



ARTour: an augmented reality collaborative experience for enhancing tourism

Menna Elshahawy¹ · Safa Magdy¹ · Nada Sharaf²

Received: 16 April 2023 / Revised: 9 August 2023 / Accepted: 11 August 2023 /
Published online: 25 August 2023
© The Author(s) 2023

Abstract

Serious games have been recently used for different purposes; a few of them have been developed to support cultural heritage purposes. Pandemics, for instance, change a lot in people's lives and cause some changes, such as social distancing and lower mobility. Additionally, individuals with physical challenges do not always have the opportunity to experience heritage sites as if they were there. Hence, arises the need for applications that encourage the precautionary measures required without totally isolating the users in similar conditions. The existing serious games in the literature have proven effective for teaching cultural heritage and enhancing tourists' experiences while at the heritage site. However, less serious games focused on giving the tourists a similar experience, but in the comfort of their homes. Therefore, this study discusses the design, development, and evaluation of ARTour. ARTour is a collaborative serious game that increases players' engagement and enhances the overall experience, without exposing them to danger during pandemics or similar situations. The player can choose between existing heritage sites, and a timeline, in order to get the full experience.

Keywords Cultural heritage · Tourism · Collaboration · Augmented reality · Virtual museums

✉ Menna Elshahawy
menna.elshahawy@guc.edu.eg

Safa Magdy
safa.ahmed@student.guc.edu.eg

Nada Sharaf
nada.hamed@giu-uni.de

¹ Computer Science and Engineering, The German University in Cairo, Cairo, Egypt

² Informatics and Computer Science, The German International University, Cairo, Egypt

1 Introduction

Serious games, also recently named as game-based learning (Ralf et al. 2016), are games that are not developed for only pure entertainment. Serious games always have another educational or therapeutic purpose (Michael and Chen 2005). Recently, they have been used for different purposes, including cultural heritage. Serious games for cultural heritage include games for teaching history, games for enhancing museum visits, and games for engaging children in the experience during the site's visit. The existing games have proven effective for teaching cultural heritage and enhancing tourists' experiences at the heritage site (Georgopoulos et al. 2017). However, few games have focused on giving tourists a similar experience in the comfort of their homes.

Recently, developers and researchers developed serious games using different, relatively new technologies, including but not limited to, Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR). Augmented Reality is a technology that can be defined as a system that fulfills three basic features: (1) a combination of real and virtual worlds; (2) real-time interaction; and (3) accurate 3D registration of virtual and real objects (Wu et al. 2013). In this way, AR alters the ongoing perception of the real-world environment by adding layers of virtual objects to the real environment. Multiple researchers even studied the prospects of using Augmented Reality to relaunch tourism after the COVID-19 pandemic is over. The systematic review expected that social distancing and reduced mobility would continue for some time, which shows that the need for mobile and web-based AR is increasing not just to ensure safety, but also to create more unique and personalized experiences (Mohanty et al. 2020). Authors also claim that AR has the potential to help in resuming safe operations after pandemics and similar situations.

The current state of research related to the area explored in this paper demonstrates the lack of serious games designed for cultural heritage with collaborative features between users. It has also been noted that most of the existing serious games that target cultural heritage are missing the collaborative experience for users, which is extremely important nowadays. Thus, in this paper, the design, the development, and the evaluation of an application called ARTour are discussed in detail. ARTour is a gamified collaborative platform for enhancing the experience of tourists via AR technology. Additionally, this study aims to investigate the proper techniques and strategies that are needed to develop an engaging collaborative experience for users in the context of cultural heritage education.

This paper is divided as follows: the following section includes details about similar applications to the focus area of this study and includes several serious games that were developed for enhancing tourism. In the section after, the design and implementation of the proposed platform are described in detail. The evaluation of the system is then discussed. This is followed by the results and discussion. Last but not least, the authors suggest some directions for future research and conclude the study.

2 Background

Augmented Reality is a technology that can be defined as a system that fulfills three basic features: (1) a combination of real and virtual worlds; (2) real-time interaction; and (3) accurate 3D registration of virtual and real objects (Wu et al. 2013). In this way, AR alters the ongoing perception of the real-world environment by adding layers of virtual objects to the real environment. Researchers stated that AR has not been used in an adequate amount in the tourism sector as it is new, complex, and technically resourceful. However, the most important reason that makes AR best for this study is the abundance of smartphone availability, as nowadays almost every person carries a smartphone that has the basic requirements for using the AR application presented. Additionally, there is much more potential for AR applications than those being used at the heritage site.

Researchers claim that Augmented and Virtual Reality technologies are placed in a crucial position in the new stage of innovative development in society, named Industry 4.0. The reason for this is that these technologies have both common and distinctive features, which is why companies use them in the process of relevant product creation. Virtual and Augmented Reality technologies involve the creation of thematically visualized content that can be used by the intended audience to meet specific needs through modern electronic devices (Iatsyshyn et al. 2020). The study (Iatsyshyn et al. 2020) differentiated between Augmented and Virtual Reality from the perspective that AR is a group of technologies that allow you to complement real-world images with different objects in a virtual environment. Unlike virtual reality (VR), which involves a completely artificially synthesized world (video series), AR involves the integration of virtual objects into natural video scenes.

ARTour is a gamified collaborative platform for enhancing tourists' experiences via AR technology. Additionally, this study aims to investigate the proper techniques and strategies that are needed to develop an engaging collaborative experience for users in the context of cultural heritage education. This paper is divided as follows: the following section includes details about similar applications to the focus area of this study and includes several serious games which were developed for enhancing tourism. In the section after, the design and implementation of the proposed platform is described in detail. The evaluation of the system is then discussed. This is followed by the results and discussion. Last but not the least, the authors suggest some directions for future research and conclude the study.

3 Related work

In recent years, a lot of researchers have exploited the use of serious games in the service of cultural heritage, education, and tourism. In order to educate people about heritage treasures and enhance their motivation to visit the tourist places and admire them, Georgopoulos et al. (2017) have constituted an attractive platform of three interconnected applications. The first application is the development of a serious game for the Ancient Agora of Athens, which has the purpose

of providing trivial information about the site in some form of a virtual tour. The second application is the development of a virtual museum for the Stoa of Attalos, which gives the user the opportunity to examine the exhibits from a closer perspective. The third application is a serious game for the Stoa of Attalos in particular. The first application works by allowing the user to have a virtual tour of the place accompanied by text about the history of the place, and then the user is redirected to a game consisting of multiple-choice questions about the text they just read. Authors try to overcome the idea of museums showing only a small part of their collections, as the rest of the collections are fragile and extremely valuable, as well as due to the space constraint. Thus, the virtual tour in the second application allows users to view and admire more pieces of monuments and thus enhance their cultural knowledge. Although the results showed that the presented applications included visitor-friendly environments and were easy to use while maintaining the accuracy and realism of the 3D models, no collaboration between users is enclosed in this application.

Researchers in Coenen et al. (2013) describe a case study on MuseUs, a pervasive serious game for use in museums, running as a smartphone application. The aim is to educate the users during their visit to a museum exhibition. The MuseUs project was conducted from a design research perspective. This research focused more on engagement and motivation than on learning effects. The central game mechanism is to allow players to match statements to art works while at a museum. According to the evaluation conducted for this study, and based on the feedback of users, younger users were more attracted to the application than their older peers. Additionally, researchers found that younger users who participated in this study would be more likely to visit the museum if an application like MuseUs was in use.

The aforementioned applications and several other AR applications (Lecllet-Groux et al. 2013), and VR applications (Skarlatos et al. 2016) did not enclose the collaboration between users. Thus, HoloCities, a shared reality application for collaborative tourism, has been recently presented by Iacoviello and Zappia (2020). Researchers stated that using the multiplayer feature will significantly encourage shared experiences and socialization in the tourism sector. The application uses the Microsoft HoloLens standalone device instead of the other Head Mounted Displays (HMDs), since it allows users to move freely without a connection to a laptop. Multiple users can collaborate when using the application to share ideas during a touristic place visit, or a tour guide might share the user's reality and holograms. Most of the users who participated in the study, believed that the application is intuitive and easy to use.

To this end, the existing work in the focus area of this paper indicates the potential of using AR technology along with the collaborative feature to enhance tourism. In this study, ARTour is a similar application to the aforementioned ones; nevertheless, it is a gamified collaborative platform that makes use of the smartphone's abundance nowadays. As discussed above, most of the applications either lack collaboration between users, can only be used during the site's visit, or employ expensive devices that are not available for most of the users. Additionally, in order to increase the engagement of users while using the platform, several game elements were included.

4 Proposed platform: ARTour

The goal of this research is to explore the effectiveness of an AR-gamified collaborative platform for enhancing tourism. As mentioned above, the social distancing regulations that arise with pandemics and severe situations and the physical challenges one might face call for newly developed solutions to overcome those challenges. Several technologies were inspected prior to the development of ARTour, including but not limited to VR and desktop applications. The former technology was excluded since the HMDs required by the VR applications are either extremely expensive and not available for most of the users or require being connected to a laptop.

4.1 ARTour design and implementation

ARTour consists of more than one mode to give the user a more vivid and unique experience. It includes the following modes; Adaptive Surroundings, Cultural Portal, and Trivia. Each of the modes mentioned focuses on an aspect that the authors target. The **Adaptive Surroundings** mode aims to increase the engagement of the player by exciting their curiosity when trying to convert the surrounding objects into objects from another era. The **Cultural portal**, which is the core of the application, aims to increase the knowledge of the users and allow them to collaborate with other players, while exploring different cultural sites. The last **Trivia** game lets the player answer questions about things they were exposed to during the first two modes. The authors believed that the competition between users and the leaderboard presented at the end would increase the engagement of the players and thus have the potential to educate them about heritage sites in an enjoyable manner. ARTour modes are described in the following sections.

4.1.1 Adaptive surroundings

The user chooses a destination and an era from a list of predefined destinations on the platform. The user can then view their surroundings in the style of the chosen destination and era. For instance, if Egypt was the chosen country and the era was the 1960s, the user could view the surrounding telephones as telephones from the 1960s. An example of this mode is shown in Fig. 1a, b. Figure 1a shows the real-world object, while Fig. 1b shows the object after getting augmented.

This mode was implemented using the Unity3D game engine and Vuforia SDK to recognize scanned objects and convert them to the desired era style. The system architecture for this mode is shown in Fig. 3a. As depicted in the figure, when the user scans the surroundings, objects are detected by the device's camera. The detected object is then sent from the camera module presented by the Vuforia SDK to the Image/Model Augmentation module, which is responsible for searching for the predefined objects in the database. When the object is recognized, the



(a) Current-form telephone

(b) Augmented 3D Telephone Model

Fig. 1 Adaptive surroundings

augmented 3D model is sent back to the module, which then converts the real-life object into a similar one with the style of another era.

Vuforia SDK offers the capability to detect both 2D (represented as images) and 3D (represented as models) targets. Both types of targets were used in this feature to cover most of the objects surrounding the user. Through Vuforia's developer tool, databases can be created to store the image targets, and then these databases are imported into Unity to be used in the scene, and accordingly, the proper augmentations can be added. For the 3D model targets, Vuforia SDK provides a model generator called Vuforia Model Target Generator, which is used to create guide views for the 3D models to be imported to Unity and hence can be used as model targets. Afterward, the model to be augmented is overlaid onto the imported model target to give the effect shown in Fig. 1b.

4.1.2 Cultural portal

In this mode, the user can choose one of the already existing touristic places, which are also predefined within the platform. The user can closely explore the site chosen. The user can also choose to see a gallery, which has a collection of the most famous paintings from the chosen city and era. Additionally, music and soundtracks that suit the user's choices are played in the background to increase player engagement. For instance, the user can have the chance to visualize what it is like to walk through Al-Moez Street in Egypt and pass by old Egyptian coffee shops with the soundtrack of Um Kulthumm's concert playing in the background. This mode also encourages collaboration between users. Each user can view and collaborate with the avatars of other players who chose the same destination and era (Fig. 2).

Fig. 2 Cultural portal: an ancient castle use case

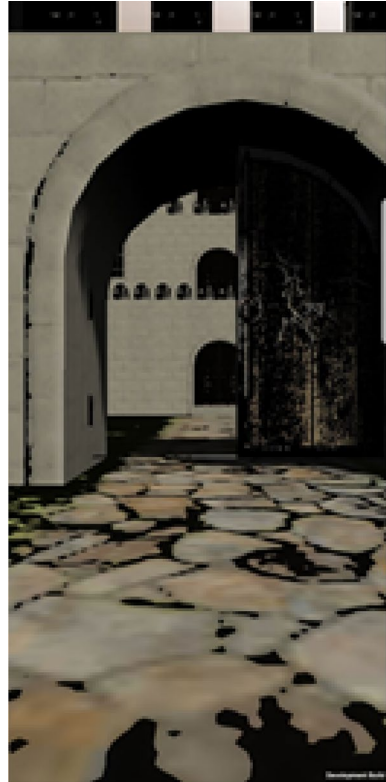
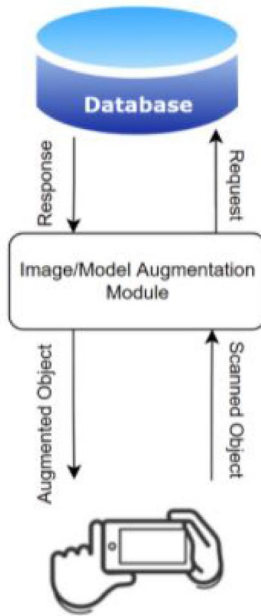
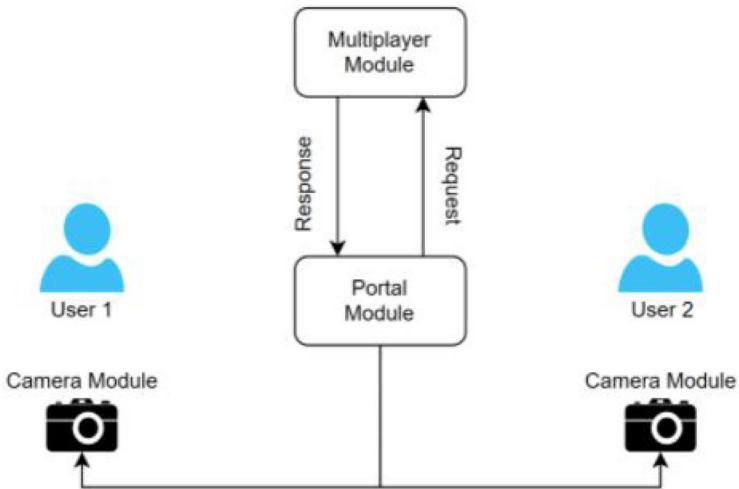


Figure 3b shows the system architecture for the multiplayer feature in this mode. Inside the scene, there are 3D models for the buildings and objects that the user can view, 2D images if needed in the gallery, and a 3D avatar that represents the user inside the scene. Through this feature, the user can walk through the scene using their smartphone by tilting the phone or the PC's keyboard. Both types of movements are supported in the application through Unity's predefined interpretation of the keys on the keyboard, or input.acceleration class that translates the mobile's orientation and axis of movement.

Concerning the multiplayer feature, it is implemented using Photon Unity Networking (PUN), which is a package imported into Unity to allow multiple users to enter the same scene at the same time. Through PUN, a room can be created with an app ID, and every user that has this app ID can enter the room under the matching rules specified in the photon script file. The matching conditions are specified during development, and they control the maximum number of users inside a scene. Using PUN, a separate avatar can be assigned to each user, and each user can control the movement of their own avatar. Furthermore, to allow the camera to follow the avatar's movement, the Cinemachine package is used. This is a package that creates a virtual camera that is attached to the AR camera in the scene and is instructed to follow the photon (avatar). Inside the photon script, it is specified that for each newly created photon, a Cinemachine camera is made to follow this photon's movement. In



(a) Adaptive Surroundings Mode



(b) Cultural Portal Mode

Fig. 3 System architecture

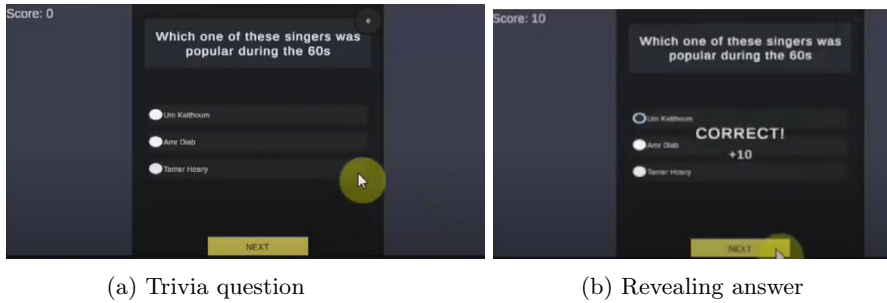


Fig. 4 Trivia example

a more elaborate manner, each user has their own camera that follows their own avatar. This is to avoid any confusion in the camera movement with multiple users.

4.1.3 Trivia game

In the portal scene, the user can press a Play button to be redirected to the next mode in the application, which is the trivia game. The trivia game is a small, serious game that is used in this application to provide users with knowledge about different cultural heritage sites in an entertaining manner. The trivia consists of a number of questions that vary according to the choice made by the user. The questions test the knowledge of users about sites and help add to their knowledge. This is inspired by what museums and tour guides offer to tourists during their visits to the site, such as brochures and talks about the history of monuments.

Although the trivia game presented gives the user the same idea, instead of presenting the information directly, the user will have it in the form of a competition. The competition resides in the idea of having the users and their peers play the same trivia, and then they can compare their scores to determine who gave the most correct answers. In order to ensure that the serious game adds to the cultural heritage knowledge of the users, whenever the user answers incorrectly, the correct answer is presented to them, thus enhancing their knowledge and admiration for the country's history. An example is shown in Fig. 4.

The serious game is a multiple-choice trivia game made to test the user's cultural knowledge and add to it. The trivia consists of a number of multiple-choice questions that are custom-made for each choice of country or age. Each question can have a timer to restrict the user to a certain time frame to answer, which makes the trivia more challenging. Furthermore, each question can have a score value, which represents the value that is added to the score in case the user answers correctly, or the value deducted from the score in case the user does not answer correctly. In the latter case, the correct answer is presented to the user in order to fulfill the application's goal of enhancing the user's knowledge of cultural heritage. After the user finishes answering the given questions, the final score is calculated, and then the user is directed to the leader board, which is the last scene in the application. The users who played together can view their rankings and compare the results.

During the design of ARTour, developers ensured that the application was flexible enough to be extended in the future. Thus, for instance, the use case of the ancient castle in the cultural portal mode can be changed to any other model. Furthermore, the trivia questions and the timing can be changed easily.

5 System evaluation

This project aims to present a new platform that helps tourists experience the heritage sites and enjoy the experience from the comfort of their homes. The platform employs two main features; the collaboration between users to explore places together and a gamified trivia game. Therefore, in order to evaluate the platform and compare it to other existing techniques and strategies, several tests were used.

5.1 Engagement level test

To ensure that ARTour is engaging for users, the engagement level test inherited from (Pearce et al. 2005), is used in this study. Engagement is the concept of how a person is committed to an activity. Several aspects define engagement. Those aspects include measuring fun, control, excitement, interest, attention and enthusiasm. The engagement test questionnaire evaluates the overall engagement of a user in a system through 11 points that can be answered on a five-likert scale. The questions for the test are shown in Appendix 1. The mapping used for this test is: “Strongly Disagree” = 1, “Disagree” = 2, “Neutral” = 3, “Agree” = 4, “Strongly Agree” = 5.

5.2 System Usability Scale (SUS)

Additionally to ensure that the system is easy to use, and is well integrated, the System Usability Scale (SUS) was used. SUS is also a standard test that has 10 questions that investigates the usability of the platform (Brooke 1996; <https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html>). The questions for the test are shown in Appendix 2. The questionnaire also can be answered on a five-likert scale and has the same mapping as the engagement test mentioned above.

5.3 Structured interview

Additional structured interviews were made with the participants of this study after using ARTour. The questionnaire includes 5 questions that compares 2 different methods that target cultural heritage education; the first one is ARTour and the second one is a video that presents the same information as the presented platform.

5.4 Evaluation phase 1

The evaluation was conducted through two phases: the first phase was during the development of ARTour. A preliminary study was conducted to help identify what users desire in such an application. A prototype for the idea of entering a different reality was investigated. The users were presented with a prototype consisting of the cultural portal scene only. The cultural portal contains a model of an ancient castle and the user can wander through the castle during the time it was built. In addition, the users were instructed to try “Google Arts and Culture”,¹ an application that allows the users to have a virtual tour in some of the currently present museums using the technology of AR. The goal is to identify whether the idea of entering a different point in history is amusing for users, to continue building upon it. Nine participants, who are all in the age range of 20–30 years old, tested the prototype and filled the engagement test.

5.5 Evaluation phase 2

For the second evaluation phase, participants were recruited randomly, their ages ranged from 21 to 30 years old. 18 users participated in the study, 10 of which were women and 8 men. Each participant had one session. Participants were asked to use the platform and watch a short documentary video that has the same information presented in ARTour. To ensure the reliability of the tests conducted, some of the participants watched the video first, and others used the platform first. When the participants started using the application, they were asked to use the three existing modes in ARTour in the correct order. Then, each participant filled both standard questionnaires mentioned above and answered the interview questions to get an impression of the presented platform.

6 Results

Evaluation phase 1 As mentioned in the previous section, this phase was only to ensure that the direction the authors considered is engaging for users, to build upon it, and to investigate the collaborative feature and AR technology more closely. The data collected from the engagement level survey reveals that users enjoyed the experience of the prototype. All the users were absorbed by the experience and found the activities interesting and enjoyable. None of the participants were bored by the activities presented during the application. This encouraged the authors to develop the remaining features mentioned in the design section and afterward conduct evaluation phase 2.

¹ <https://artsandculture.google.com/>.

Evaluation phase 2 Data was collected and analyzed in order to gain an understanding of the platform in terms of engagement and usability. The calculations and results of the tests used for this study are presented below.

1. **Engagement Level Test:** The collected data was analyzed, and the results showed that users find the platform engaging and enjoyable ($M = 90.1$, $SD = 8.7$). Additionally, participants mentioned that they enjoyed the adaptive surroundings' mode and were intensely immersed in trying to convert their surroundings to a different era's style.
2. **System Usability Scale (SUS):** The SUS yields a single number for each participant, representing a composite measure of the overall usability of the system being studied. The results were calculated based on the scoring method mentioned by Brooke (1996). As mentioned by Brooke (1996), the threshold for the test is 68. Thus, the average results of the test of participants ($M = 90.7$, $SD = 9.6$) reveal that ARTour is a usable and user-friendly platform.
3. **Structured Interview:** Almost all of the participants mentioned that they prefer ARTour over other methods like a written document or a video. Almost 70% of the participants believed that the application might be more informative than the used documentary video, since it is more engaging and enjoyable because of the trivia game included. Participants also stated that sharing the experience with peers motivates them to explore more about the culture. The application is recognized as an interesting method of learning about cultural heritage in comparison with regular informative methods such as documentaries.

7 Future research directions

There are a lot of ideas that can enhance the platform and need further investigation and a closer look. For instance, in order to enrich the collaborative experience, authors suggest embedding the ability to actually interact and talk with other players during the site's visit. Also, one of the features that might increase players' engagement is to allow each user to choose the shape and characteristics of their avatar to allow personalized experiences.

The authors are also in the process of developing a treasure hunt game in the Cultural Portal mode, where users can collaborate in teams to find treasures hidden within the sites. The Cultural Portal mode is to be enhanced by adding 3D models of more heritage sites. This would give the user the ability to explore more places to increase their knowledge and enjoy the experience. Another mode is to be added where an actual tour guide can take other users on a tour around different heritage sites. As mentioned previously, because of the flexibility of the platform, developers aim to have a flexible framework where users can add 3D models, soundtracks, or paintings of their countries.

8 Conclusion

In conclusion, ARTour is an application that aims to facilitate and enhance the collaborative touristic experience for users, as it allows them to become tourists from wherever they are. The application tries to fill the gap discussed in the related work section, which is allowing the users to become tourists without the need to be physically present in the touristic area or the timeline, and also be able to do this with friends. There are multiple features offered by the application to provide a vivid and interesting touristic experience, such as the option to change surroundings to suit the style of another country and the timeline chosen, which gives the sense of being present at that point in history. Furthermore, the portal scene gives the users the opportunity to walk through and explore popular places and enhance their knowledge while wandering in the gallery, where they can view information about famous people and places at that time in that country while listening to popular songs related to that country. Lastly, the users can compete together using the trivia game that is customized according to the choice of country, where they can test their knowledge of cultural heritage.

During the design of this game, several challenges were faced, such as choosing 3D models that are realistic to ensure that users are more engaged. Additionally, the collaborative experience between users was challenging and might be even more complicated with a larger number of users using the system simultaneously. Also, creating collaborative groups that can play or engage together should be based on several aspects, such as the language and the age range. For future studies, artificial intelligence and machine learning modules might be used for those purposes in order to enhance the overall experience of players.

A preliminary engagement test was performed to ensure that the application's idea is preferable to the users, and the results confirmed that. After the prototype was finished, another testing phase was conducted where the users were presented with the application versus a documentary to compare them and identify which method is more effective and enjoyable. An engagement test was conducted together with a system usability test and a comparison test to be able to cover all aspects of the application. The results showed that AR technology has potential in the tourism sector, especially if the collaborative feature between users is added. Additionally, the results show that a trivia game or a competition actually increases the engagement of users in an application that targets enhancing tourism.

Appendix 1: Engagement level test questions

1. I felt in control of what I was doing
2. I was absorbed intensely by the activity
3. I found the activities enjoyable
4. I thought about other things
5. I found the activities interesting
6. I was frustrated by what I was doing

7. The activities bored me
8. I was aware of distractions
9. The activities excited my curiosity
10. I knew the right thing to do
11. It required a lot of effort for me to concentrate on the activities.

Appendix 2: System Usability Scale (SUS) questions

1. I felt in control of what I was doing
2. I think that I would like to use this system frequently.
3. I found the system unnecessarily complex.
4. I thought the system was easy to use.
5. I think that I would need the support of a technical person to be able to use this system.
6. I found the various functions in this system were well integrated.
7. I thought there was too much inconsistency in this system.
8. I would imagine that most people would learn to use this system very quickly.
9. I found the system very cumbersome to use.
10. I felt very confident using the system.
11. I needed to learn a lot of things before I could get going with this system.

Funding Open access funding provided by The Science, Technology & Innovation Funding Authority (STDF) in cooperation with The Egyptian Knowledge Bank (EKB).

Declarations

Conflict of interest There are no conflicts of interest to be declared.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Brooke J (1996) SUS-A quick and dirty usability scale. *Usabil Eval Ind* 189:194
- Coenen T, Mostmans L, Naessens K (2013) Museums: case study of a pervasive cultural heritage serious game. *ACM J Comput Cult Herit* 6(2):8–1819. <https://doi.org/10.1145/2460376.2460379>
- Georgopoulos A, Kontogianni G, Koutsafis C, Skamantzari M (2017) Serious games at the service of cultural heritage and tourism. In: *Tourism, culture and heritage in a smart economy: third international conference IACuDIT*, Athens 2016. Springer, Berlin, pp 3–17

- Iacoviello R, Zappia D (2020) Holocities: a shared reality application for collaborative tourism. In: IOP conference series: materials science and engineering, vol 949. IOP Publishing, p 012036
- Iatsyshyn AV, Kovach VO, Romanenko YO, Deinega II, Iatsyshyn PAV, OO, K, G, Y, Artemchuk VO, Burov OY, Lytvynova SH (2020) Application of augmented reality technologies for preparation of specialists of new technological era
- Leclet-Groux D, Caron G, Mouaddib E, Anghour A (2013) A serious game for 3d cultural heritage. In: 2013 Digital heritage international congress (DigitalHeritage), vol 1. IEEE, pp 409–412
- Michael DR, Chen SL (2005) Serious games: games that educate, train, and inform. Muska & Lipman/Premier-Trade, Florence
- Mohanty P, Hassan A, Ekis E (2020) Augmented reality for relaunching tourism post-covid-19: socially distant, virtually connected. *Worldwide Hosp Tour Themes* 12:753–760
- Pearce JM, Ainley M, Howard S (2005) The ebb and flow of online learning. *Comput Hum Behav* 21(5):745–771
- Ralf D, Göbel S, Effelsberg W, Wiemers J (2016) Serious games: foundations, concepts and practice. Springer, Cham
- Skarlatos D, Agrafiotis P, Balogh T, Bruno F, Castro F, Petriaggi BD, Demesticha S, Doulamis AD, Drap P, Georgopoulos A, Kikillos F, Kyriakidis PC, Liarokapis F, Poullis C, Rizvic S (2016) Project ima-reculture: Advanced vr, immersive serious games and augmented reality as tools to raise awareness and access to european underwater cultural heritage. In: Ioannides M, Fink EE, Moropoulou AI, Hagedorn-Saupe M, Fresa A, Liestøl G, Rajcic V, Grussenmeyer P (eds) Digital heritage. Progress in cultural heritage: documentation, preservation, and protection—6th international conference, EuroMed 2016, Nicosia, Cyprus, October 31–November 5, 2016, Proceedings, Part I. Lecture notes in computer science, vol 10058, pp 805–813 . https://doi.org/10.1007/978-3-319-48496-9_64
- System usability scale (sus). <https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html>. (2013)
- Wu H-K, Lee SW-Y, Chang H-Y, Liang J-C (2013) Current status, opportunities and challenges of augmented reality in education. *Comput Educ* 62:41–49. <https://doi.org/10.1016/j.compedu.2012.10.024>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.