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Towards the Physical Instantiation of Virtual People and Components in Physical Mixed-Reality Tele-Presence Environments

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Abstract. Interaction between virtual and physical worlds is an area of growing importance as technology increases the amount of virtualization in our lives. However, to-date, most of this work has focused on translating the physical world into a virtual representation, with little attention being paid to instantiating the virtual in the physical world. This paper addresses this latter issue. In particular we examine how a virtual student can be given a presence in a real smart classroom in order to have better interaction with local students within a shared environment. In this 'work-in-progress' (concept) paper, we propose a novel augmented-reality based approach that identifies and synchronises the remote and local environmental states (people and environment) so as to provide a more naturalistic mixed reality shared environment.

Keywords. Telepresence, Augmented Reality, Augmented Virtuality, Mixed Reality, Indoor positioning system.

Introduction

There is an increasing interest in the applications of tele-presence systems in many domains such as business, health, entertainment and education. As a result, there has been much research into the use of telepresence for a business meeting, and education.

Many recent studies [1][2][3] have been concerned with the use of mixed-reality concepts to achieve interactive communication amongst remote and local people in 3D virtual-reality environments. One reason, besides averting the isolation of remote students, is to support e-learning in terms of learning from anywhere and anytime with feeling as being there. For instance, Gardner [1] and Schmidt [4] stated that representing remote students as avatars on a screen in a real smart classroom will underpin the students engagement and increase the feeling of 'being there' through virtual connections to their real teacher and fellow students.

However, users of virtual environments enjoy limited interactions with the real environments and people. Therefore, studies towards developing and increasing the interactivity of remote virtual students in the real environments are required. So far, however, there has been little investigation on increasing the interactivity of remote virtual students in physical smart spaces based on the dynamics of interconnecting physical objects and people with their virtual counterparts.

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This research works aims to address this shortfall and investigates the problems in mixed-reality and augmented technologies in order to increase the presence of virtual remote users in the smart real spaces based on their dynamic locations and motions within a real space. Moreover, the application of this approach will seek to underpin the learning and teaching spaces to increase productivity, particularly for collaborative tasks.

Mixed Reality (MR)

A Mixed Reality concept can be used as an advanced tele-presence method, which connects a virtual environment with a physical environment [5]. With regard to the Reality-Virtuality Continuum as shown on figure 1, mixed-reality has been divided into two components: Augmented Reality and Augmented Virtuality, where the world is mostly real, or virtual (computer generated), respectively. Whereas the two extremes at either end of Mixed Reality continuum are the reality and virtuality (i.e. where the world is 100 percent real or computer generated). As a result, [6] observed that "*the most straightforward way to view a mixed reality environment, therefore, is one in which real world and virtual world objects are presented together within a single display, that is, anywhere between the extreme of the Virtuality Continuum*" [6]. Mixed Reality Teaching and Learning Environment (MiRTLE), from the university of Essex [7], and the Holodeck system from the University of Hawaii [4] are examples of mixed-reality learning environments.

Figure 1. Milgram's Reality-Virtuality Continuum [7].

MiRTLE project is empirically designed using Wonderland Project open source, which is a popular software tool for creating 3D virtual spaces [8]. The Open Wonderland project is a Java-based system that is a purpose-built world that targets education, business, and government applications.

The concept of MiRTLE project is that it allows remote students to virtually (in a 3D environment) interact with local students and their teacher. Consequently, remote students can share programmes such as a word processor and Internet browsers. The remote student's presence takes the form of an avatar with his login name superimposed on it.

MiRTLE has been deployed in iClassroom, which is a high-tech teaching environment at University of Essex. It consists of speakers, microphones, and voice-bridge (in the system) to enable voice communications between remote and local students. Furthermore, the iClassroom also includes an IP camera and a large display screen which are both parts of MiRTLE components. Thus, physical students can be viewed in the virtual world screen through the IP camera, which is mounted on the iClassroom's screen. The virtual students are displayed in the real environment through the screen positioned at the rear of the iClassroom. This screen allows the teacher and real students in the iClassroom to see virtual students in the lecture as shown in Figure 2.

Figure 2. Lecturer's View of Remote Students (left) and Remote Students' View of the Lecture (right).

Moreover, the view of remote student's avatar can be viewed on the screen based on the user's preferences[7][5]. Therefore, the virtual student's existence in the real world is screen-based, which can be seen as a limitation in terms of having more interactive communication in physical classrooms with real students.

Augmented Reality (AR)

The term 'Augmented Reality' (AR) was defined by Caudell and Mizell [9]. AR is a real-world (physical) environment whose elements are augmented by computer-generated sensory input such as sound, video, graphics or GPS data. It relates to a more general concept called mediated reality in which a view of reality is modified by a computer [10]. AR systems consists of three key points [11][12]:

- Binding real and virtual objects in a real environment.
- Registering real and virtual objects with each other.
- Making the use of 3D and 2D objects in a real environment.

In educational spaces, using the AR configurations is an obvious alternative for promoting engagement and motivation among educators in classrooms. For instance, an AR based game called "Learning Words", which uses a head mounted display (HMD) device, was developed and tested amongst 32 pupils. The result indicates that more than 80% of the audience preferred AR systems over conventional systems for learning [13].

Augmented Virtuality (AV)

The virtual environment that embedded real objects inside it is one of the Milgram's Reality-Virtuality continuums, which is referred to as Augmented Virtuality (AV). It is the opposite of augmented reality as the main environment is virtual and the real object is attached to it. This can be used as a means to combine a richly layered, multi-modal, 3D real experience into a virtual environment (VE) [6]. However, this advanced technology has not received a significant attention by researchers as AR [14]. AV's are limited to a few domains such as 3D video-conferencing systems [14][15].

Tele-presence systems

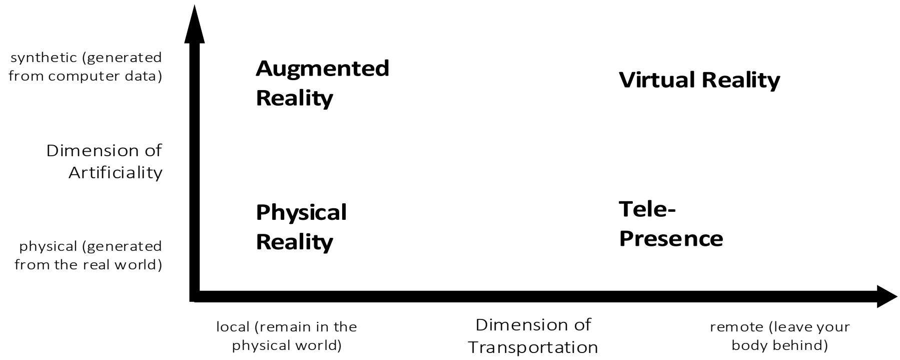

Figure 3. Broad classification of shared spaces according to transportation and artificiality [16].

The Telepresence concept describes a set of technologies, such as high definition audio, video, and other interactive elements that enable people to feel or appear as if they are present in a place which they are not physically in. It is mainly used as a collaboration tool. Telepresence is used by companies to help create a more "in person" meeting experience over a converged network [17].

According to Bengler and Passaro [18], the AR can be classified as a distinct technique from the telepresence and virtual environments as shown on figure 3.

In the remainder of this paper we discuss this further, in fifth parts. The first part describes related work. In the second section, a conceptual view of the project architecture is presented. The learning scenario is described in the third section. Then, the fourth section is to illustrate the research challenges. Finally, we draw a set of conclusions.

1. Related work

Recent studies [3][2] have considered the development of tele-presence systems in order to facilitate interactions and communications between remote and local physical students without a spatial limitation. In [3], the system allows users to meet face-to-face in virtual reality, which is an immersive tele-conferencing environment. However, this study focused more on a virtual world, and does not embed virtual people in the real world to allow interactions with real people.

Another study [19] proposed a teleoperation system that can undergo the feel of existence in an agent robot. Although this system can allow the process to provide a feeling of mutual tele-existence, the appearance of human beings as robots is not natural, which may make the interaction with the human operator unreal in terms of sharing the senses such as talk – touch and so on.

In [20], the system is basically proposed to enable a remote user to communicate physically with the local user. Their aim is to make the means of communication tangible via the remote user being imitated by an avatar, which in turn, is tied to a physical humanoid robot in order to utilise human senses such as voice, sight and touch. However, a drawback to this system is to provide the motion of the tangible avatar in the environment when the system, for example, has multi-students such as in a real smart classroom. Moreover, the appearance of the avatar in different locations within the real environment, based on a virtual person's movement, is not addressed. To be more precise, the student still lacks the ability to control his actions and easily move around in the real environment as real students.

This study seeks to overcome the limitations explained above and extend the process of the avatar motions in the real environment based on his/ her movements in the virtual synchronous environment. This is poised to enable more involved interactions with distributed students, objects, and smart devices. Moreover, local students do not need to use the extra devices such as HMD in the smart classroom in order to communicate with their remote virtual fellows. Students might use smart mobile phones, which allow them to interact with our system through the advanced features of their screens, speakers, microphones and cameras.

2. Conceptual view of proposal system

Our on-going research project is based on the MiRTLE concept [1]. However, the extension and development in our new approach is aimed at finding more interactive and active real classroom by bringing the virtual students and enabling them to move and interact with their different located real peers by conversations and sharing tasks. We referred to this new system as MiRTLE+.

The MiRTLE+ architecture is advancing a new approach of synchronising the motions of virtual people, the movements of objects in the real classroom from the virtual, and the shared spaces for sharing smart spaces. Figure 4 shows the main view components in mixed reality environments (real and virtual classrooms) divided into three types of artifact: (1) people, (2) objects and (3) shared spaces. All of them are mirrored in both classrooms, as discussed in the following sub-sections.

The middle layer among the environment connection layers is responsible for communications in order to send and receive data through the Ethernet cables. Moreover, this layer contains the web-services communication and process.

The layer on the left side of figure 4 is the data storage layer. Its role is to maintain required system data such as storing users' profiles, files representing languages between environments and their components and the users' paths of motions and group joining, which can be used later for pedagogical purposes.

The main layer on the right side of figure 4, which is the new challenge of this paper, is the MiRTLE+ layer. Their components (i.e. ubisense sensors and tags, smart devices, PCs, and the wireless network) are distributed around the real classroom. Thus, the key role of this layer is to identify either the virtual or real students once they log in or are captured by sensors (respectively), which can be applied on the classrooms' objects as well. The virtual students' motions are tracked from the virtual camera and exist in the real classroom in order to be watched and communicated by their real fellow students in the real classroom.

This layer is communicated with the connection layer, which in turn deals with the controller linked between the connections and each classroom in order to send and receive the commends to the whole mixed classrooms.

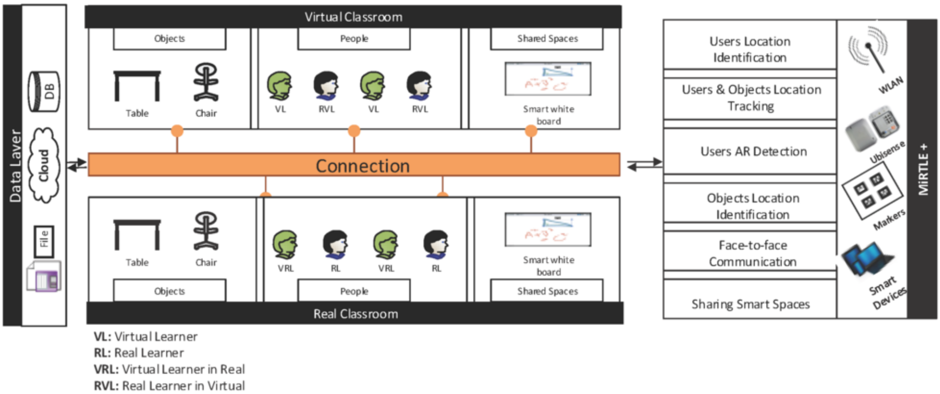

Figure 4. High level architecture of the system.

The following subsections address the importance of each group of elements in the identical real and virtual classrooms:

2.1. People

Remote and real students can meet each other either in the virtual or real smart classroom as shown in figure 4 that the green user is a local student, whereas the blue one is a remote student (This may not be clear in a black and white printed paper). With regards to the communication, each distant learner can move in the real classroom exactly as they do in a similar virtual classroom using a keyboard or mouse. Thus, a local student can point out within the environment to watch his fellows as well as chatting with them in different locations in the real classroom, as depicted in figure 5.

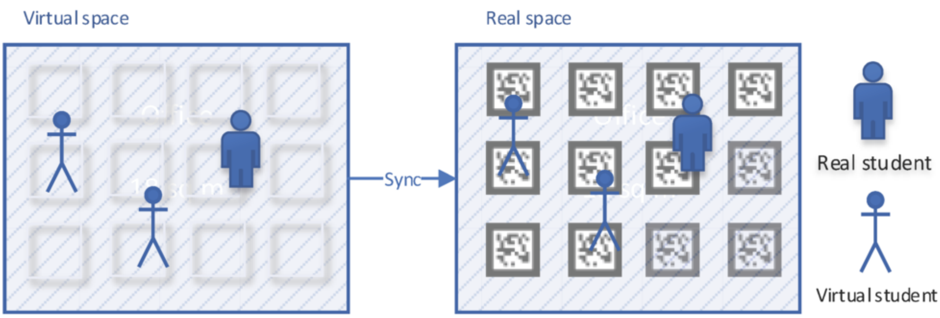

Figure 5. Augmented-based users' locations identifications.

2.2. Objects (seats and tables)

In figure 6, the object location tracking concept is quite similar to that of user motions discussed previously. Nevertheless, additional functionalities are that each object (e.g. a chair) has a location identity in the environment as well as the allowance to be utilised by students, and can be augmented by them (e.g. to sit down), and thus the movement of the real chair for instance will be tracked and changed in the virtual classroom to allow either the virtual user or logged in real user to use it. However, as a constraint of the objects movements in the system, real objects in the real environment will not be synchronised if they were firstly moved or changed from the virtual environment.

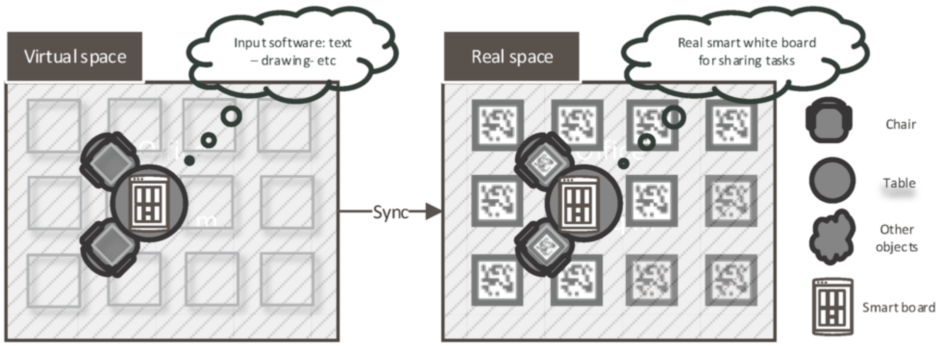

Figure 6. Objects and shared spaces locations.

2.3. Shared spaces

Figure 6 also shows that the smart board located on the circular tables is a part of the shared spaces. A shared space is defined as any smart device (e.g. smart whiteboard, iPad) where students both remotely and locally can meet and achieve a given task. For example, this project has basically two students, four chairs and a table, and a smart whiteboard placed horizontally on the table.

2.4 Pedagogical developments for the system

In terms of the pedagogical perspective, the MiRTLE+ is considered being more collaborative learning environment. Collaborative learning environment (CLE) is where learners work in groups, exchange thoughts, and solve problems in order to provide more effective learning; CLE is well documented on [21]. Thus, MiRTLE+ aims to increase the interactivity of students' progress, enabling them to move among groups (tables), and to exchange knowledge on differently located tables in the real educational environment (remotely).

3. Scenario

This section illustrates a *'fictional scenario'* in a mixed-reality classroom proposed in our model MiRTLE+. This is aimed to provide a proof of concept of the system during the learning process. In this scenario, we assume that two students (local and remote) will be assigned to achieve a learning task (unite of learning) as follows:

3.1. Choosing your location in the classroom

Ahmed and John are students at the University of Essex. Ahmed lives in Colchester and can attend classes in person. John is a part time student and he currently works in London, however he can attend remotely using his computer. They both study English language at the International Academy department, which uses the MiRTLE system in order to deliver lectures to remote students. One of their modules is called Listening and Speaking, which is based on a collaborative conversation where each student chooses his partner in order to talk and listen to them.

In the proposed MiRTLE+, there will be a real classroom (iClassroom) where given tasks will be carried out by students. Thus, John logged in using his laptop and joined the virtual world, his avatar sitting on a virtual chair and sitting a virtual table). Also, Ahmed entered the real smart classroom physically, sat down on one of the available chairs at one of the group meeting tables. In order to meet the class requirements, he logged-in to the same virtual environment to occupy similar a virtual chair and table but, in this case, using his smart phone or iPad.

As Ahmed and John are close friends, they prefer to sit next to each other. Therefore, having completed their logins Ahmed is able to sit, virtually, next to each other.

As the class proceeds, Ahmed (in the real classroom) can move his iPad to point out to an adjacent chair where he can talk and listen to John in real time. Ahmed (in a remote location) can see on his PC screen his avatar next to an avatar of John. The front mounted camera on Ahmed's screen (in the virtual remote environment), captures his expressions, gestures and audio which is used to construct his avatar and communicate with the other participants.

3.2. Task sharing

Both Ahmed and John are sitting down on real tables in different locations doing the sharing tasks, Ahmad in the real classroom, and John by remote connection in a real smart classroom. One of the class requirements is to undertake a brainstorming task collaboratively. It is common in such tasks to use a paper and pen in order to share the ideas and write them down. Therefore, the smart electronic board located horizontally on the table can be used as a sharing device for writing or drawing. Whereas Ahmed can do that physically in real classroom, John from connected virtual environment can see the same board on front of him on the virtual table, which is updated in real-time with latest lists or drawings from the discussion of brainstorming.

3.3. Objects animations

Ahmed and John can move around and choose their seats in the real classroom. One day, Ahmed came early to the iClassroom and logged in to the joined virtual environment. He then found his group and sat down with them on the joint tables. However, all four chairs on that table are equipped by his group's fellows, whereas the next group's table has an extra empty chair. Ahmed moved this chair to their table for John, who just virtually entered the iClassroom. Therefore, the chair location should automatically be changed in the virtual joint table.

4. Challenges

To achieve the main goal described in this paper, we have conducted a literature review of related areas together with an investigation of suitable research tools and systems. From this research we have concluded that the project should focus mainly on a combination of location identification within mixed reality environments and facilitating collaboration amongst people and environment's objects. This is poised to increase interactivity in the learning environment. To be more precise, a number of questions need to be addressed as follows:

- Since we plan that the virtual and real environments will be mirrored, we phrase this into a question as follow:
    - How can this be achieved so as to synchronise the content (people - objects) of both environments?
- Is the collaboration amongst remote (augmented) and local students in the real environment better than a conventional collaboration in terms of teaching and learning?
- Would the combination of mixed-reality, physical manifestation of remote people in the real environment, collaboration tools (sharing documents, diagram, and pictures similar to the real collaboration), and movable objects (e.g. chairs) enhance the collaboration techniques?
- Would the movements of virtual students in the real environment create more effective and interactive connectivity in terms of feeling being there?

5. Conclusion

This paper has introduced a new approach of combining augmented and mixed reality and telepresence technologies in order to synchronous the users, objects and shared spaces in the real environments based on their dynamic locations and movements. Furthermore, it provides a high level description in order to visualise the virtual students in the real environment, who can be tracked and seen by the real students. Pedagogically, the purpose is to enhance the learning process using a collaborative learning environment in an augmented based mixed-reality smart classroom.

Our future research aims to continue the investigation into the best techniques for tracking the locations of people and objects' in synchronised classrooms. The purpose is to enable more engaged communications amongst students in the classroom, and better learning in a collaborative learning environment. In the next phase of this work, we will implement the MiRTLE+, which will enable us to evaluate the pedagogical and technical outputs, and examine to what extent our systems meet the research challenges. We look forward to present ongoing progress at future conferences.

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