic episodes with a simple endless runner mechanic. For instance one minigame is about the attempt of Marion to escape from an orphanage in order to find her mother (Fig.2.14).



Figure 2.14 Marion is trying to find her mother

The Game finishes when Marion finally finds her mother by describing how they managed to escape their situation and immigrate to resettle in another European country.

The last application presented in this thesis is a *Serious Game in the Stoa of Attalos* (Koutsaftis et al. 2015). In this application (Fig.2.15), which is still in its development phase, the player is encouraged to search and detect parts of original material which can be found scattered on the walls of the reconstructed building. This aims at the deeper understanding by the player of the reconstruction and, in rare cases, of still standing ancient parts at the time of the reconstruction. A counter will help the player to monitor the progress and channel his efforts.

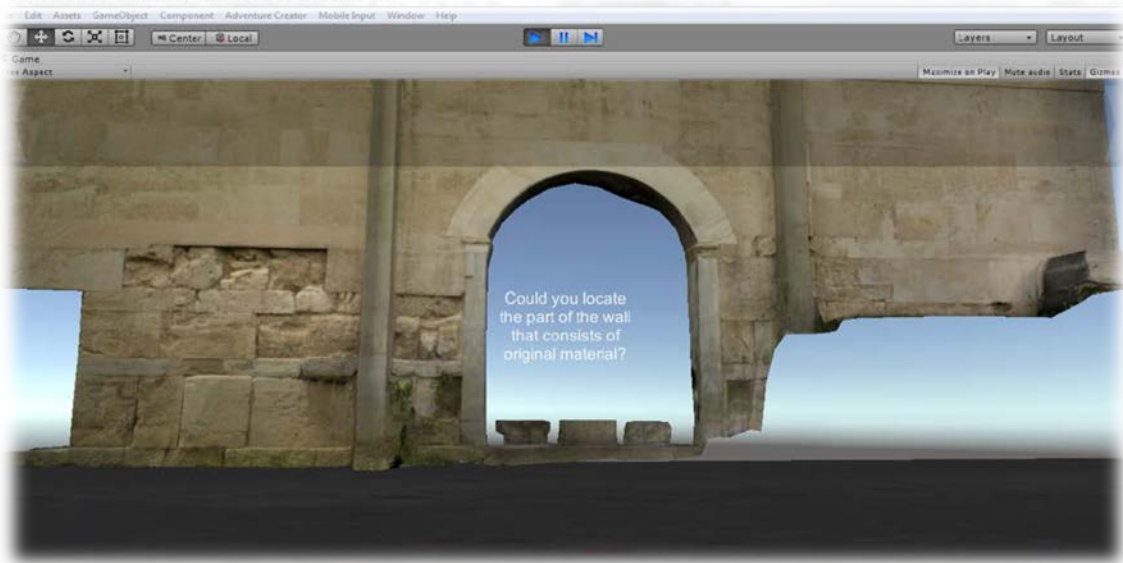
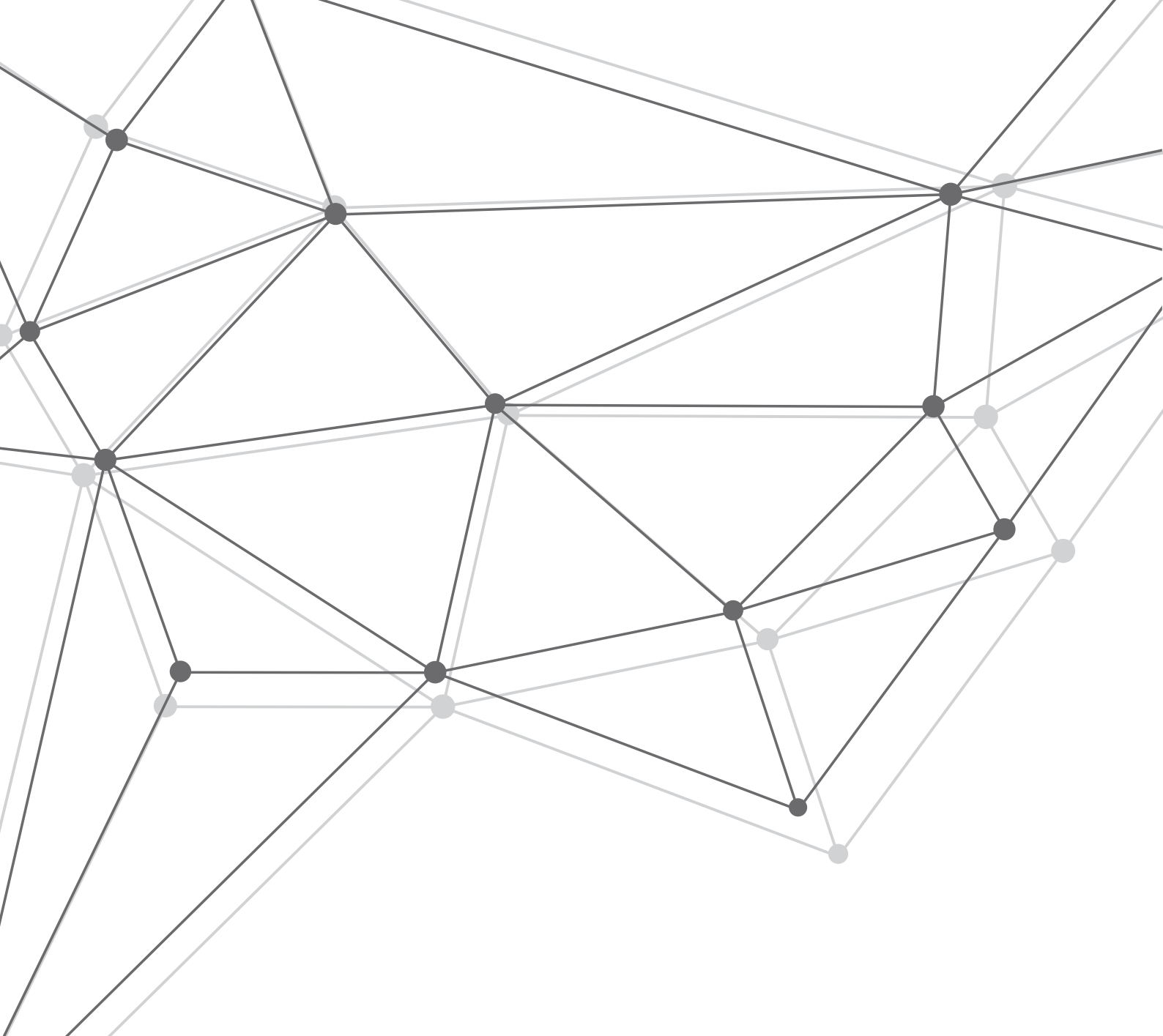


Figure 2.15 Serious Game in the Stoa of Attalos
(Koutsaftis et al. 2015)



3rd CHAPTER

DATA FOR THE
GAME DEVELOPMENT

3.1 ANCIENT AGORA OF ATHENS

The Agora was the heart of Ancient Athens, the focus of political, commercial, administrative and social activity, the religious and cultural center and the seat of justice. The excavations of the Athenian Agora (Fig. 3.1) have uncovered about thirty acres on the sloping ground northwest of the Acropolis. Material of all periods from the Late Neolithic to modern times has been excavated, shedding light on 5000 years of Athenian History. The area was occupied long before it became the civic center of Athens. During the Late Bronze Age it was used as a cemetery, and some 50 graves have also been found, dating from 1600 to 1100 B.C. These are mostly chamber tombs, for multiple burials. It continues its use as a cemetery throughout the Iron Age and over 80 graves, both burials and cremations of that period have been found. Several dozen wells reflect the position of houses and indicate that the area was given over to habitation as well.

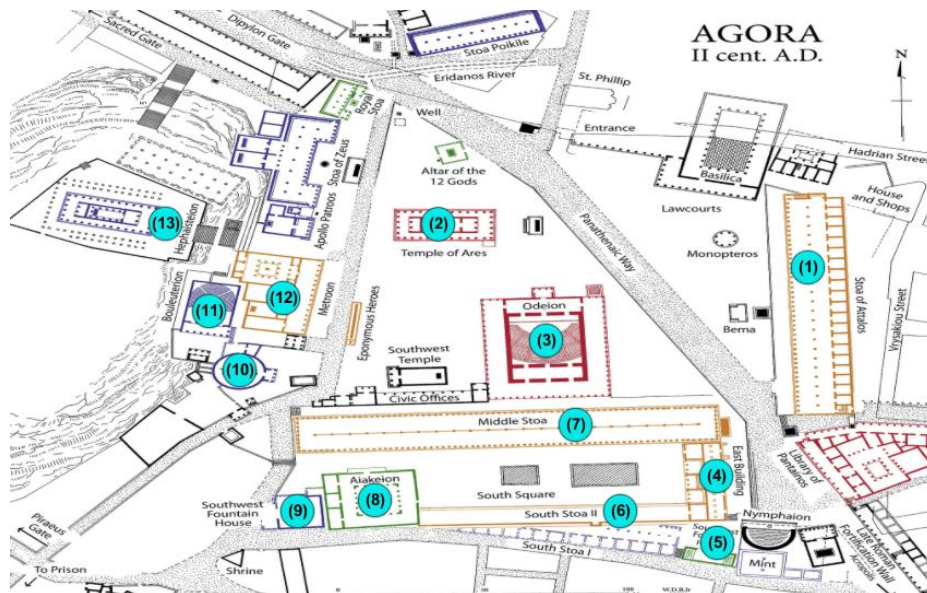


Figure 3.1 Map of the Ancient Agora of Athens
<http://ascsa.net/research?v=default>

A gradual change from private to public land seems to have occurred during the middle of the 6th century and the first certain public building or monument was erected in the 520 B.C. during the tyranny of the Peisistratides. The creation of the new democracy in 508 B.C. led to the construction of the Old Vouleftirion on the site of the later Metroon, the setting of boundary stones and, perhaps, the construction of the Royal Stoa.

The Persian destruction of 480 B.C. left the city a shambles, but the buildings in the Agora were repaired and many more were added in the 5th and 4th centuries to accommodate the Athenian democracy at its height. The Stoa Poikile, Tholos, New Vouleftirion, Stoa of Zeus Eleutherios, South Stoa I, Mint and Lawcourts were all

added to the periphery of the great square, as were fountain houses, temples and shops.

The rise of Alexander Macedon caused the political decline of Athens and the 3rd century B.C. saw Athens dominated by his successors. Recovery in the 2nd century was fueled by Athens' reputation as the cultural and educational center of the Mediterranean, and the philosophical schools founded by Plato, Aristotle, Zenon and Epicurus flourished. Three large stoas were built in the Agora in the 2nd century: the Middle Stoa, South Stoa and the Stoa of Attalos. Also the archive building Metroon was rebuilt with a colonnaded façade.

The influence of Rome became clear in Athens in 86 B.C. when Sulla besieged the city after it sided with Mithradates of Pontus. Despite this poor choice, the city flourished, thanks again to her reputation for education and culture. Temples were built in the Agora to accommodate worship of the imperial family and a great Odeion or concert hall was set down in the middle of the square late in the 1st century B.C. Athens prospered through the 2nd century under the emperor Hadrian (117-138 A.D.) and is described in detail by the traveler Pausanias in the years around 150 A.D.

Hard times began in the 3rd century, when the city was destroyed by northern invaders, the Herulians in 267 A.D. When the city was rebuilt, the old Agora was not even within the new fortified circuit. The area was given over to a variety of large villas in the 4th and 5th centuries A.D. The buildings show the effects of further barbarian incursions: Visigoths under Alaric in 395 A.D., the Vandals in 470s and the Slavs in 582. The area was abandoned in the 7th century and only recovered with the growth of the city in the 10th century A.D (Camp 2003).

Below the information of each monument, which participates in the game, is described. The order which is followed is according the game's order.

3.1.1 Stoa of Attalos (1)

The Stoa of Attalos is lying in the East side of the Agora square and was built during the reign of Attalos II of Pergamon at 150 B.C. Attalos II studied in Athens under the philosopher Carneades before becoming a king. In a sense, this is a gift from a loyal alumnus, and what he gave the Athenians was a shopping mall. Double colonnades on two storeys provided shaded walkways in front of forty-two shops that were let out by the city. White Pentelic and blue Hymettian marble were used, along with limestone for the walls. The faceting of the lower part of the outer colonnade reflects the intense use of the building; lots of people and goods will have passed through, rubbing and banging against the columns, so there was little point in fluting them at the level of potential damage and wear. The column capitals used upstairs for the inner colonnade are of an unusual type ("Pergamene"), a late adaptation of early Egyptian prototypes. The Stoa served as the main commercial

center for the Athenians for centuries; it was destroyed by the Erulians in 267 A.D. and then incorporated into the new fortification wall, which preserved its northern end up to roof level. It was fully reconstructed in 1953–1956 to serve as the site museum. It houses storage facilities in the basement, a public display area on the ground floor, and offices and workrooms on the first floor. Parts of the original building were left or incorporated at the south end, so the visitor can check the validity of the restoration. The reconstruction demonstrates the effectiveness of the Stoa as the ideal architectural form for a public building in Greece: the colonnaded walkways provide light and fresh air for literally thousands of people, while protecting them from the intense sun of summer or the wind and rain of winter (ASCA, 1957).

3.1.2 Temple of Ares (2)

Just north of the Odeion lay the ruins of a building identified by Pausanias as a temple of Ares. The foundations are of Early Roman construction and date, but the marble pieces of the superstructure, now assembled at the western end of the temple platform, are of the 5th century B.C. They can be restored as a Doric peripteral temple, close in plan, date, and size to the Hephaisteion. Roman masons' marks carved on the blocks indicate that the temple originally stood elsewhere, was carefully taken apart with all the pieces labeled, and then re-erected on the new foundations built for it in the Agora. This is the best example of a phenomenon known as "wandering temples," of which there are several similar examples in the Agora, dating to the early years of the Roman Empire. Outstanding examples of Classical architecture were brought in from the outlying villages of Attica, largely deserted at this period, and were reused in downtown Athens, presumably for the worship of deified Roman emperors; it was a relatively cheap and effective way to honor the new order. The probable origin of the Ares temple architecture is the sanctuary of Athena Pallenis, where large foundations for a temple have been found but with no trace of any superstructure. The area of the northwest corner is where the Panathenaic Way, leading from the main gate of Athens, the Dipylon, entered into the Agora square. This was accordingly the appropriate place for Hermes, primitive markers used by the Athenians to mark all entrances (ASCA, 1957).

3.1.3 Odeion of Agrippa (3)

Late in the 1st century B.C. the Athenians were given money for a new marketplace by Caesar and Augustus, and the northern half of the old Agora square was filled with two new structures, the Odeion of Agrippa and the Temple of Ares. A large concert hall or Odeion was given to the Athenians by Marcus Vipsanius Agrippa, the son-in-law and general of Augustus, in the years around 15 B.C. It was a

huge two-storeyed structure that must have dominated the square. The auditorium, with its raised stage and marble-paved orchestra, seated about 1,000 spectators. It was surrounded on three sides by a cryptoporticus at the lower level, with stoas above. The exterior of the building was elaborated with Corinthian pilasters. Entry to the Odeion was either from the upper level of the Middle Stoa on the south or through a modest porch at ground level on the north. The great open span of the auditorium eventually proved too great and the roof collapsed in the years around 150 A.D. The structure was rebuilt as a lecture hall, with the seating capacity reduced to about 500, and a far more elaborate facade was built at the north, using massive pillars carved in the form of giants which they have snaky tales and tritons which have fishy tails. The loss of this Odeion for concerts presumably prompted Herodes Atticus to build his handsome new odeion on the south slopes of the Acropolis in the years around 160 A.D. The Odeion of Agrippa was destroyed by the Herulians in 267 A.D. It was rebuilt in the early 5th century A.D. as part of a sprawling complex, perhaps a palace, with numerous rooms, a bath, and several courtyards, which extended southward all the way across the old South Square. The Giants and Tritons were reused for a monumental entranceway, and their present position on high piers dates to this last phase of the building (ASCA, 1957).

3.1.4 East Building (4)

This small building closed the east end of the newly formed South Square of the Agora. Built between the Middle Stoa and the South Stoa II, it must date from the middle of the 2nd century B.C. A continuous wall on its midline divided the building into two halves. Because of the steep rise in ground level the floor of the east half was somewhat over a meter higher than that the west. The East Building is running southward from the east end of the Middle Stoa. Its eastern half takes the form of a long hall with a marble chip floor and stone slabs designed to carry wooden furniture, presumably tables. The furniture supports are perhaps best interpreted as holding bankers' or money changers' tables and suggest that the South Square served primarily a commercial function. The western half of the building consisted of four rooms and a stairway designed to take people down to the lower (ground) level of the South Square (Camp, 2003).

3.1.5 Holy Apostles Church (5)

The church of the Holy Apostles, dating from early in the 11th century A.D., is the only standing monument of the many buildings that covered the Agora in mediaeval times. After undergoing repeated alterations and enlargements through the centuries the church was restored to its original form in the years 1954-1957 with the aid of a grant from the Samuel H. Kress Foundation of New York. The plan of

the church is a unique variant of the cross-in-square with apses at the ends of the four arms of the cross, the western apse being enclosed by a low narthex. Four columns help to support the dome. The outer walls are decorated with “kufic” ornament in brickwork. The altar and the altar screen, as also the marble floor, have been restored on the evidence of the original fragments. The few wall paintings that have survived in the main body of the church date from the 17th century. On the walls of the narthex have been placed some contemporary paintings removed from the Chapel of St. Spyridon that formerly stood above the Library of Pantainos. Here too, in the left corridor, are a few fragments of painting from the Church of St. George in the Temple of Hephaestus. The richly carved marble slab in the north end of the narthex is the front of a sarcophagus for which an alcove had been thrust out here early in the history of the church (ASCA, 1957).

3.1.6 South Stoa II (6)

South Stoa I was replaced in the 2nd century B.C. by a simple one-aisled colonnade, South Stoa II. Since the floor level of the new Stoa was 2 was 0.5 meters lower than that of its predecessor, the construction involved extensive quarrying and the complete destruction of the northern half of South Stoa I. The building had only two steps above which rose a row of thirty Doric columns; setting marks for two of the columns are preserved at the East of the Stoa. The original near wall was of large, regular porous blocks with a backing of conglomerate. Near the middle of the back wall was a niche for a fountain. The water was delivered by a small underground channel coming from the south and was poured into a basin formed by a parapet across the front of the niche. All structural parts of the Stoa were of re-used material taken from the Square Peristyle at the northeast corner of the Agora when that building was demolished to make away the Stoa of Attalos. This applied to steps, columns, entablature and back wall. The building was suffered in the Roman attack of 86 B.C. and was subsequently dismantled. Industry intruded and flourished in the first and early part of the 2nd century A.D. Great quantities of slag from the smelting iron and chips from the working of marble were found in the excavation. In the time of Hadrian (117-138 A.D.) the industrialists were banished, and the area was cleaned up. At this time part of the back wall of the Stoa was rebuilt in concrete of which a long section remains in the middle part; but there is no reason to believe that the colonnade was ever restored (ASCA, 1957).

3.1.7 Middle Stoa (7)

The Middle Stoa is an elongated building 147m by 17.5m, which ran east-west across the old square, dividing it into two unequal halves. At just under 150 meters long, it is the largest building in the Agora, with Doric colonnades at both

north and south as well as an Ionic colonnade down the middle. Traces of a narrow parapet that ran between some of the columns can be made out on individual drums. The original steps and three columns remain in situ as its eastern end; to the west, only the heavy foundations of reddish conglomerate survive. Except for its size the Middle Stoa is a relatively modest building, made of limestone, with a terracotta roof. It was built between ca. 180 and 140 B.C and it was continuously used even during of the Roman era. Foreign architects are believed to have been responsible for its construction; hence it present particular design and construction elements not usual for that time in the era. Today the foundations of this majestic building and some individual parts of it are visible in the site.

3.1.8 Aiakeion (8)

Immediately to the east are the poor remains of a large square enclosure, open to the sky and measuring about 30 meters on each side. Built in the early 5th century B.C., at the command of the oracle of Apollo at Delphi, it was dedicated to Aiakos, a hero of the island of Aegina. By the early 4th century B.C. it was used for the storage and distribution of substantial amounts of grain. Aiakos was one of the judges of the underworld and the results of judgments handed down in Athens were displayed on the walls of the building (Camp 2003).

3.1.9 Fountain House (9)

One of the largest fountains of the city, the building is dated based on pottery to the years around 350–325 B.C. The Fountain house initially was L-shaped so as to conform to the line of the ancient street leading out of the Agora. A row of interior columns divided the building into two parts: the outer a porch, the inner a basin. The water was drawn over a parapet set between the inner columns. A fragment from the top of the parapet, made of hard limestone yet deeply worn by the water pitchers, has been placed on a foundation at the north edge of the building. Somewhat later a room was added at the northeast corner where the most fastidious could take their water from flowing spouts. The rise in ground level which was caused by the construction of the Middle Stoa in the 2nd century B.C. necessitated the massive retaining walls now so conspicuous along the north and west sides of the building. The fountain house, like its neighbors was destroyed in 86 B.C. and was subsequently restored only in a very shabby way. Though this is the largest fountain house yet found in Athens, we do not know its ancient name (ASCA, 1957).

3.1.10 Tholos (10)

The Tholos, recognizable by its round shape, served as the headquarters of the prytaneis (executive committee) of the boule (senate of 500), according to Aristotle. Here the fifty senators were fed at public expense, and at least seventeen spent the night in the building, available to deal with any emergency, whatever the hour. In a sense, then, the Tholos represents the heart of the Athenian democracy, where citizens serving as senators could be found on duty twenty-four hours a day. Built around 465 B.C., the building was an unadorned drum, with six interior columns, the stumps of three of which are visible in the western half of the building, supporting a conical roof of large diamond-shape terracotta roof tiles which are on exhibit in the museum. In the time of Augustus a porch was added after a pavement of marble chips was put in, still visible at a number of points. Finally in the time of Hadrian the Tholos was extensively remodeled. The inner columns were cut down and the building was domed. The floor was paved with marble slabs embedded in mortar and the walls were riveted with marble. In all periods of the Tholos a small room was attached in the north side; a few blocks only, belonging to various periods, are preserved today. This was probably the kitchen (ASCA, 1957).

3.1.11 Vouleftirion (11)

The New Vouleftirion occupied a terrace cut back into the hillside northwest of the Tholos. It was built at the end of the 5th century before Christ apparently to take over the function of its eastern neighbor, the Old Vouleftirion. It was in the Vouleftirion that members of the council of 500 held the meetings in which they exercised their committee work and prepared legislation for the Assembly. The Council, made up of 50 from each of ten tribes, was chosen by allotment each year, and these tribal groups of 50 served in succession as group chairmen of the Council. The outline of the New Vouleftirion may be seen in cuttings for its foundation walls, some blocks of which remain. To the south of the building the hillside has also been cut back and faced with retaining walls to south and west to form a fore-court or open square in front of the building. The interior arrangements include beddings for columns, and it seems clear that the auditorium faced east. For the original seating arrangements little evidence exists. The condition of the dressed bedrock within the area suggests, however, that in the beginning the seats were of wood and supported on wooden beams. A number of curved marble floor slabs found within the building and now lying along its west side indicates that at some later date curved seating of stone has installed. Two large bottle-shaped cisterns cut in the rock just west of the building, gathered rain water from its roof. They are joined by a tunnel with a cistern to the southwest of the Tholos which probably took its water from the roof of that building. The capacious reservoir was no doubt intended primarily to meet the housekeeping needs of the Tholos (ASCA, 1957).

3.1.12 Metroon (12)

The Metroon was built in the 2nd half of the 2nd century B.C. and it consists of four rooms of various sizes sharing an Ionic colonnade that faces eastward toward the square. Three steps of Hymettian marble and an Ionic column base of Pentelic marble are preserved towards the south end of the colonnade. In the line of the north wall a pair of orthostates remains in position. Elsewhere only the foundations are preserved. The building accommodated both the sanctuary of the Mother of the Gods, from which it took its name, and the state archives. The second room from the south, which has the plan of a small temple, was probably the actual sanctuary of the goddess. The heavy foundation in front of the building opposite this room will have held the altar; two periods may be distinguished. The first and the third room from the south presumably contained the actual state documents, written on papyrus and parchment. The large northern room, which had two storeys around a central court with an altar at its middle, has some resemblance to a contemporary house and may indeed have served as an official residence. The mosaic pavement in the third room from the south does not belong to the original building but dates from a partial reconstruction in the 5th century A.D. It lies at a much lower level than the original floor of the building. In the same late period the northern room was rearranged in the form of the basilica. The area inside the Metroon has been excavated to bedrock, which lies in some places as much as three meters below the top of the front foundation. Remains of several earlier buildings have come to light (ASCA, 1957).

3.1.13 Temple of Hephaestus(13)

Overlooking the Agora from the hill to the west (Kolonos Agoraios), is the Hephaisteion, the best preserved example of a Doric temple in mainland Greece. It was dedicated jointly to Hephaistos the god of the forge, the Roman Vulcan and Athena the goddess of arts and crafts, and dates to the second half of the 5th century B.C. It is built largely of Pentelic marble and carries a lavish amount of sculptural decoration. The Labors of Herakles occupy the east facade, while the labors of Theseus adorn short sections of the long north and south sides. The Theseus scenes gave rise to the popular name of the temple, the "Theseion," which survives in the name of the district of the modern city and the nearby Metro station. Battle scenes surmount the east and west porches, with a lively centauromachy at the west. The two bronze cult statues, done by Alkamenes and described by Pausanias, disappeared long ago. Traces of a garden planted around the temple in the 3rd century B.C. were found in the excavations. The building owes its remarkable state of preservation to two factors: Athens is not in a major earthquake zone, and the temple was converted into a Christian church in the 7th century A.D., saving it from later quarrying for building material, though deep depressions in the steps

show where the lead used to seal metal clamps was gouged out. Conversion to a church led to the deliberate mutilation of the sculptures, except for the Minotaur at the southeast corner who has retained his head. In the early 19th century the church was used as the Protestant cemetery, and many European philhellenes who died in the War of Independence were buried here (ASCA, 1957).

3.2 AVAILABLE DATA

For the game development different kind of photogrammetric data were used. In this chapter it will be described briefly the procedures followed for the creation of these data.

3.2.1 DSM Image & Orthoimage

For the creation of terrain, on which 3D models of the monuments will be placed, a raster DSM image and the corresponding orthoimage for the terrain with a GSD of 50 cm were available for the creation of the 3D textured terrain (Fig. 3.2). These data were originated from the National Cadastre and Mapping Agency S.A (www.ktimatologio.gr).

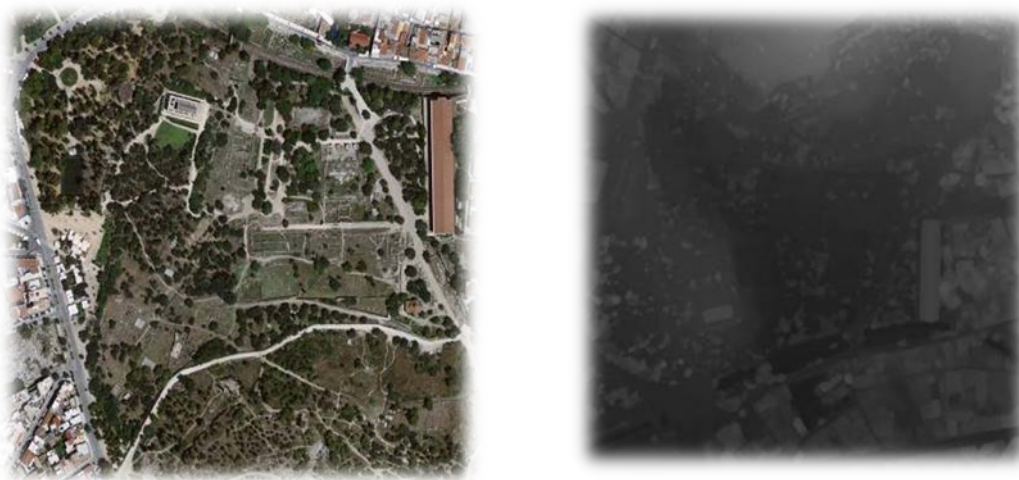


Figure 3.2 Orthoimage of Ancient Agora (left) and its raster DSM (right)

3.2.2 3D models of Monuments

For the game development different kind of 3D models were used. These models vary as far as their source is concerned as it seems in Table 1. Also they vary as far as their epoch because some models illustrate the existing situation and some others have been historically reconstructed.

Category	Name
1	ToF laser scanner & overlapping images
2	ToF Laser scanner with colour information
3	3D Historical reconstruction
4	Structure from Motion (SfM)
5	3D Warehouse library
6	Other methods

Table 3.1 3D models categorization

3.2.2.1 ToF laser scanner & overlapping images

This category includes the 3D models of the Giant of the Odeion of Agrippa and the southwest side of the Middle Stoa foundations. The 3D model of the southwest side of the Middle Stoa was created in previous work (Karageorgou et al. 2010). A ToF laser scanner was used for scanning the object and vertical overlapping high resolution digital images were taken using a special tripod from approximately 7m height. Furthermore numerous GCP's were pre-marked and surveyed in a local reference system. The acquired point clouds were registered into one, which was georeferenced in the local system. In cases where the scanner failed to measure points, densification of the point cloud was achieved using digital photogrammetric methodology. The point cloud was processed within Geomagic Studio v10 in order to create the 3D model without texture. Then carefully selected digital images were then oriented and draped over the scan model so as to produce the 3D textured model of the foundations of the Middle Stoa (Fig. 3.3)



Figure 3.3 Middle Stoa foundations
(Karageorgou et al. 2010)

In previous work was created the 3D model of the Giant of the Odeion of Agrippa (Kitsakis, 2011) too. Similar as the foundations of the Middle Stoa, a ToF laser scanner was used in order to scan the model. The registration of the four different point clouds was carried out in Geomagic Studio. For the texturing phase digital images for each side of the statue were taken. The texturing was performed in

3D Reshaper software in which 5 points were measured in images and on 3D model in order to texture each side of the statue and finally to create the 3D model of the Giant (Fig. 3.4).



Figure 3.4 Giant statue of Odeion of Agrippa (Kitsakis 2011)

3.2.2.2 ToF laser scanner with colour information

The Temple of Hephaestus (Fig. 3.5), except the interior, belongs to this category which 3D model was created with the use of a Time of Flight (ToF) which assigns colour information of each point recorded. Different point clouds were registered into one and then the mesh was created.



Figure 3.5 Temple of Hephaestus

The 3D mesh of the building, which has colour information, was opened with Geomagic studio software in which texture maps were created in order to apply texture to the final model. The models were divided in four different parts: the

crepis, the colonnade, the frieze and the roof. Texture maps were created for each part of the building. After the creating of the texture map of each part; the texture was applied automatically to the models and no one procedure was carried out for this job.

3.2.2.3 3D Historical Reconstruction

In this category belongs the reconstructed model of the southwest side of the Middle Stoa created in previous work (Kontogianni et al. 2013). The reconstructed model of the Middle Stoa (Fig.3.6), created in 3ds Max software, was carried out according different kind of available data including: old drawings, images, existing literature for ancient architecture and for the monument and finally experts' assumptions.



Figure 3.6 Middle Stoa
(Kontogianni et al. 2013)

Especially the artifacts which is consisted the sima were created with Structure from Motion (SfM) technique and according to Table 3.1 belong to the 4th category. Furthermore all the available data which were used they were evaluated according to their verisimilitude in terms of accuracy and likelihood (Kontogianni et al. 2013).

3.2.2.4 Structure from Motion (SfM)

In the 4th category are models created with the Structure from Motion (SfM) algorithm for orienting the images. In this category belong the artifacts of the Middle Stoa as it is mentioned above, the 3D model of the Holy Apostles church and the roof of the interior of the Temple of Hephaestus.

For the 3D models of the Holy Apostles church digital images with large overlap were taken from each side of the building except the north, because of trees which made the photo shooting difficult, in order to create the 3D model of each side of the church. Agisoft Photoscan software was used for the 3D models creation.

Then these models were inserted in Geomagic studio, they were scaled and then were registered into one, with the use of Manual Registration tool, which allows the user to make a registration of two or more overlapping scans by using corresponding characteristic points in overlapping areas (Fig. 3.7).

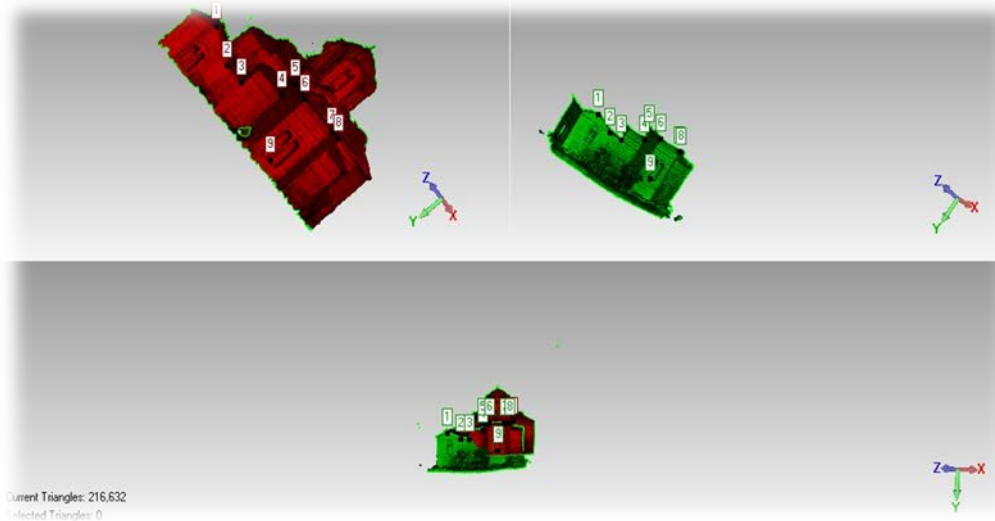


Figure 3.7 Registration of point clouds

This procedure was carried out for the north side of the church with its dome. For the other parts of the church the registration was performed manually by using the scale and move tools of the software. Because the church has symmetric shape the 3D model of the north side is the same as south and it is taken from this and registered to the final model (Fig. 3.8).

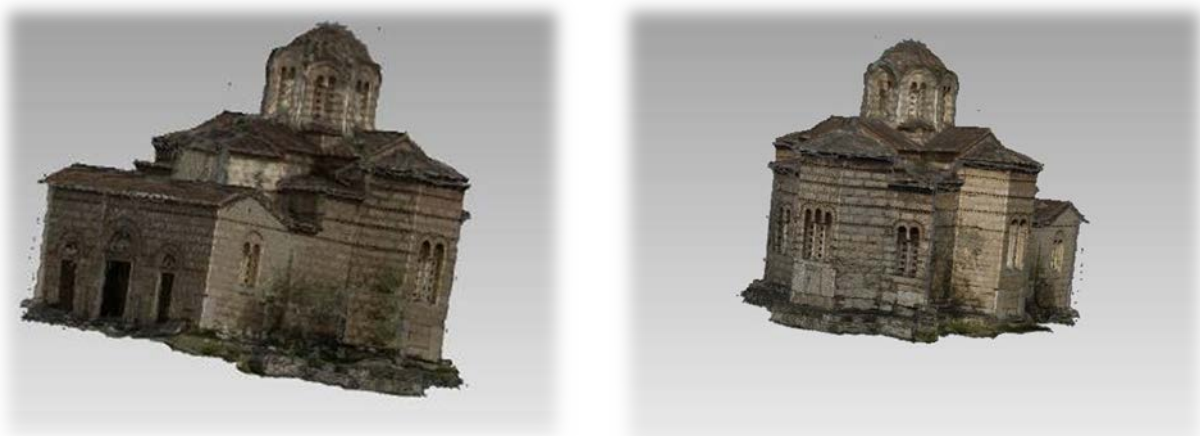


Figure 3.8 Holy Apostles Church

For the 3D models of the artifacts digital images were taken for creating the final 3D model but for the procedure was used the 123D Catch web service by Autodesk. These different models were inserted in 3D Studio Max software and

registered into one for the sima's creation (Fig. 3.9) with the use of scale, move and rotate tools.



Figure 3.9 Part of the Sima of the Middle Stoa
(Kontogianni et al. 2013)

The roof of the interior of the Temple of Hephaestus (Fig. 3.10) created with the same method as the two models previous mentioned. Digital images with large overlap were taken in order to create the 3D model of the roof which was created with the use of Agisoft Photoscan software.



Figure 3.10 3D textured model of the interior roof of the Temple of Hephaestus.
In this case the roof

3.2.2.5 3D warehouse library

In 5th category belong the models which were taken from the 3D Warehouse library (<https://3dwarehouse.sketchup.com/>). These models have created in Sketchup software in which user can create a 3D model of an object/building according to its floor plan and then is textured with images that user has taken with his own camera or taken from the Internet. When the 3D model is ready user can

upload to the Internet in order to other users see it and many times use it. The 3D model of the Stoa of Attalos (Fig. 3.11) was taken from this website.

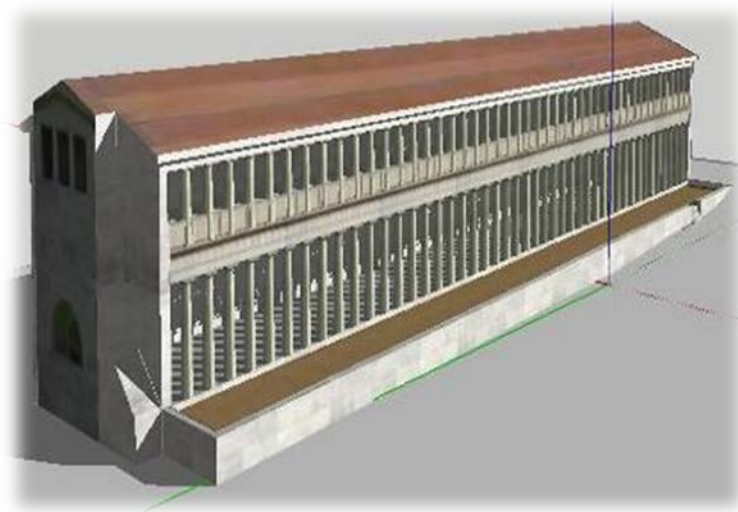


Figure 3.11 Stoa of Attalos
(<https://3dwarehouse.sketchup.com/>)

Finally from the 3D warehouse library were taken and other 3D models of the monuments (Fig. 3.12) so as to complete the final result. These monuments are: The east Building, the South Stoa II, the Temple of Ares, the Vouleftirion, the Metroon, the Aiakeion, the Tholos and the Fountain House.

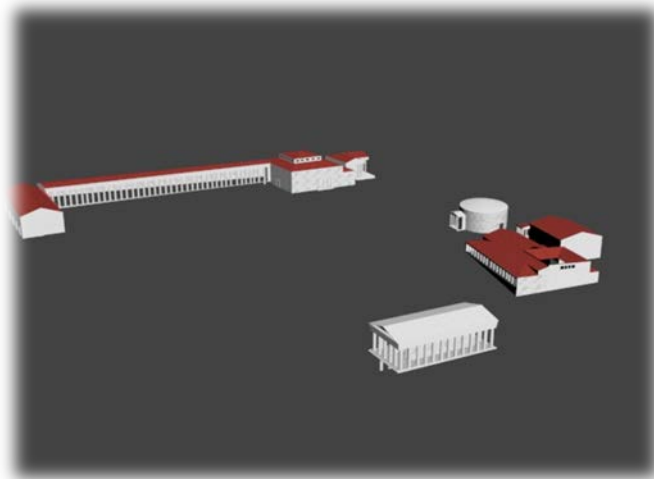


Figure 3.12 3D models from 3D Warehouse library
(<https://3dwarehouse.sketchup.com/>)

3.2.2.6 Other methods

The interior of the Temple of Hephaestus belongs to this category, except its roof, whose model was a result of a combination of the ToF laser scanner with colour information and some images of the interior. Namely the model of the monument was inserted in Geomagic software from which the interior was extracted. Then the roof was removed because its model was created with the Structure from Motion

(SfM) technique. The interior of the Temple of Hephaestus does not have information about the texture so it was decided to use images in order to texture it. The procedure was performed in Geomagic Studio software in which, with the use of common characteristic points both in the 3D model and the images the texturing phase was carried out (Fig. 3.13).

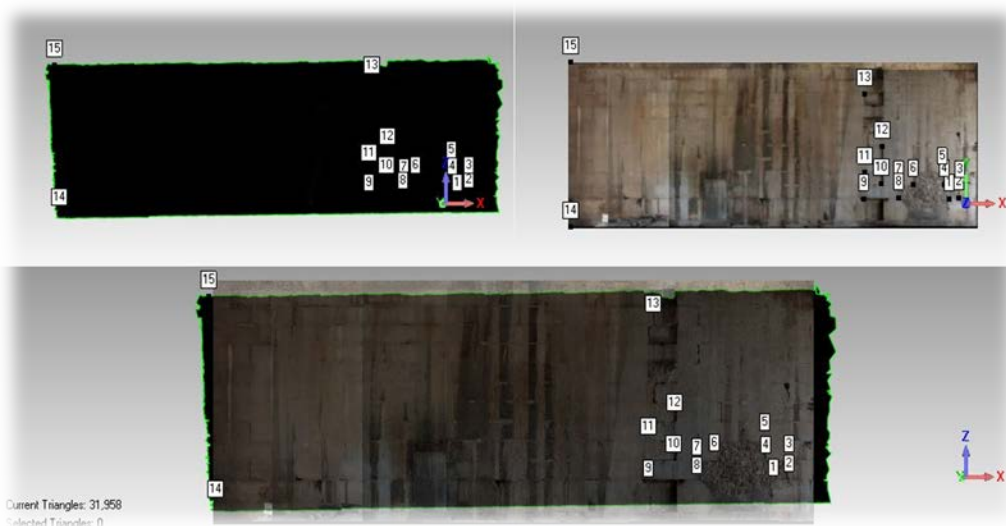
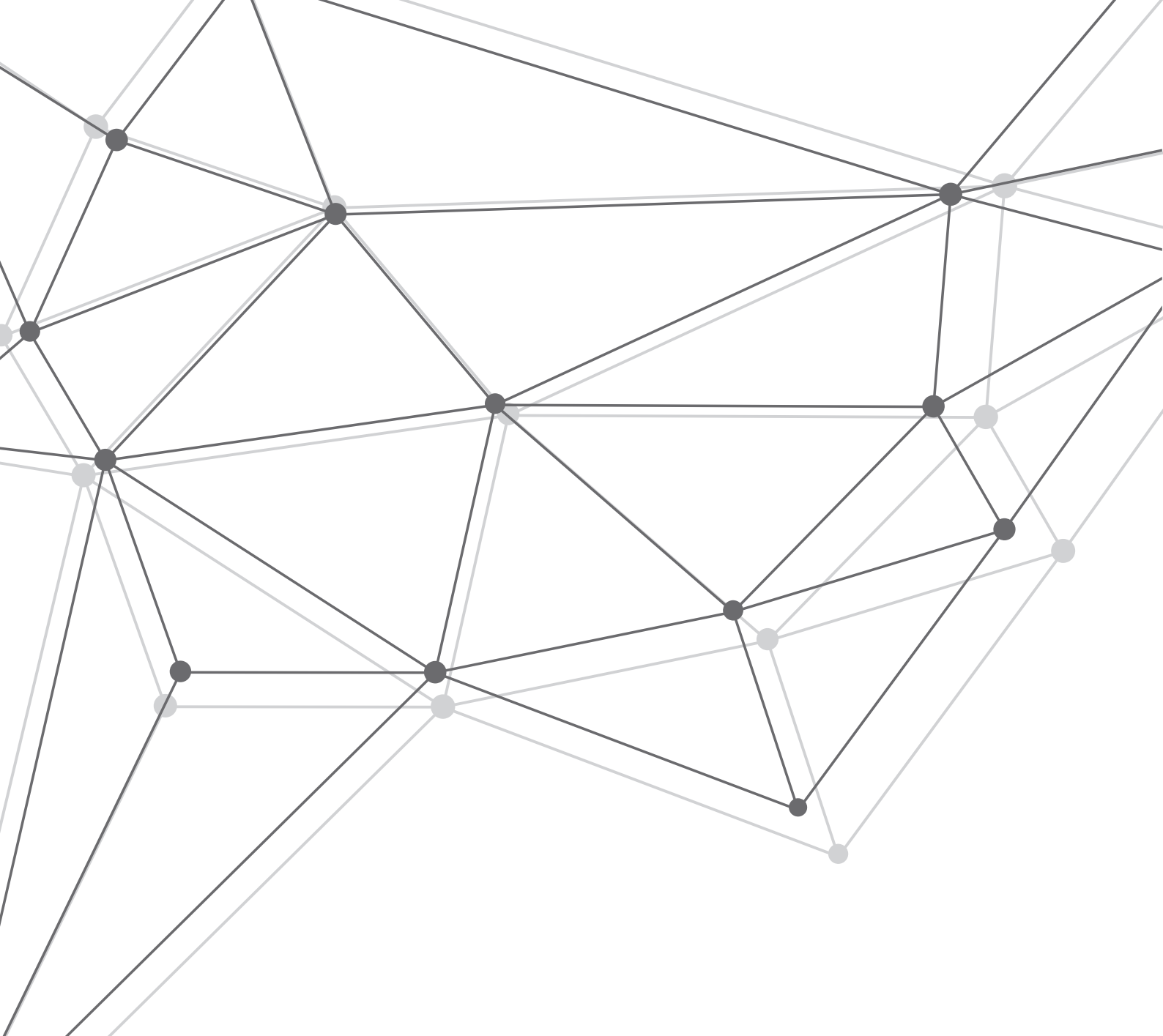


Figure 3.13 Texturing of the interior of the Temple of Hephaestus

The procedure was performed particularly for each part of the interior. Especially for the west and north side the orthoimages produced in previous projects were used. For the east side High Dynamic Range (HDR) images of the interior were used and for the south it was decided to use the orthoimage of the north side for the result to be more close to reality, as there was no available orthoimage or other image. For the floor a beige color from the colour palette in the Unity was used in order for the result be more realistic. In Figure 3.14 the above results of the interior of the Temple of Hephaestus are presented.



Figure 3.14: Interior of the Temple of Hephaestus



4rd CHAPTER

GAME
DEVELOPMENT

4.1 GAME ENGINE

Unity 3D® is a flexible and powerful development environment for creating multiplatform 2D and 3D games for PC, consoles, mobile devices and websites. There are two versions of Unity; the first one called Unity Pro and is available for a fee and the second one is called Unity Personal and is free. For the Serious Game application for the Ancient Agora it was decided to use the Personal edition of the software because its free edition has all the tools which are needed for creating of this specific game application.

In Unity personal edition the user can utilize many tools which are very useful for a game development. Unity personal edition can make games for 2D and 3D environments. Moreover the personal edition of the software can manage 3D models in many file formats (obj, fbx etc.) and the user can edit them via changing colours, textures, delete parts and many other actions which can be performed in other software which mainly manage 3D models. Furthermore it offers a very good lighting tool with more than one options for illuminating the game scene with realistic results. The creation of virtual tours of a 3D environment is a very powerful tool of the Personal edition of the software. These tours can be made with two options: the First person controller with which the user can navigate in the scene with the help of the arrow keys of the keyboard and the mouse; the second is the third person controller with which the user can navigate with the help of an avatar. Furthermore the GUI tools can add more information of the scene such as information of the scene or maybe some buttons for easier navigation in the game. The use of User Interface (UI) tools can help significantly in the game creation. With the UI tools the user can insert text for the game, can add images, can use buttons and many other operations which are necessary for the creation of many games. Additionally music can be added in the scene for a more realistic result when someone plays the game. Finally, Unity 3D® software has an “asset store” in which game developers may acquire many specialized tools that help developing an application. These assets may be free or in many cases the user has to pay a fee in order to be able to use them.

4.2 SCENARIO

A very basic step before the game development is the creation of the scenario according to which the game will be developed. For the Serious Game of the Ancient Agora of Athens, the scenario includes offering the possibility for virtual tours of the agora as it is today and as it was at a specific time in the 2nd century A.D. when it was as its peak (Camp 2013). All the monuments which have been mentioned in a previous chapter existed in 2nd century A.D. except, of course, from the Holy Apostles Byzantine church. Furthermore the scenario includes a simple quiz

game with five questions for each monument which the user is supposed to be able to answer. These questions are about the history of the monument, about its architecture, its position on the map/image etc. If the answers are right the user is able to continue with the next question. In case that he answers wrongly, he does not lose, as it happens in many games, but he will be presented with the correct answer and a relevant explanation (Kontogianni et al. 2015).

The player will begin with the first monument which is the Stoa of Attalos and by clicking on it a virtual tour will be enabled. The user will continue with the questions of the monument. These questions are of escalated difficulty, which means that the last question will be more difficult than the first. When the user finishes with the questions a new monument will be unlocked and he will continue as previously described. Furthermore at the beginning of the game there is an optional training stage in which the user can learn some important facts about Ancient Greek Architecture and especially about Ancient orders and temples. In this training stage the user will be asked whether he wishes to learn some things about Ancient Greek Architecture. If he selects “yes” he will learn about Ancient architectural orders and temples. In case he will select “no”, he will continue with the game. Furthermore the player has the option to see some instructions about the game before he continues. Figure 4.1 illustrates the flowchart of the application.

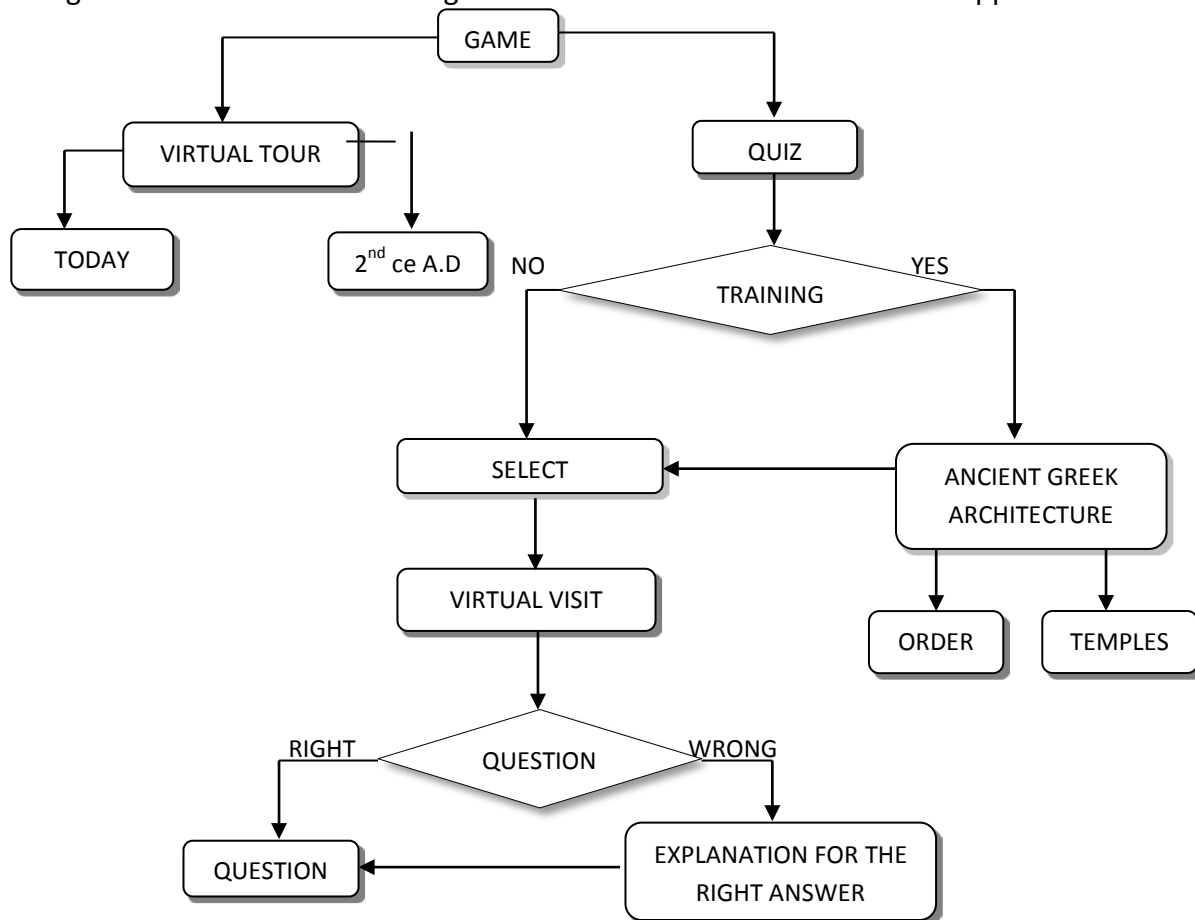


Figure 4.1 Flowchart of the application

4.3 DATA INTERGRATION

4.3.1 Terrain creation

Firstly an empty terrain was created in Unity software, which must have the same resolution as the DSM image. The DSM image is in 32-bit format which is not manageable by the software. In this case the Photoshop software was used in order to convert the 32-bit image to a raw 16-bit format. Furthermore in Photoshop the changing of the image dimensions was carried out in order that the final DSM image has the same resolution as the empty terrain. The first time when the raw image was inserted into Unity, it seemed that the terrain was not illustrated correctly, as it seemed to appear as a mirror reflection. This problem was caused because Photoshop and Unity software have different dimension systems. So the DSM image was flipped vertically in Photoshop in order to be right when it will be inserted again in Unity. Then the processed DSM image was inserted in Unity and was applied to the empty terrain (Fig. 4.2).

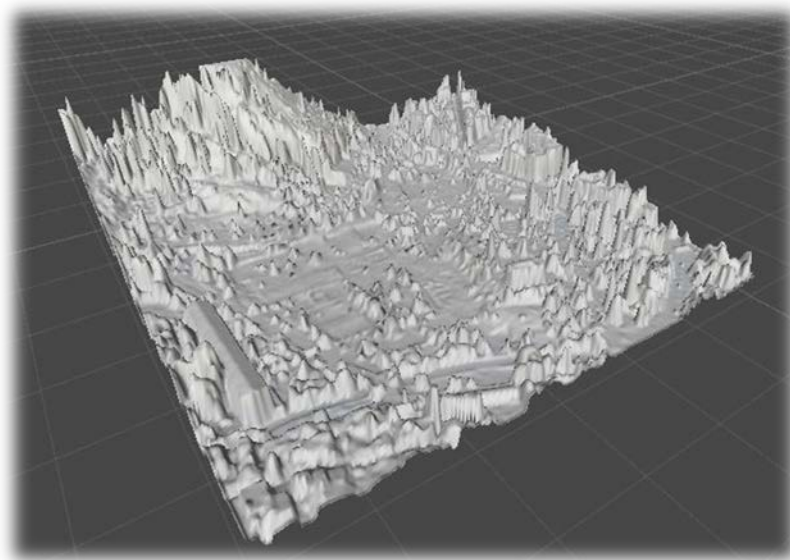


Figure 4.2 Unsmoothed terrain

As it is apparent from figure 4.2, the terrain has many abrupt variations due to buildings and trees which are present in the area and which affect the description of the terrain. For the game development these variations are not necessary, because they will cause difficulties in putting the models in their position and finally building the game. This unprocessed terrain was edited with tools available in Unity in order to reduce these abrupt variations and finally smooth the terrain (Fig. 4.3). Then the orthoimage of the same area was used in order to texture the terrain (Fig. 4.3). For correct texturing the orthoimage when inserted must have the same dimensions as the terrain (Kontogianni et al. 2015).

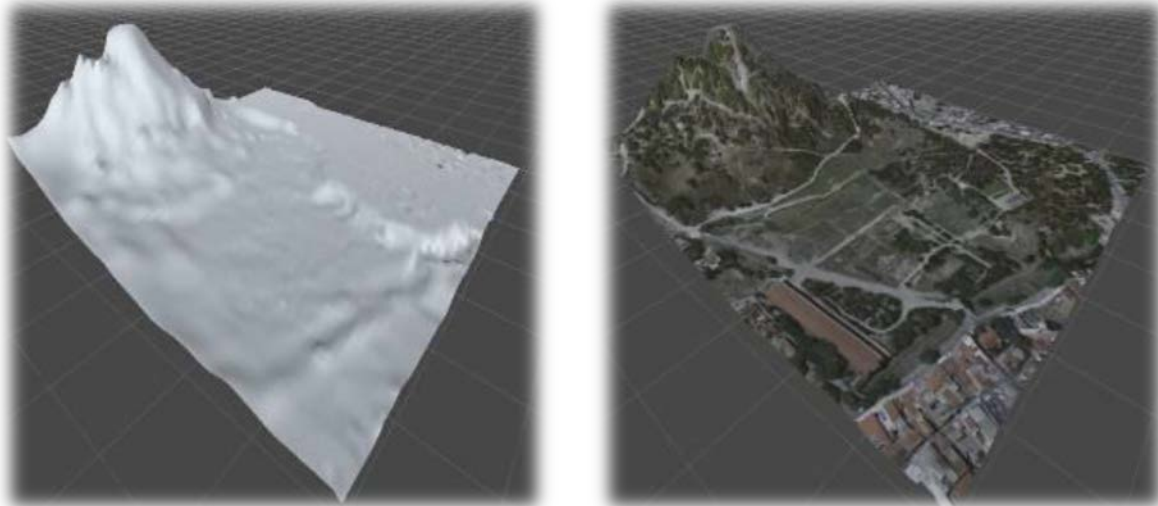


Figure 4.3 Untextured terrain (left) and textured terrain (right)
(Kontogianni et al. 2015)

4.3.2 3D Models

The available 3D models of the monuments are in different file formats (obj, max, wrp, wrl, dae) because of the different methods with which they were created. It was decided that all models should be in the same file format and especially in the fbx format which is easily manageable in Unity. The Autodesk FBX Converter software was used in order to convert all the files to fbx format. Moreover in the cases of the Temple of Hephaestus and the Middle Stoa foundations, it was decided to keep the 70% of the information so as to insert them without size problems in Unity. Then the 3D models were inserted into the software environment. Because the different dimension systems used by Unity and the other software, with which 3d models were produced, the position of the 3D models, when inserted, was not on the terrain. Especially Unity's dimension system is pixels, while the other software reference system is metric. In this case the 3D models were moved and rotated manually in order to be inserted into their right position. This was achieved with the use of the relevant tools in Unity and with the use of a map of the Ancient Agora in which the right position of the monuments is illustrated. Furthermore all the models of the monuments were scaled, with the scaling tool, in order to have the right scale.

After the insertion of all the models, some problems were presented (Kontogianni et al. 2015). The first problem is about the texture of the models which was not applied to the models and had to be manually reloaded. The second problem appeared in the case of the 3D models of the Holy Apostles church and the Temple of Hephaestus for which the texture was too dark and it did not represent the reality (Fig. 4.4).



Figure 4.4 Temple of Hephaestus (left) and Holy Apostles church (right) with the wrong texture (Kontogianni et al. 2015)

The problem was created because Unity, except the texture, applies colour information in the textured models. This colour was grey and it was the reason that the models were too dark. The problem was solved by changing this colour from grey to white in Unity colour pallet and finally the models had the right colour for their texture (Fig. 4.5).



Figure 4.5 Temple of Hephaestus (left) and Holy Apostles church (right) with the right texture (Kontogianni et al. 2015)

Another problem was presented in the case of the Giant of The Odeion of Agrippa. Firstly it was tested if the problem is the same with the one for the Temple of Hephaestus and the Holy Apostles church. The colour of the texture was restored but the problem still persisted. After careful investigation the problem source was detected in the lighting and especially at the source of the lighting which was from the skybox. In this case the source of the light was changed to gradient and some factors were also changed (Sky colour, Equator colour, Ground colour) in order for the final result of the model of the Giant, to be closer to the reality according to images of the monument (Fig. 4.6).



Figure 4.6 Giant with the wrong source of lighting (left) and the right source of the lighting (right)

Furthermore the 3D models from the 3D warehouse library had some errors such as the colour of the models and the colonnade of the Temple of Ares in which columns penetrate the ground. The first problem was corrected after their insertion in Unity in which 3D models were colorized according the colours of the Middle Stoa in order for all the models to look the same for more realistic result. The second problem which is about the Temple of Ares was resolved in the 3ds Max software in which the model was inserted and the height of the problematic colonnade was decreased. Furthermore, some trees, taken form the 3D warehouse library, were added for a more realistic result. The next step is the developing of the Serious Game application, which will be described in the next chapter. Figure 4.7 shows the game environment with all the models.



Figure 4.7 An overview of the game environment (Kontogianni et al. 2015)

4.4 APPLICATION DEVELOPMENT

4.4.1 Lighting

The first procedure for the game development is the lighting of the scene. Lighting is a very important procedure in the development stage of the games because it can give more realistic results. This function was performed firstly by creating the lights which are necessary of the area. The selection type of light is directional. This type does not have any identifiable source position so the light's object can generally be placed anywhere in the scene. So all objects are illuminated as if the light is always from the same direction (unity3d.com). For the application, two lights were created, one as *main* and the second as *fill* for the result to be more realistic and closer to the reality. Furthermore a new material was created in order to be applied to the sky in the game environment. This specific material is a skybox/6 sided shader in which each side was textured so as to apply the textures of the skybox (Fig. 4.8)



Figure 4.8 Skybox

4.4.2 Virtual Tours

For the application, two virtual tours of the Ancient Agora were created. The first one presents the area as it is today, in the 21st century, and the second one as it was in the 2nd century A.D when it was at its peak. The virtual tours for the Ancient Agora of Athens were performed with the use of the First Person Controller tool available in Unity. This tool included a camera attached in a simple 3D mesh and the player can move around by simply using the arrow keys of the keyboard and the mouse. In this procedure there is also the ability to change the speed with which the user can move. Furthermore the name of each monument was annotated beside or above of each model with the use of UI tool (Fig. 4.9) in order for the player to recognize which monument he virtually visits (Kontogianni et al. 2015).

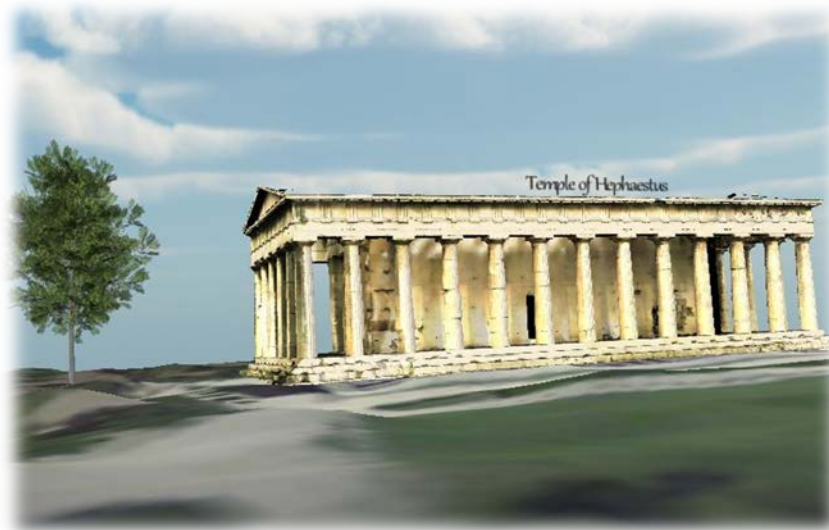


Figure 4.9 Temple of Hephaestus with its name above of the model (Kontogianni et al. 2015)

4.4.3 Quiz Game

The first step is the creation of a selection menu that every game must have. This selection menu can help the user to play the game. For the case of the Ancient Agora of Athens this Selection Menu (Fig.4.10) has the choice which tour the user wants to follow. As it is mentioned above these choices are the virtual tour of today and the virtual tour of the area at a specific time in the past. Additionally the user has the ability to choose to begin playing the game. Furthermore a help tool was added for the player to read some instructions about the game before continuing. For illustrating the text in the game, the ancient Greek font “DIOGENES” (<http://www.dafont.com/diogenes.font>) was used in order to give to the game a more Ancient Greek style.



Figure 4.10 Main Menu of the game

As it can be seen from Figure 4.10 a button for the main menu was used. A simple script was created in C# programming language for the use of these buttons. The script gives the opportunity to the player to continue to the next step when he presses the appropriate button. Moreover a simple scene was created which bears the word “Loading” (Fig. 4.11) in order for the player to understand that he should wait for the next step.



Figure 4.11 Loading image

When the user selects the “play” in order to continue with the game he will see a message which asks if he wants to learn more things about the Ancient Greek Architecture. If the user selects “yes” he will be presented with a text window, which allows him to learn more things about Ancient Orders (Doric, Ionic and Corinthian) and about all kinds of Ancient Greek Temples. If he selects “no” then he will continue with the game. In Figure 4.12 an example of this stage with Doric order and Ancient Temples is presented.

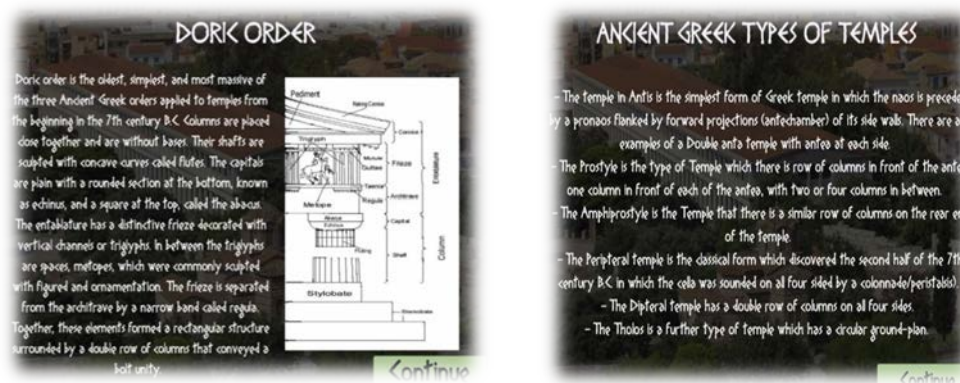


Figure 4.12 Training stage about Ancient Greek orders and temples

After finishing with this training stage the user will continue with the game. Firstly he will see an image of the Ancient Agora with all the monuments which are participating in the game. As it can be seen in Figure 4.13, the monument that the user can visit is designated with its button in yellow colour. The other monuments

are still “locked” to the user and they have red colour labels until the user unlocks them as the game progresses. When the player finished with a monument, in the image, its colour becomes green and the next monument is unlocked (Fig. 4.13).



Figure 4.13 Map of the Ancient agora visit the monument (left) finished with the monument (right)

In the Virtual tours, a GUI window was created with the help of C# language which enables the player to click on it in order to continue to the question or to go back to the main menu. In the case of the Temple of Hephaestus this GUI window has the option to visit the inside of the monument. This GUI window exists in both Virtual Tours of the Ancient Agora in which the user can go back to the main menu or to continue with the other Virtual tour. When the user selects a monument, he can then be toured around it (Fig. 4.14). Furthermore in the virtual tour of each monument there is a GUI window with some historical information about the monument.

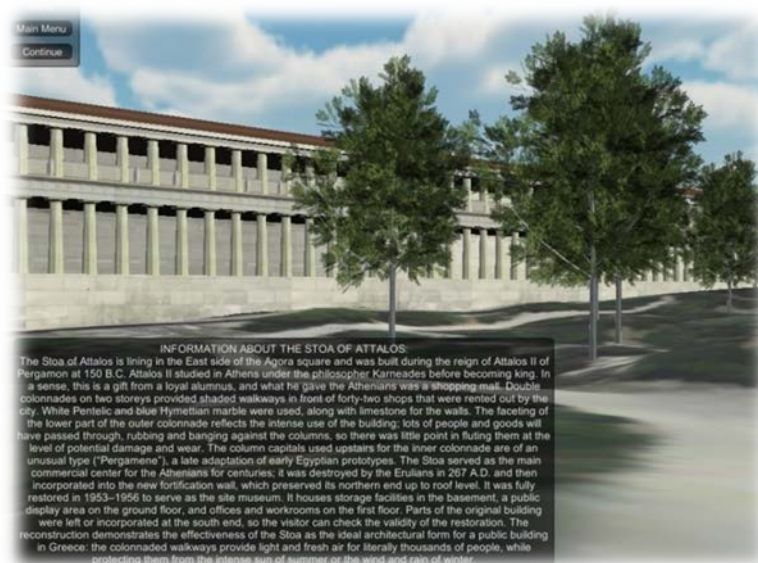


Figure 4.14 Virtual tour of the monument with its information and the GUI window in the left corner

When the player clicks the “continue” button he will continue with the questions. For each monument five questions were created. These questions are based on the text which the user should have read before continuing with the quiz. Each question (Fig. 4.15) has three possible answers and only one is the right one. The player can click on the answer that he knows or believes that is right. The questions are about the history and the architecture of the monument. In some cases the question may include the location of the monument or select which building is the referred monument.



Figure 4.15 Types of the questions for the monuments

In case the choice is right the user will continue with the next question. In this case the button of the right answer when pressed is colored green (Fig. 4.16) and the game automatically continues to the next question. If he answers wrongly, then automatically a new window with the right answer is loaded. In case of a wrong answer the relevant button is momentarily colored red (Fig. 4.16).

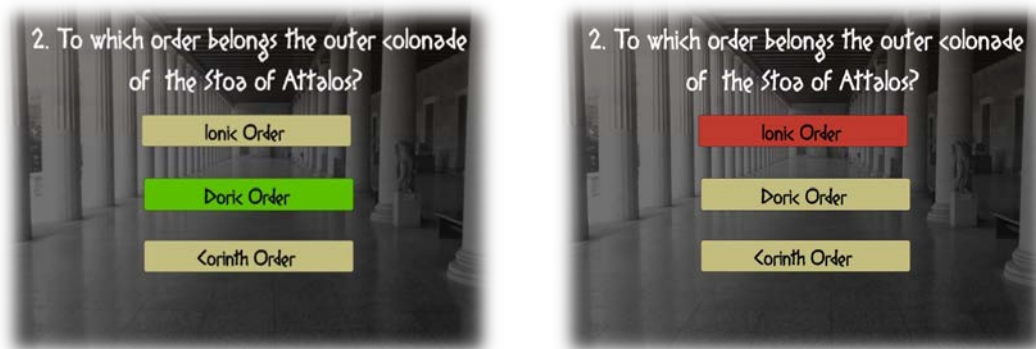


Figure 4.16 Wrong Answer (left) and right answer (right)

Especially this new window has a message which says that the answer is wrong and it explains the reason, mentioning the right answer through its theoretical background (Fig. 4.17). Where necessary a drawing or an image of the monument is presented for better understanding. For each monument the scenes of the answers and the questions have a background image with images of the monument. After completing all the questions of each monument the player returns

to the map and he may continue with the next monument which has just been unlocked.

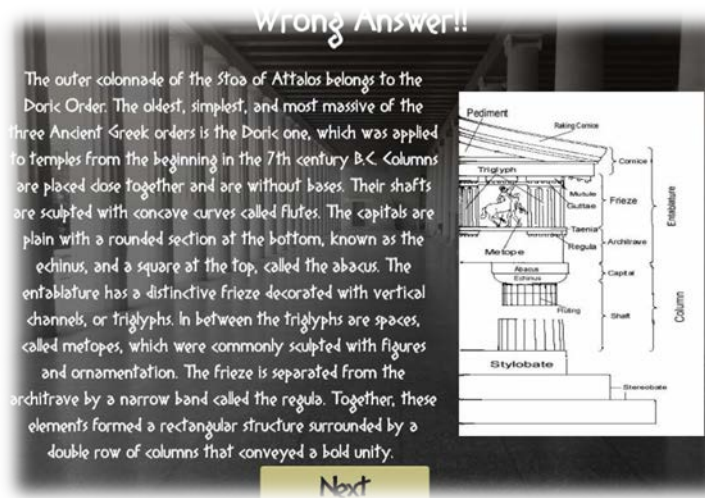


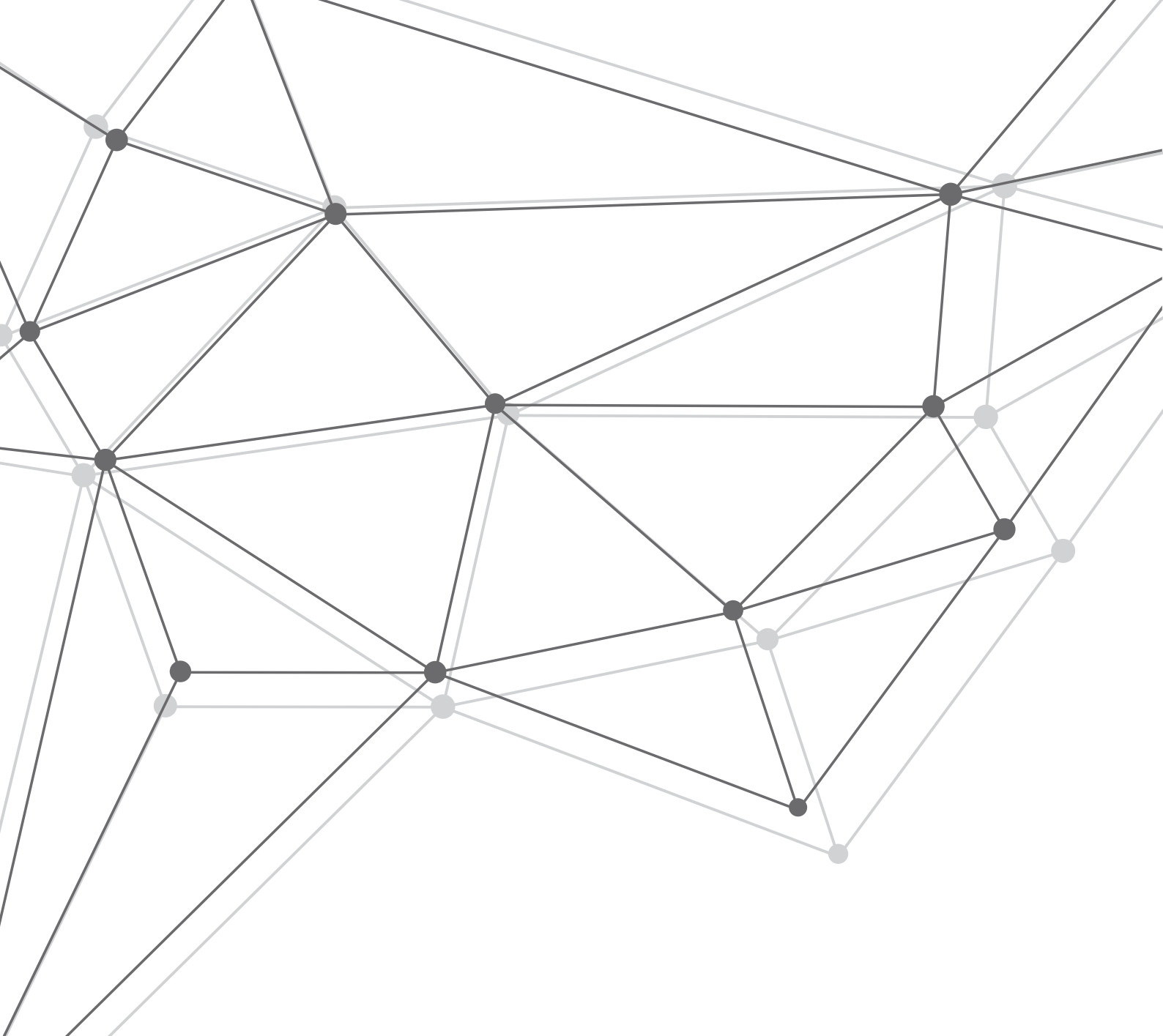
Figure 4.17 Explanation of the right answer

The game finishes when the player answers all the questions for all monuments. At the end of the game the player will see the map of the Ancient Agora (Fig. 4.18) in which he sees a message saying “Congratulations!!! You completed the game” and furthermore he will see all the monuments with green colour which means that he has finished with all the monuments. With the use of the escape button he will quit from the game at the end.



Figure 4.18 End of the game

The escape button was created in C# language in such a way, that when pressed the user will quit the game. However when he wants to play the game again he will have to start from the beginning.



5th CHAPTER

EVALUATION- IMPROVEMENT

5.1 GENERAL

In this chapter the evaluation process for the Serious Game application is presented. This evaluation was carried out by a number of people of different age and, education level and who evaluated the application by answering certain questions. The questionnaire can be online or not and includes general questions, questions about the impact which the Serious Game has had and also included free comments in order for the players to express their opinion about the application if they wish so. For developing an evaluating questionnaire it is advisable to use ready questionnaires available on-line or from experts in order for the evaluation to be more valid.

In the next paragraphs the procedure of how this questionnaire was created and the editing of this questionnaire which constitutes the evaluation of the game with some statistics are presented. Finally some improvements were carried out in the Serious Game application some according to the players' comments.

5.2 CREATING THE QUESTIONNAIRE

The questionnaire which was used for the evaluation for the application for the Ancient Agora of Athens, was taken from the Internet ([http://learningcities.turnhout.preview.anaxis.be/uploads/learningcities.turnhout.be/Gelijke Kansen Onderwijs/downloads/7. PP2 Serious Game 3.4 evaluation sheet EN.pdf](http://learningcities.turnhout.preview.anaxis.be/uploads/learningcities.turnhout.be/Gelijke%20Kansen%20Onderwijs/downloads/7_PP2_Serious_Game_3.4_evaluation_sheet_EN.pdf)) and was edited in order to respond to the needs of the game. It includes general questions about the player such as the age, the academic level, and the gender. Other questions are about the experience with Cultural Heritage, about using of computer or other devices and if they are game players. The questions about the tested Serious Game concern whether the Serious game can be considered as a game, the realism of the script, the 3D models and the questions. Furthermore some questions about the aim, the duration and the game environment were added in the questionnaire. Also questions if the virtual tour, the information about each monument, and if the questions have contributed to help the feeling of the player to be more involved in the game and about the difficulty of the game questions. Another group of questions includes the impact which the game had to the players, about enjoying the game, if the players learnt about the monuments, how they felt while playing and finally if the game is user friendly. At the end of the questionnaire the player has the option to add his free comments about the game. These comments will help significantly towards the improvement of the tested Serious Game.

The questionnaire of the evaluation of the game was created in Google forms (<https://docs.google.com/forms/>). This platform gives the ability to the user to

create an online questionnaire for whatever purpose he wants. All the above mentioned questions were added to this platform and the questionnaire was created. Furthermore the design of the questionnaire was performed with themes which Google form has and the link with the questionnaire with the game were send to a group of people in order to play and evaluate the application. The questionnaire's evaluation is presented in the Appendix.

5.3 EVALUATION

The Serious Game application with a link with the evaluation's questionnaire was sent to a group of approximately 200 people from which only 26 (i.e. 13%) people took part, played the game and responded to evaluate it. The table with the results of the evaluation is presented at the Appendix. From the participants 11 were men and 15 women. Most of the players belong to the 18-30 years old category and a few belong to other categories. The educational level of the players is presented in figure 5.1 and it consisted mainly from people who have a master's degree.

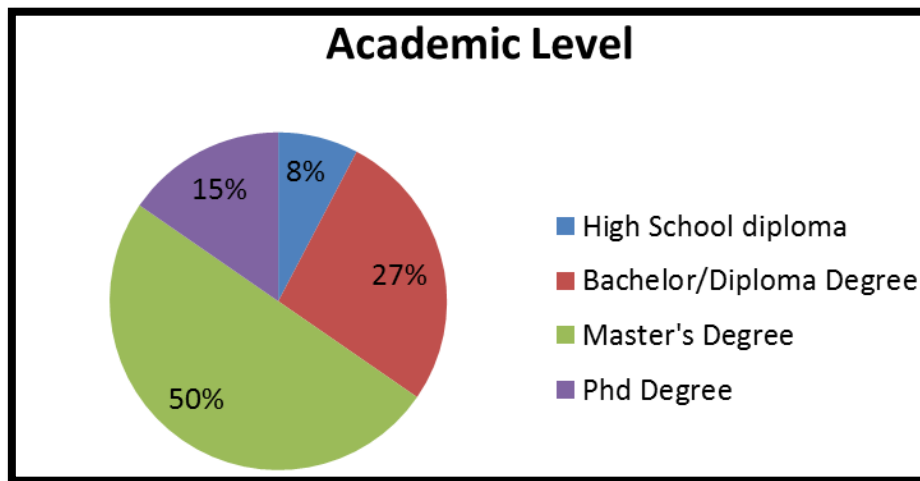


Figure 5.1 Academic level of the players

It is observed that half (13 people) of those who participated to the evaluation have a master's degree and the majority consists of women at the category age 18-30 years old. Only two players have a High school diploma, six have a bachelor or diploma degree and four players have a PhD degree of whose three belong at the 46-65 age category.

The majority of the players are experienced in Cultural Heritage field in a percentage of 81 % as it is presented in figure 5.2

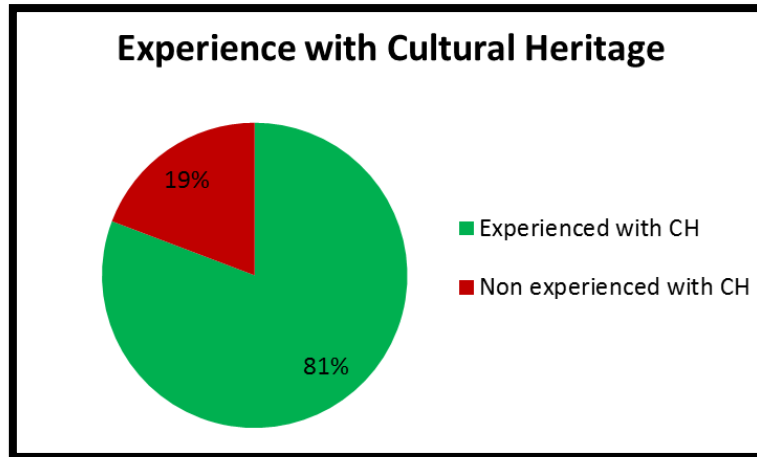


Figure 5.2 Diagram about the experience in Cultural Heritage

From those who are experienced with Cultural Heritage the majority are women and mainly belong at the 18-30 years age category. Furthermore all the participants own computer devices at their home such as PCs, smartphones, tablets and laptops. The players answer that they utilize the Information Technology (IT) for searching information and for using Microsoft office at the same percentage. Only a few players said that they used IT for all the purposes contained in the questionnaire and only one just for one i.e. for social networking.

To the question if they consider themselves as players a percentage of 69% answered that they are not players and 31% consider themselves as players. The majority of people who answered that they are players play games once a month and play different kind of games (Internet, Online, Mini games in smartphone and tablets). However people who consider themselves as non-players answered that they play online and Mini games. Also the questionnaire had a question if they have ever played a Serious Game. Only three of the players answered yes who belong at the same age category (18-30) and they are two women and one man. The Serious Games that they mentioned are the *League of Legends*, *Counter Strike*, *Internet Chess*, *Sims*, *Darfur is dying*. Furthermore seven people (27%) answered that they consider that a Serious Game is not a game.

The next questions, to which players should answer, were about the tested Serious Game for the Ancient Agora of Athens. The questions were about if the script, the story of the game, the 3D models and the questions were realistic. In Figure 5.3 the diagrams presenting the statistics of these answers are presented.

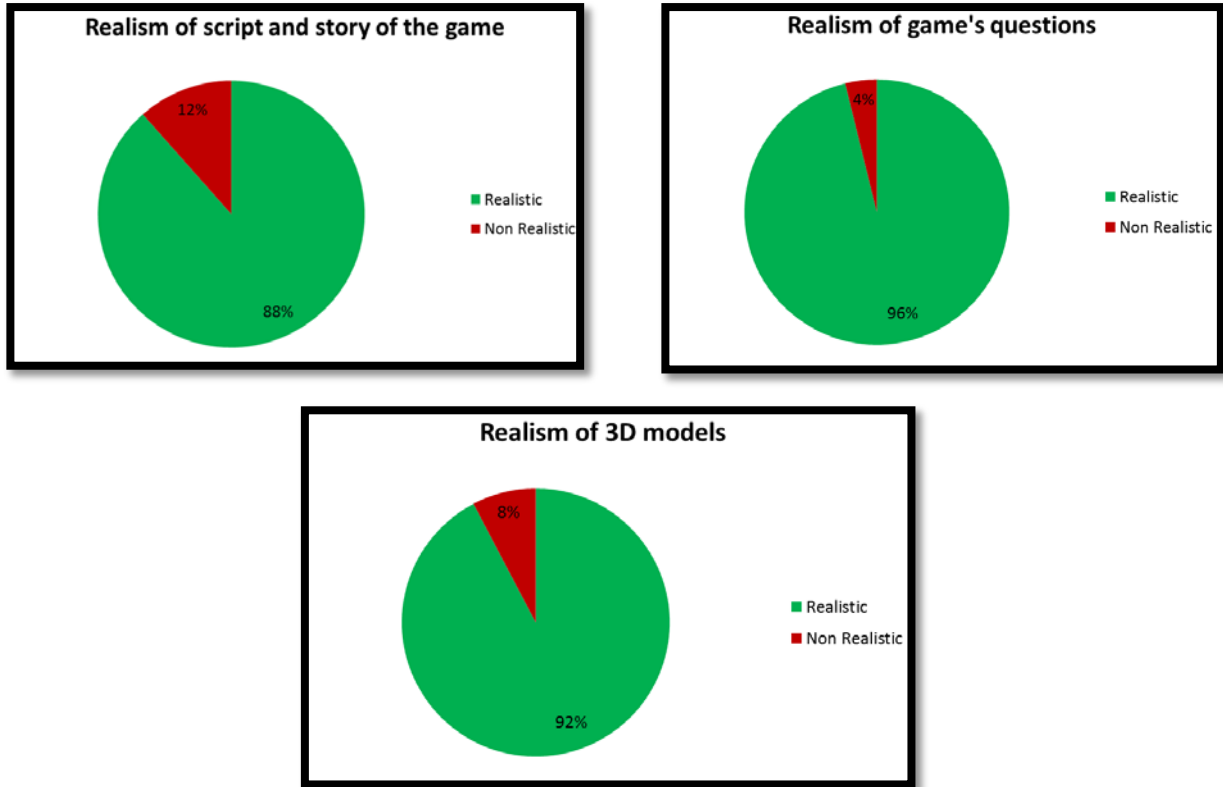


Figure 5.3 Diagrams with the realism of script/story, questions and 3D models

From Figure 5.3 it is evident that the players found the story of the game realistic to a percentage of 88%, the questions to a percentage of 96% and the 3D models to a percentage of 92%. It is observed that in the above three cases the percentage of non-realism is low. Also from those who answer that the story of the game is not realistic only one is not experienced with the Cultural Heritage field. Also only one player among 26 participants answered that the script/story, the questions and the 3D model were not realistic. Furthermore this person holds a High school diploma and he/she has played Serious Games applications.

To the next question the players had to answer if the Serious Game application is user friendly. It is observed according to figure 5.4 that the answers vary but the majority found the game to be user friendly.

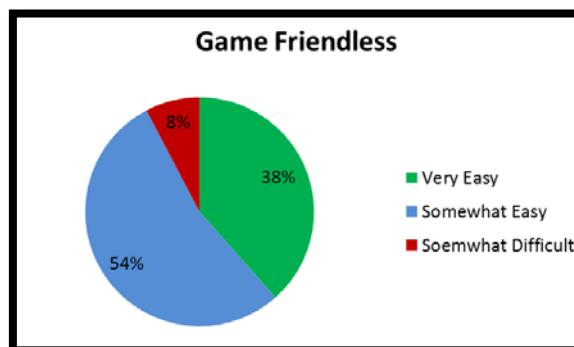


Figure 5.4 Diagram about game user friendly

The majority of the players believe that the aim of the game is clear and only a few players believe that the aim of this application is rather confusing. About the duration of the game the players think that is correct to a percentage about 65% and a little long to a percentage about 35%. To the question if the players have had the feeling that they were hooked, the answers vary as it is apparent from the percentages in Figure 5.5.

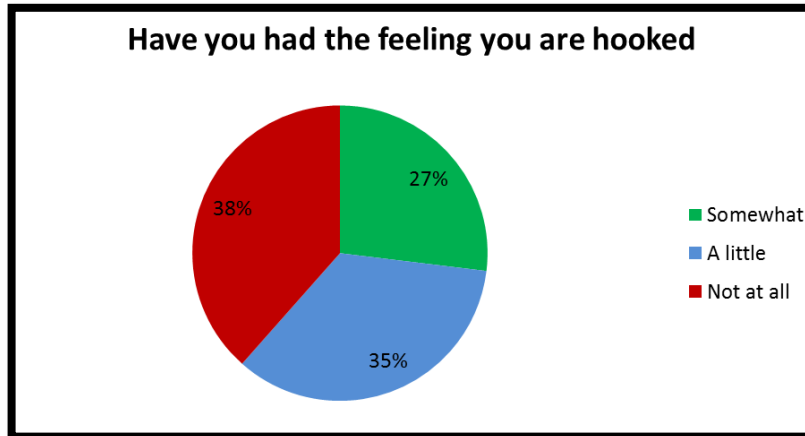
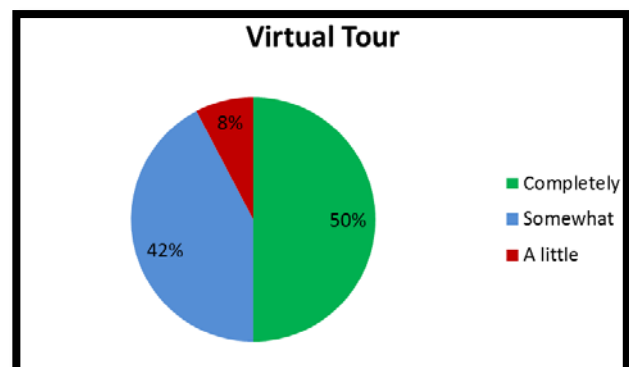
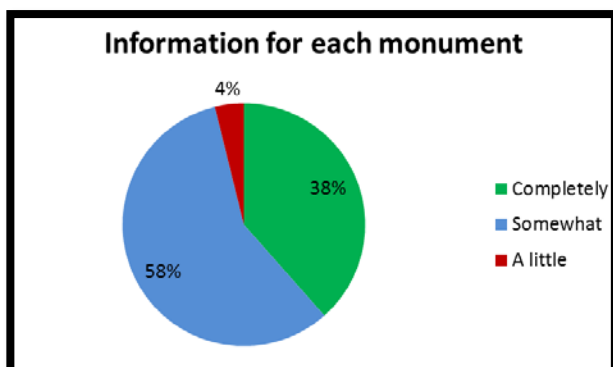


Figure 5.5 Diagram about game hooking

It is obvious from figure 5.5 that the percentages of “Not at all” and “A little” answers are almost the same and the 27% of the players believe that they had the feeling that they were hooked. From those who answer “Somewhat” in this question there are three that they are not experienced with the Cultural Heritage field. All of them find the game user friendly and their answers about the duration of the game were divided.

The next question is about some aspects which may help the players to be more involved in the game. These aspects were: the information about each monument, the virtual tour and the questions. The results of these questions are presented in Figure 5.6.



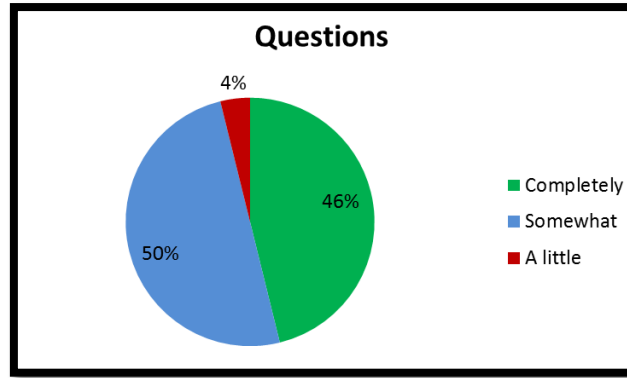


Figure 5.6 Diagram with the aspects which help the player to be involved in the game

It is observed that the mentioned aspects in the pie diagrams help the majority of the players to be involved in the game. The questions and the information about each monument have the same percentages in the “A little” answer. In the virtual tour this percentage is a little high as it is seen in figure 5.6.

Moreover the players found the questions mainly easy to a percentage of 81% and only a small percentage (19 %) found them difficult. Only one player among the five who found the questions difficult has no experience with the Cultural Heritage field. All the others have experience with this specific field.

The next set of questions is about the impact which the game has to the participating players. The results of these questions are presented in Figure 5.7.

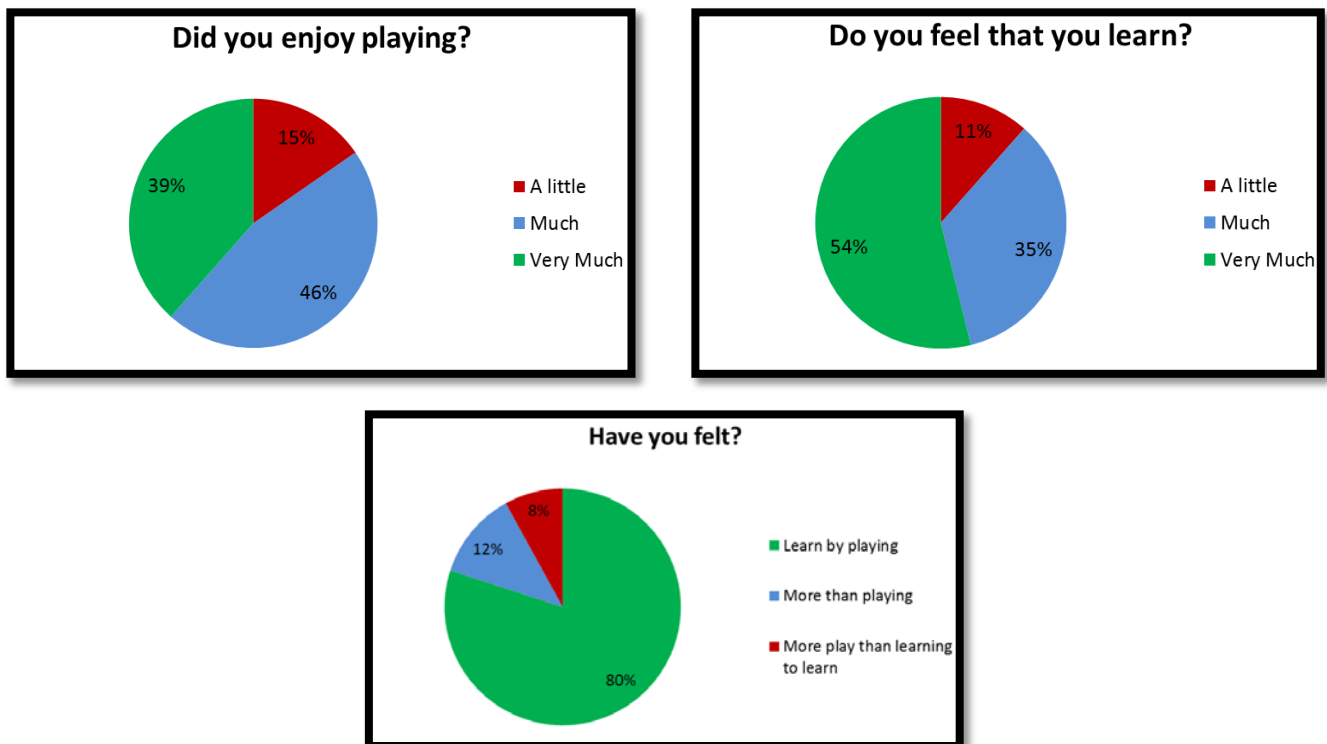


Figure 5.7 Diagrams with the impact of the game

As it may be seen from figure 5.7 the participants enjoyed playing the application for the Ancient Agora of Athens and they believe that they learned many things about the site. Furthermore the majority of the players felt that they learnt these things by playing the game. The players who were not experienced with Cultural Heritage enjoyed playing the game and felt that they have learnt about the Ancient Agora by playing.

Finally the players had the ability to leave their comment/review for the tested Serious Game in order the application to be improved in the next step. The players made the following comments.

- The addition of an “exit” button
- The stabilization of the movement of the mouse
- The decrease of the speed with which the mouse is moving.
- The change of the position of the “Continue” button to the lower-right corner of the screen
- The addition of a compass in order for the players to know where they are in the area.
- The addition of a final level with questions about all the monuments.
- The player will begin the game with whichever monument he wishes.
- The addition of a point system.

Some of these comments were used to improve the game environment and they are presented in the following chapter.

5.4 IMPROVEMENTS

As mentioned previously the improvement of this game was carried out according to some of the comments which the players made at the evaluation stage after playing the game. The first improvement was about the addition of an exit button in order for the players not to press the esc button in order to exit the game. For this reason in the virtual tours a GUI button was added to which a simple script in C# language for quitting the game was attached. The position of this GUI window was decided to be at the position of the continue button. So the second improvement was the movement of the continue button. According to the players it would be more useful for this button to be placed at the lower-right corner of the screen (Fig. 5.8).

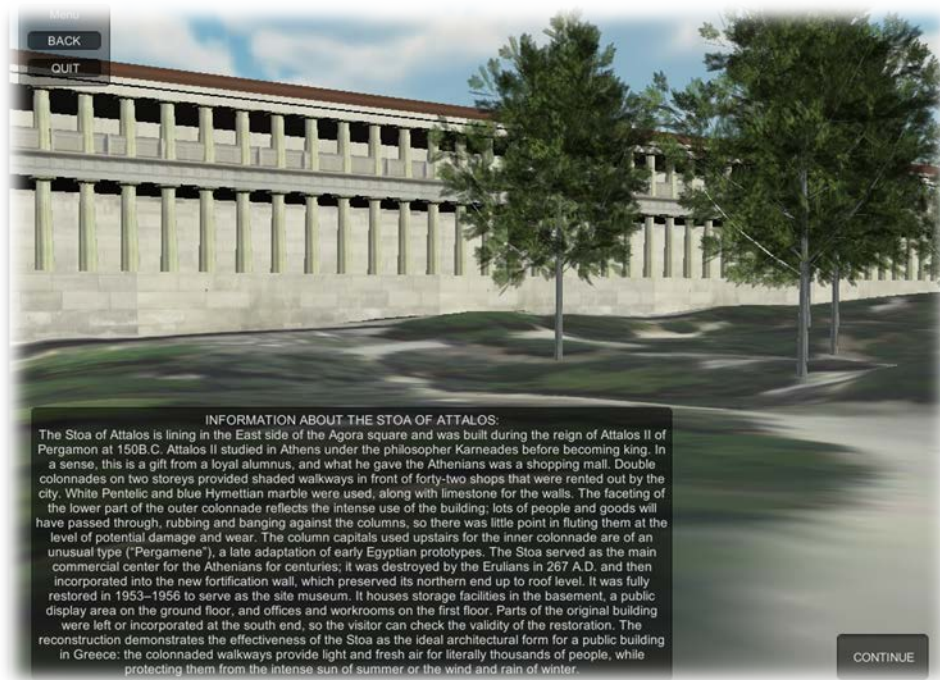


Figure 5.8 Game environment with the improvements for the “EXIT” and “CONTINUE” buttons

The exit button was not placed in the question and answers scenes because the result was not so functional. In this case the player should press the esc button from the keyboard in order to quit the game. Some other small improvements which carried out at the GUI buttons were the renaming of the “Main Menu” button to “BACK” and the letters of the buttons which became capitals to become more user’s friendly.

Another problem which the players mentioned was the mouse speed which was high. As a result the mouse swerved so quickly which was not so manageable for the player. This problem was solved by decreasing the speed in both axes at the Mouse Look script which was attached at the camera and at the First Person Controller.

Another improvement which was implemented according the players’ comments was the addition of a minimap in order to help the users to know where they are in a greater area. This procedure was performed by creating a new camera, in the scene, which was orthographic and was placed above the terrain. Furthermore some parameters of the camera were changed in order for the camera to be at the right position and illustrate the area correctly. A script in C# language was attached in the camera in order to follow the First Person Controller. In the case of the virtual tours the minimap was placed at the lower-left corner of the screen as it is seemed in figure 5.9.



Figure 5.9 The game environment of the virtual tour with the minimap at the down-left side

In the cases of the virtual tours of the monuments at the quiz game the minimap was placed at the lower-right corner of the screen (Fig.5.10) because the text box with the information about each monument is placed at the left side of the screen.

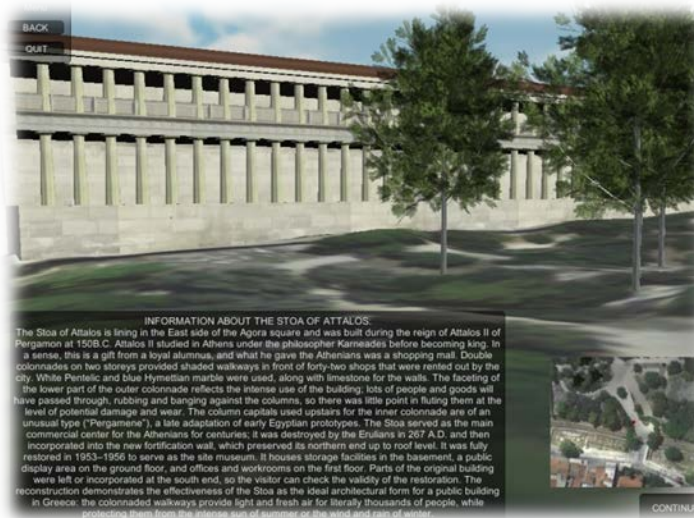


Figure 5.10 The game environment of the virtual tour with the minimap at the down-right side

The last improvement which was carried out was the addition of music in the cases of the virtual tours. The kind of music which was selected is instrumental and it is free of Intellectual Property Rights and taken from the internet (<http://www.freemusicarchive.org/>). The selected track which is MUSIC TRACK was input in the game environment by using the Audio Source tool in Unity software in which the selected music track was inserted (Fig. 5.11).

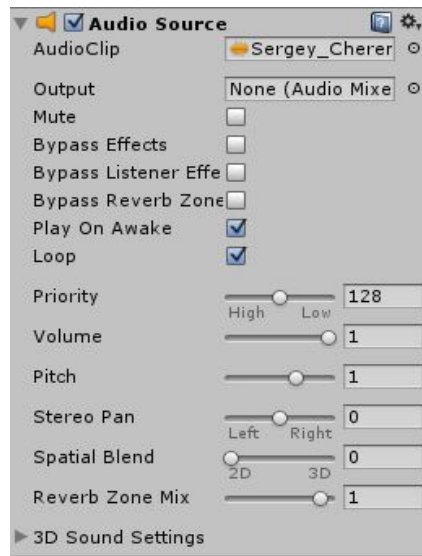
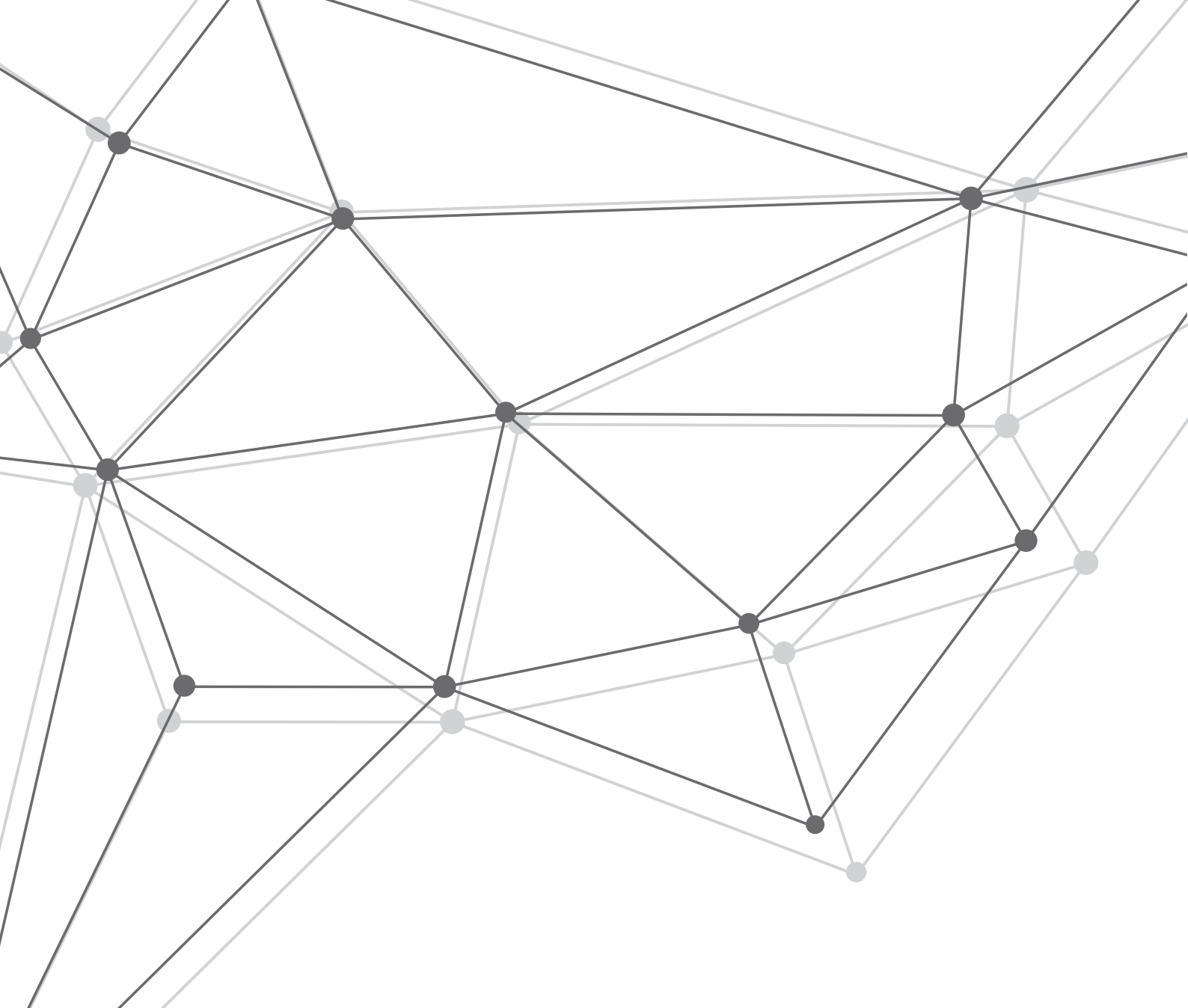


Fig. 5.11 Audio source tool



6th CHAPTER

CONCLUDING
REMARKS-FUTURE
PERSPECTIVE

6.1 CONCLUDING REMARKS

Concluding this thesis it is advisable to mention some concluding remarks.

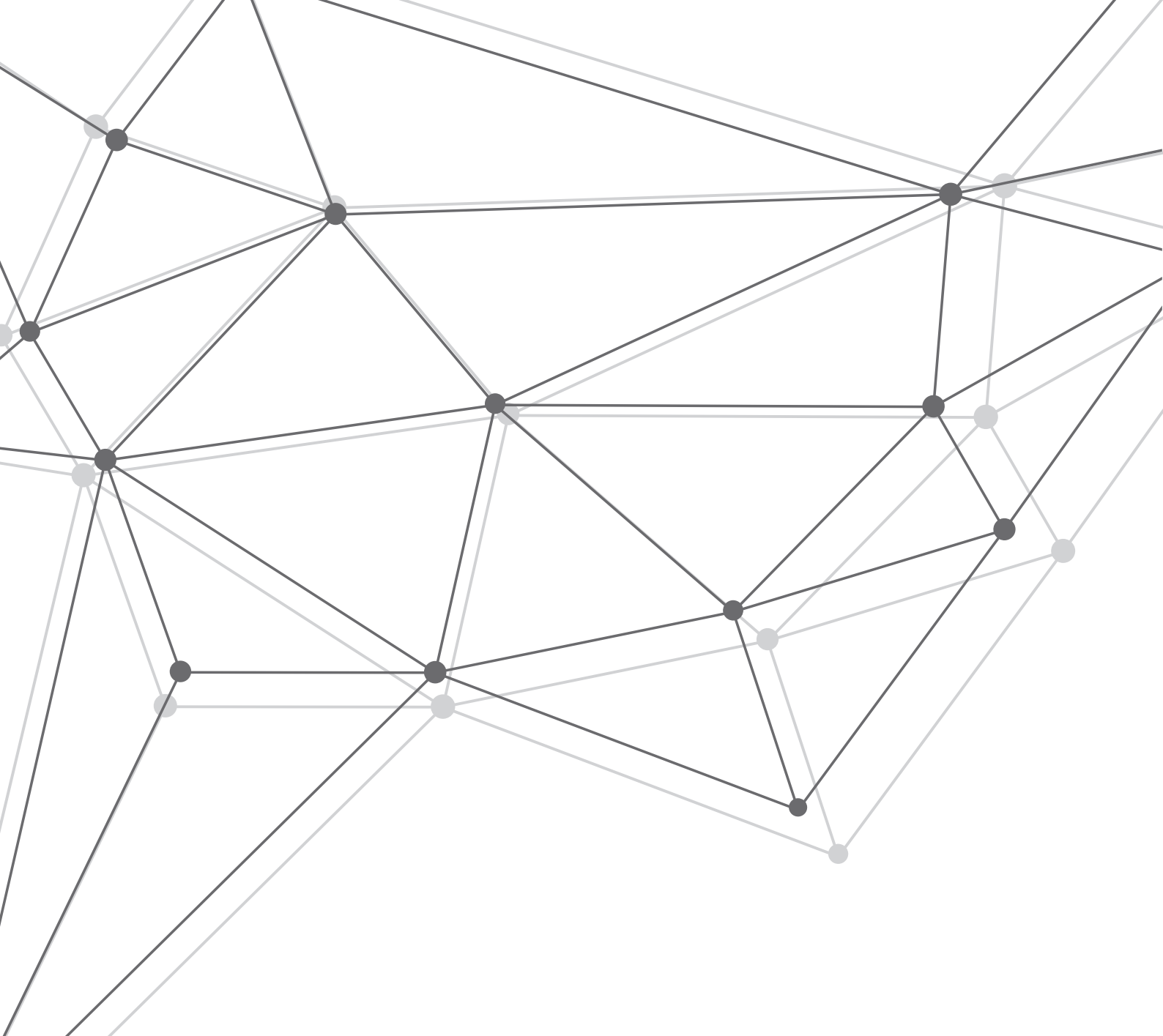
- Serious Games are games that educate the players in many scientific fields via playing. The application about the Ancient Agora of Athens helps players who are not experienced with the Cultural Heritage field learn many things about the monuments of the Agora. This was a clear outcome from the statistical processing and the evaluation of the questionnaires, which was carried out at the end of the project.
- The field of Serious Game in the Cultural Heritage field is interdisciplinary so it is advisable to collaborate with scientists from many different scientific fields. Especially Archaeologists and Historians for the information about the monuments and the questions, Electrical Engineers for the game design, Photogrammetrists and Geomatic Engineers for the 3D models.
- It was difficult to manage 3D models which were created with a Time of Flight (ToF) laser scanner because of their huge file size. This happens because these models have far more points, hence they are more accurate and more detailed than the 3D models taken from 3D warehouse library. So it is advisable to lower a little the percentage of the information but not very much because information may be lost which is useful for the educational purpose of the game. Also 3D models created with the Structure from Motion (SfM) technique are more manageable because they usually have smaller file sizes than the laser scanner 3D models.
- As it was mentioned above, 3D models from the 3D warehouse library are not so accurate and in many cases they include mistakes. This problem could be fixed if the historical reconstruction is performed very carefully such as in the case of the southwest side of the Middle Stoa.
- The Structure from Motion (SfM) method is more suitable in cases that the monument still exists, because the models from SfM are more manageable by Unity and can illustrate the reality as well as TLS models. In cases that the monument does not exist anymore, it is preferable to make a very good historical reconstruction according to old drawings, experts' assumptions etc.
- The interior of the Temple of Hephaestus was created using TLS and colour information was added later. This product presented serious problems when inserted into UNITY and the result was unacceptable. In this case the 3D model of the interior should have been created with

another method such as the SfM method which is appropriate for gaming purposes and illustrates the reality very well.

6.2 FUTURE PERSPECTIVE

In this chapter some future outlooks, which are based on the evaluation stage, about the Serious Game application are presented. The first one is about the addition of a point evaluation system, with which the player will “lose” if he answers wrongly in more than e.g. two questions (Kontogianni et al. 2013). Maybe this point system might give more points if a question is difficult or if the players lose points by answering wrongly. Furthermore the game could offer the ability to the player to save the game in order to continue playing later whenever he wishes. This will be carried out at the beginning of the game in which the player can enter his name in order to save the game. Saving of the game could be done whenever the player wants.

Another function that it would be good to be included is the addition of more questions at the end of the game, which will be about all the monuments. This would help the players to establish whether they have improved their knowledge about the monuments. This stage could be also at the beginning of the game in order for the user to see what he knows about the monuments for the Ancient Agora and in this way to establish the improvement. Furthermore the player could begin with the monument of his choice and not with the first monument that it was defined by the game developer.



REFERENCES

Abt C. C., 1987. *Serious games*, University Press of America, ISBN 978-0819161482, pp 196.

Adamo-Villani N. & Wright K., 2007. *SMILE: an immersive learning game for deaf and hearing children*. *ACM SIGGRAPH 2007-34th International Conference and Exhibition on Computer Graphics and Interactive techniques*, San Diego California, 7-9 August.

Alvarez J. & Michaud L., 2008. Serious games. Advergaming, edugaming, training and more. , IDATE, Montpellier, France.

Anderson E. F., McLoughlin, L., Liarokapis, F., Peters, C., Petridis, P., De Freitas, S., 2010. Developing serious games for cultural heritage: a state-of-the-art review. *Virtual reality*, 14(4), pp. 255-275.

Arnold D, Day A., Glauert J., Haegler S., Jennings V., Kevelham B., Laycock R., Magnenat- Thalmann N., Maim J.,Maupu D., Papagiannakis G., Yersin B., Rodriguez-Echavarria K., 2008. *Tools for populating cultural heritage environments with interactive virtual humans*. EPOCH Conference on Open Digital Cultural Heritage Systems, Rome Italy, 25-26 February, pp.25.

Bellotti F., Berta R., Gloria A. D. & Primavera L., 2009. Enhancing the educational value of video games. *Computers in Entertainment (CIE)*, 7(2), pp. 23.

Bellotti F.,Berta R., De Gloria A., Dursi A., Fiore V., 2012. A serious game model for cultural heritage. *Journal on Computing and Cultural Heritage (JOCCH)*, 5(4), pp. 17.

Burton, J. & others, 2005. News-game journalism: History, current use and possible futures, Citeseer.

Buttussi F. & Chittaro L., 2010. Smarter phones for healthier lifestyles: An adaptive fitness game. *Pervasive Computing, IEEE*, 9(4), pp. 51-57.

Camp J. M., 2003. *The Athenian Agora: a short guide*, American School of Classical Studies at Athens, ASCSA, ISBN 978-0876616437, pp.32.

Ceconello M.,Spagnoli A., Spalazzo D., Tollino U., 2015. Playing Design Mobile Serious Games to Valorize Design Culture in the Urban Space. Digital Heritage International Congress, Digital Heritage 2015, Granada Spain, 28 September-2 October.

Chen F. X., King A. C. & Hekler E. B., 2014. *Healthifying exergames: improving health outcomes through intentional priming*. In *Proceeding of the 32nd Annual ACM conference on Human factors in computing systems*, Toronto Canada, 26April-1 May, pp. 1855-1864.

Christopoulos D. & Gaitatzes A., 2009. *Multimodal interfaces for educational virtual environments*. PCI 2009-13th Panhellenic conference on Informatics, Thessaloniki Greece, 10-12 September pp. 197-201.

Christopoulos D., Mavridis P., Andreadis A. & Karigiannis J. N., 2011. *Using Virtual Environments to Tell the Story: "The Battle of Thermopylae"*. 3rd International conference on Games and Virtual Worlds (VS-GAMES 2011), Athens Greece, 4-6 May, pp. 84-91.

Coenen T., Mostmans L. & Naessens K., 2013. MuseUs: Case study of a pervasive cultural heritage serious game. *Journal on Computing and Cultural Heritage (JOCCH)*, 6(2), p. 8.

Boyd Davis S., Moar M., Jacobs R., Watkins M., Riddoch C., Cooke K., 2006. 'Ere be dragons: heartfelt gaming. *Digital Creativity*, 17(3), pp. 157-162.

De Freitas S. & Liarokapis F., 2011. Serious games: a new paradigm for education?. In: *Serious games and edutainment applications*. Springer, Online ISBN 978-1-4471-2161-9, pp. 9-23.

De Paolis L., Aloisio M.G., Celentanto M.G., Oliva L., Vecchio P., 2011. Otranto in the Middle Ages: a Serious Game for the Edutainment. *International Journal of Information and Education Technology*, 1(1), pp. 47-57.

Dimitropoulos K., Manitsaris S., Tsalakanidou F., Nikolopoulos S., Denby B., Al Kork S., Crevier-Buchman L., Pillot-Loiseau C., Adda-Decker M., Dupont S., Tilmannes J., Ott M., Alivizatou M., Yilmaz E., Hadjileontiadis L., Charisis V., Deroo O., Manitsaris A., Kompatsiaris I., Grammalidis N., 2014. *Capturing the intangible: An introduction to the i-treasures project*. In proceedings on VISAPP 2014: 9th International Conference on Computer Vision Theory and Applications, Lisbon Portugal, 5-8 January.

Doulamis A., Liarokapis F., Petridis P. & Miaoulis G., 2012. Serious games for cultural applications. In: *Intelligent Computer Graphics 2011*, Springer, Online ISBN 978-3-642-22907-7 pp. 97-115.

Edery D. & Mollick E., 2008. *Changing the game: how video games are transforming the future of business*, Ft Press.

El-Hakim S., McDonald G., Lapointe J.F., Gongo L., Jemtrud M., 2006. On the digital reconstruction and interactive presentation of heritage sites through time, In Proceedings of the 7th International Conference on Virtual Reality, Archaeology and Intelligent Cultural Heritage (VAST 2006), Nicosia Cyprus, 30 October-4 November.

Frischer B., 2008. The Rome Reborn Project. How Technology is helping us to study history. *OpEd, November*, Volume 10.

Froschauer J., Berger H., Merkl D. 2010. *Design and evaluation of a Serious Game for immersive cultural training*. 16th International Conference on Virtual Systems and Multimedia (VSMM 2010), Seoul Korea, 20-23 October, pp. 253-260.

Froschauer J., Arends M., Goldfarb D. & Merkl D., 2012. *A serious heritage game for art history: Design and evaluation of THIATRO*. 18th International Conference on Virtual Systems and Multimedia (VSMM 2012), Milan Italy, 2-5 September, pp. 283-290.

Froschauer J., Merkl D., Arends M. & Goldfarb D., 2013. Art history concepts at play with THIATRO. *Journal on Computing and Cultural Heritage (JOCCH)*, 6(2), pp. 7.

Gaitatzes A., Christopoulos D. & Papaioannou G., 2004. *The ancient olympic games: being part of the experience*. 5th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage (VAST 2004)., Oudenaarde, Belgium, December 7-10, pp. 19-28.

Giang H.N.K., Ferchin P., Di Angelo M., 2015. Medieval Craftsmen at Castle Waldenfels Historical Reconstruction Work as Serious Game, Digital Heritage International Congress, Digital Heritage 2015, Granada Spain, 28 September-2 October.

Goins E., 2010. *Art history in the 21st century: The integration of museum collections and social networking games*. International Conference on Education and New Learning Technologies, Barcelona Spain, 5-7 July, pp. 5516-5525.

Goins E. & Egert C., 2013. *Moving beyond mobile tours: Creating hybrid spaces through narrative and gameplay in the museum collection*. Digital Heritage International Congress, Digital Heritage 2013, Marseille France, 28 October-1 November, pp. 425-428.

Greitzer F. L., Kuchar O. A. & Huston, K., 2007, Cognitive science implications for enhancing training effectiveness in a serious gaming context. *Journal on Educational Resources in Computing (JERIC)*, 7(3), pp. 2.

Gustafsson A., Katzeff C. & Bang M., 2009. Evaluation of a pervasive game for domestic energy engagement among teenagers. *Computers in Entertainment (CIE)*, 7(4), pp. 54.

Hall T., Ciolfi L., Bannon L., Fraser M., Benford S., Bowers J., Greenhalgh C., Hellstrom S.O., Izadi S., Schnadelbach H., Flintham M., 2001. *The visitor as virtual archaeologist: explorations in mixed reality technology to enhance educational and*

social interaction in the museum. In proceedings of the Conference of Virtual Reality, Archaeology and Cultural Heritage(VAST 2001),Athens Greece, 28-30 November pp. 91-96.

Jacobson, J. & Holden, L., 2005. *The virtual egyptian temple*, World Conference on Educational Media and Technology, Montreal, Canada, 25 June, pp. 4531-4536.

Johnson, W. L., Wang, N. & Wu, S., 2007. *Experience with serious games for learning foreign languages and cultures*, In proceedings of the SimTect Conference, Queensland Australia, 4-7 June.

Jacobson J., Handron K., Holden L., 2009, Narrative and Content Combine in a Learning Game for Virtual Heritage. *Distance Education* 9.2 (2009), pp. 7-26.

Karageorgou M., Barakou A., Briana D., Siora E., 2010, 3D model of the south-western corner of the Middle Stoa in the Athens Agora, Large scale surveys student project, Msc in Geoinformatics , School of Rural & Surveying Engineering, NTUA (in Greek).

Kelly H., Howell K., Glinert E., Holding L., Swain C., Burrowbridge A., Roper M., 2007. How to build serious games. *Communications of the ACM*, 50(7), pp. 44-49.

Kitsakis D., 2011. *Evaluation of photogrammetric methods of 3D data acquisition*. Diploma Thesis, National Technical University of Athens (in Greek).

Kontogianni G., Georgopoulos A., Saraga N., Alexandraki E., Tsogka K., 2013. 3D VIRTUAL RECONSTRUCTION OF THE MIDDLE STOA IN THE ATHENS ANCIENT AGORA. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XL-5/W1, pp. 125-131.

Kontogianni G. & Georgopoulos A., 2015. Exploiting Textured 3D Models for Developing Serious Games. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XL-5/W7, pp. 249-255.

Kontogianni G. & Georgopoulos A., 2015. A Realistic Gamification Attempt for the Ancient Agora of Athens. Digital Heritage International Congress, Digital Heritage 2015, Granada Spain, 28 September-2 October.

Koutsaftis C. & Georgopoulos A., 2015. A Serious Game in the Stoa of Attalos: Learning Basic Principles of Protection of Cultural Heritage, 1st Panhellenic Conference Digitization for Cultural Heritage, Volos Greece, 24-26 September.

Koutsaftis C. & Georgopoulos A., 2015. A Serious Game in the Stoa of Attalos: Edutainment, Heritage Values and Authenticity. Digital Heritage International Congress, Digital Heritage 2015, Granada Spain, 28 September-2 October.

Laamarti F., Eid M. & Saddik A. E., 2014. An overview of serious games. *International Journal of Computer Games Technology*, Volume 2014, pp. 11.

Lecllet-Groux D., Caron G., Mouaddib E. & Anghour A., 2013. *A Serious Game for 3D cultural heritage*. Digital Heritage International Congress, Digital Heritage 2013, Marseille France, 28 October-2 November, pp. 409-412.

Lee J., Kang K. K., Kim J.W., Lee J., Goo B., 2014. TouchBim: A Touch Screen Kiosk for Education of Korean Traditional Wooden Building. In: *Proceedings of EuroMed 2014 – International Conference on Cultural Heritage, 3-8 November, Limassol, Cyprus*.

Lepouras G. & Vassilakis C., 2004. Virtual museums for all: employing game technology for edutainment. *Virtual reality*, 8(2), pp. 96-106.

Lercari N., Onsurez L., Schultz J. & others, 2013. *Multimodal reconstruction of landscape in serious games for heritage: An insight on the creation of Fort Ross Virtual Warehouse serious game*. Digital Heritage International Congress, Digital Heritage 2013, Marseille France, 28 October-2 November, pp. 231-238.

Lercari N., Mortara M. & Forte M., 2014. Unveiling California History Through Serious Games: Fort Ross Virtual Warehouse. In: *Games and Learning Alliance*. Springer, pp. 236-251.

Liestol G., 2014. Along the Appian Way. Storytelling and Memory across Time and Space in Mobile Augmented Reality. In: *Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection*. Springer, pp. 248-257.

Losh E., 2006. *The palace of memory: virtual tourism and tours of duty in Tactical Iraqi and Virtual Iraq*. In proceedings of the 2006 International Conference on Game Research and Development, Perth Australia, 4-6 December, pp. 77-86.

Maim J., Haegler S., Yersin B., Muller P., Thalmann D., Van Gool L. 2007. *Populating ancient pompeii with crowds of virtual romans*. In Proceedings 8th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST 2007), Brighton UK, 26-30 November.

Marsh T., Wong W.L., Carriazo E., Nocela L., Yang K., Varma A., Yoon H., Huang Y., Kyriakakis C., Shahabi C., 2005. *User experiences and lessons learned from developing and implementing an immersive game for the science classroom*. In proceedings of the HCI International Conference., Las Vegas USA., 22-27 July.

Michael D. R. & Chen S. L., 2005. *Serious games: Games that educate, train, and inform*. Muska & Lipman/Premier-Trade, ISBN 1592006221.

Moffat D. & Shapiro A., 2015. Serious Games for Interactive Stories about Emotionally Challenging Heritage. Digital Heritage International Congress, Digital Heritage 2015, Granada Spain, 28 September-2 October.

Mortara M., Catalano C.E., Belloti F., Fiucci G., Houry-Panchetti M., Petridis P., 2014. Learning cultural heritage by serious games. *Journal of Cultural Heritage*, 15(3), pp. 318-325.

Muller, P., Verreunoghe T., Ulmer A., Van Gool L., 2005. *Automatic reconstruction of Roman housing architecture*. Recording Modeling and Visualization of Cultural Heritage. Taylor & Francis Group, London, ISBN 041539208

Wycherley R., 1957. *The Athenian Agora: Results of Excavations*. American School of Classical Studies at Athens.

Perez-Valle A., Aguirrezabal P. & Sillaurren S., 2014. Playhist: Play and Learn History. Learning with a Historical Game vs An Interactive Film. In: *Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection*. Springer, pp. 546-554

Rebolledo-Mendez G., Avramides K., De Freitas S. & Memarzia K., 2009. *Societal impact of a serious game on raising public awareness: the case of FloodSim*. In Proceedings of the 2009 ACM SIGGRAPH Symposium on Video Games, New Orleans USA, 3-7 August, pp. 15-22.

Sawyer B. & Rejeski D., 2002. *Serious games: Improving public policy through game-based learning and simulation*.

Sawyer B., 2009. *Foreword: From virtual U to serious game to something bigger, Serious games: Mechanisms and effects*, Routledge, London UK.

Scarle S., Dunwell I., Bashford-Rogers T., Selmanovic E., Debattista K., Chalmers A., Powell J., Robertson W., 2011. *Complete motion control of a serious game against obesity in children*. In proceedings of the 3rd International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES 2011), Athens Greece, 4-6 May, pp. 178-179.

Shih D.-T., Lin C. L. & Tseng C.-Y., 2015. Combining Digital Archives Content with Serious Game Approach to Create a Gamified Learning Experience. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XL-5/W7, pp. 387-394.

Sylaiou, S., Liarokapis, F., Kotsakis, K. & Patias, P., 2009. Virtual museums, a survey on methods and tools. *Journal of Cultural Heritage*, 10(4), pp. 520-528.

Troche, J. & Jacobson, J., 2010. An exemplar of Ptolemaic egyptian temples. *In Proceedings 38th Conference on Computer Applications and Quantitative Methods in Archaeology (CAA 2010)*, Granada, Spain, April .

Wong, W. L., Shen C., Nocera L., Carriazo E., Tang F., Bugga S., Narayanan H., Wang H., Ritterfeld U., 2007. *Serious video game effectiveness*. In proceedings of the International Conference on Advances in computer Entertainmeny technology,Salzburg Austria, 15-17 June, pp. 49-55.

Zielke, M. A., Evans M., Dufour F., Christofer T., Donahue J., Johnson P., Jennings E., Friedman B., Ounekeo P., Flores R., 2009. Serious games for immersive cultural training: Creating a living world. *IEEE computer graphics and applications*, Issue 2, pp. 49-60.

Zyda M., 2005, From visual simulation to virtual reality to games, *Computer*, 38(9), 25-32.

Sites

unity3d.com, Unity 3D software, (last visited 30/9/2015)

<https://3dwarehouse.sketchup.com/>, 3D warehouse library (last visited 25/7/2015)

<http://www.seriousgamesinstitute.co.uk/>, The Serious Games institute (last visited 10/10/2015)

<http://www.seriousgamesassociation.com/>, Serious Games Association (last visited 14/10/2015)

<https://en.wikipedia.org/wiki/Mancala#History>, Mancala Game (last visited 5/9/2015)

<http://www-01.ibm.com/software/solutions/soa/innov8/cityone/>, IBM CityOne (last visited 5/9/2015)

www.socialimpactgames.com, Political and Religious Games (last visited 5/9/2015)

<http://earth.google.com/rome/>, Low resolution 3D model of Rome (last visited 15/6/2015)

<http://www.seriousgamesinstitute.co.uk/applied-research/Roma-Nova.aspx>, Roma Nova project (last visited 15/6/2015)

www.couchsurfing.org, Couchsurfing network (last visited 15/6/2015)

<http://ascsa.net/research?v=default>, American School of Classical Studies (last visited 14/10/2015)

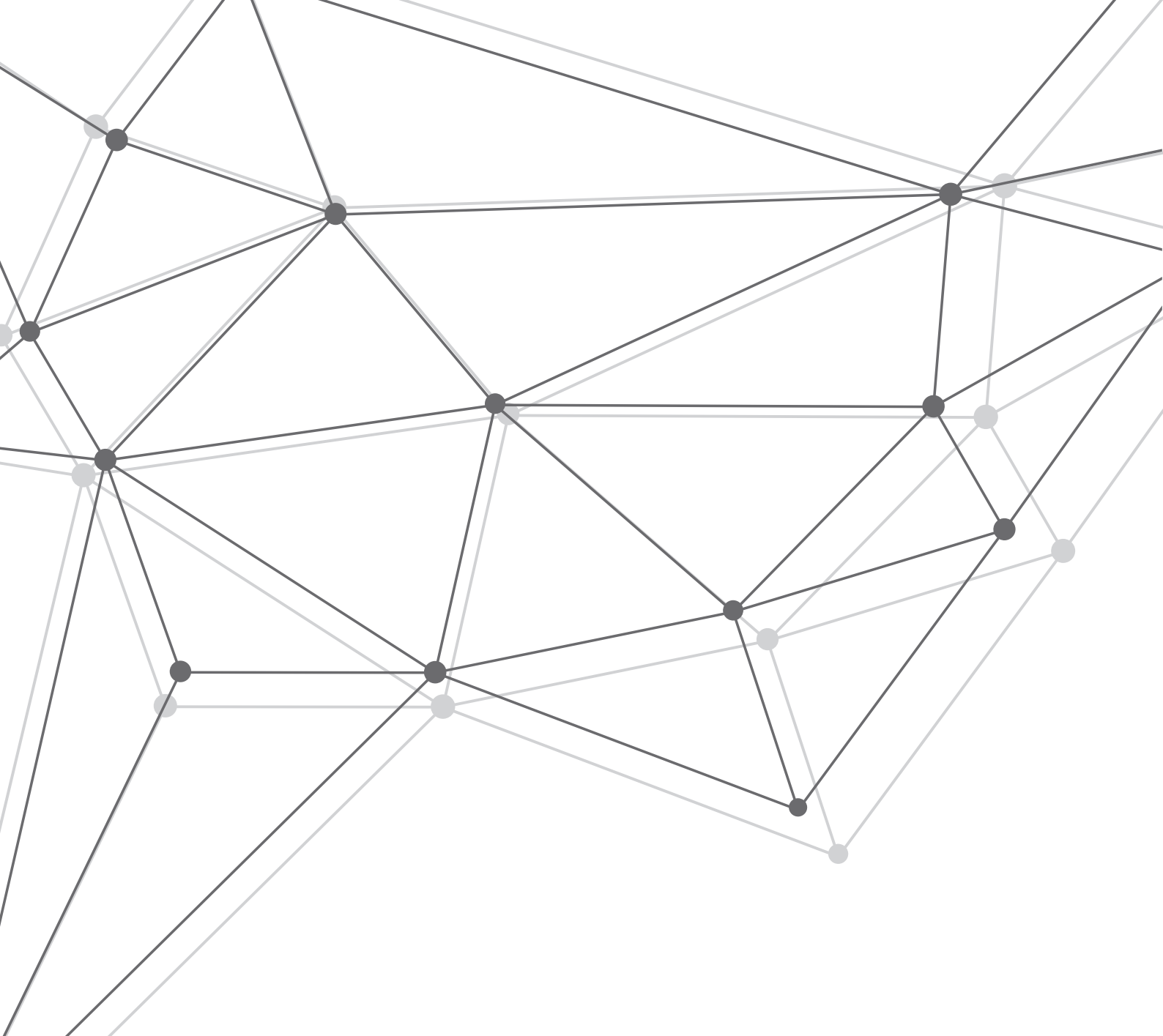
www.ktimatologio.gr, National Cadastre and Mapping Agency S.A (last visited 25/2/2015)

<http://www.dafont.com/diogenes.font>, ancient Greek font "DIOGENES" (last visited 30/6/2015)

http://learningcities.turnhout.preview.anaxis.be/uploads/learningcities.turnhout.be/Gelijke_Kansen_Onderwijs/downloads/7_PP2_Serious_Game_3.4_evaluation_sheet_EN.pdf, online evaluation questionnaire (last visited 10/10/2015)

<https://docs.google.com/forms/>, Google forms (last visited 10/10/2015)

<http://www.freemusicarchive.org/>, Free Music Archive (last visited 14/10/2015)



APPENDIX

1. EVALUATION QUESTIONNAIRE

a. Who are you?

1. You are

- Man
- Woman

2. Your age

- 12-18
- 19-30
- 31-45
- 46-65
- above 66

3. Your academic level

- Student
- High School diploma
- Bachelor/Diploma degree
- Master degree
- PhD Degree

4. Are you experienced with Cultural Heritage?

- Yes
- No

b. Computer and you

1. Are you equipped with computer(s) at home?

- Yes
- No

2. If you answer yes please specify the computer devices that you have (PCs, Tablets, Smartphones etc.)

3. Do you use a center or any other public service to connect to Internet?

- Yes
- No

4. For which purpose do you use IT (computer devices)?

- Office (Word, Excel etc.)
- Social networking (Facebook, Tweeter etc.)
- Leisure
- Multimedia (Photo, music, video)

- Games
- Administrative procedures
- Searching for information

5. Have you ever had any computer training?

- Yes
- No

c. Video games and you

1. In general do you consider yourself as ...

- Player
- Non player

2. If player do you rather play

- Daily
- Once or twice a week
- Once or twice a month
- Once a month

3. Do you play video games out of the Internet

- Yes
- No

4. Do you play video games online?

- Yes
- No

5. Do you play free online computer or smartphone mini games?

- Yes
- No

6. Have you ever played a Serious Game?

- Yes
- No

7. If you answer yes please mention the name of the game(s) that you have played.

d. Your opinion about the Serious Game under evaluation

1. Do you consider that this Serious Game is a game?
 - Yes
 - No

2. Are the script and the story realistic?
 - Yes
 - No

3. Are the game questions realistic?
 - Yes
 - No

4. Are the 3D models of the monuments realistic?
 - Yes
 - No

5. Is the game user friendly?
 - Very easy
 - Somewhat easy
 - Somewhat difficult
 - Very difficult

6. The aim of the game is
 - Clear
 - Rather confusing

7. The duration of the game is
 - Too long
 - A little long
 - Correct
 - A little short
 - Too short

8. Have you had the feeling you are hooked?
 - Completely
 - Somewhat
 - A little
 - Not at all

9. Did the following aspects contribute to help your feeling to be more involved in the game?

The information about each monument

- Completely
- Somewhat
- A little
- not at all

The virtual tour

- Completely
- Somewhat
- A little
- not at all

The questions

- Completely
- Somewhat
- A little
- not at all

10. How did you find the game questions?

- Very difficult
- Difficult
- Easy
- Very easy

e. Your opinion about the impact

1. Did you enjoy playing

- Very much
- Much
- A little
- Not at all

2. Do you feel that you learnt something about the monuments?

- Very much
- Much
- A little
- Not at all

3. Have you felt

- More play than learning to learn
- More than playing
- Learn by playing

4. Is the game user friendly?

Yes

No

Free comments

Do you have any more comments?

The Contribution of 3D Models to Serious Games Applications

2. EVALUATION'S ANSWERS

You are	Your age	Your academic level	Are you experienced with Cultural Heritage?	Are you equipped with computer tools at home?	If you answer yes please specify the computer tools that you have (PCs, Tablets, Smartphones)	Do you use a center on any other service of the municipality to connect to Internet?	For which purpose have you got for IT utilization?	Have you had computer training?	If you answer yes which training have you had	In general do you consider yourself as someone	If player do you rather play	Do you play video games out of the Internet?	Do you play video games online?	Do you play free online computer or smartphone mini games
Male	19-30	Bachelor/Diploma Degree	Yes	Yes	PC, Smartphone	Yes	Searching for information	Yes		Player	Once a month	Yes	No	Yes
Male	19-30	Master degree	Yes	Yes	PCs, Tablets, and Smartphones	No	Work	Yes		Non player		No	No	No
Female	19-30	Master degree	Yes	Yes	pc, smartphone	No	Office (Word, Excel etc.)	Yes		Non player		No	No	No
Female	19-30	Master degree	Yes	Yes	laptop and smartphone	No	Searching for information	No		Non player		Yes	No	Yes
Female	19-30	Master degree	Yes	Yes	Pcs, Smartphone	Yes	Searching for information	Yes		Non player		No	No	Yes
Female	19-30	Master degree	Yes	Yes	PCs, Tablets, Smartphones	Yes	Office (Word, Excel etc.)	Yes		Non player	Once a month	No	No	Yes
Male	19-30	Master degree	Yes	Yes	PCs, Tablets, Smartphones	Yes	Office (Word, Excel etc.)	Yes		Player	Once or twice a week	No	Yes	Yes
Male	19-30	Bachelor/Diploma Degree	No	Yes	Pc, Tablets, Smartphones	No	Searching for information	Yes		Non player	Once a month	Yes	No	No
Male	31-45	Master degree	No	Yes	PC	Yes	Searching for information	Yes		Non player	Once a month	No	Yes	No
Female	19-30	Master degree	Yes	Yes	pc, laptop, tablet, smartphone	Yes	for all the above mentioned	No		Non player		No	Yes	Yes
Female	31-45	Master degree	Yes	Yes	pcs, smartphones	No	ola ta pano	No		Non player		Yes	No	No
Female	19-30	Bachelor/Diploma Degree	Yes	Yes	PC, tablet, smartphone	Yes	Searching for information	Yes		Non player		No	No	No
Female	31-45	Bachelor/Diploma Degree	No	Yes	pc	No	Social Networking (Facebook, Tweeter etc.)	Yes		Player	Daily	No	Yes	Yes
Female	19-30	Master degree	Yes	Yes	PCs and smartphone	No	Office (Word, Excel etc.)	No		Non player		No	No	Yes
Female	19-30	Master degree	Yes	Yes	pc	No	Searching for information	Yes		Non player		No	No	No
Female	19-30	Bachelor/Diploma Degree	No	Yes	PC	Yes	Searching for information	Yes		Player	Once a month	No	Yes	No
Female	19-30	Bachelor/Diploma Degree	Yes	Yes	PCs, Smartphones	No	Office (Word, Excel etc.)	No		Player	Daily	No	Yes	Yes
Male	19-30	Student	Yes	Yes	Pc-Tablet-Smartphone	Yes	Office (Word, Excel etc.)	No		Player	Daily	No	Yes	Yes
Female	19-30	High school Diploma	Yes	Yes	PC	No	Searching for information	No		Non player		Yes	Yes	Yes
Male	19-30	Master degree	Yes	Yes	desctop,laptop,smartphone	No	Office (Word, Excel etc.)	No		Non player		No	Yes	Yes
Female	19-30	Bachelor/Diploma Degree	Yes	Yes	PC, Smartphone	Yes	Office (Word, Excel etc.)	Yes		Player	Once or twice a week	Yes	Yes	Yes
Male	46-65	Phd degree	Yes	Yes	PC, TABLET, SMARTPHONE, NOTEBOOK	No	ALL THE ABOVE	Yes		Non player		No	No	No
Male	46-65	Phd degree	Yes	Yes		Yes	Searching for information	Yes		Non player		No	No	No
Male	19-30	Master degree	No	Yes	PC	Yes	Office (Word, Excel etc.)	Yes		Player	Once a month	No	Yes	Yes
Female	46-65	Phd degree	Yes	Yes	PC, TABLET	No	Office (Word, Excel etc.)	Yes		Non player		No	No	No
Male	46-65	Phd degree	Yes	Yes	PC, Tablets, Smartphones	No	Office (Word, Excel etc.)	Yes		Non player		No	Yes	Yes

The Contribution of 3D Models to Serious Games Applications

2. EVALUATION'S ANSWERS

Have you ever played a serious game?	If you answer yes please refer the name of the game that you have played	Do you consider that the Serious Game is a game?	Are the script and the story realistic?	Are the game questions realistic?	Are the 3D models of the monuments realistic?	Is the game user friendly?	The aim of the game is	The duration of the game is	Have you had the feeling you are hooked?	Did the following aspects contribute to help your feeling to be more involved in the game?			How did you find the questions	Did you enjoy playing?	Do you feel that you learnt something about the monuments	Have you felt
										Information for each monument	Virtual Tour	Questions				
No		Yes	Yes	Yes	Yes	Somewhat easy	Clear	Correct	Somewhat	Somewhat	Somewhat	Somewhat	Easy	Much	Very much	Learn by playing
No		Yes	Yes	Yes	Yes	Somewhat easy	Rather confusing	Correct	A little	Somewhat	Completely	Somewhat	Difficult	Much	Much	Learn by playing
No		Yes	Yes	Yes	Yes	Somewhat easy	Clear	Correct	Not at all	Completely	Completely	Completely	Easy	Much	Very much	Learn by playing
No		Yes	Yes	Yes	Yes	Very easy	Clear	A little long	A little	Completely	Somewhat	Completely	Easy	Much	Very much	Learn by playing
No		Yes	Yes	Yes	Yes	Very easy	Clear	A little long	Somewhat	Somewhat	Completely	Completely	Difficult	Very much	Very much	Learn by playing
No		Yes	Yes	Yes	Yes	Somewhat easy	Clear	Correct	Not at all	Completely	Completely	Completely	Easy	Very much	Very much	More than playing
No		No	Yes	Yes	Yes	Somewhat easy	Clear	Correct	Not at all	Completely	Completely	Completely	Easy	Very much	Very much	More than playing
No		Yes	No	Yes	Yes	Somewhat easy	Clear	Correct	Somewhat	Completely	Somewhat	Somewhat	Easy	Much	Much	Learn by playing
No		Yes	Yes	Yes	Yes	Very easy	Clear	A little long	Somewhat	Somewhat	A little	Somewhat	Difficult	Much	Very much	Learn by playing
No		No	Yes	Yes	Yes	Somewhat difficult	Clear	Correct	A little	Completely	Somewhat	Completely	Easy	A little	Very much	Learn by playing
No		No	No	Yes	Yes	Somewhat difficult	Rather confusing	Correct	Not at all	Completely	Completely	Completely	Easy	A little	Much	More than playing
No		Yes	Yes	Yes	Yes	Somewhat easy	Clear	A little long	A little	Somewhat	Completely	Somewhat	Easy	A little	Very much	Learn by playing
No		Yes	Yes	Yes	Yes	Somewhat easy	Rather confusing	A little long	A little	Somewhat	Somewhat	Somewhat	Easy	Much	Much	Learn by playing
No		Yes	Yes	Yes	No	Somewhat easy	Clear	A little long	Not at all	Somewhat	A little	Somewhat	Easy	Much	Much	Learn by playing
No		Yes	Yes	Yes	Yes	Very easy	Clear	Correct	A little	Completely	Completely	Completely	Easy	Very much	Much	More than playing
No		No	Yes	Yes	Yes	Very easy	Rather confusing	A little long	A little	A little	Completely	Somewhat	Easy	Much	Much	Learn by playing
No		Yes	Yes	Yes	Yes	Very easy	Rather confusing	Correct	Not at all	Completely	Completely	Completely	Easy	Very much	Very much	More play than learning to learn
Yes	League of legends - Counter strike -Internet Chess	Yes	No	No	No	Somewhat easy	Clear	Correct	Not at all	Somewhat	Somewhat	Somewhat	Very easy	A little	A little	More play than learning to learn
Yes		Yes	Yes	Yes	Yes	Very easy	Clear	Correct	A little	Somewhat	Somewhat	Completely	Easy	Much	Much	Learn by playing
No		No	Yes	Yes	Yes	Very easy	Clear	Correct	Not at all	Somewhat	Somewhat	Somewhat	Easy	Much	A little	Learn by playing
Yes	Sims, Darfur is dying, etc.	Yes	Yes	Yes	Yes	Somewhat easy	Clear	A little long	Not at all	Somewhat	Completely	Completely	Easy	Very much	Very much	Learn by playing
No		No	Yes	Yes	Yes	Somewhat easy	Clear	Correct	A little	Somewhat	Somewhat	Somewhat	Difficult	Very much	Very much	Learn by playing
No		No	Yes	Yes	Yes	Somewhat easy	Clear	Correct	Somewhat	Somewhat	Somewhat	A little	Difficult	Very much	Much	Learn by playing
No		Yes	Yes	Yes	Yes	Somewhat easy	Clear	Correct	Somewhat	Somewhat	Completely	Somewhat	Easy	Very much	Very much	Learn by playing
No		Yes	Yes	Yes	Yes	Very easy	Clear	Correct	Not at all	Completely	Somewhat	Completely	Easy	Very much	Very much	Learn by playing
No		Yes	Yes	Yes	Yes	Very easy	Clear	A little long	Somewhat	Somewhat	Completely	Somewhat	Easy	Much	A little	Learn by playing

3. FREE COMMENTS AT THE EVALUATION

- Congrats!
- Exit button, stable position when mouse moves (middle click for stabilizing maybe?),"Continue" should be under the monument info box for extra user-friendliness!
- Improve the level of interaction and in general the whole game experience, it is advisable to use key words corresponding to certain components of the monument via animation maybe
The game may be characterized as user friendly but there are certain issues to be fixed (for example to move right down the continue button and to provide the user with more control over the cursor's movements..it is not stable yet...)
In a previous question, i chose the option that this is not a game (the question could have a third option if i might suggest)..this is a game, BUT a game is always a fun process which intrigues the user and keeps him interested... so when referring to a serious game this is more of an urgent need, since there is a certain scope which is to educate as well as to entertain the users... it would be great if the user could navigate smoothly through the scene as he prefers (it might be characterized a bit static as it is, motion features would provide more realism to the overall tour) and to improve the visuals (more colors and more characteristic symbols etc, maybe some animations in the questions following the tour etc)... i would strongly advice the text box to be more "phantasmagorical" (maybe to be a colored pop-up text box next to the corresponding model)...
Include photographs of the monuments in order to have an actual visual... this is fun because the user might "compare" the model to the reality..it is a game after all... we need to keep in mind that gamers are getting excited over graphics quality and the level of detail and realism..
The user must have the option to interrupt the gaming process at his liking...
This is an extra comment, not really important for the game's purpose but gamers exist within the game via an avatar.. you might like to include a simple type of an avatar or some fun character posing as a guide... to this i might include the option of music in the game..
Other than that a game serving education on cultural heritage is a very interesting concept, the selected route is just excellent, and the 3D models are satisfactory! there is also a fair amount of questions for each monument serving the main purpose of the game, which is to educate the user...you might want to include a list of overall questions (concerning all monuments) at the end..
- Needs improvement!
- Congratulations for the serious game!!!! I enjoyed playing. However, I think that your English needs to be improved.
- Some monuments were not completed 100%.
- Good Luck
- Nice Game. A compass will be a great idea.
- Too simple questions
- Point System at the questions. Maybe this point system might give more points if a question is difficult or if the players lose points by answering wrongly.

The player could begin with the monument of his choice and not with the first monument that it was defined by the game developer.

The player can see the explanation of the right answer not only in the case of wrong answer but and when he answers right.



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APPLICATIONS

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