Panoramic Audio and Video: Towards an Immersive Learning Experience

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Abstract. Historically, learning has been seen as part of the human process to achieve a status, income and a better future. Traditionally students travel to attend lectures or participate in brainstorming and training sessions benefiting from the interaction afforded by the physical learning environment, the classroom, and the wider University facilities. However, financial pressures arising from national and global competition are putting pressure on Universities to find more cost-effective ways of delivering education. While distant learning has been always there, it is clear that this approach needs substantial improvements in order to deliver a similar learning experience to physically attending a university. To these end, this paper presents a novel immersive telepresence system that allows remote or distant students to customize their virtual presence at seminars and lectures based on a 360° panoramic video projected onto a 180° curved projected screen (an immersive shell). Audio is also collected with 3D information in order to be reproduced more naturally at the remote location. The arrangement is intended to provide online learners with a more faithful replication of human perception, akin to what they would experience in a real learning environment. Technically, to do this we use a 360° mirror to capture the lecture room scene and transmit it to remote locations where it is reconstructed the original image from spherical to Cartesian coordinates providing a novel but natural immersive experience. This paper describes the motivation, model, computational architecture and our main findings.

Keywords. Telepresence, Immersive environment, Panoramic audio, Panoramic video.

Introduction

Financial pressure are putting pressures on Universities to look for more cost-effective ways to deliver education.. At the same time there is a new generation of students that are more comfortable with online systems which, together with advances in online technology has driven our motivation for this work.

Beyond education, another market and technology driver is the gaming industry which seems to grow at an exponential rate. As a result, numerous educationalists are looking at games technology to understand the core of values that attract users, so the ideas could be applied to education. Having studies these areas, in this paper we propose a new model combining traditional teaching methods with immersive media, taking advantage of the gaming interfaces and workflow to produce an effective interaction between remote and local attendees.

The term “Telepresence” was coined back to 1980 by Marvin Minsky, a Massachusetts Institute of Technology professor, who described it as “*the ability to present and manipulate objects in the real world through remote access technology*” [1]. Later the term has come to refer to remote manipulation paired with a high quality sensory feedback where the end-user “perceives” the remote space as “local” in order to perform the task more effectively.

Following this definition, Bill Buxton redefined Telepresence to include telecommunication, as “*telepresence is the use of technology to establish a sense of shared presence or shared space among geographically separated members of a group*” [2], where presence is considered in terms of two spaces: that of the person and that of the task.

Traditional videoconferencing is a good attempt to establish this shared personal space. However, as technology advances, videoconferencing is increasingly focusing on achieving the sensory feeling of “being there”.

Towards those ends we have created an immersive telepresence system that facilitates physically dispersed students, or groups, to collaborate around a shared task with a sense of shared presence. At one end of the link, the local space (e.g. a lecture theatre), a 360° mirror lens is placed in the room, from where a spherical image is captured and then transmitted to a remote location in real time. Once this stream is delivered, it is converted from polar to Cartesian coordinates to create a panoramic video that is projected onto a 180° screen. 3D audio is also collected in order to reconstruct a more natural sound image at the remote learner end by using binaural techniques and directional speakers or headphones.

This setup allows remote viewers to participate in events as though they were local participants, enjoying much greater control over their visual and audio context.

This work was inspired by other immersive projects such as the “*Mixed Reality Teaching and Learning Environment”* (MiRTLE), an Open Wonderland platform [3] which uses virtual reality in the form of avatars to bring geographically dispersed learners together [4]. The work described in this paper advances this field in two important respects; first it replaces avatars with video of real people and secondly it collects panoramic audio at 2 different levels; one for pure audio transmission to the remote user, and a second to calculate the dimensional position of the source, thereby enabling the audio to be recreated and spatially controlled by the end user.

1. Distance learning

Distance learning in its most basic form (e.g. sending materials by post) has been around for more than a century. While traditionally it has been accepted as a method to get on to the education ladder when resources such as time, money and commitment are not fully available nowadays, in addition, it is evolving as a way to provide an extra-curriculum option for people with busy lives . Some Universities have found that distant delivery of lectures has allowed them to have multiple campuses on different locations. This enables them to project their cultural and academic values to other cities, countries and even continents or societies, making better use of their best resources, their individuals, and at a lower cost. Other Universities have used online learning to massively expand their student numbers, for example Shanghai Jiao Tong in China has 40,000 distant learners taking the same examinations as those in their real campus [4].

Some of the issues in the past, with relation to distant learning, have been addressing the quality of the educational experience as compared to that experienced by students in traditional programs. It has been found that the format of delivering the content has little effect on student achievement, as long as the technology is appropriate for the content and all participants have access to the same technology and resources. [5]. The use of online content has been extended from remote learners to local students who want to review a lecture that has ended. Digital lecture recording and capturing has flourished in recent years.

Recent statistics from the High Education Statistic Agency (HESA) [6] have shown that over 10% of the students enrolled at UK Universities during 2010-2011 were studying through distance learning, while another 10% undertook some kind of distance module during their university studies. All of them have used some remote presence tools for collaborative work, such as Skype®, Facebook® groups, Moodle® forum, course message boards, YouTube® videos and similar tools.

Traditional methods for distance learning originally involved sending books, tests and videos by post to registered students but have now been replaced by more modern methods. For example, some institutions created their own radio and TV programs to support learning. Videos were introduced and later the internet, the largest repository of learning material to-date. Some Universities have produced a number of courses with more up-to-date resources such as screen capture, RSS audio recording, web pages often centralising learning resources, via systems such as Moodle®, offering message boards and resources available 24/7 to suite the student needs. Social tools such as Tweeter®, Facebook®, YouTube®, Second Life®, etc, have also been added by many universities as part of the student experience, communication and marketing.

2. Social Interaction and Social Presence

What make students engage in an online learning? Beyond the chosen subject itself there is a social view that emerges in support of online learning as the individual join a community group [7][8]. There are 3 interrelated elements that have to be considered:

A. Social Presence

Social presence is defined as the degree to which the student feel socially and emotionally connected to others in the group, projecting themselves as “real” people, independent of the communication medium used [9][10], and should extend beyond geographic boundaries to allow the remote individual to belong to the group [11]. Socio-cognitive theorists describe learning as an interactive group process in which learners actively construct knowledge and then build upon that knowledge through the exchange of ideas with others [12].

Studies on social presence [13][14] determined that social presence was composed of three subjective elements: co-presence, intimacy, and immediacy. None of them naturally available at distance learning, so the need to build a model that takes those into consideration is a paramount for the success of any distant education program. In this “value social interaction“ and ”learning interaction” are the key factors needed to achieve learner satisfaction and goal achievement, which is basically the final goal of any teaching institution.

B. Cognitive Presence

Describes the extent to which the student is able to construct meaning through sustained communication, reflection and discourse or, as Garrison defined:”The exploration, construction, resolution and confirmation of understanding through collaboration and reflection in a community of inquiry” [15] .

C. Teaching Presence

The glue element to bring all these together is the teaching presence, by designing, facilitating and providing direction to cognitive and social presence, thereby allowing students to achieve their full potentials. In this way the educator is responsible for providing emotional presence that will lure and engage the student into being inquisitive in order to better progress [15].

2.1. Emotions

Emotions are universal phenomena that people experience in everyday events throughout their lives, and obviously are present in online learning communities [9]. Online objects, such as emoticons, have been created in order to communicate emotions while socialising online **Error! Reference source not found.**. Research on emotional presence within online communities demonstrates the salience of emotion in online learning. Thus, as Harasim stated, “emotion must be considered if not a central factor, at least as a ubiquitous, influential part of learning” [31].

Interaction in any traditional classroom is far more complex than the interaction that occurs in any online course. While the two instructional environments are different, the main asset in a traditional classroom is the pedagogical value of synchronous interactive communication. The student “feels” part of the process and the event, not as external observer but at the pedagogical core. The importance of interaction in distance education has been acknowledged and researched [19][20]. In a traditional classroom the lecture and the scenario will provide visual cues that the student will add into the learning process to reinforce their experience. Because of the lack of this connection, remote students may fall into the feeling of isolation and lack of connection toward the lecturer and fellow students. Thurmond et al. reported that students who responded more positively to knowing their instructors also tended to believe that there were a variety of ways to assess their learning, reporting more timely feedback from the instructor; and participating more actively in course discussions [21]. Their research also found that students were more satisfied with their courses and reported greater learning when more of their course grading was based on participating in live discussions [22] and they believed that their participation in discussions enhanced their learning. These findings revealed a positive relationship between high levels of group activity in the courses and their learning. But how is it possible to use distance learning technology to promote discussion with remote students and to engender timely feedback?

3. Sense of Community

In a seminal 1986 study, McMillan and Chavis [23] sought to describe a sense of community and offered four criteria necessary for an acceptable definition. Their model, to define sense of community, applies equally to both place-based and non-place-based communities, and their elements equally apply. '*Membership'* is concerned with boundary issues, often represented by feelings of belonging to or sharing something in special. '*Influence'* looks at an individual's sense of mattering, being shaped by the group, and able to make a difference. '*Needs'*, or more specifically the integration and *fulfillment of needs*, deals with reinforcement and distribution of common resources.

Emotional connection speaks to a community's shared history, similar experiences, and common world-view. The ability to identify other members of the community allows people to determine how to spend resources and time and with whom they feel comfortable. The feeling that the individual can influence or add value to a group will increase the social value, in a bidirectional way. In order to be attracted to the group, an individual must have the potential of influencing the group otherwise he will see it as a burden. The individual association must be rewarding to members and successes relating to the group should bring them closer together.

In conclusion, a group of people with shared values and membership, with similar goals and priorities, will be easily able to focus on specific tasks in a consistent and mutually beneficial way. Sharing emotional events is crucial in creating sense of connection between those members, and in order to provide this emotional connection there is a requirement for some kind of direct interaction between them, based around common task and goals.

It is also evident that people who expend time and energy on projects will feel more emotionally involved in the outcome than those that don't. In addition, providing support, identity and emotional connection can offer the attraction needed for people to progress towards their personal goals.

4. Gaming applied to Learning

Games illustrate the importance of the points made in the preceding section. In multi-participant online games, individuals are given a task, shared with other members in two ways, one as contender to achieve the best individual score and a second as a collaborator helping a team to achieve its goal.

Research has shown that Multiplayer Online Games (or Massively Multiplayer Online Role-Playing Games - MMORPG), like 'World of Warcraft', teaches online players very important life skills such as teambuilding, communication and leadership. Those skills can be combined and be extended to more traditional learning subjects such as economics, sociology, math and science, taking advantage of the learning culture created around MMORP [23].

According to Slater [25] an *Interactive Animated Pedagogical Agent* consists of Adaptation, Motivation, Engagement and Evolvement. The two first agents are easily understood:

A. Adaptation: evaluates the learner's understanding throughout the interaction, adapts the lesson plan accordingly. It also ensures a learner has a good understanding of the basics before progressing to more sophisticated concepts

B. Motivation: this prompts students to interact by asking questions, offering encouragement and providing feedback;

But how can teachers engage and evolve with distant learners through the course of a lesson? Games create engagement, which is one of the cornerstones of any positive learning experience. According to Karl M. Kapp, a learning expert, game-based mechanisms can help to create a meaningful learning experience [26]. The paper we cite [26] shows how to create and design games that are effective and meaningful for learners. Gamification is the use of game thinking and mechanism to engage audiences and solve problems. This term comes from the videogame industry and the development of the internet. Zicherman [27] introduce the concept of a flow zone and illustrate a boredom area to where the player loses interest, and the anxiety area, where the player will probably shutdown the system.

Inspired by Self-Determination Theory (SDT), Deci et al [27] determined that the more control someone has in choosing what to do, the better the chance the person will be internally motivated to do it. People who want to do something because it is fun are more likely to succeed with their intentions than those who are doing something for a reward or to "learn something." When someone is taken into a playful space then the flow of learning will come naturally, with disregard of age, background or any other characteristic. Many of those examples in real-world include museums, libraries, zoos, and botanical gardens [28]. Many of these leisure's settings employ game elements to help users find personal connections with the non-game setting and their cultural value behind the scene [29]. The phrase "*Ludic learning space*" was coined by Kolb and Kolb to define a space where play is used to help someone explore and learn about a topic or, to use his words; "free and safe space that provides the opportunity for individuals to play with their potentials and ultimately commit themselves to learn, develop, and grow" [30]. Those spaces are designed in such way that individuals can choose to enter, "leave themself behind" and engage in play. In conclusion, if opportunities are created then individuals will explore the given space, discover that is meaningful to them and then engage, reflect, participate and allow themselves to be transformed by the system [31].

5. Panoramic Model for Telepresence

The concepts described in the preceding sections led us to design a novel 360° panoramic video and audio telepresence system. We took on board the findings of earlier research that the environment should be as close to a real classroom as possible and that the participants should feed social and emotionally engage, and in control.

We therefor specified and built the system described in the proceeding sections. Using this system we gave gathered measurements and recommendations in which we present in this paper. We have solicited a number of healthy subjects without visual or auditory impairment to assist us in this experimental work. It is important to remember that this project does not aim to provide a 3D image that can deceive the brain into a false belief of contextual presence [4] but rather to provide a 3D immersive experience where the users can directly manipulate the direction of view and its field of view without affecting others' field of view (FOV).

5.1. Human Stereoscopic Field of View

5.1.1. Horizontal Field of View

For most people, the central field of vision, where both eyes observe an object simultaneously, covers an angle between 50° to 60°, depending on the visual ability of the individual. This area is called "binocular field" and any object within this field provides a sharp representation, with a precise depth perception where colour and spatial discrimination is possible. Any work on visual reconstruction, to present an item as "real", needs to be focussed within this area. There is a 30° preferred angle (15° per eye from the centre of the axis), and a 70° of immediate field of view (35° per eye).

Outside those angles our peripheral vision resides, where the information collected is treated in a different manner but may be as important as the central one. Although our peripheral vision is not as good as central for performing detailed work, but it is especially important and good at detecting motion and pre-fetching tasks [31].

A very small eye movement can provide a large set of new data on the horizontal axis, up to 200°. See Figure 2.

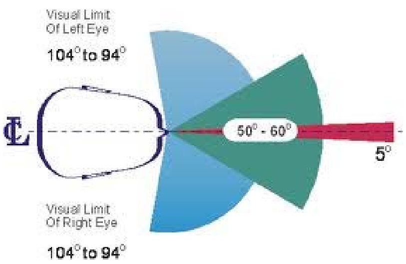

Figure 1. Horizontal Field of View.

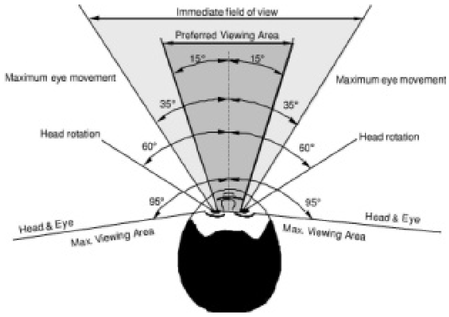

Figure 2. Horizontal field of view and head rotation.

5.1.2. Vertical Field of View

In relation with the vertical field of view, people have developed a different way of perceiving the surrounding space, probably more related to walking and hunting activities. The upper limit is 50° from the normal line of sight, while it is 70° from the same axis for the lower area. It differs if the subject is seated or standing by up to 5° at the preferred viewing area, and same for the area where colour, space and shapes can be discriminated, amounting to 55° in total [33]. See Figure 3 for more information.

For optimal viewing on any projected image, the field of view should be larger than 36° per eye, a total FOV of 72°, with an upper bound of 70°, a total FOV of 140° including the peripheral vision, before the viewer begins to feel uncomfortable and will be induced to nausea and disorientation.

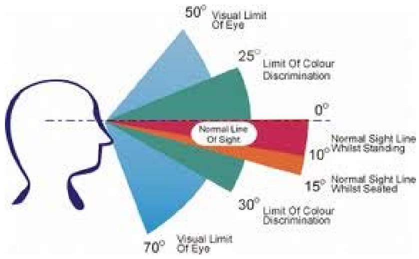

Figure 3. Vertical Field of View.

6. Proposed System Architecture

6.1. Spatial Video Capturing and Reconstruction

Images are collected from the main location (where the event takes place), such as lecture or seminar room, via a spherical mirror setup in the middle of the room, at a specific height to emulate a seated subject attending the event. This is a 360° mirror supported on a tripod, and with a webcam pointing down toward the center of the mirror. The resulting image is a polar coordinated image (Figure 4 and 5).

Figure 4. Spherical mirror and camera.

Figure 5. Polar image transmitted

This image is captured by the local *Flash®* application embedded into the website responsible for broadcasting the event, before being transmitted via the internet using a Media Server, using the RTMP protocol.

At the remote end (e.g. a solitary student) the image is received through a standard web browser using a *Flash®* application embedded into a webpage for portability reasons. This remote application performs the image conversion from polar to Cartesian coordinates, and then presents it to the end-user as a 360° panoramic real-time video where the user can use the mouse to move the visibility window left or right to meet their own needs. We provide a system called 'Camera Mouse' to allow hands-free mouse control, via a camera pointing toward the user's face and recognizing any intention of movement.


Figure 6. Polar to Cartesian conversion

Once the image is converted at the receiving end, it is projected onto a specially manufactured 180° screen *"immersive shell"* (Figure 7), produced by Immersive Displays UK and named *ImmersaVu*®. This immersive shell is adaptive, and can be set to different heights to accommodate events that need standing or seating for greater realism. Distant students at home can use their standard web browser and screens.

Figure 7. Immersive shell

6.2. Spatial Audio Capturing and Reconstruction

The audio is collected through an anechoic mono microphone and transmitted along with the video signal.

At the same time 3 other micro systems, made of a single board computers, with an USB microphone attached to each, stream the signal onto the internet, together with a spatial reference in relation to the panoramic video. Therefore a 3D map of the audio source location can be reproduced. These 3 systems are located equidistant from each other to facilitate triangulation. See Figure 8.

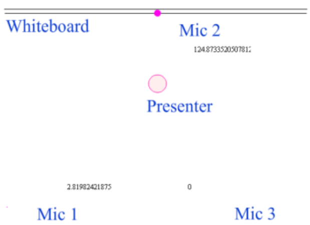

Figure 8. Audio triangulation


Figure 9. Audio capturing system – Mic 3

These microsystems are *Raspberry Pi*® devices driving a *Samson*® USB microphone chosen for its high gain and quality. The audio source location stream is transmitted by using *ffmpeg*® engine producing 3 different streams, one per microsystem. If more precise location algorithm is needed then a number of microsystems can be added to the overall system. The main audio, used during reproduction, is sent together with the RMTP video signal, through the Media Server.

For the audio reconstruction, the end-user receives the audio file as standard audio, with the RMTP video signal, through the *Flash*® application. This signal is combined with an Impulse Response from a HRTF database (Head-Related Transfer Function). With the IR of the original room the end-user is able, by convolution reverb, to reconstruct the original sound into a binaural output from a mono anechoic audio stream.

The values for the HRTF database are provided for each 5° angle of the 360° location. So every time an end-user drags and drops a panoramic video 5°, either to the left or to the right, then a new binaural output will be played [34].

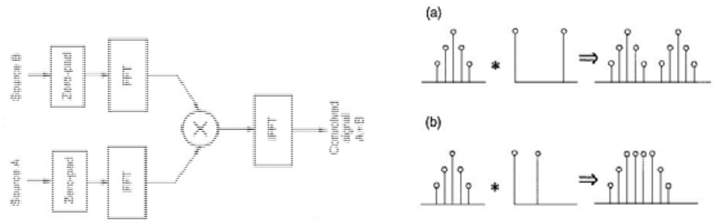

Figure 10. Convolution and output signal

Once the audio signal has been convolved with the related IR (Figure 10), it is then played either though the directional loudspeakers or by headphones. We have used a HHS-3000 Hypersonic directional loudspeakers® for this setup. These directional loudspeakers point directly to where the subject's head should be located.

For binaural reproduction, a set of standard loudspeakers won't work due to the nature of the binaural audio that needs precise ITDs (inter-aural time differences) and ILDs (inter-aural level differences). Because loudspeaker-crosstalk from conventional stereo loudspeakers interferes with binaural reproduction, either a set of headphones are required, or a specific and complex crosstalk cancellation system is needed. In this case we have found that hypersonic directional speakers deliver the narrow beam of audio required to avoid crosstalk, which provides a similar level of performance to headphones [35].

7. Evaluation

The system has been evaluated at different intervals with different users, in an ongoing process when new versions have been created plus it has been presented in numerous demonstrations. Feedback from those people has been gathered and incorporated into the project.

From a technical viewpoint, the system can be regarded as being composed of two distinct sides; the collection and transmission of local video and audio, and the reception and reconstruction at the remote end. A very important strength of the system is that it has flexibility built-in as one of the requirements, allowing users to interact in multiple ways and thereby providing the ability for it to evolve as new technologies emerge. *Ado*be Flash® is used as the current platform because of its portability and ability to support rapid prototyping but, in the future, any other platform, such as Java could be used. There are some limitations with AS3 and its library that could be overcome by Java and need to be researched in future work. The process of video reconstruction is a memory and processor intensive task and so we have added elements to the transmission interface in order to regulate quality *vs.* speed during transmission, but need to conduct further investigation to avoid unwanted pixelation and distortions. Also, further work is needed to perform workbench tests to confirm if Bitmap Data handling should take place on the server side, instead of the client.

From a user viewpoint while we have yet to undertake a formal user evaluation, we have through the development of the system involved users. A, common view of all those who have experienced the system is that it opens a new range of possibilities, not just for remote lone learners but also for local classroom based users. Part of this feedback has led to the development of a browser-only version for those people accessing the system without an immersive shell. Now that we have completed the technical work on the platform, we plan to conduct a more formal user-study but in the meantime, we hope these less formal insights prove helpful.

8. Conclusions

For any distant learning model to succeed is necessary to consider the needs of the individual and the relation with their environment and group; that is y the way that they perceive it. When modeling a group, a priority is to allocate a space where the learners can grow and fulfill their intentions. Being part of a group is an important key to improving the relationship between the distant learner, the teacher and other peers. The success of each participant will be manifested in the success of the group.

We have presented a model, based on panoramic immersive media system, capable of deconstructing and reconstructing remote spaces to give access and additional information to distant learners and local groups. This model provides key elements for the success of online activities such as learning, by providing communication and engagement, and creating a ludic space that is not limited to the academic activity but to any life learning scenario. Thus, we hope that this work provides a new perspective for online education that go beyond the current state of the art by offering panoramic real-time video and audio connections that are controllable and more engaging to users.

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