Virtual and Augmented Reality interfaces in shared game environments: a novel approach

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Abstract. Augmented Reality (AR) and Virtual Reality (VR) have been usually addressed as two separated worlds and recent studies try to address the problem of merging the AR and VR applications into a single "environment", providing a system that relies on both paradigms. The constant release of new hardware interfaces for both wearable AR and Immersive VR opens up new possibilities for the gaming area and many others. However, even if there are researches that explore the usage of AR and VR in the same application, videogames are deployed for one environment or the other depending on their strengths and flaws and the type of experience they can offer to the player, in order to exalt the peculiarities of the chosen medium. A novel approach would be to provide a multiplayer system that enables the users to play the same (or similar) experience through either an AR or VR interface: the player could freely choose the interface, based on several factors such as hardware availability, environment, physical limitations or personal preferences. In this paper, a preliminary study on a multiplayer game system for both AR and VR interfaces is proposed. A chess game experience is provided and a comparison through a System Usability Scale (SUS) questionnaire allowed to establish if both interfaces provided a satisfactory game experience and to highlight both hardware limitations and further interface enhancements.
Keywords: Augmented Reality, Virtual Reality, Shared Environment.

1 Introduction

Since its definition in 1994 by Milgram and Kishino [1], the term Mixed Reality (MR) has been used to denote all the technologies adopted to merge the real world with virtually generated contents. Depending on the content which is more relevant in the Mixed Reality experience, it is possible to further distinguish between Augmented Reality (AR), used to define any case in which the real world is enhanced through virtual objects, and Augmented Virtuality (AV), used to describe a virtual world enriched with real video elements.

Overall, Mixed Reality and Virtual Reality (VR) are characterized by the presence (or absence) of the real world: for this reason, different types of interaction paradigms are adopted when deploying an application for one of these two technologies. Since Virtual Reality relies only on computer generated contents, the game experience and the interface aim at casting off the user into a fictional reality, detached from the real world. On the other hand, since Mixed Reality (and especially AR) environments are based on real world elements, the game experience is determined by the interaction of the player with the real world, whereas the virtual elements have the purpose of guiding the user and providing a feedback to its actions.

Among the diverse fields of use for both AR and VR, the entertainment industry has always covered a main role in the progress and improvements of these two technologies, due to the significative income of this industry [2] and the desire of videogame players to be part of the game [3]. AR and VR have numerous applications in the entertainment area [4-7] and most importantly they can be applied to create videogames [8-12].

Till now, AR and VR have been usually addressed as two separated worlds: videogames are deployed for one environment or the other depending on their strengths and flaws and the type of experience they can offer to the player, in order to exalt the peculiarities of the chosen medium. Even if the two interfaces are merged together into a single application, till now only two options are adopted: they are either used subsequently in a single player application to provide different kinds of interaction, or they provide different kinds of interaction to different users in a multiplayer environment.

In this paper, a preliminary study on a multiplayer game system for both AR and VR interfaces is proposed. The system enables the player to play the same game both with an AR, wearable device (the Microsoft Hololens) and an immersive, VR one (the Oculus Rift). A chess game experience is provided for both devices since the environment is not relevant to the game mechanics but only to the interaction model. A comparison between the two devices through a System Usability Scale (SUS) questionnaire allowed to establish if both the AR and VR interfaces provided a satisfactory game experience and to highlight both hardware limitations and further interface enhancements.

The paper is organized as follows: Section 2 briefly explores the state of the art of AR and VR for gaming. Section 3 analyzes what an ideal AR-VR framework should look like whereas in Section 4 our solution is described. In Section 5 the tests performed to compare the user interfaces are presented together with the results analysis. Finally, Section 6 provides the conclusion and possible future works.

2 State of the Art

First examples of commercial VR headsets for gaming can be dated back to the early nineties, such as the Nintendo Virtual Boy and the Virtual I-O iGlasses. Due to the huge improvements in computer graphic cards started in the second half of the nineties, the VR market was abandoned in favor of traditional videogames till 2010, when new, technological compelling hardware solutions for VR were released, such as the Oculus Rift, and later the HTC Vive. Until the mid-noughties, the technological progress kept AR as a domain for researchers, since costly, ad-hoc hardware was necessary for playing AR games. The release of smartphones, tablets and other wearable devices allowed everyone to possess an AR enabled hardware; at the same time, scientific researches on AR during the noughties explored and investigated computer graphic algorithms for

AR, leading to the concept of AR frameworks and toolkits, such as the ARToolKit[1] and the Metaio SDK[2]. Thus, with both hardware and software solutions for AR, the entertainment industry started investing in such technology.

First researches on AR for gaming can be dated back to the late nineties [13-14]. Human Pacman, presented by Cheok et al. in 2004, is probably the first attempt at merging AR and VR in the same experience [15]. In this outdoor game, one player embodies Pacman in his/her efforts to collect all the coins available through the level, whereas the other players represent the ghosts that try to stop Pacman. With all these players interacting through an AR, wearable interface, Pacman can rely on an external helper represented by a player that can watch and monitor the position of all the AR players through a VR interface. Epidemic Menace is another example of multiplayer system with players cooperating with both AR and VR interfaces, whereas the game mechanics, perspectives and interaction with other users change depending on the chosen interface [16].

Other recent studies try to address the problem of merging the AR and VR applications into a single environment, providing a system that relies on both paradigms. However, the proposed results can be classified in two categories: the first one comprehends all the applications that embody the Augmented Virtuality paradigm; these applications are usually experienced through Immersive Virtual Reality hardware. Clash Tanks is an example of this category, since the player is immersed in a virtual reality cockpit with a virtual monitor displaying real word camera input of a physical robot, enhanced through AR chassis' decorations [17]. The second category comprehends applications whose interfaces change between virtual and augmented reality depending on the game flow; these applications are usually base on handheld, mobile devices such as smartphones and tablets. Example of this approach are the driving safety game proposed by Vera et al. [18] and the Eduventure game proposed by Ferdinand et al. [19]. Overall, even if there are researches that explore the usage of AR and VR in the same application, a system which allows the users to play the same game with both an AR or a VR interface has not been investigated yet.

3 Shared Reality Environment Analysis

Linking the AR and the VR worlds, as if they are two overlapped realities, means to represent the same things seen from different point of views, generating new unexplored forms of interaction. Setting up a conjunction between an AR world and a VR one concerns at least three different issues: the creation of a proper connection; the development of different AR and VR interfaces; the analysis of the frame of reference.

A multiplayer-cooperative system requires the development of a reliable communication protocol. Since the AR player can freely move around in the real environment, a wireless system is expected. Moreover, players can be delocalized in different zones of the world, thus short-distance communication protocols, such as Bluetooth, are not suitable and a connection passing through the Internet is necessary. The most known

[1] ARToolKit, https://www.hitl.washington.edu/artoolkit/

[2] Metaio, https://en.wikipedia.org/wiki/Metaio

communication typologies are client-server and point to point. The choice of the protocol type strongly depends on the type of shared environment that has to be realized.

Interfaces represent one of the most critical aspects of an interaction system. In a shared reality environment different users that belong to either AR o VR should be able to interact using the interface that most suit their specific environment. The AR interface should offer a proper interaction with both the real world and the virtual one to establish a synergy between them. On the other hand, the VR interface has to allow the user to properly interact with the virtual world; the main difference with respect to the AR interface lies in that the VR user acts and moves in the real environment but his/her interactions occur only in the virtual environment. Moreover, since a shared reality environment is based on an interaction among two or more users, these interfaces have to exchange data in real time to ensure an efficient use of the system.

In a shared reality scenario, at least two different frames of reference exist: the system of reference of the AR user and the one of the VR user. While in the VR system the player is just placed in a global reference system, the AR system results to be slightly more complex. In order to augment the real world, data relative to position, orientation and scale of a target should be extracted. Once the system has acquired them, it is possible to generate at least two distinct systems of reference, called *target centered mode* and *camera centered mode*. In the first approach, when the target has been tracked, the target itself is placed in the origin of the global reference system and the player position is relative to the target. On the other hand, in the camera center mode, the player is placed in the origin and the target position is user-related.

To establish a link between the AR and VR system of references, it is possible to realize two different systems: absolute system of reference or distinct systems of reference. In the first system, only one frame of reference exists and therefore a reliable connection must be established to synchronize all the 3D models among the players (for instance, a client-server architecture). In the second configuration, the AR frame and the VR one are separated and the transformations are applied independently of the virtual assets in each reference frame. Only transformation's data are exchanged, thus a client-server architecture results to be redundant and a point to point connection could be preferred.

4 The Proposed System

It is unusual to think about an application, and more specifically a videogame, that is designed independently from the environment: even if the context or theme could be shared among virtual and augmented reality games, the game experience is mostly different. It seemed relevant to select a tabletop game for our research instead of a videogame for several reasons. Firstly, deciding otherwise would mean to select a game designed either for virtual reality and then to port it to augmented reality or the opposite: however, this choice would probably advantage the original experience versus the port; in some cases, it could even be impossible to provide the same experience for both environments. Secondly, the most famous tabletop games have been ported into virtual reality environment, such as Monopoly, Scrabble or Risk. Among them, chess seemed the most appropriate as a use case for multiple reasons: it is well known world-wide, it has already been used to research AR game interfaces (e.g. [20][21]) and it offers a strategic deepness that could allow to evaluate if and how the interface affects the game experience, whereas this could be less feasible with a more simplistic game. Lastly, since the developing of AR/VR videogames is still not widespread, it is not possible to find adequate references or guidelines to develop them from scratch. Thus, a well-known tabletop game consists indeed in a legitimate choice.

The aim is to compare two different interfaces in a chess shared gaming environment. Specifically, this shared scenario is composed by two users that can play using an AR device and a VR one. The VR user can interact with a virtual chessboard using an immersive virtual device, whereas the AR user plays with a real chessboard composed by real and virtual pieces, using an AR wearable device. It consists of a multi-user system: different players, using distinct interfaces, can exchange data interactively. In the subsequent paragraph, the configuration of this project is presented.

4.1 System Architecture

In a chess game, only the start and the end positions of the piece that it is going to be moved by one player have to be exchanged, thus the proposed system is composed by two different reference's systems that exchange data in real time on a socket connection. The transformations relative to the 3D assets (movement and rotations of the game piece) are applied locally in each system of reference. The proposed use case consists of two devices connected on the same LAN: an Oculus Rift DK2 Kit has been used for playing in the VR environment and the Microsoft Hololens[4] glasses have been used for the AR scenario. Since the AR user plays with the real chess board, an image target has been employed to correctly align the virtual assets on the game grid. The software architecture has been realized using Unity3D as IDE. In addition, the AR application has been developed using three external libraries: the MixedRealityToolkit-Unity[5] for managing the interaction, the Vuforia library[6] for the target detection and the LiteNetLib[7] library for the socket communication. The VR application has been developed using the SteamVR Plugin[8] to get access to the Oculus Rift DK2 hardware.

4.2 Game Play

The VR user visualizes and interacts with the 3D assets. Specifically, with a virtual chessboard and the virtual chess pieces. Differently, the AR user interacts with his real pieces against the virtual representation of the enemy pieces.

The AR user is the white player while the VR user is the black one. At the beginning of the game, the AR player moves, changing the position of the real white piece. At the same time, the virtual representation of the corresponding white piece is moved on the

[4] https://www.microsoft.com/it-it/hololens
[5] https://github.com/Microsoft/MixedRealityToolkit-Unity
[6] https://developer.vuforia.com/downloads/sdk
[7] https://github.com/RevenantX/LiteNetLib
[8] https://assetstore.unity.com/packages/templates/systems/steamvr-plugin-32647

VR application, thus the two environments remain aligned. When the VR user plays moving a black virtual piece, the corresponding 3D piece is moved in the AR application on the real chessboard.

4.3 Interfaces

Since users play the same game using two different systems of interaction and visualization, two different interfaces have been developed. Nevertheless, the sequence of interactions is identical for both the environments (VR and AR) and it is represented by the following work-flow: piece selection and piece movement.

VR Interface The Oculus DK2 does not provide any form on interaction, thus an XBOX 360 joystick has been added to properly interact with the game. Several on-line chess games[9] allow the user to select and move the desired piece without occluding the remain pieces. In addition, when the piece has been selected, the available moves are highlighted on the chess board. In order to achieve this behavior, it is possible to utilize the user's gaze to interact with the chess board. Firstly, a ray-cast is performed, starting from the center of the virtual camera. Then, when the ray-cast hits a tile of the virtual chess board, the tile is highlighted in yellow and a small 3D cube (called cursor) is rendered at the hit coordinates. To select a piece, the user has to look to the tile containing a movable piece, highlighting it, then he/she can select it using the "A button" on the joystick. Then, the available moves for the selected piece are shown on the chessboard, highlighting the corresponding tiles. If one or more of the available moves intersect an enemy piece, that specific tile is highlighted in red. The user can then select the final tile and , the corresponding piece is moved when the "A button" is pressed.

Since in the AR experience the player could freely move around the real environment to change his/her view point, the same feature was added through the software to the VR interface: the user can freely rotate the chessboard around the global y and x axes to analyze the game field from other perspectives. Moreover, since several chess games offer either a single top view to visualize the entire game board or a 45° view, both have been made available to the user through shortcuts.

AR Interface The AR interface is composed by three different layers: gaze layer, gesture layer, and sound layer. The gaze layer manages the interaction with the tiles of the chessboard. Although the main functioning is the same as the gaze of the VR interface, there are some differences. Firstly, the AR user is interacting with the real chessboard, thus it has been necessary to instantiate a virtual chessboard aligned with the real one but invisible to the user. In this way, when the ray cast hits the virtual hidden chessboard, a 3D cursor is rendered on the real chess board and the corresponding virtual tile is highlighted, correctly aligned with the real one. In order to establish a connection between the real piece and its virtual representation, a mechanism to synchronize the real move and the virtual one must be pursued. The Hololens glasses is capable of recognizing two gestures, the air tap and the bloom gesture. Taking advantage of this capability, a connection between the real piece and the virtual one can be established: firstly, when a tile containing a real movable piece is highlighted, it can be selected

[9] https://www.chess.com/, http://www.chesscube.com/

using the air tap gesture and the available moves are shown on the real chess board. If one or more of the available moves intersect an enemy piece, that specific tile is highlighted in red. Then, the VR interface receives the data regarding the piece that is going to be moved. Afterwards, the AR user, moving the 3D cursor on an available tile, can select it performing another time the air tap gesture. Finally, the VR interface receives the data regarding the final position and the virtual piece is moved in the VR application.

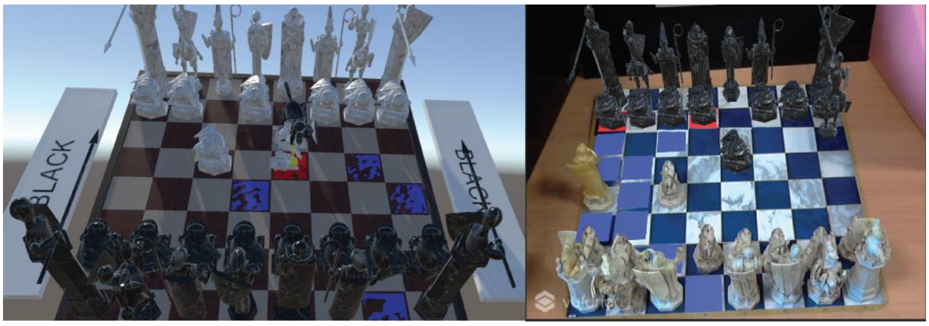

Figure 1: in both environments, when the player has to move the piece, the available moves are shown on the game field.

To complete the synchronization, the AR user has to physically move the real piece on the tile selected during the procedure described above. In order to ease this action, a pre-recorded voice informs the user to move the real piece. Moreover, the user can activate or deactivate a virtual green grid overlapped on the real chessboard to better understand the position of the virtual pieces. To exploit the virtual models and to improve the entertainment of the players, animations have been used to represent the attack and the “death” of the virtual 3D pieces. Animations have been widely used to enhance the game experience, they can convey emotions, motivations and intentions to viewers [22]. Finally, a side user interface is provided in both environments to inform the user about the identity of the current player. Fig. 1 shows the AR and the VR interfaces.

5 Tests and Results Analysis

In order to compare the usability of the AR and VR interfaces, some tests have been held at the Politecnico di Torino. Users were either master-degree students, Ph.D. student or research assistant of the Computer Science Department. Twenty volunteers took part in the test, 12 men and 8 women, with ages that ranged between 21 and 34 years. Testers have been divided into 10 pairs, and each player tested both interfaces. A questionnaire has been created and proposed to the users, using the System Usability Scale (SUS) [23] ranked with a five *Likert scale*. The questionnaire was divided into three different sections: the first one was about user’s information, whereas the second and third sections were composed by SUS questions to evaluate either the VR or AR interface.

To illustrate the procedure of the test, we refer to the two users participating one test session as user A and B. Each user was randomly assigned an interface (e.g., the AR one for user A and the VR one for user B). Then, both testers started playing a training session to properly understand the interfaces and the interaction paradigm. When the users feel ready, they could start a proper chess playing session, lasting 10 minutes. At the end of the session, each user had to complete the SUS questions related to the adopted interface (either the AR or VR one). Then, the users had to swap interfaces, play another training session to understand the interfaces functionalities and finally start another chess playing session of 10 minutes. Finally, each user had to complete the SUS questions related to the adopted interface (either the AR or VR one).

Tests have been evaluated with a number of participants (20) too small to obtain results with statistical validity. Despite this, the proposed study can be suitable to lay the foundations for future developments. The average score of each question and the final SUS score has been calculated using the procedure illustrated in [23]. Overall both interfaces have been evaluated to more than good on the SUS score scale (Fig. 2), so it is reasonable to consider the interfaces deployment through the proposed framework successful. However, since the AR interface has obtained a lower score, it would be useful to understand how to improve it in order to obtain a score comparable with the VR interface.

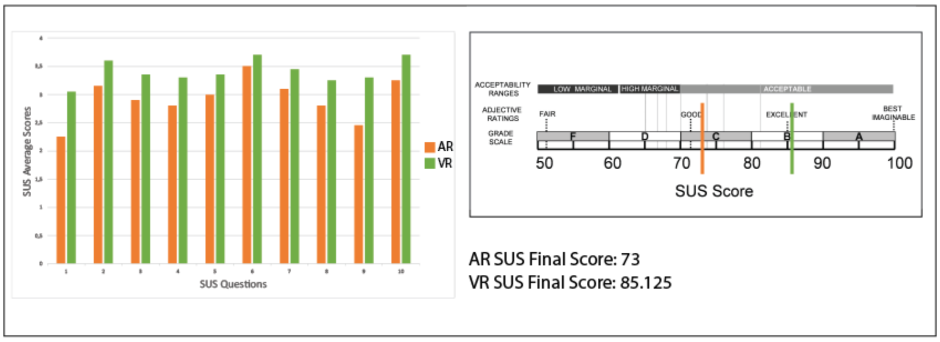

Figure 2: The SUS average score of each question (on the left) for the AR (orange) and VR (green) interfaces. The SUS final score (on the right).

One can identify several problem classes: Hardware related problem, Interaction problem and Visualization problem. The first issue is related to the AR device: since the HoloLens glasses have a very limited field-of-view (FOV) that is around 35°, testers could not watch the entire chess board at a time and they were forced to change their point of view. Moreover, the FOV limitation did not allow users to clearly detect the moves of the VR opponent. Thus, the AR player sometimes could not see that a move had been made, so he couldn't follow the game flow anymore.

The underlying reasons of the second problem can be related in a weak link between the virtual environment and the real world. In fact, the AR input modality forced the user to interact at first with the virtual world and then with the real one. It is conceivable to presume that this “double” interaction has required a substantial cognitive workload that has obliged the user to focus only on the interaction and not on the game itself. Moreover, some users had trouble executing the tap gesture to select the game pieces.

The last issue is related to the difficulty of perceiving the depth on the game field. When a virtual game piece was covered by a real one (or vice versa), the AR user was not able to realize which piece was in front of the other, forcing user to change his/her position to inspect the game board from a side view. The purpose of the virtual grid was to reduce this issue, but it was used only by two players, thus it is not possible to ascertain its effectiveness.

6 Conclusions

In this study, a novel, multiplayer game system for both AR and VR interfaces that allows players to experience the same (or similar) experience has been proposed. In order to assess the effectiveness of the system, a usability comparison between an AR interface and a VR one has been proposed. Prior works have come up with AR and VR based interfaces that are part of the same game. However, interfaces and functionalities are developed based on the specific characteristics of the input/output hardware, thus the provided game experiences are substantially different between AR and VR.

The same game experience can be conveyed to different users that are playing using different interfaces. Both interfaces have been deemed suitable for interacting with the same contents. Notwithstanding the interfaces belonged to different environments, the same functionalities were given. If for a given environment it is possible to obtain a specific interaction thanks to the software, in the other one the same interaction can be obtained thanks to the hardware. Moreover, this study suggests that it is possible to establish an effective communication between an AR and VR worlds if the experience content is independent of the hardware. Finally, the test results prove that both the overall system and the proposed AR and VR interfaces are suitable for a shared game experience. Future developments will be focused on integrating the automatic SquareOff [24] chessboard to avoid the “double” interaction of the AR player.

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