Investigating the Main Characteristics of 3D Real Time Tele-Immersive Environments through the Example of a Computer Augmented Golf Platform

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ABSTRACT

This paper aims to identify and define the characteristics of 3D Real Time Tele-Immersive Environments (RT-TIE), which is central to the 3D-LIVE European Research Project. A RT-TIE allows a "twilight space" which is a space where users can be physically and virtually present. The main characteristics of these kinds of environments are: the use of real time interactions and immersive technologies, high costs (in most of the cases), a design process oriented on end-users and a disruptive user experience. Finally, a list of guidelines based on literature is suggested for the design of an augmented golf platform that is implemented in the context of the 3D-LIVE project.

Categories and Subject Descriptors

H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems – *artificial, augmented, and virtual realities.* H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *User-centered design, Input devices and strategy, Evaluation/methodology, Graphical user interfaces.* H.5.3 [**Information Interfaces and Presentation**]: Group and Organization Interfaces – *Web-based interaction.*

General Terms

Design, Experimentation, Human Factors, Measurement, Performance, Theory, Reliability.

Keywords

Mixed Reality, Sport, Simulation, Interaction.

1. INTRODUCTION

Many publications deal with virtual reality and augmented reality. However, there are other dimensions as outlined in the continuum of Milgram (Figure 1).

This paper focuses on the concept of "Mixed Reality" (MR).

Designing a MR environment specifically involves Virtual Reality (VR), Augmented Reality (AR) and Augmented Virtuality (AV) technologies. In other words, one could deduce that MR environments are necessarily in real time and tele-immersive for supporting interactions among users [22].

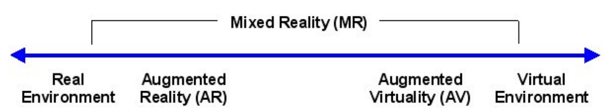

Figure 1. The reality-virtuality continuum by Milgram[1]

The aim of this paper consists to identify the main characteristics of a Real Time Tele-Immersive MR Environment. This is done through the illustration of the 3D-LIVE European Research Project and especially the augmented golf use case. This project investigates and develops a Real-Time Tele-Immersive platform that is co-created with users and evaluated through the assessment of both Quality of Service (QoS) and Quality of Experience (QoE) [16].

This paper is organized as follows. The next section provides a definition of Real Time interaction and Tele-Immersive environment within Mixed Reality. The third section identifies several characteristics for designing systems based on these technologies. The fourth section describes the 3D-LIVE platform example in which the characteristics must be integrated.

2. DEFINITION OF REAL TIME TELE-IMMERSIVE (MR) ENVIRONMENT

According to Milgram and colleagues [1], the term "mixed reality" refers to the creation of a space where users can be physically and virtually present while sharing interactions, emotions and experience. When the MR environment is located at the frontier between AV and AR [2], it becomes a "twilight space", mimicking the frontier of either the dawn or the sunset, between night darkness and daylight and vice versa. A MR platform is composed of technologies capable of bringing virtual objects in the reality and real objects in the virtuality.

A VR application is a computer simulation of real or imaginary environments that is interactive, immersive, visual, audible and / or haptic,. Its purpose is to propose to one or more person(s) a

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sensorimotor and cognitive activity in an artificial world, digitally created, which can be imaginary, symbolic or a simulation of some aspects of the real world [3]. To do so, the virtual reality combines a device for interaction, a virtual environment and a device for the presentation of information's [4]. Interaction systems used in VR applications can be common devices (*e.g.*, mouse, joystick), body or hand motion capture devices (*e.g.*, data glove) or the sound input devices (*e.g.*, microphone). The virtual environment consists of 3D entities (*i.e.*, 3D objects, avatars) that interact in real time and change according to the user behavior [5]. To fully immerse people in the virtual environment, it is also necessary to add some visual feedback (*e.g.*, Cave Automatic Virtual Environment, stereoscopic glasses), proprioceptive and cutaneous feedback (*e.g.*, touch, heat) and audio feedback (*e.g.*, a 3D spatial effect sound).

According to this above description, a MR system is necessarily in real time and tele-immersive. A real-time interaction is obtained if the user does not perceive any lag (latency) between his action in the virtual environment and the sensory response. This constraint is often difficult to satisfy and when real-time interaction is not possible, the application must avoid too much disturbance to the user even if he perceives this lag time [6].

Defanti (1996) firstly defined the term of Tele-immersion technology as follow: "*the union of networked virtual reality and video in the context of significant computing and data mining*"[7]. Since Defanti's definition, research on Tele-immersion has considerably improved performance issues in a way that the focus is now more on supporting usability and collaborative interaction. Tele-immersion also deals with the "*creation of persistent virtual environment enabling multiple globally situated participants to collaborate over high-speed and high-bandwidth networks that connected to heterogeneous supercomputing resources and large data stores*" [7]. This is achieved using computers that recognize the presence and movements of individuals and objects, track these individuals and images, and reconstruct them onto one stereo-immersive surface.

3. CHARACTERISITCS OF A REAL TIME TELE-IMMERSIVE PLATFORM

The main technical challenges of a 3D RT-TIE platform are listed in the table 1. For each challenge, solutions can be deployed impacting seriously the cost and the most common characteristics of this type of platform: a strong usability and user experience and the use of real time interactions and immersive technologies. In order to provide such a User Experience, a methodology must be applied to engage users early in the design process. These characteristics are presented in the following sections.

Technical Characteristics	**Solutions envisaged**	**Cost**	**UX**
Virtual Environment	3D world matching reality. Scan of real terrain.	Med.	High.
Input Devices	Depend on the scope of applications. Users may want to interact with natural interfaces. (e.g. a golf club for golf applications). [4]	Med.	High.
Visualization [3-5]	CAVE	High	High
	HMD	Med.	High
	Wide Screen	Med.	Low.
Indoor Human Motion Capture	Tracking with several Microsoft Kinect sensors.[18]	Med.	High
	Optical tracking.[3]	High	High
	Inertial sensors tracking. [24]	High	High
Indoor Human 3D Reconstruction	Tracking with up to 5 Microsoft Kinect sensors.[18]	Med.	High
Outdoor Human Motion Capture	Inertial sensors on the body.[24]	High	High
Outdoor objects tracking (balls)	RFID chip is the ball.[25]	High	High
	Gesture analysis to predict ball trajectory. (inertial sensors).[13]	Low	High
	GPS tracking.	Low	High
	Radar + camera to determine initial conditions of a shot. (see Fig. 5)	High	High
Activity Analysis	Reconstructed Skeleton Analysis.[18]	Med.	Med.
	Inertial sensors analysis.[13]	Med.	High
Environment Reconstruction	Weather adaptations in the Virtual Environment depending on real weather.	Low-Med.	Med.
Voice Interactions	Embed Voice Communications system.	Low	High

Table 1. Technical Characteristics of a 3D RT-TIE, envisaged solutions and impacts on the cost and User Experience.

3.1 A Strong Usability and User Experience

User experience can be seen as a consequence of multiple interactions between a user and a product within a specific context that appears after carrying out an evaluation [8]. User experience depends on different aspects along the sensorial, perceptual, cognitive, emotional and social as well as technological, economical and ethical dimensions [19].

Physiological indicators are important for reflecting sportsmen's competitiveness and form a good basis for coaches to monitor and manage training sessions. VR can provide a live monitoring of these performances. Using appropriate sensors, the VR simulation provides valuable live information on the training session that gives the opportunity to adjust the training session in real time. Therefore, physical and biological measures influence the 3D environment in order to make the training as efficient as possible [9].

The realism of the 3D environment and the available interactions are possible parameters deeply impacting the user experience of the perceived virtual world. However, social factors should not be ignored as they have also an impact on the user experience [16].

If a sportsman is supposed to share his experience with someone else, it is really important for him to physically feel his presence. Using avatars and real time communication are usual means to enhance the feeling of presence. This is already used in virtual worlds like “Second Life”. Nevertheless, it is not enough in virtual sport games due to the nature of this activity. For instance, in a virtual golf game, two players who play together do not have only to talk to each other. They need also to see the gesture and resulting impact on the trajectory of the golf ball (e.g. putting swing).

3.2 Real Time Interaction and Tele-Immersive Technologies

Real time and Tele-Immersive technologies, also known as VR technologies include the whole devices and systems that allow the user to live a MR experience. A typical VR system is characterized by the architecture described in Figure 2.

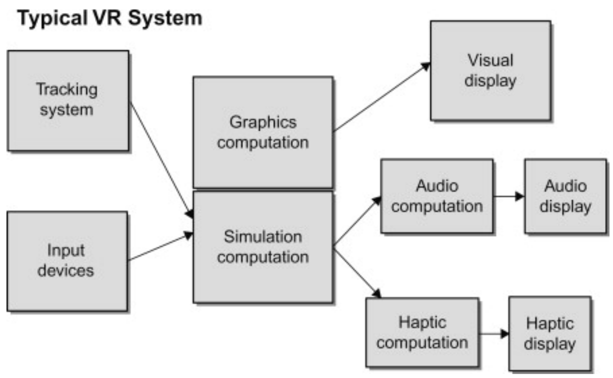

Figure 2. Components of a typical VR system [10]

3.2.1 *Virtual Environment*

VR defines a collection of technologies that allow users to interact with a 3D world in real time using their natural senses. As such, a virtual environment can be supporting several applications: product design, medical-procedures training or, in our case, sportsmen’s training. The effectiveness of any virtual environment used for training can be measured using three criteria: it must be sufficiently realistic, affordable, and validated to assess its efficiency. In other word, it is only by satisfying all of these criteria that a virtual environment built for training sport skills may become an accepted tool [11].

3.2.2 *Input Devices*

In order to interact with the virtual world, the user uses input devices. The interaction has to be as natural as possible. Keyboards and mice are the most usual devices. However, for a specific use, like sport simulation such as golf, these devices are not suited. Indeed, that kind of training application, which is a motor-skill learning application, requires a VE that would ideally encode more complex aspects of movements.

For example, an augmented golf application requires specific input devices for the motion capture of a golf ball and its trajectory analysis Moreover, social interactions, through the use of headset devices, can improve the degree of immersion.

3.2.3 *Vizualisation*

The output devices are components stimulating user senses. Feedback to the user must occur in real time, with a minimum latency between his acts and what he feels. Firstly, for visual stimuli, common systems are computer monitors, data projectors (on large walls), Head-Mounted Displays (HMD), and Cave Automatic Virtual Environment (CAVE). In the case of golf simulation, the preferred device is the CAVE (Figure 3). This device provides a high degree of physical immersion. It is made of three screen walls, a roof screen and a floor screen. The user can move in the three-square meters space. This immersive environment is commonly equipped with motion tracking.

Figure 3. A CAVE Visual Display

It is also possible to use a simple rear-projected screen, which allows more freedom of movement to the user, who only wears a pair of polarized glasses to view in stereoscopy the environment. Even if this solution is less immersive, it has the advantage to be much cheaper and to be easily transportable.

An audio system can also be used. Its role is to allow the communication with a coach or another user for supporting the social side of immersion. It can also reinforce the immersion feeling in the virtual environment. Indeed, 3D sound systems, which can provide the feeling of wind, are very important elements that can bring the immersion even further [23].

Other devices, such as haptic technologies could be part of the system. However, it is not really mandatory for a golf simulator as the user already uses a real golf club and hits a real golf ball.

The efficiency of the training highly depends on the immersion provided by the virtual environment. It will only be possible with a dynamic simulation of the virtual world. Indeed this world must reproduce almost realistic environmental conditions and human behaviors. For instance, the ball trajectory has to react in function of the wind, which can change between two swings. Real-time weather conditions augmenting the VR, through the design of a RT outdoor environment reconstruction and rendering, could be an important module for improving the degree of immersion.

3.2.4 *Indoor Motion Capture*

Motion capture is the process of recording a live motion event and translating it into usable mathematical terms that can be treated by computers. A number of key points are tracked in space over time in order to obtain a single three-dimensional representation of a performance. These points have to be placed in the areas that best represent the motion of the tracked subject. For instance human motion is tracked by placing key points on joints [12].

Today, technologies used are among optical, electromagnetic and inertial sensors. More than capturing the motion of a person, these technologies allow a full 3D reconstruction of the user, generating a time-varying dynamic textured mesh almost in real time. For instance, CERTH/ITI team has developed a real-time 3D reconstruction (of moving human) approach using four Kinect cameras that rebuilds the human appearance [18] (see Figure 4).

Figure 4. Multiple Kinect-based real-time 3D reconstruction based on CERTH/ITI approach [18]

Body and motion capture is used for two main goals: body reconstruction and activity recognition. The first one allows building a realistic avatar that increases the degree of immersion. Activity recognition allows improving the performances of sportsmen by analyzing their movements. It provides three-dimensional data of the golfer's swing that allow improving his swing plan. Moreover, the presence of an avatar moving exactly like the real user enhances the presence feeling of the other sportsman. The social interaction is expected to bring a much deeper feeling of presence.

3.2.5 Outdoor Motion Capture

The outdoor motion capture intends to provide the same added value than described in the previous section. However the sensors to deploy cannot remain the same due to unlimited areas where user tracking is needed. The most appropriate solution seems to be a suit gathering inertial sensors retrieving joints orientations of the user. The XSens[24] solutions allow such applications with body sensors connected to a Smartphone. Solutions with less inertial sensors

3.2.6 Ball Trajectory

In every ball sports, the ball trajectory is a crucial phenomenon. Golf is not an exception, and moreover it is a difficult problem due to the aerodynamic of a golf ball that is quite complex. It requires handling a lot of parameters in order to be able to properly simulate the trajectory. Two situations can be considered:

- Acquire the trajectory of a real situation in order to include it into the virtual environment;
- Simulate the trajectory of the virtual ball of a user in a virtual environment.

A real golf ball trajectory can be tracked using a combination of video tracking and radar (see Figure 5). Actually these devices are only used by professional athletes, and are designed by few companies. Connected to software, they allow an analysis of the ball's trajectory as well as the launch conditions (the way the ball is hit).

Figure 5. A FlightScope Radar

The case of a sportsman playing in a virtual environment is quite different. Indeed, he may have a screen in front of him. Using a CAVE is not necessarily appropriate due to the use of real golf clubs that can destroy the equipment around. The usual way to proceed consists to capture the golfer swing, to pick up initial values and then extrapolate the end of the trajectory using appropriate physic equations. This requires tracking the ball on the first meter of its trajectory, or knowing all launching parameters. While ball tracking on a short distance was the most common way to compute ball trajectory, inertial sensors placed in the golf club allows capturing swing data and deduct the ball trajectory [13].

3.3 VR Technologies Expensiveness

One of the main issues with the use of VR technologies remains the associated cost. The use of VR not only means the use of costly hardware, but also of software, maintenance, validation and trained personnel. Even if the software is entirely developed using free open-source software, hardware is still costly. In most of the cases, the financial investment is part of a global strategy to develop a VR platform. For example, a CAVE is almost prohibitive for a single project. Only few hours' usage of a CAVE could be affordable for a single project. This kind of investment is only possible for labs or big companies [14] for a shared usage among projects. Hence cannot be included in a RT-TIE platform.

However, we can expect that in a few years VR technologies will become more common and thereby cheaper. Some devices are yet more affordable, such as stereoscopic projectors, which allow developing virtual environments even if the budget is limited.

3.4 Methodology: Engaging Users in the Design Process

3.4.1 Safety

Previously considered as a sedentary activity, console and computer gaming are now using motion sensors to provide new gaming experience. Those games can simulate sports, but expose players to real injuries. Consequently, various investigations have to be conducted in order to prevent and manage them. Currently, there is still limited available data. Most of the injuries seem to concern upper limbs (78%) [15]. Lower limbs, cervical spine and facial injuries are quite rare.

Some key concerns are identified. The effect of a mismatch between visual and physical cues is not really understood: there is minimal resistive force and the virtual sportsman may disrupt the normal kinematic chain while creating greater velocities of motion and thus unusual patterns of injury. It is also mentioned that user may spend more time in virtual training session, hence, exposing his body to fatigue injuries.

3.4.2 Acceptability

While new technologies are very often invented and developed by research labs, they become real innovations only when they are accepted by users and adopted by the society at large.

Virtual Environment (VE) brings users in an illusion of reality, which is different from our “physical” reality. People’s mind is not familiar to deal with VE. While VEs are designed to be more and more immersive, users still have feelings telling them that it is not the reality, which influences their senses. Some people don’t want to spend time to adapt themselves to this new experience and prefer staying to more traditional techniques. They doubt that VE can provide experiences in a faithful way to reality, and open various possibilities. However, advanced training facilities are pioneering the use of new technologies (e.g. VE, AR, MR) in different sports. Sportsmen are just starting to use this kind of new technologies that support more efficient training sessions, meaning that, most probably, it will take time before everyone adopt these technologies.

4. GUIDELINES FOR THE 3DLIVE PROJECT

After a brief description of the 3D-LIVE European Research Project, the following sections explain that it is important to characterize physical and social aspects and to choose very interactive and immersive devices in order to improve user experience in the twilight space. Then, a set of guidelines is provided for better anticipating the necessary effort and related costs while considering the safety issues and real users’ needs.

4.1 The 3D-LIVE Project

The 3D-LIVE project aims to develop and experiment user driven mixed reality platforms that fully immerse remote users in “augmented sport” experiences.

Three sports have been selected for experimenting the 3D-LIVE real-time immersive environments in order to better understand both research and business aspects. The technology platform will be adapted and several configurations will be released for each case. A Jogging scenario allows a minimum of two users to run together through the streets of a city (actually: Oulu in Finland). One of them runs indoor on a treadmill while another runs outdoor in the street. Their main objective is to remotely run next to one another in the twilight space. A Skiing scenario is quite similar to the Jogging one: an indoor skier goes down a ski slope in a simulator while an outdoor skier practices in the real environment (Actually: Schladming in Austria). The added value is the fact that the outdoor skier should see indoor avatars thanks to an augmented reality see-through mask.

Finally a Golfing scenario allows several golfers to play together as a team within a well-known scramble formula (actually: Laval golf course in France). These three scenarios have been designed with the goal to experiment and assess the real-time potential of different Tele-Immersive technologies from a user experience point of view.

Each user has a specific configuration in order to feel immersed in his side of the twilight space. For instance, “indoor” users use high VR technologies while outdoor users take advantage of the last improvements of augmented reality technologies. “Augmented reality” means the addition of visual contents generated by a computer in the field of view of the users in order to give them appropriate information at the right time. The underlying objective of the 3D-LIVE project is to develop a methodology to measure both the Quality of Service (QoS) and Quality of Experience (QoE) in the context of 3D RT-TIEs. While QoE allows evaluating the user experience, the correlated QoS allows setting up new limits and new requirements for live Future Internet infrastructures and applications in mixed environments [16].

4.2 Characterizing Physical and Social Aspects for Improving User Experience

As explained previously, the 3D-LIVE project aims to create a new kind of RT-TIE for augmented sport experienced by two users: one of them located in the reality – a golf course – and one another immersed in a virtual restitution of this distant place. Therefore, the aim is not to simulate a real environment but to emulate an existing one as virtual. Moreover, the fact that the golf session takes place in a VE allows many enhancements. The sportsman is able to follow his own physical data and by extension the effectiveness of his training (according to his own objectives). These data are transmitted in real time or afterwards to a coach, allowing him to review the training program.

The other important part of the 3D-LIVE project is about the integration of social interactions in this RT-TIE experience. The objective is to increase the feeling of presence and immersion in order to consequently improve the user experience. The literature shows that social interactions and their level of realism have an important effect on the sense of presence in virtual environment [17]; if social interactions are smartly integrated, they can improve the feeling of presence. Empirical studies are presently conducted on the impact of social interactions on user experience through the degree of presence and immersion. Outcomes will help to use social interactions in a way that improve the user experience of a RT-TIE platform.

4.3 Choosing Immersive Devices for designing the twilight space

The augmented golf scenario of the 3D-LIVE project uses a wide range of devices for supporting indoor and outdoor players. Indeed, in order to play together in real time, two distant players (e.g. one is in a room with a full screen, the other stands on the golf course) are equipped with various devices.

Given the CAVE safety rules, the indoor player must be rather situated in front of a wall-projected screen equipped with a net for stopping the flight of the golf balls. Kinect cameras surrounding him are intended to capture body and gesture motion (depending on the speed rate) for body reconstruction to be displayed to the outside player. This tracking solution is not fast enough to capture shot gestures, consequently another tracking solution should be used during the shot phases. Inertial sensors can be set on his golf club to capture the swing plan and compute the trajectory of the golf ball. The outdoor player can also use golf clubs equipped with inertial sensors for capturing his golf swing plan. With an AR application, the outdoor player can point the ball position with the accuracy that GPS can provide today, then the inertial sensor on the golf club aims to estimate the trajectory of outdoor shots as well. The visualization of players’ balls positions on the virtual representation of the golf course are displayed on the wall screen for the indoor player and on a mobile device screen for the outdoor player.

The computation of the ball trajectory has an accuracy taking into account environmental factors (e.g. wind speed, temperature, humidity). Values of environmental factors should be captured and transmitted in real time by sensors placed throughout the golf course.

The project aims also to design some sort of social interactions. For example, the two players must use a headset enabling them to interact through voice communication and view the text messages of the followers on their screens.

The different solutions matching user and safety requirements, a high impact on UX, medium costs are summarized in the Table 2.

4.4 Anticipating the necessary effort and related costs

Costs are determined by the resources needed in terms of development and experiments, as well as specific equipment or the renting of technical platforms for conducting experiments. The use of emerging technologies, often still in development, induces higher costs. In order to create the best experience, the different technologies have to be carefully selected while checking their availability on the market or only for developers. Moreover the different selected solutions and technologies should correspond to a targeted audience; Fitness centers can easily invest money in appropriate simulators but citizens would prefer more affordable solutions. For example, based on the use of their wall screen or projector with additional low cost technologies.

4.5 Designing a Secured and Expected System for Users

It is necessary to consider as well the security of the 3D-LIVE experimenters. For instance, it could be necessary to avoid too long effort by controlling the time of the experiment sequences, or while recruiting, ask people if they had several physical injuries in the past that may not be compatible with a specific experiment sequence. To avoid injuries, there is a need to develop a solution that does not absolutely simulate the reality but rather match the best with the reality. As a consequence, algorithms containing real advanced equations must be develop to obtain the most appropriate user behavior. During the usage sequences, people should be able to reproduce the body motions they would have done in the reality and receive the proper corresponding feedbacks.

Finally, real-time Tele-Immersive platform designers need to take into account the fact that common people are not so used to new technologies. Therefore, they should choose solutions that are innovative while not disturbing users too much. For example: they need to be careful with the use of stereoscopic displays. Experiential Design [20] induces to engage users not only at the earlier design stage but also in the co-creation activities in order to better understand what can be innovative and adopted at the same time. According to the user experience life cycle [21], usage feedback is analyzed in order to prepare a new design iteration involving revision of some components depending on their acceptance rate.

Technical Characteristics	**Solutions chosen for the golfing scenario.**
Virtual Environment	A map of the real terrain topology is available. A 3D scene matching the real golf course is modeled.
Input Devices	A real golf club will be the input device for shots. A tactile monitor screen will be the input device for the game interactions.
Visualization	A wide screen to display the virtual environment. A monitor to handle game interactions and overall information. Immersive systems like CAVE or HMDs do not match safety requirements. A tablet will allow the outdoor user to visualize Augmented reality content on the golf course.
Indoor Human Motion Capture	Tracking with several Microsoft Kinect sensors during all game phases but the shots due to fast movements.
	1 sensor on the golf club allowing the gesture analysis and ball trajectories estimations.
Indoor Human 3D Reconstruction	This is not planned for the golf scenario as this does not match golfers' requirements.
Outdoor Human Motion Capture	Inertial sensors on the body and the golf club will be deployed and connected to the outdoor mobile device (a tablet).
Outdoor objects tracking (balls)	Due to costs and efficiency estimations, a fusion of gesture analysis thanks to 1 inertial sensor on the golf club and GPS data coming from the tablet will track the ball positions and trajectories of the golf ball.
Activity Analysis	Golf gestures are too fast to be reconstructed by Microsoft Kinect sensors accurately. The inertial sensor on the golf club can be the core of activity assessment.
Environment Reconstruction	Wide area weather information will be retrieve real time on site to change the virtual weather basic conditions (rain, cloud coverage, sun, wind).
Voice Interactions	An embedded Voice Communications system must be integrated.
User Physiological State	The physiological state of the golfers is not a predominant feature.

Table 2. Summary of solutions recommended for the 3DLive Golfing scenario sorted by technical characteristic.

5. CONCLUSION

This paper investigated the main characteristics of a 3D RT-TIE. More specifically, it addresses the 3D-LIVE golf use case that is an exploration of a computer augmented golf experience.

This paper suggests three contributions. Firstly, Real Time Tele-Immersive Mixed Reality can be defined as: (1) a twilight space shared by different users representing the frontier between virtuality and reality; (2) based on VR technologies. Secondly, it highlights four characteristics of Real Time Tele-Immersive Mixed Reality: strong user experience, real time interaction and immersive devices, VR technology expensiveness and apply a design process engaging users. Thirdly, it proposes four main guidelines for designing a computer augmented golf platform in the context of the 3D-LIVE Project: (1) characterize physical and social aspects for increasing the degree of presence and immersion, hence improving the user experience; (2) choose interactive and immersive devices for designing the twilight space; (3) anticipate the necessary budget; and finally (4) apply a design process allowing to engaging users at the earlier design stage.

This paper is intended to allow designers to develop an efficient computer augmented environment, which will be further evaluated in the context of the 3D-LIVE project in order to empirically characterize this emerging concept of RT-TIE in Mixed Reality.

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