A Serious Game for Understanding Ancient Seafaring in the Mediterranean Sea

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***Abstract*—Commercial sea routes joining Europe with other cultures are vivid examples of cultural interaction. In this work, we present a serious game which aims to provide better insight and understanding of seaborne trade mechanisms and seafaring practices in the eastern Mediterranean during the Classical and Hellenistic periods. The game incorporates probabilistic geospatial analysis of possible ship routes through the re-use and spatial analysis from open GIS maritime, ocean, and weather data. These routes, along with naval engineering and sailing techniques from the period, are used as underlying information for the seafaring game. This work is part of the EU-funded project iMareCulture whose purpose is in raising the European identity awareness using maritime and underwater cultural interaction and exchange in the Mediterranean sea.**

I. Introduction

One of the most important tasks in maritime archaeology is the accurate documentation of underwater cultural heritage (UCH). Many archaeological excavations and projects [1], [2], [3], [4] have already developed tools and methods for 3D reconstruction of underwater objects through the use of photogrammetry [5], rapid scanning [6] and the utilization of optic and acoustic sensors. While the documentation of UCH assets is a very important task, the dissemination and distribution of the outcomes and knowledge derived from it is of equal, if not higher, importance. Perhaps the primary limiting factor is the fact that a vast number of CH assets are located underwater and therefore are inaccessible to anyone other than the researchers involved in the excavations. In fact, even for the researchers involved it becomes very hard to visualize and hypothesize about possible scenarios involving UCH assets [7].

The technological requirements for applying serious games to cultural heritage have been previously explored and the most characteristic case studies were presented in [8]. In particular the case studies have been categorized into three types of computer-game-like applications including: prototypes and demonstrators; virtual museums; and commercial historical games. The state-of-the-art in Serious Game technology is identical to the state-of-the-art in Entertainment Games technology but the pedagogical approach differs according to the needs of the serious game.

In this work, the objective is to contribute to the dissemination of UCH and its context, through a serious game that is attractive to the wider public. The game, with a main theme on ancient seaborne trade, is based on historical and archaeological data, as well as on probabilistic analysis of real geospatial data. To this end, this work aims at furnishing the background geospatial information required for agent-based modeling of seafaring practices in the Mediterranean Sea within the context of a serious game. More precisely, the information consists of geospatial on-location data collected for a number of major ports that were involved in the trade of various commodities such as metals, olive oil and wine during the Classical period (5th - 4th centuries BC); these ports are used as origin and/or destination ports in the serious game. Geospatial data on environmental conditions include digital representations of the coast of the Mediterranean Sea and its islands, as well as digital terrain models of the Mediterranean coastal zones. Additional data include wind speed and direction from numerical models of weather prediction, as well as speed and direction of ocean currents derived from numerical models of ocean circulation. Preference is given to open geospatial data, which is then integrated in a geospatial database for easy query and visualization within a Geographic Information System (GIS). In addition, and given a set of possible embarkation and destination ports, spatial analysis is conducted to: (1) compute the least cost paths between these locations as possible proxies for the ship routes using average environmental conditions, (2) identify the best sailing season for certain sea routes, and (3) identify areas within the Mediterranean Sea that are prohibitive for seafaring, e.g., due to high prevailing waves.

II. Related work

A plethora of work has already been reported for the design and development of tools for underwater cultural heritage and can be better categorized in terms of function [trade] and technique [nautical technology].

Trading: Apart from the ships themselves, shipwrecks are also key finds for the study of trade, trade routes and contacts, i.e. prominent subjects of interest in modern history and archaeology. Starting from the Bronze Age (e.g. [9]), the Mediterranean seaborne trade has attracted the attention of the scholars of all periods, from the early Iron Age to the end of the Byzantine period (see e.g. [10] and [11] respectively). Arnauds work ([12], [13]) on the analysis of ancient geographers, as well as Mortons ([14]) book on the environmental factors of seafaring in the Aegean, are fundamental, if we want to understand the variables that determine navigation and sea routes in antiquity ([15], [16], [17]). It is generally accepted, however, that the selection of sea routes is produced by complex interactions, such as winds, currents, topography, and seasonal weather patterns combined with technologies of shipping, propulsion and navigation ([18]), that drawing sea routes on the map is impossible (see Leidwangers [19] work on modelling distance with time in ancient seaborne connectivity) and that only commercial flux networks can be documented. With harbours as nodes of connectivity [20], Network Theory provides the tools for the creation of models based on quantified data, such as the intensity, the frequency and the dynamics of contacts [21].

Nautical technology: Seafaring is defined as the use of the sea for travel or transportation and constitutes a central research field in maritime archaeology [22]. Seafaring is broadly controlled by: (1) motivation, (2) environmental conditions, and (3) nautical technology [23]. Given an origin-only or an origin-destination harbour setting, the interaction of nautical technology and environmental conditions, i.e., the process of seafaring, is being modelled in a Geographic Information Systems (GIS) context using the notion of travel cost surfaces and least-cost path algorithms ([24], [19], [25]). Such models, however, use average conditions for winds and currents, and hence cannot be regarded as truly representative of the possibly extreme conditions that are encountered during sailing. Simulation approaches to seafaring provide a promising alternative to least-cost-path based analyses [26]. In this approach a virtual vessel embarks from a coastal location and interacts with the winds and currents according to its structural characteristics and the motivation and skills of the navigator. Simulation models of seafaring represent in a more realistic way complex human-environment interactions within the framework of agent-based models (ABMs); such models are increasingly adopted in archaeological scenario building [27].

III. The Seafarers

We designed and implemented a prototype for a serious game, named "The Seafarers", aiming at providing users with knowledge about seafaring based on real geospatial and archaeological data. The Seafarers game which takes place in the Mediterranean sea during the Classical period is a strategy game incorporating gameplay designed with the objective to allow the users to learn by playing, how ancient seafarers traveled the Mediterranean sea, traded goods, and enriched their cultures. It has been developed using Unity 5.6 and has been designed to support other devices such as tablets and mobile phones and desktops. As previously mentioned, this prototype game is part of a larger project whose goal is to raise awareness of European identity by focusing on maritime CH.

IV. Game Development Principles and Parameters

Below we describe the major game development principles and various parameters of the game.

The main idea is to develop a seafaring game which will enable the following: the public will become aware of the ships, sea routes and commerce in the Mediterranean, using extensive storytelling about commerce, harbors, ship engineering, sailing, etc. Available geospatial, archaeological and geo-political data of the Classical period are incorporated throughout the game in order to enhance the learning process through playing.

We have identified the target audience to be the general public, museum visitors, etc. Identifying the target audience dictated the choice for platforms which in this work are web browsers, touch-screen devices with iOS or Android operating systems, desktops with OS or Windows operating systems.

The setting for the game is the waters and coastal regions of the Aegean sea and the eastern Mediterranean. We have followed a participatory design process involving different stakeholders, interdisciplinary teamwork consisting of experts in maritime archaeology, game studies, education, cultural heritage and computer science, player centred design, iterative and incremental game development, integration of play and learning.

The objective of the game is to maximize wealth by carefully deciding cargo provisions and market destinations given different narratives.

Navigation is performed by allowing the user to plot the best course to mitigate risks posed by weather, piracy, and geographical hazards. Geospatial data including maps of (a) wind intensity and direction, (b) frequency of turbulent waters, (c) frequency of pirates are incorporated in the navigation engine. During the journey the player has to answer to grave threats and promising opportunities at sea and at anchor.

The game will take place in a simple environment and iconography with abstract stylistic elements of the Classical antiquity, presented in a bright, playful style. A mix of 2D and 3D assets, as appropriate for strategy-based games. This particular look and feel will allow the users to learn how ancient seafarers traveled the Mediterranean sea, traded goods, and enriched their cultures by playing as a merchant from the era.

We have implemented a generic game structure supported through appropriate component/tools to create different versions of the serious game specialized to new situations by authoring different non-linear narratives, geospatial regions, trading rules, commodities, cost factors, routes, etc. The game is stylized and accessible to players of all ages. The prototype version is specialized for the Map of the Mediterranean as shown in Figure 2 featuring ancient ports, and seafaring practices during the Classical period. These are based as accurately as possible on archaeological data.

A variety of different tools have been used for the design and development of the game. Although the game was developed within the Unity editor, Twine, an open-source narrative design tool, is what drives the content creation for the user-driven narrative portions of the game. Cradle, an open source Twine importer for Unity, forms the backbone of the game's narrative interaction system. Projeny is a package management tool for Unity which facilitated the incorporation, tracking, and maintenance of various internally authored plugins. Photoshop, licensed through the Creative Cloud service, was used as a both a planning and 2D asset production tool for many user interface elements. Audacity, another open source tool, was used to prepare many of the audio assets used for playback in the game.

A. Learning Objective

The learning objective of the game is to make the player knowledgeable about nautical/maritime practices during the Classical period and to learn about the sea routes, ship types, and commerce in the Mediterranean. The learning content is based on evidence reported by archaeological excavations both underwater and on-land which describe the geo-political context during that era, and reports on weather patterns and surging seas. We have selected prominent ports of the eastern Mediterranean for which there is sufficient archaeological documentation. Existing knowledge about the commodities, contacts and relations among the coastal trade centers under consideration is incorporated in the narrative.

B. Character Creation

At the beginning of a new session, the player is prompted to enter a name for their character and to select a home from a list of ports, as in Figure 1. Players are not restricted to any particular region of the map. The chosen port becomes the home port from where he/she will stockpile goods and launch trade voyages.

Ports: The following ports are included in this game: Chios, Corinth, Delos, Faliro, Heracleion-Thonis, Kition, Mende, Mytilene, Paros, Phalasarna, Piraues, Rhodes, Salamis, Samos, Sidon, Thasos and Tyre.

(a) Dropdown collapsed. (b) Dropdown expanded.

Fig. 1: Character creation interface.

Once the character creation process is complete, the player is equipped with coins, a modest fleet of trade vessels, and a stockpile of commodities to begin trading with. Furthermore, any insights attached to the player's home port are unlocked at this time, in order to support the fantasy that this is the city where their character lives and works.

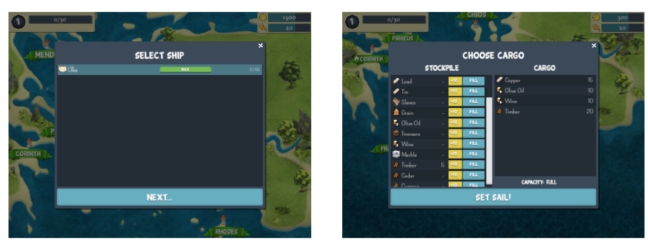
C. Map

In addition to serving as the player's window into the ancient era, the map view provides controls for inspecting foreign ports (green labelled banners) and active voyages (animated ships).

Fig. 2: Map interface.

D. Voyage Preparation

To prepare a voyage, a player must choose which of their available ships to send (Figure 3a), as well as what commodities from their stockpile it will be loaded with (Figure 3b). Each ship has a fixed cargo capacity, based on its class, that cannot be exceeded.



(a) Ship selection. (b) Cargo loading.

Fig. 3: Voyage preparation interface.

Because each ship is modelled individually, players may find themselves in situations where all of their ships are at sea. In this event, no new voyages will be possible until a ship has returned and become available again.

Ship Classes: The game supports 3 classes of ships as follows: Olkas (round ship), Merchant Galley and Trireme.

E. Trading

The trade window (Figure 4 is accessible by using the map control for a voyage that has arrived at its destination. Audio and visual cues are used to notify the player when a voyage has docked.

In the trade window, the player can choose which items in their ship's cargo to sell, as well as what quantities of commodities they wish to purchase and load back onto their ship for their return voyage. A label indicates the net value of the trade, which is paid out in coins. In addition to the +/- symbols prefixing the net amount, a graphical cue (tipped scales) indicates to the player whether the trade is favourable to them or not. The player can only demand as many commodities as will fit onto their ship.

Fig. 4: Trade interface.

Commodities: The game supports the following commodities; Cedar, Copper, Cypress, Fineware, Gold, Grain, Lead, Marble, Olive Oil, Silver, Slaves, Timber, Tin and Wine.

F. Tasks/Actions

The player has three main tasks during the game: (a) to gain insights into the local economies and cultures of distant harbors by exploring personalized narratives, and use these insights to inform his/her trading (Figure 5a, 5b), (b) to watch as his/her trade ships cross the seas, following routes just like the ones taken by ancient sailors, and (c) help his/her ships reach their destinations safely by responding to dynamic narrative moments and avoiding obstacles e.g. bad weather, war, etc which would otherwise negatively affect their trade.

(a) No insights unlocked. (b) All insights unlocked.

Fig. 5: Port interface.

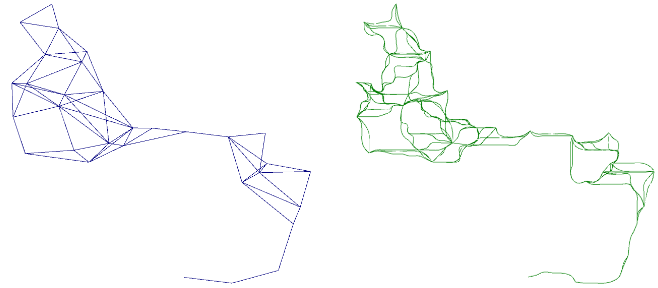


Fig. 6: Left: Trade network, with intermediate vertices where a direct voyage may not have been likely. Right: Interpolation of down-sampled edge paths, used to display voyages to the user in scaled time.

V. Development

A. Trade Route Finding

Voyages are planned using a two-tiered A*-based approach. First, a sparse graph of shore points (see Figure 6, left) is used to determine a conceptual route. For each leg of the conceptual route, a discrete grid is queried to find the best path across the surface of the water. Each grid cell stores its traversal cost, which is sampled initially from a high-resolution composite map which combines all of the necessary cost functions. The map in use at the time of writing is depicted, down-scaled, in Figure 7.

1) Generation of Composite Risk Maps: Mediterranean connectivity via shipping routes is a topic of major importance in the EU funded project iMareCulture. As part of this work we have developed a special software tool that facilitates the task of calculating ship routes through the eastern Mediterranean Sea. This software takes as input weather conditions, starting and ending point of a sea route, and returns the respective number of travelling days between the given points. Moreover, given only the starting point, the software returns the respective day isochores describing how far the ship may travel from the starting point in 1-2-3-4 etc days. Several assumptions mentioned in related bibliography [19] are exploited so far so as to implement this work. However these assumptions may change according to several factors. We have employed realistic weather conditions from real data provided for the area under study (Figure 7. Moreover, we plan to incorporate knowledge from naval engineers, regarding the achieved speeds related to wind speed and sea currents and make our assumptions more realistic. These assumptions will regard all available ship types such as the Kyrenia ship etc. Finally we plan to also release this software as a web service, available to everyone, requiring minimal GIS knowledge to run and provide usable results.

Using our software, a novel feature is the following: one can calculate all possible routes from any Mediterranean port to every other point of the same sea. Moreover, we will try to minimize all subjective assumptions present in related work: wind and sea currents will be taken from our day to - day database following therefore real weather changes, avoiding generic mean values of weather conditions, while ship behavior will be modeled using naval engineering approaches.

Fig. 7: Black: solid land. Grey: neutral. Fuscia: dangerous seas. Green: shoreline visibility break. Blue: shallow waters.

Paths queried from the discrete grid are reinterpreted as Hermite splines to produce more natural looking motion as ships are moved across the map. (Figure 6 right)

B. Storytelling

Branching narratives are a form of interactive storytelling often used in computer games [28]. Here the users can influence the flow of the story choosing among offered options. In our example (Figure 10), the user decides if he will allow a passenger to embark the ship. According to this decision, the story separates into two different branches.

For narratives creation we use Twine narrative design tool (Figure 9). Imported Twine stories are seeded using information about the player's unique session. Narratives might feature details based on the cargo, destination, port of call, or current map location of a given ship, as well as long-term player statistics.

Narratives can be triggered at various points throughout a voyage, or when some progression parameter is satisfied as shown in Figure 8.

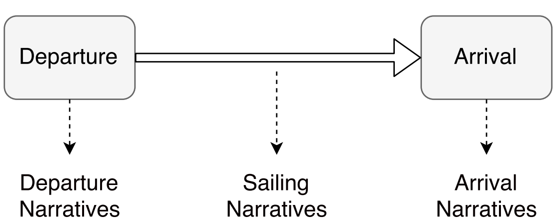


Fig. 8: Narrative triggers throughout a voyage.

Additional conditions can be used within Twine itself in order to perform further validation that a story should be presented to the user. If this validation fails, a custom escape command is used to indicate to the narrative manager that the story should not be shown to the user.

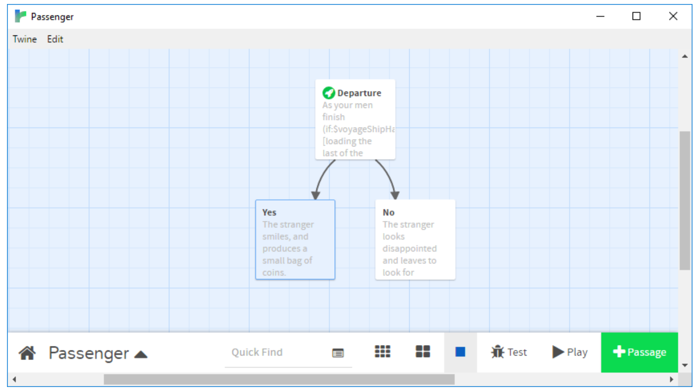


Fig. 9: Overview of a story in Twine.

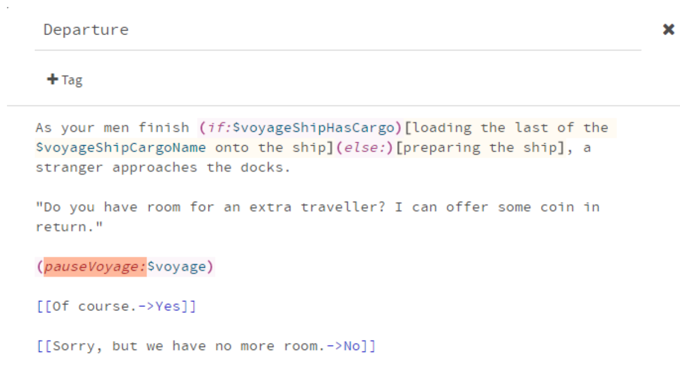


Fig. 10: Text editor for a story passage in Twine.

C. Economy and Trade

In order to make the gameplay more realistic we have developed a simplified economic model. The model allows for runtime changes in the economy e.g. fluctuations in prices, which coupled with the narrative can provide additional motivations for merchant actions. For example, the player is in one port and learns about a war in a neighboring state which has as a consequence the fluctuation in the price of commodities in the general vicinity or something like that. Thus, using the developed economic model allows for historically relevant narrative justifications for the experiences of the player in the game. If olive oil is one price in one place and higher or lower somewhere else then ideally the player should understand why e.g. prices might be lower in olive growing regions for instance.

D. Implementation Details (General)

Runtime Serialization. Since Unity's built-in serializer only operates on edit-time data, and mobile applications extend beyond the abilities of traditional serializers (users expect progress to be saved instantaneously, without any delay), a bespoke solution was required. Readers/writers are defined for low-level language types. Higher-level classes/structures are analyzed recursively, defining compound readers/writers that comprise all member variables. The resulting metadata can be used to read/write the serialized data for any member variable in O(1) time. Serialized data is written to binary files, each one storing any number of instances of a top-level structure.

Tweening. Unity's animation system has been mainly geared toward character animation requirements, making small UI related animations cumbersome to implement. For this reason, a tweening system was written to allow common animations to be played back using motion curves. Interruptions and other edge-cases situations are handled gracefully.

Text localization. Building a game with a target audience across several languages required at least some form of string localization. A simple table editor was implemented, with rows acting as string IDs, and columns representing one of the supported languages.

UI extensions. Unity's built-in UI components do not support the popular and powerful model view controller (MVC) design pattern or any other common UI architectures/patterns whatsoever. To address this, a collection of classes and interfaces was defined which would allow any existing code to be wrapped in a reactive/observable component, which could then be consumed by the custom UI components, which listen for and response to any changes in the data.

External assets In addition to many assets authored especially for the Seafarers game, permissively licensed images and sound files were sourced from the following repositories [29], [30], [31], [32], [33].

VI. Evaluation

At this phase, the prototype game has been evaluated by expert users, members of the research team, and is undergoing a final cycle of revisions based on the experts' comments and evaluations. An extended evaluation by potential game users will take place at a later time. In the experiment we wanted to assess both the usability of the game and the effectiveness of the game in terms of the learning objective. This was done through questionnaires which the experts had to answer after playing the game. Effectiveness survey involved 9 participants, and usability survey 15 participants.

A. Effectiveness

The questions were related to the content in the game and their purpose was to measure the knowledge acquired during gameplay. The research team conducting the experiments included computer science and human-computer interaction researchers. The experiments received approval by the University Research Ethics Committee.

Experts: The experiment involved three expert users from civil engineering and maritime archaeology.

Procedure: The participants, after playing the game, answered questions which assessed whether the learning objective "to learn about the ship routes, ship types, and commerce in the Mediterranean" was met.

Results: The consensus amongst the experts was that the information contained in the game relating to the ship types, geospatial locations and landmark insights were clearly portrayed in the game. Furthermore, they all indicated that the information about the commodities such as cost and each port's specialty commodity should be more emphasized.

B. Usability

The questionnaire contained seventeen (17) statements addressing visibility, feedback, ease of learning and user control. The participants were asked to evaluate the statements on the 5-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree". The statements were mixed, both positive and negative, and responses were translated into unified usability scale ranging from "Strongly Negative" to "Strongly Positive". The experiment involved 15 participants.

Results In order to identify weak and strong points, the distribution of responses was visualized as shown in Figures 11, 12. Questions with high percentage of negative responses identify weak points that need improvement. The recommendations are in compliance with the results of effectiveness evaluation: lack of more precise and visible information on commodity costs and voyage preparations made learning more difficult and decreased user satisfaction. The strong points identified were visibility of the status and the context of the player/ship.

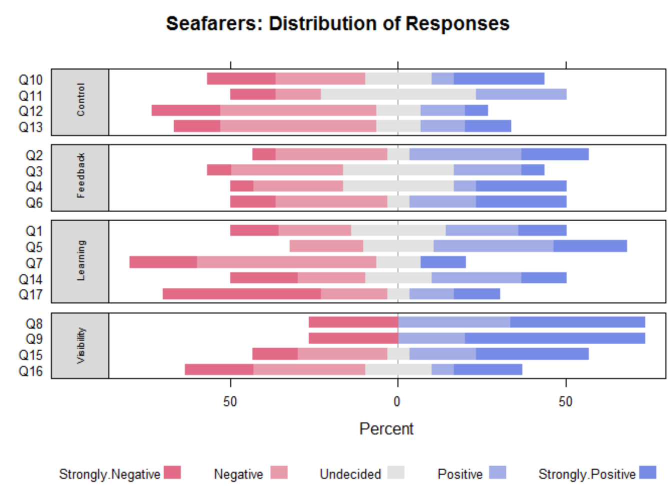


Fig. 11: Usability survey: distribution of responses (percentage).

VII. Conclusion

This paper presents the development process used in the creation of a multi-platform serious game called Seafarers along with its distinguishing features. The main purpose of Seafarers is to engage the public in the general theme of maritime archaeology and to provide them knowledge and insight into ancient seafaring practices. A distinguishing feature of Seafarers is that its design and structure are generic to support specialization to different situations simply by authoring and embedding new components like geospatial maps,

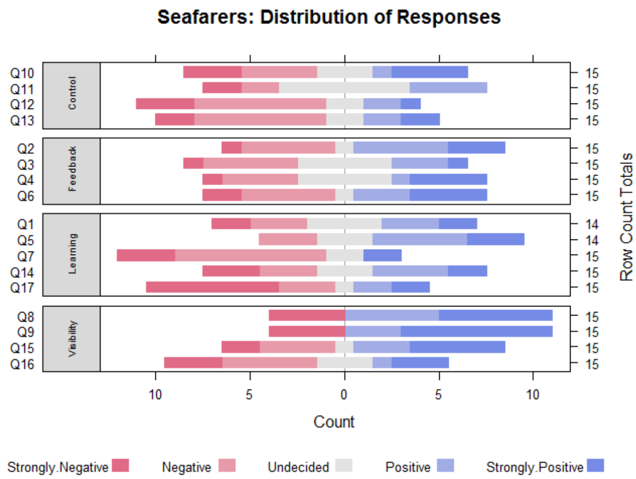


Fig. 12: Usability survey: distribution of responses (count).

ocean data, non-linear narratives, commodities, trade practices, etc. Specifically, the prototype incorporates seafaring practices in the Mediterranean during the Classical period, embedded with actual authenticated data provided by archaeologists, topographers, and cultural heritage specialists. It is this specialization capability which provides Seafarers the potential to become an excellent cultural education tool. Seafarers is also a very good example of successful multi-continental, multi-institutional and multi-disciplinary cooperation - civil engineers and archaeologists from Cyprus, Human Computer Interaction (HCI) and Educationists from Bosnia and Herzegovina, cultural sociologists and computer scientists from Canada and Czech Republic. Underwater cultural heritage education is part of this large EU funded project and the Seafarers serious game addresses one of the principal objectives and associated deliverable in the project. This extended cooperation among various stakeholders from different backgrounds has been one of the primary contributors to various innovative elements in Seafarers.

References

[1] Stella Demesticha. The 4th century BC Mazotos shipwreck, Cyprus: a preliminary report. *International Journal of Nautical Archaeology*, 40(1):39–59, 2011.

[2] Pierre Drap, J Seinturier, G Conte, A Caiti, D Scaradozzi, SM Zanoli, and P Gambogi. Underwater cartography for archaeology in the venus project. *Geomatica*, 62(4):419–427, 2008.

[3] Hanumant Singh, Jonathan Adams, David Mindell, and Brendan Foley. Imaging underwater for archaeology. *Journal of Field Archaeology*, 27(3):319–328, 2000.

[4] James R Wiseman and Farouk El-Baz. *Remote sensing in archaeology*. Springer Science & Business Media, 2007.

[5] Dimitrios Skarlatos, Stella Demestiha, and Stavroula Kiparissi. An openmethod for 3d modelling and mapping in underwater archaeological sites. *International Journal of Heritage in the digital era*, 1(1):1–24, 2012.

[6] Qing Gu, Kyriakos Herakleous, and Charalambos Poullis. 3dunderworld-sls: An open-source structured-light scanning system for rapid geometry acquisition. *arXiv preprint arXiv:1406.6595*, 2014.

[7] Irene Katsouri, Aimilia Tzanavari, Kyriakos Herakleous, and Charalambos Poullis. Visualizing and assessing hypotheses for marine archaeology in a vr cave environment. *Journal on Computing and Cultural Heritage (JOCCH)*, 8(2):10, 2015.

[8] Eike Falk Anderson, Leigh McLoughlin, Fotis Liarokapis, Christopher Peters, Panagiotis Petridis, and Sara De Freitas. Developing serious games for cultural heritage: a state-of-the-art review. *Virtual reality*, 14(4):255–275, 2010.

[9] Eric H Cline. *Sailing the Wine Dark Sea: International Trade and the Late Bronze Age Aegean Bar S591*, volume 591. British Archaeological Reports Limited, 1994.

[10] Richard Nathan Fletcher. Opening the mediterranean: Assyria, the levant and the transformation of early iron age trade. *Antiquity*, 86(331):211–220, 2012.

[11] Cécile Morrisson. *Trade and markets in Byzantium*. Dumbarton Oaks Research Library and Collection, 2012.

[12] Pascal Arnaud. *Les routes de la navigation antique: itinéraires en Méditerranée*. Editions Errance, 2005.

[13] Pascal Arnaud. Ancient sailing-routes and trade patterns: the impact of human factors. *Maritime archaeology and ancient trade in the Mediterranean. Oxford: Oxbow Books*, pages 61–80, 2011.

[14] Jamie Morton. *The role of the physical environment in ancient Greek seafaring*, volume 213. Brill, 2001.

[15] Tomislav Bilić. The myth of alpheus and arethusa and open-sea voyages on the mediterraneanstellar navigation in antiquity. *International Journal of Nautical Archaeology*, 38(1):116–132, 2009.

[16] Atholl Anderson and Katherine V Boyle. *The global origins and development of seafaring*. McDonald Institute for Archaeological Research, University of Cambridge, 2010.

[17] James Beresford. *The ancient sailing season*, volume 351. Brill, 2012.

[18] Thomas F Tartaron. *Maritime networks in the Mycenaean world*. Cambridge University Press, 2013.

[19] Justin Leidwanger. Modeling distance with time in ancient mediterranean seafaring: a gis application for the interpretation of maritime connectivity. *Journal of archaeological science*, 40(8):3302–3308, 2013.

[20] Johannes Preiser-Kapeller and Falko Daim. *Harbours and Maritime Networks as Complex Adaptive Systems: International Workshop" Harbours and Maritime Networks as Complex Adaptive Systems" at the Römisch-Germanisches Zentralmuseum in Mainz, 17.-18.10. 2013, Within the Framework of the Special Research Programme (DFG-SPP 1630)" Harbours from the Roman Period to the Middle Ages"*. Römisch-Germanisches Zentralmuseum, 2015.

[21] Carl Knappett. *Network analysis in archaeology: New approaches to regional interaction*. Oxford University Press, 2013.

[22] Alexis Catsambis, Ben Ford, and Donny L Hamilton. *The Oxford handbook of maritime archaeology*. Oxford University Press, 2014.

[23] Andrew J Dugmore, Andrew F Casely, Christian Keller, and Thomas H McGovern. Conceptual modeling of seafaring, climate, and early european exploration and settlement of the north atlantic islands. *The Global Origins and Development of Seafaring. McDonald Institute for Archaeological Research, Cambridge*, pages 213–225, 2010.

[24] George Indruszewski and C Michael Barton. Cost surface dem modeling of viking age seafaring in the baltic sea. *Beyond Illustration: 2D and 3D Digital Technologies as Tools for Discovery in Archaeology, International Series*, pages 56–64, 2008.

[25] JML Newhard, NS Levine, and AD Phebus. The development of integrated terrestrial and marine pathways in the argo-saronic region, greece. *Cartography and Geographic Information Science*, 41(4):379–390, 2014.

[26] Benjamin Davies, Simon H Bickler, and A Traviglia. Sailing the simulated seas: A new simulation for evaluating prehistoric seafaring. In *Across Space and Time: Papers from the 41st Conference on Computer Applications and Quantitative Methods in Archaeology, Perth, 25–28 March 2013*, pages 215–223. Amsterdam: Amsterdam University Press.

[27] Gabriel Wurzer, Kerstin Kowarik, and Hans Reschreiter. *Agent-based modeling and simulation in archaeology*. Springer, 2015.

[28] C.A. Lindley. *Story and narrative structures in computer games*. Sagas,Sagasnet reader. Munich, 2005.

[29] Kenney Assets. Kenney Assets. http://kenney.nl/assets, 2010. [Online; accessed 8-May-2017].

[30] Open Game Art. Open Game Art. https://opengameart.org/, 2015. [Online; accessed 8-May-2017].

[31] Free Sound. Free Sound. https://www.freesound.org/, 2005. [Online; accessed 8-May-2017].

[32] Icon Archive. Icon Archive. http://www.iconarchive.com/, 2017. [Online; accessed 8-May-2017].

[33] Assetstore. Assetstore. https://www.assetstore.unity3d.com/, 2017. [Online; accessed 8-May-2017].