Auragame: A Case Study of a Zero Programming Augmented Reality Game

Luís Fernando Maia[1,2*] Willian Rodrigues[2†] Windson Viana[2‡] Fernando Trinta[2§]

[1]Federal Institute of Maranhão (IFMA), Campus Caxias, Brazil
[2]Federal University of Ceará (UFC), GREaT, Brazil

Abstract

In this paper, we present a study conducted to assess an Augmented Reality (AR) game called Auragame, developed using an AR platform (Aurasma) without software coding. The game was created to demonstrate the potential of AR authoring tools in developing usable and entertaining applications. Auragame proposes players to solve a set of enigmas by gathering facts in the form of augmented reality objects, spread throughout the environment. Additionally, Auragame requires users to handle physical objects and explore the real world through a set of tasks and challenges, thus revealing the possibilities for expanding game design and interaction. By developing and assessing Auragame, we claim that a game framework developed for people with little or no programming knowledge can be used to create fun pervasive applications by using AR features. We implemented a usability evaluation of the game with 20 users. Results indicate Auragame was considered entertaining by players and its game flow was proven to be intuitive.

Keywords: Augmented Reality; Location-based games; Game authoring tool.

1 Introduction

In the past few years, Pervasive Computing and Augmented Reality (AR) have received great attention from both industry and academia. Pervasive Computing aims at providing services and content for users in their everyday environment, according to the user context (e.g., location, access device and user's activity). Augmented Reality is a computer generated set of graphical information displayed over the user's view of the physical world. A myriad of games and applications have been developed exploiting these paradigms in numerous areas, ranging from viewing of 3D objects in teaching and guidance to complex location-based games[1][2][3].

Pervasive games represent a new age for both entertainment and interaction by extending the gaming experience out to the physical domain through combining hybrid interfaces, mobile device equipment, wireless networking, positioning systems, and context-aware technologies [4]. In recent years, pervasive games have achieved great popularity due to the technological advances of mobile devices. Currently, even low cost smartphones present GPS tracking, camera and network access, hence being capable of executing AR and pervasive applications.

Nevertheless, developing pervasive games presents challenging issues, since programmers have to cope with high turnover, cheating, heterogeneity of devices and platforms, network costs, and disconnections [5][6]. Likewise, designing pervasive augmented reality games is a difficult task since it may include Image Processing and Computer Graphics features. Authors of [7] enumerated a series of guidelines to assist in this process, and numerous works have been devoted to design or enhance frameworks, SDKs and authoring tools for building pervasive and augmented reality applications[8].

Authoring tools are widely used to ease the drawbacks in developing pervasive and augmented reality games. These systems focus on the game development with a small number of lines of code. Over the years, Authoring tools have been used successfully to develop numerous types of software. For instance, AR applications [9][10][11], ubiquitous games [12], mixed reality learning software[13][14], game-based training [15], among others.

Augmented Reality (AR) platforms are widely available on the Internet. For instance, Aurasma[1], Metaio[2], Total Immersion[3], Argon[4], and Wikitude[5], among others, provide tools to develop AR applications. Most approaches use an ordinary viewer for virtual objects, triggered by a specified object or event. This genre of software is known as AR browsers, and they usually consist of platforms or applications that allow users to bind virtual content (like images, videos, texts, etc.) to triggers (can be a marker, an ordinary picture, or even GPS coordinates). Once a user points the camera to a marker, or moves to a determinate location, the software renders the assigned virtual object on top of the scene captured by the camera. It is important to point out that most of these tools do not demand coding, therefore non-programmers can easily build interactive applications using AR technology.

We claim that AR platforms can be used by non-programmers to build fun and entertaining AR games. Therefore, this work builds on the following research question:

- Is it possible to successfully develop fully featured, usable, and amusing pervasive augmented reality games using AR tools with zero programming?

In order to answer the research question, we have developed and assessed a pervasive augmented reality game called Auragame. The game relies on marker based technology, and was designed to require users to move throughout the environment, searching for numerous augmented reality media. Therefore, Auragame uses only the camera for image recognition, and no GPS tracking.

Given its simplistic design, Auragame can be implemented in most AR platforms. However, likewise Figueiredo et al.[16], we have opted for using Aurasma[17] due to its widespread popularity, free availability, and for not requiring any programming knowledge.

The Aurasma platform is composed of an online content editor and an AR browser application available for iOS and Android devices. Although Auragame was developed by a team of Computer Science researchers, no coding was used since Aurasma only allows

*e-mail: luis.maia@ifma.edu.br
†e-mail: willianrodrigues@great.ufc.br
‡e-mail: windsonviana@great.ufc.br
§e-mail: fernandotrinta@great.ufc.br

[1]https://www.aurasma.com
[2]https://www.metaio.com
[3]http://www.t-immersion.com
[4]http://argon.gatech.edu
[5]http://www.wikitude.com

authors to graphically bind markers to AR content. Results indicate Auragame is considered entertaining, immersive, and easy to play.

The rest of this paper is organized as follows. After this introduction, Section 2 presents the plot of Auragame. In Section 3 we present the interactions and mechanics featured in this work. Section 4 introduces the game development methodology and the field trials carried on during development. In Section 5, we present the evaluation conducted to assess Auragame in terms of usability and entertainment, and discuss their results. Finally, in section 6, we conclude our paper and present future directions for our research.

2 The Game Plot

The game plot of Auragame is loosely based on Greek Mythology and Superheroes from comic books. It starts by introducing four heroes, which were trapped by Cerberus, a three-headed dog that guards the entrance of the Underworld. The players have to solve puzzles given by Cerberus to release the heroes. For instance, the first puzzle is a simplified adaptation of the enigma known as Einstein's Riddle[18], where players have to figure out the position, name, age, clothing color, weapon, arch enemy and the power of each hero, as depicted in Figure 1. Moreover, Cerberus has spread a collection of Auras throughout the building players are in. An Aura is a mystical energy carrying facts, and can be attached to objects, markers, and portraits of the real world. Therefore, players have to find Auras to compile relevant facts and solve the enigmas.

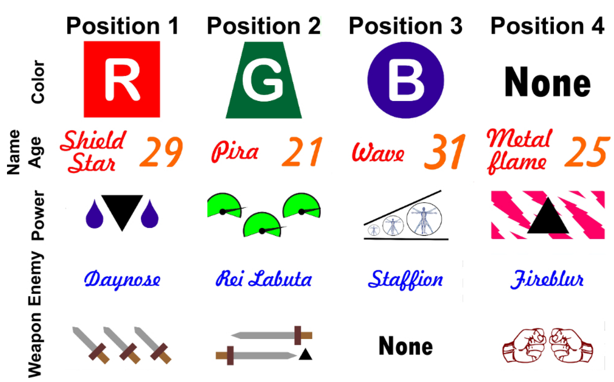


Figure 1: Figure showing the first puzzle completed.

An introductory video was attached to an initial marker, so players can be informed of the game plot, as well as how to find facts. In some cases, Auras provide tips to places and objects containing other Auras, so users have to navigate through the environment seeking such assets.

3 The Game Play

We have built the game play of Auragame on top of the interactions between markers and AR content. These different types of interactions give rise to a set of mechanics that form the game. Therefore, in order to understand the game play of Auragame, it is necessary to comprehend the functionality of each interaction and their corresponding mechanics.

Additionally, the content of an Aura can be composed of a combination of animated 3D objects, images, texts, videos, and sounds. Thus, compiling relevant facts to solve the enigma demands linking multiple media content. For instance, an Aura plays sounds of thunders while displays a message indicating a hero, so players have to deduce the hero has thunder as his power, and use that information to solve a piece of the puzzle. We expected the combination of such interactions would increase the immersion of players.

3.1 Interactions

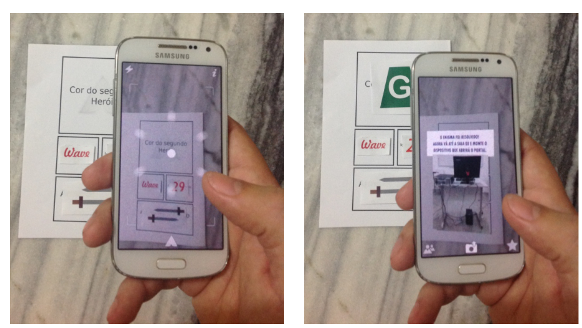
We have taken advantage of Aurasma's ability to recognize both ordinary markers and snapshots of real world scenes to explore multiple types of interactions. In this context, interactions can be understood as the way resources of the real world can be used to trigger AR content. Therefore, we have defined the following resources for interaction: (*i*) Explicit markers, (*ii*) Implicit markers, (*iii*) Assembled markers, (*iv*) Physical objects, and (*v*) Assembled objects.

Explicit markers are the most traditional and popular assets used in AR applications. In general, they are colored or black-and-white artificial images, hence they look unnatural to the environment as users have no trouble identifying them. In Figure 2 (a), a user inspects the content of an Explicit marker. We called Implicit markers, the man-made images found inherent in the environment. For instance, signboards, advertisement posters, wall paintings, etc. Since Implicit markers are part of the environment, their use increases immersion by embedding the game into the real scenario. Figure 2 (b) shows a signboard is used as an Implicit marker.

(a) (b)

Figure 2: Pictures of users viewing Auras of Explicit (b) and Implicit (a) markers.

Another important concept introduced by Auragame is the Assembled markers. In this case, users have to combine explicit or implicit markers to form another image, thus generating a new marker, as shown in Figure 3. In the game context, each individual piece of the initial puzzle has its own Aura, and the correct assembling of the puzzle builds a new marker, and thus a new Aura. For being flat images, explicit and implicit markers, as well as Assembled markers, are precise and easy-to-track by the image recognition algorithm.



(a) (b)

Figure 3: Assembled Marker. A user trying to trigger an Aura using an incomplete (a) and a complete (b) puzzle.

Snapshots of physical artifacts can also be recognized as markers by the image recognition algorithm. Thus, Auras can be attached to physical objects, such as, fire-extinguishers, trash cans, furniture, among others. This characteristic gives rise to the interactions called Physical objects and Assembled objects. The former is achieved by viewing a real world object from a specific angle, while the latter requires players to merge multiple physical objects to generate a new artifact to be tracked, likewise the Assembled markers approach. For instance, the game recognizes a table and its chair as an Assembled object only if they are joined together, so users have to arrange the objects correctly to observe their Aura. Figure 4 (a) presents a fire-extinguisher being used as a marker to trigger an Aura, while Figure 4 (b) shows a fully mounted computer as an example of an Assembled object. The assembled computer became a marker, which triggers a video using AR.

(a) (b)

Figure 4: Both physical objects (a) and assembled objects (b) can be used as markers.

There are some issues when recognizing Physical and Assembled objects, mostly caused because the recognition algorithm requires players to view the scene at a specific position and angle. To overcome such drawback, we have left messages indicating the appropriate points for viewing Auras of such artifacts. Moreover, as ordinary AR applications usually do not employ real objects as markers, both approaches were introduced in the last phases of the game, after users have experienced the possibility of interaction with the real world by viewing implicit markers and assembling a jigsaw.

The interactions introduced in this work can be adapted to other applications. We claim that schools, galleries, parks, etc. can host games similar to Auragame, or implement the interactions for other purposes.

3.2 Mechanics

The mechanics were designed based on the previously defined interactions, and can be defined as the necessary activities players must perform in the real world to accomplish an interaction. The first mechanic developed was called *World Exploring*, since it requires users to navigate through and explore the environment. The mechanic is introduced by some Auras attached to explicit markers. These Auras display pictures of signboards or present messages referring to specific places in where an Aura containing a relevant fact to solve the problem is placed. In this kind of activity, we make use of Implicit markers or Physical Objects interactions to attach Auras to signboards, immutable physical objects, or wall paintings, as shown in Figure 5 (a).

The second mechanic introduced by the game was called *Jigsaw*, and is achieved from the arrangement of ordinary markers in a particular way, so the application recognizes the final combined image as an Assembled markers interaction, thus displaying a new Aura. Auragame explores this mechanic after a team finishes the enigma, by selecting some pieces of the answer to form the desired jigsaw, as illustrated in Figure 6 (b).

Finally, a mechanic called *Object Assembling* was introduced. It starts when an Aura presents a picture of a fully built object and a message mentioning a constructing process. In this case, players have to find the dismantled pieces of the gadget, gather them up, and use the Assembled object interaction to visualize its Aura, as shown in Figure 7.

(a) (b)

Figure 5: Users viewing Auras (b) of implicit markers (a).

(a) (b)

Figure 6: Users exploring explicit markers (a) and assembling the Jigsaw to view its Aura (b).

(a) (b)

Figure 7: Players assembling a computer from its pieces (a) to view an Aura (b).

4 Game Development

Auragame is the result of enhancements on both usability and entertainment, compiled from the feedback given by users and the observations made by our staff, during field trials. The current version is composed by 35 Auras, of which 25 are associated with regular markers, and the rest is attached to wall paintings, physical objects and jigsaw. Regarding content, there are 20 Auras composed by simple messages and 15 Auras displaying audiovisual content, such as videos, sounds, and images.

The game was designed to be played in groups, where the group that first solves the puzzle is considered to be the winner. Hence, players of the same group collaborate meanwhile competing against players of other groups.

4.1 Scenario selection

Recognizing real world images and physical objects as augmented reality triggers is a key feature the proposed mechanics are based upon. Therefore, several tests using Auragame were conducted to assess its capability to successfully cope with the task. Aurasma's mobile application provides a method to evaluate whether an image or object is suitable to be detected by its image recognition algorithm. The software is very intuitive and easy to use, due to its focus on non-programmers.

We have opted to establish Auragame in a two floor building containing classrooms, snack bar, offices, and open areas. Thus, players have enough space to move around, as well as many physical objects to interact with. This indicates the game can be adapted to take place in schools, museums, universities, etc.

4.2 The Game flow

The game is divided into four sequential phases, named (*i*) Solving the puzzle, (*ii*) Assembling the jigsaw, (*iii*) Building the magic portal and (*iv*) Finding the final Aura. Each phase can explore one or more mechanics and interactions, as presented in Figure 8.

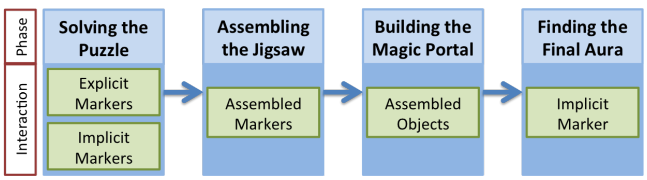


Figure 8: Phases of the game and their interactions.

The game starts by defining the groups and providing them a mobile device running the AR browser, a set of pieces that composes the puzzle, and a paper, so players can take notes if wanted. Each group has a single mobile device, so players within a group have to collaborate and forward synchronously, as shown in Figure 6 (a). The only explanation given to the users is that Auragame is an AR game composed by enigmas, the group that solves all enigmas first is awarded the winner, and a first marker is introduced. The aura of this marker contains a video detailing the background and motivation behind the game, followed by further instructions on how to use the mobile device to access Auras.

No additional information is given to the players, and they have to discover and experience the mechanics according to the demands of the game. In our trials, the markers were distributed evenly at each floor of the building, hence users had to move along the environment looking for explicit markers.

At first, the game is an augmented reality adaptation of the Einstein's Riddle, until new mechanics are gradually introduced by the game itself. For instance, when scanning an explicit marker, a message informing the information being sought is hidden in another place, followed by a picture of a signboard, as shown in Figure 9. Therefore, players have to explore the environment looking for that signboard, thus the World Exploring mechanic is introduced.

The introduction video roughly presents the Jigsaw mechanics, since it does not clearly mention the solved puzzle is also a marker. However, after scanning markers and real world objects to fully build the jigsaw, all players naturally pointed the camera to it, expecting to visualize its Aura. After solving the puzzle, a new phase starts by requesting players to assemble a real object. In this case, the Aura attached to the jigsaw indicates a place players have to go, and shows a picture of a personal computer, mentioning it has to be built in order to unlock its Aura.

The last phase is introduced by the Aura of the assembled object. At this moment, a video shows the portal being opened and a message informing the group has released the heroes. However, the message also says that, to completely defeat Cerberus, the heroes need to use the DNA of a magical elixir hidden in that very building, so the group must find it. This ultimate task is concluded once users find the drawing of a DNA in one of the many wall paintings of the building 5 (a). Finally, the game finishes by showing Cerberus locked and congratulating the group.

(a) (b)

Figure 9: Explicit markers (a) introducing the World Exploring mechanics (b).

It is important to highlight that all the phases of Auragame were implemented using exclusively the features available in Aurasma, and no coding was required during the entire process.

4.3 Implementation

The Aurasma platform is composed of two main tools, the content editor (a website that allows users to bind media to markers, manage channels, and add specific actions), and the mobile application (responsible for processing images from the camera and rendering the media content). The platform implements the concept of channels, which are a collection of markers and their corresponding media created by a user. Channels are subscribed by multiple users via the mobile application to access the content created on the website.

After selecting the objects and scenarios to be tracked, pictures of the markers and the media content were submitted to the Aurasma platform and compiled into a channel, as shown in Figure 10. This step is implemented via the content editor, where each trigger, in this case markers and pictures, was connected to a media content.

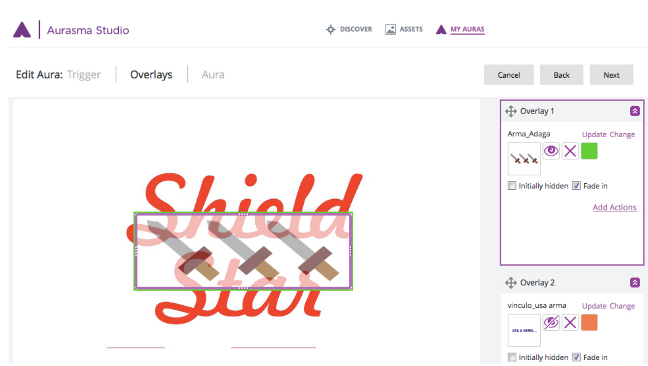


Figure 10: Markers and medias are bound using the content editor of Aurasma.

During implementation, we have noticed the image recognition algorithm is sensitive to changes in lightning, so a better feedback on what is being tracked would improve usability under such conditions. During our evaluation, players reported to have minor issues when detecting two of the markers. However, the application allows users to turn the flash on, which usually fixes the problem.

4.4 Field Trials

Pervasive and ubiquitous games represent a rather challenging area for Human-Computer Interaction researchers and cognitive scientists. The work of [19] discusses the most common challenges when evaluating Human-Computer Interaction on ubiquitous systems, while [20] claims evaluation trials are crucial in assessing the usability, playability and quality of experience aspects of pervasive game prototypes. Therefore, field trials planned to capture those factors are becoming common in pervasive games [21][22][23]. In this context, we have designed Auragame driven by an incremental process based on field trials, as an effort to reduce challenges during development and evaluation.

During Auragame development, three major trials were performed. The first trial comprised 20 players, divided equally into 4 groups, the second trial included 2 groups of 4 players, and the third trial was composed of 2 groups of 3 players. After each trial, players were invited to provide feedback regarding usability, entertainment, drawbacks and suggestions. These data were used to enhance the next versions, so forming an incremental development cycle.

The first prototype did not present all the mechanics and the game was played in a room with markers stuck on the walls. This version mainly focused on evaluating the difficulty level of the enigma, and the Explicit markers and Assembled markers interactions. After this trial, we have identified some markers presented issues to be correctly tracked, and the jigsaw contained too many pieces, thus the image recognition failed recognizing the whole jigsaw as correct. To overcome such problems, the inaccurate markers were replaced, and the jigsaw was simplified to require key parts of the complete answer.

In the second trial, the World Exploring and Object Assembling mechanics were added. In general, players were excited about these mechanics, and reported they expected more of them in the game. However, users suggested the messages requesting them to explore the environment should be more precise as they have had trouble understanding where to go or what to search for. Furthermore, players reported difficulty finding the correct position and angle to view Auras in physical objects. As a result of this trial, Auras indicating World Exploring mechanics were revamped to deliver clearer messages, present pictures of places or objects, and indicate the observation point for viewing physical objects.

The last trial was conducted with all the mechanics and improvements from earlier tests. In this release, sounds and videos were added to some Auras to increase immersion. After this trial, players reported the messages and objectives of the game were clear, the game flow was easy to follow, and they had no problem understanding the tasks. Also, they have stated that video and sounds drawn their attention and asked for more audiovisual facts.

The field trials proved to be vital to the success of Auragame development, since they led the design of new features and provided the necessary feedback to enhance intuitiveness.

5 Evaluation

A key contribution of this work is to demonstrate that usable and entertaining AR games can be developed using AR tools with zero programing. Therefore, after the field trials, an evaluation of Auragame was implemented aiming at measuring its usability and playability.

5.1 Participants

In total, 20 participants (17 male, 3 female), aging between 18 and 33, assessed Auragame. The group was composed of undergraduate students of a game development course, and postgraduate students of Computer Science, all selected by convenience.

5.2 Materials

All tests were conducted during the day, at about the same hour of the day, so as to avoid illumination issues. Each group received a configured device, running the AR application. In the tests, we used two Samsung Galaxy S4 mini and a Motorola Moto G. All devices presented similar performance during the activities.

5.3 Instruments

After finishing the game, players answered a questionnaire composed of 15 questions in the Likert scale and 2 open questions, in which they could leave their positive and negative impressions. The inquiries are based on the work of Savi et al. [24], and below we show a sample of 6 questions extracted from the questionnaire.

- Q1 - The game flow (its content, variation and tasks) kept my focus.
- Q3 - I stayed focused on the game and did not notice the time was passing.
- Q7 - I had fun with other people while playing the game.
- Q9 - The game is challenging, and its tasks are not too easy nor too difficult to perform.
- Q10 - The game evolves properly, presenting new challenges and varied tasks.
- Q13 - I will recommend this game to a friend.
- Q15 - The game is very different from any other I have played before.

5.4 Procedures

All groups were told they would have to discover and solve some enigmas, and that no further information would be provided. Each group was followed by an experimenter, who observed the players without interrupting their activities. The experimenter would only interfere to solve technical issues. For instance, to fix a problem with the mobile device.

5.5 Results

For the analysis, we have combined the five Likert responses (i.e., strongly agree, agree, neither agree or disagree, disagree, and strongly disagree) into three categories: agree, neither agree or disagree, and disagree.

During the tests, we have observed the usability provided by the game met our expectations, since 95% of users claimed to have never played a game like Auragame before (question Q15). Nevertheless, all teams have successfully managed to understand each phase, play all the mechanics, and finish the game with no further instructions. Therefore, the main goal of the evaluation was to ensure the game usability is satisfactory, and assess its entertainment.

Results showed all users agreed the game flow retained their attention (question Q1), and 90% of the subjects claimed to stay focused on the game and did not notice the time was passing (question Q3). These numbers reflect the series of incremental changes that were made according to the feedback gathered from early tests during the development phase.

Regarding the challenges presented by the game, roughly 80% of users stated that the tasks proposed were not too easy nor too difficult to perform (question Q9) and that the game evolves properly (question Q10). Moreover, some users suggested the game should have more tasks using World Exploring and Object Assembling mechanics, as they were considered more challenging and entertaining.

Results also indicate the game entertained most players, as all users claimed to have had fun while playing (question Q7), and 85%

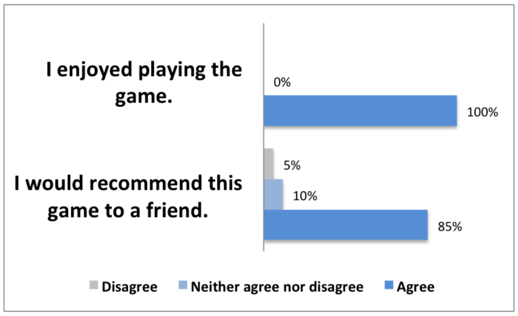


Figure 11: Results of entertaining questions.

informed they would recommend the game to a friend (question Q13), as shown in Figure 11. However, some key aspects revealed the need for improvements. For instance, Figure 12 shows that 35% stated the game immersion was not good enough, while 25% did not agree the tasks of the game presented an appropriate difficulty level.

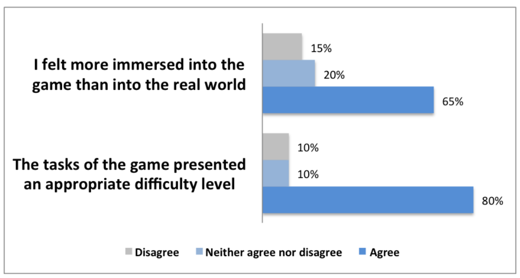


Figure 12: Analysis of immersion and level of difficulty.

In the open questions, players provided feedback to overcome the main drawbacks of Auragame. A third of users suggested to add a countdown to the game, claiming it would make the phases more exciting. Approximately half of evaluators recommended to increase the amount of audiovisual media in favor of reducing simple messages. In their opinion, the game videos and sounds should be present in most Auras, as they enrich immersion.

Since we expect to use this kind of game in school contests and gymkhanas, the survey presented questions to confirm whether players felt the game stimulated them to collaborate as a team and to compete against other groups. In this test, 95% of users agreed the game provides both collaboration and competition, as depicted in Figure 13.

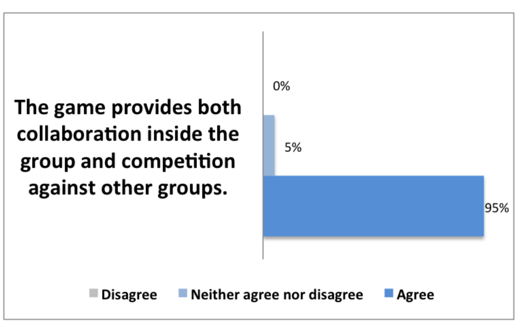


Figure 13: Auragame presents both collaboration and competition characteristics.

5.6 Limitations

Some players reported to have issues when viewing the Aura of physical objects, even when positioned at the correct viewing location. This happens because Aurasma's image recognition algorithm is sensitive to changes in illumination, especially in open environments. Therefore, further detailed data regarding the parts of a picture being tracked could improve image detection. Unfortunately, the focus of Aurasma on end users has driven the platform to hinder such level of configuration. Hence, this issue can prevent games from being played in some environments.

In one case, a mobile device presented issues loading the Auras after a software crash. When this situation occurs, the application requires Internet connection to download the game assets. The experimenter following the group replaced the device and the game continued.

A great limitation of Auragame is its dependency on orchestration. Benford et al. defines orchestration as techniques, human support (e.g., actors), and infrastructure used by developers to manage live game action behind the scenes [25]. According to the classification of pervasive games into generations proposed by Kasapkis and Gavalas [26], Auragame can be designated a second generation game for its use of recent technology and smartphones, although it presents first generation traits, namely heavy orchestration.

The great weakness originated by this heavy orchestration is the dependency of Auragame on the facility it was designed to be played in, and the demand of efforts to setup the game. For instance, developers have to place all explicit markers and arrange real world objects to be used in the game, thus to play Auragame at a different location implies repositioning all explicit markers and reconfiguring all real world objects in the platform.

For being students of Computer Science and Game Development, all users have advanced knowledge of games and computing, therefore they provided detailed evaluations of game features, interaction and flaws. This characteristic of the group impacted on the questionnaire, as the open questions provided better feedback. Consequently, new tests comprising participants from target populations (e.g., school students and museum users) must be conducted.

Although Auragame was developed by a team of Computer Science researchers, no coding was used since Aurasma only allows authors to graphically bind markers to AR content. Therefore, a future study must be conducted to assess whether games produced by users with no programming background using authoring platforms, such as Aurasma, can also deliver games with good usability and entertainment.

Another limitation of Auragame originates from the Aurasma platform, that was designed not to build AR games, but to work as an AR browser with customizable content. Therefore, the platform lacks game design and managing features, as well as game ruling and image recognition configurations. Such features can be provided in a similar platform to substantially broaden game authoring capabilities and improve marker detection without demanding programing skills.

6 Conclusion

In this work, Auragame was introduced and assessed to prove the potential of currently available AR tools for developing AR games with no software coding. The game was built through an incremental process based on field trials. We have presented concepts of mechanics and interactions for AR applications used in the game, as well as validated them through a study case experiment.

Tests were conducted to assess the entertainment and usability of Auragame, and the results indicate an affirmative answer to the proposed research question. Most users evaluated the game as entertaining, agreed to have fun while playing, and claimed to recommend the game to a friend. The usability of the game presented good performance, and despite most users claimed to have never played a game such as Auragame before, all groups have managed to complete the enigmas successfully.

Additionally, we state that this type of application can be successfully used in scholarly activities, like contests and gymkhanas. Auragame can be played in groups, and the analysis of data gathered from the case study shows the game presents an appropriate difficulty level, providing both collaboration within members of a team and competition against players of other teams. In the future, we expect to exploit these mechanics and interactions in varying environments and applications (e.g., schools, museums and parks). We plan to evaluate whether Auragame can be used as a template for non-programmers to build other games.

Additionally, the evaluation of the Auragame proves that a fun and usable AR game can be successfully built without coding by using only specific authoring tools. We believe this research lays the groundwork for the development of more advanced game authoring tools for users with non-programming background.

The greater flaws reported by users such as the lack of time management, image recognition issues, and further insertion of mechanics like World Exploring and Object Assembling, can all be solved by developing and using an authoring tool designed specifically for this type of game. We expect such tool can also provide a means to reduce or even eliminate the need for orchestration.

Finally, we believe AR is going to become even more popular due to the popularization of new devices and improvements in AR tools and SDKs. Auragame illustrates the capability of current technology, thus opening possibilities to apply the features presented in this work to many areas.

References

[1] E. FitzGerald, A. Adams, R. Ferguson, M. Gaved, Y. Mor, R. Thomas, W. Hall, and M. Keynes, “Augmented reality and mobile learning: the state of the art,” *11th World Conference on Mobile and Contextual Learning (mLearn 2012)*, vol. 1, no. 1994, pp. 62–69, 2012.

[2] G. F. Alves, E. V. Souza, and P. M. Sousa, “Realidade virtual e aumentada aplicada na educação na disciplina de química – rvaq,” in *Computer Games and Digital Entertainment (SBGAMES), 2015 Brazilian Symposium on*, Nov 2015.

[3] J. L. Lindemann and M. G. Malheiros, “Desenvolvimento de rpg usando realidade aumentada em dispositivos móveis,” in *Computer Games and Digital Entertainment (SBGAMES), 2014 Brazilian Symposium on*, Nov 2014.

[4] V. Kasapakis, D. Gavalas, and N. Bubaris, “Pervasive games research: A design aspects-based state of the art report,” in *Proceedings of the 17th Panhellenic Conference on Informatics*, PCI ’13, (New York, NY, USA), pp. 152–157, ACM, 2013.

[5] J. R. M. Viana, N. P. Viana, F. A. M. Trinta, and W. V. d. Carvalho, “A systematic review on software engineering in pervasive games development,” in *2014 Brazilian Symposium on Computer Games and Digital Entertainment*, pp. 51–60, Nov 2014.

[6] B. Wietrzyk and M. Radenkovic, “Enabling rapid and cost-effective creation of massive pervasive games in very unstable environments,” in *Wireless on Demand Network Systems and Services, 2007. WONS ’07. Fourth Annual Conference on*, pp. 146–153, Jan 2007.

[7] R. Wetzel, R. McCall, A.-K. Braun, and W. Broll, “Guidelines for designing augmented reality games,” in *Proceedings of the 2008 Conference on Future Play: Research, Play, Share*, Future Play ’08, (New York, NY, USA), pp. 173–180, ACM, 2008.

[8] C. Noleto, M. Lima, L. F. Maia, W. Viana, and F. Trinta, “An authoring tool for location-based mobile games with augmented reality features,” in *Computer Games and Digital Entertainment (SBGAMES), 2015 Brazilian Symposium on*, Nov 2015.

[9] M. Gandy and B. MacIntyre, “Designer’s augmented reality toolkit, ten years later: Implications for new media authoring tools,” in *Proceedings of the 27th Annual ACM Symposium on User Interface Software and Technology*, UIST ’14, (New York, NY, USA), pp. 627–636, ACM, 2014.

[10] J. Barbadillo and J. R. Sánchez, “A web3d authoring tool for augmented reality mobile applications,” in *Proceedings of the 18th International Conference on 3D Web Technology*, Web3D ’13, (New York, NY, USA), pp. 206–206, ACM, 2013.

[11] M. Shin, B.-s. Kim, and J. Park, “Ar storyboard: An augmented reality based interactive storyboard authoring tool,” in *Proceedings of the 4th IEEE/ACM International Symposium on Mixed and Augmented Reality*, ISMAR ’05, (Washington, DC, USA), pp. 198–199, IEEE Computer Society, 2005.

[12] E. Marchiori, J. Torrente, A. del Blanco, I. Martínez-Ortiz, and B. Fernandez-Manjon, “Extending a game authoring tool for ubiquitous education,” in *Ubi-media Computing (U-Media), 2010 3rd IEEE International Conference on*, pp. 171–178, July 2010.

[13] C. Orliac, C. Michel, and S. George, “An authoring tool to assist the design of mixed reality learning games,” in *21st Century Learning for 21st Century Skills*, pp. 441–446, Springer, 2012.

[14] H.-K. Jee, S. Lim, J. Youn, and J. Lee, “An augmented reality-based authoring tool for e-learning applications,” *Multimedia Tools Appl.*, vol. 68, pp. 225–235, Jan. 2014.

[15] A. T. Erdem, B. Utku, T. Abaci, and Ç. E. Erdem, “Advanced authoring tools for game-based training,” in *Proceedings of the 2009 Summer Computer Simulation Conference*, pp. 95–102, Society for Modeling & Simulation International, 2009.

[16] M. J. G. Figueiredo, J. Gomes, C. Gomes, and J. Lopes, “Augmented reality tools and techniques for developing interactive materials for mobile-learning,” in *13th International Conference on Education and Eductional Technology (EDU’14)*, pp. 63–72, 2014.

[17] H.-P. D. Company, “Aurasma - the world’s leading augmented reality platform.” `http://www.aurasma.com`. Accessed: 2015-06-02.

[18] J. Stangroom, *Einstein’s Riddle: 50 Riddles, Puzzles, and Conundrums to Stretch Your Mind*. Bloomsbury, 2009.

[19] C. Bezerra, R. M. C. Andrade, R. M. Santos, M. Abed, K. M. de Oliveira, J. M. Monteiro, I. Santos, and H. Ezzedine, “Challenges for usability testing in ubiquitous systems,” in *Proceedings of the 26th Conference on L’Interaction Homme-Machine*, IHM ’14, (New York, NY, USA), pp. 183–188, ACM, 2014.

[20] V. Kasapakis, D. Gavalas, and N. Bubaris, “Pervasive games field trials: recruitment of eligible participants through preliminary game phases,” *Personal and Ubiquitous Computing*, pp. 1–14, 2015.

[21] L. Chen, G. Chen, and S. Benford, “Your way your missions: A location-aware pervasive game exploiting the routes of players,” *International Journal of Human-Computer Interaction*, vol. 29, no. 2, pp. 110–128, 2013.

[22] R. Zender, R. Metzler, and U. Lucke, “Freshup—a pervasive educational game for freshmen,” *Pervasive and Mobile Computing*, vol. 14, pp. 47–56, 2014.

[23] B. Kirman, C. Linehan, and S. Lawson, “Blowtooth: a provocative pervasive game for smuggling virtual drugs through real airport security,” *Personal and Ubiquitous Computing*, vol. 16, no. 6, pp. 767–775, 2012.

[24] R. Savi, C. G. v. Wangenheim, and A. F. Borgatto, “A model for the evaluation of educational games for teaching software engineering,” in *Software Engineering (SBES), 2011 25th Brazilian Symposium on*, pp. 194–203, Sept 2011.

[25] S. Benford, C. Magerkurth, and P. Ljungstrand, “Bridging the physical and digital in pervasive gaming,” *Commun. ACM*, vol. 48, pp. 54–57, Mar. 2005.

[26] V. Kasapakis and D. Gavalas, “Pervasive gaming: Status, trends and design principles,” *Journal of Network and Computer Applications*, vol. 55, pp. 213 – 236, 2015.