Dynamic spatial positioning system based on sounds and augmented reality for visually impaired people

C Kirner[1], C S Cerqueira[1,2], T G Kirner[1]

[1]Department of Mathematics and Computer Science, Federal University of Itajubá (UNIFEI), Itajubá, MG, BRAZIL

[2]Space Engineering and Technology, National Institute for Space Research (INPE), São José dos Campos, SP, BRAZIL

ckirner@gmail.com, christophercerqueira@gmail.com, tgkirner@gmail.com

[1]*http://www.unifei.edu.br*, [2]*http://www.inpe.br*

ABSTRACT

This paper presents an application which intends to exercise spatial association of a three dimensional stimulus with its corresponding motor feedback, inspired on the Ping Pong Game. The application uses a low cost and easily built artifact, enhanced with an augmented reality layer provided by a free authoring tool. The augmented reality resources empower the artifact with sound feedback, so visually impaired people can use it. Besides, the visual feedback can be useful for non-visually impaired people and also for therapists, who can prepare exercises, promoting a therapeutic application and involving social inclusion capabilities.

1. INTRODUCTION

Developers of serious games address purposes others than pure entertainment, such as education, defense, scientific exploration, health care, etc. (Abt, 1987). The lack of physical activity is a critical health concern for individuals that are Visually Impaired (VI), because they usually have few opportunities and incentives to engage in physical activities. In this sense, it is important to provide situations to support an adequate fitness and a healthy standard of living for them (Azuma, 1987).

Technology helps create health serious games, once the success and proliferation of video games are growing making them more relevant and more responsible (Beato et al, 2009).

One technology, which can be easily used into serious games presenting low cost, is the Augmented Reality (AR). Early AR definitions say that AR was obtained only through visual elements (Cerqueira and Kirner, 2012; Farlex, 2012); however, the use of audio and haptic interactions, associated in time and space, extends the AR definition.

In addition, the development of interactions using audio and haptic resources expands the AR concept to a wider definition, which involves the real world empowered with virtual objects (visual, audio, and haptic) with their related drivers (projectors, speakers, and haptic devices).

Artifacts, including the interactive ones, can be implemented using AR, once it provides a low cost and can be easily distributed to interested users. Several interactive artifacts for rehabilitation are being developed, most of them applied in motor rehabilitation. There are few examples focusing on cognitive rehabilitation (Grasielle et al, 2007; Gunasekara and Bendall, 2005; Kato and Billinghurst, 1999).

Interactive artifacts based on AR technology may fulfill the following requirements: (Kirner and Kirner, 2011):

- The artifacts for cognitive application have to involve multi-sensory knowledge, perception, memory, attention, logic and motor control, in order to allow the preparation of cognitive exercises.
- The physical parts of the artifact has to be built with ordinary materials, involving a simple process, presenting availability and low cost. For this, it could be adopted materials such as Styrofoam, cardboard or wood, to implement the physical structure, always followed by instructions and templates.

- The logical parts of the artifact have to use AR. Authoring tools for rapid prototyping can make easy the development of applications.
- The user interactive actions on the artifact must be tangible. This property, due to the coincident physical and virtual points, allows the interactions, since when the user touches the interacting device (pointer) in the artifact, he “feels” the contact and the virtual action point is enabled. This characteristic is important, because it gives more comfort to the user. When the points are placed into the 3D space, without physical association, they demand more ability and concentration from the user, to collide the pointer with the virtual points.

A simple way to mix virtual information in the physical user environment is using a webcam, which captures a live video stream of the real world, and track some features, allowing the computer to add virtual information to the real world. Figure 1 shows examples of AR setup with a camera (Kirner et al, 2012a). The system in Figure 1a uses a top, non-mirror view, where the camera is placed with a tripod, the video seem on the monitor is the same view of the user, and the artifact can be seem on the real and mixed worlds. Figure 1b uses a mirror view, usually achieved by a notebook camera, and the artifact is usually hold by the user body to be seem by the camera, which does not easily allows the user to see the real and augmented artifact.

Figure 1. *Augmented reality examples. (a) Non-mirror view and (b) Mirror view.*

Serious games focus on three inter-related aspects: rehabilitation, socialization and inclusion.

Rehabilitation is defined (Kirner et al, 2012b) as a dynamic process of change in lifestyle, due to a disease or traumatic incident. The success of a rehabilitation program depends on several factors, such as timing, type of program, medical management, and discharge planning. This can be achieved by multidisciplinary ways, including medical, nursery or socialization (Lee, 2012). Socialization is an essential element, which is defined as the acquaintances of necessary skills for people perform as a functioning member of their society, giving them the conditions to be socially included (O’Neil, 2011).

This article presents a computer-based application, inspired on the Ping Pong game, using a low cost and easily built artifact, which aims at providing cognitive and motor development exercises, as well as socialization. The application uses AR technology, which is responsible to give sound feedback to visually impaired users and visual feedback to therapists and non-visually impaired users.

The following sections present the Related Works, showing some cases using video game controller; the Artifact, which shows the development of a grid artifact that helps in the game; Interaction, which shows how the augmented reality layer performs to create the application; User, showing how the research can be used by user and therapists; and the Conclusions and future works.

2. RELATED WORK

Some related studies include rehabilitation efforts, based on pure augmented reality and on video-game controllers, as the Nintendo Wiimote Controller (Morelli et al, 2010).

Kirner and Kirner (2010) developed a cognitive serious game focused on rehabilitation, related to memory and association activities. In this serious-game, an artifact (Figure 2a and 2b) was developed in order to empower an AR layer.

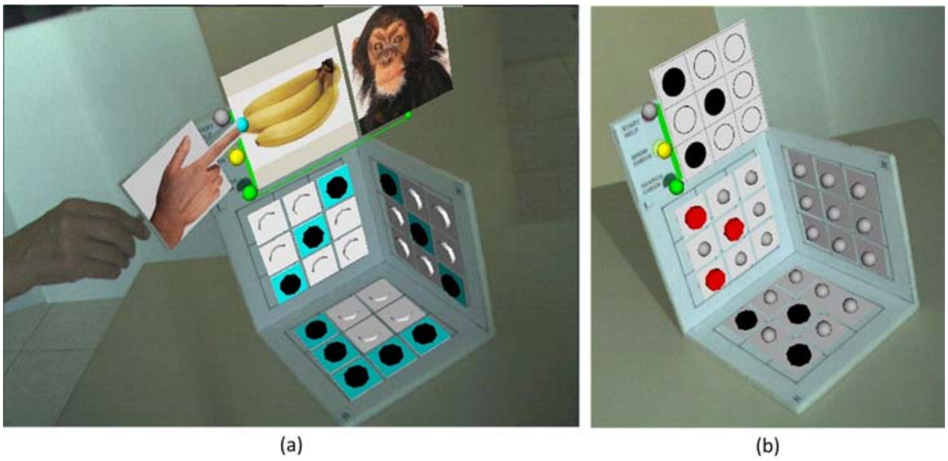

Figure 2. *(a) and (b) examples of artifacts empowered with AR.*

Another application is the blindHero (Rego et al, 2010; Yuan and Folmer, 2008). In it, the user, wearing a haptic glove, receives the input stimulus to press the guitar button (Figure 3a). In the VI-Tennis application (Morelli et al, 2010), the user receives tactile feedback (from the Wiimote Controller) and audio cues to play the game (Figure 3b).

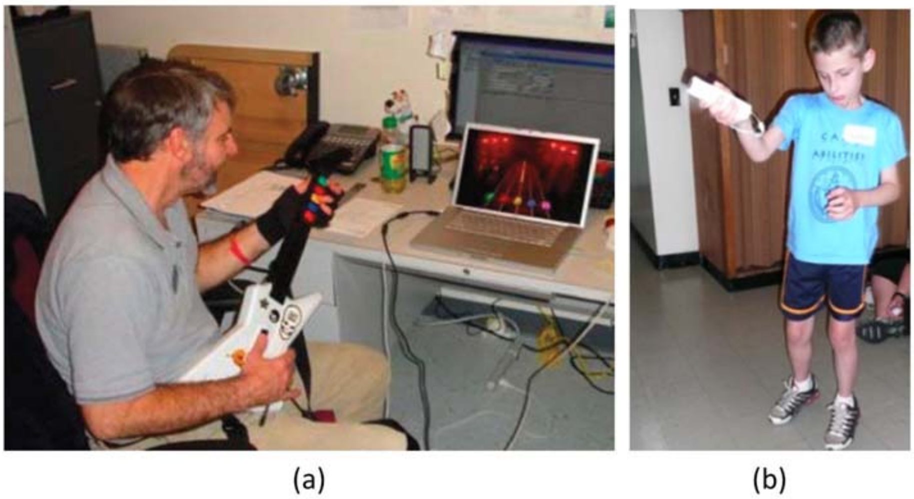

Figure 3. *(a) blindHero application; (b) VI-Tennis application.*

3. ARTIFACTS

In general, games interfaces applied to visually impaired people are developed to give tactile and audio feedback, using different textures and sounds. To move into the game space, the user must have a three-dimensional (3D) sound perception. One way to implement the spatial perception based on sound is varying frequency and acoustic intensity in the space using the three coordinate axes:

- Horizontal axis. The audio is placed using stereo balance.
- Vertical axis. The audio is placed by the frequency, in which a higher pitch indicates a higher height and a lower pitch indicates a lower height.
- Deep axis. The audio is placed in association with the volume, in which higher volumes indicates that the object is closed to the user.

Figure 4a shows the 3D audio placement, which helps the VI user to interact with the game. Figure 4b shows how to control the object speed (in this case, a ball). Four stages, defined by four time intervals, control the ball speed, so, with long time intervals the speed is decreased and with short time intervals the speed is increased.

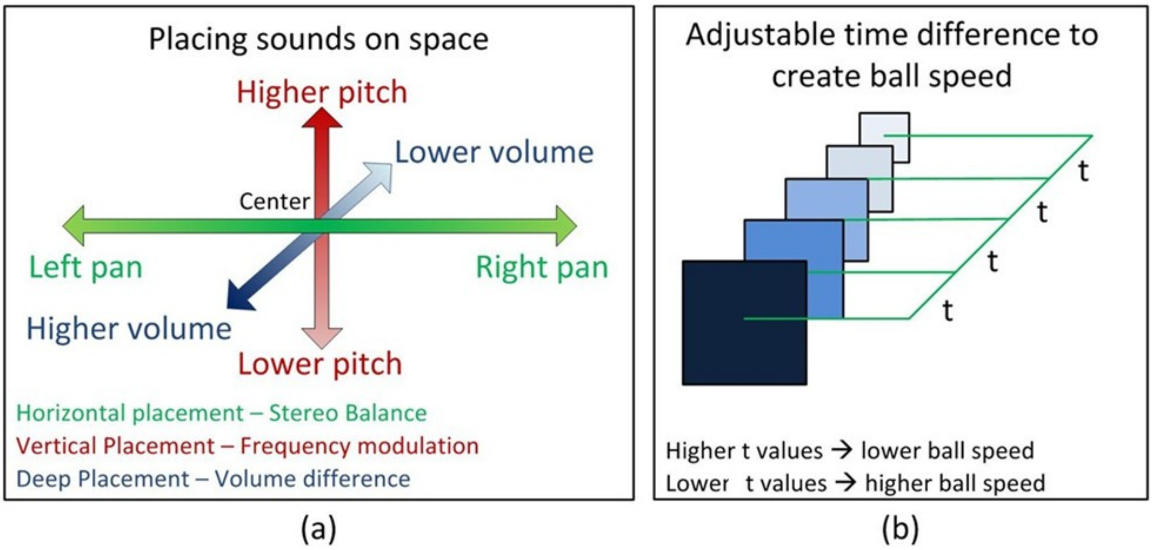

Figure 4. *(a) Sound placement into a 3D space; (b) Adjusting the time intervals to control ball speed.*

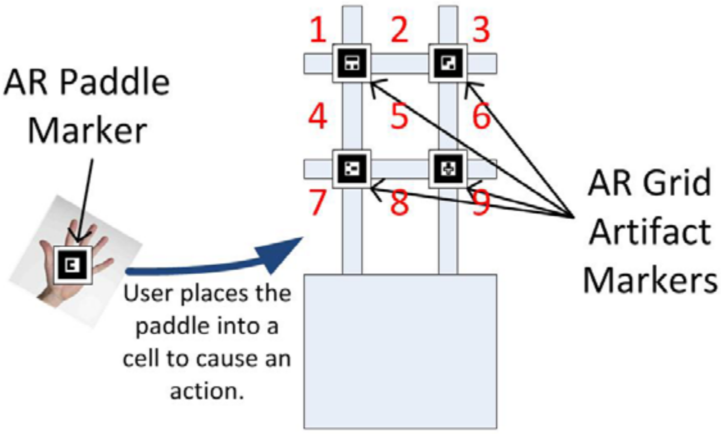

Figure 5. *Grid Structure with nine cells and four AR markers on the Artifact.*

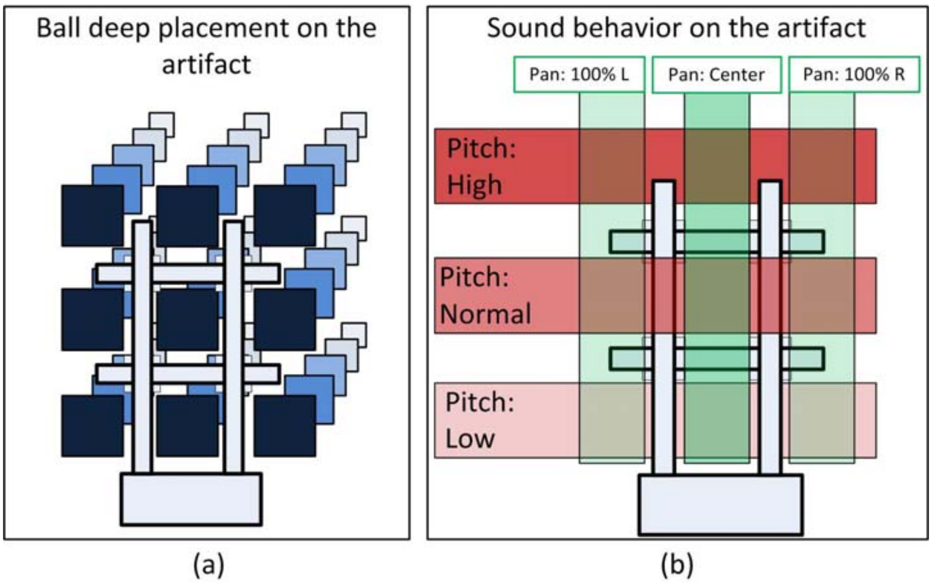

Figure 6. *(a) Deep placement; (b) Sound behavior.*

To achieve an interface that helps the VI user to play the game, a Grid Structure (Figure 5) with AR markers was developed. Thus, the VI user can place the paddle into the correct playing space, in order to correctly hit the virtual ball.

The inclusion of the virtual layer enables the AR properties. In this sense, each artifact cell has a deep placement (Figure 6a), to create the sensation of ball movement. The vertical and horizontal placement are interlaced, to provide nine possible combinations of pan and pitch (Figure 6b), so that the user can find the correct cell by its sound; for example, a ball coming in left pan and with low pitch indicates to the user that this ball is in the bottom left cell.

A second artifact was built to provide real time changes made by therapist. It has three more cells on the top of the grid (Figure 7a) and it is used to select the ball speed. Figure 7b shows the rear (camera) view of the artifact, where the augmented reality markers is captured by the camera. Figure 7c shows both artifacts: the user artifact, on the left, and the therapist artifact, on the right. Figure 7d shows the prototype being used by a therapist with paddles. The upper paddle controls the ball speed and the lower paddle controls the position where the visually impaired person has to place his/her paddle on his/her artifact to hit the ball using sounds driven his/her movements.

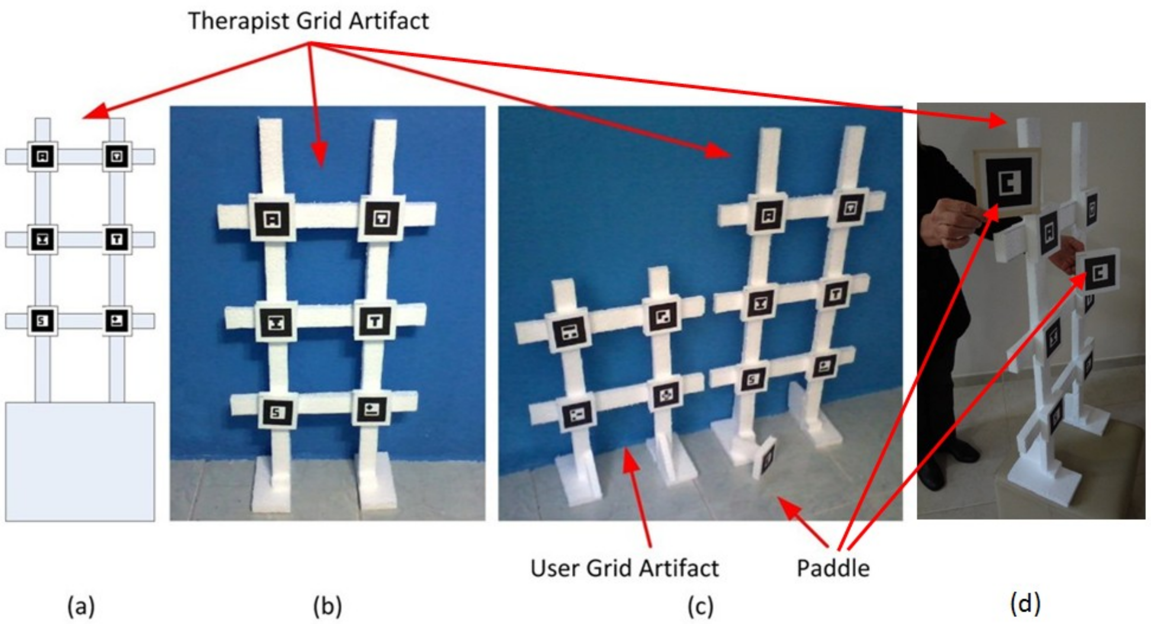

Figure 7. *Artifact Views: (a) Conception; (b) Therapist; (c) User and Therapist; (d) Prototype in action.*

The prototype artifacts were developed using Styrofoam, which is an easy to use material. A final artifact could use wood or plastic material. In this work, we used the cheapest material.

In order to create the AR layer, it was decided to use the marker approach (Cerqueira and Kirner, 2012), offered by the basAR application, which will be explained in the Interaction Section. The user artifact includes four markers and the therapist artifact has six markers. Each paddle presents only one marker. All markers must be different from each other, to be correctly recognized.

4. INTERACTION

The development of the AR application followed some hardware and software requirements:

- Hardware: computer with a webcam, capable to run the software.
- Software: program used to create the augmented world.

In these experiments, a notebook with an incorporated webcam was used to acquire the real world and the markers' information. The software chosen was the basAR (Behavioral Authoring System for Augmented Reality) developed by Cerqueira and Kirner (2012), which allows a programming procedure based on action points. Action points are reactive zones placed apart from the marker reference that, when stimulated by a control markers (the paddle), may give visual and auditory feedback.

Figure 8 exemplifies how the action points work. A base marker holds the points and, when the control marker action point collides with the base points, it causes programmed feedback.

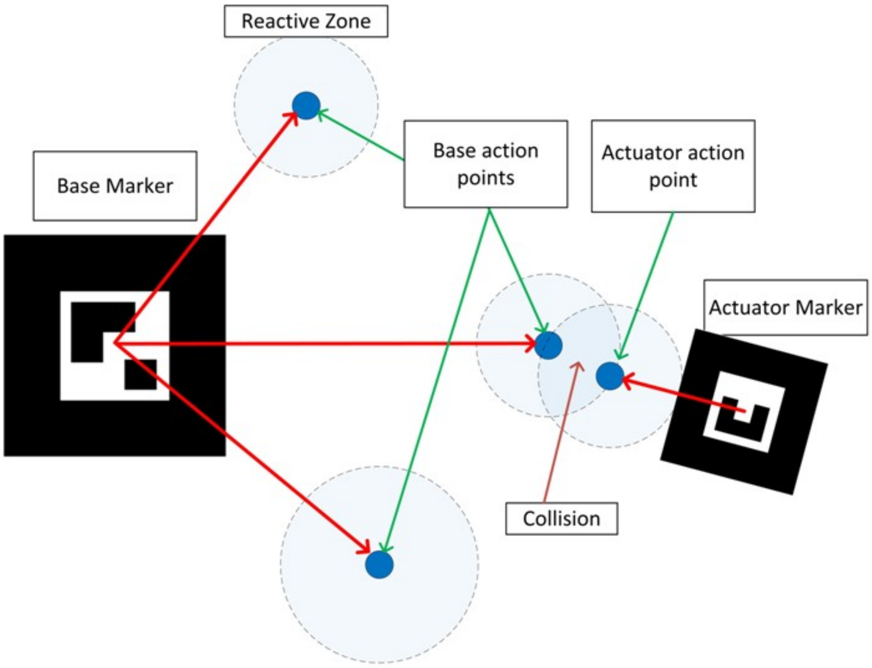

Figure 8. *How basAR action point works.*

Each artifact has a number of action points related to the amount of grid cells, (the user has nine points, and the therapist has twelve points).

The basAR Authoring Language (basAR-AL) uses a state machine concept driven by events, which can be divided into user interaction, programmed changes and math results.

- The user interaction makes changes on the state machine, by action point collisions.
- The programmed changes make changes on the state machine, going to a new state, when the old one is activated.
- Math results make changes on the state machine, by testing some variables. Depending on the result, the state machine can move to other state.

Additional information about the basAR-AL tool is available on the basAR documentation (Cerqueira and Kirner, 2012).

Possible use scenarios for the AR application here discussed are presented in the next section.

5. USING THE APPLICATION

The application discussed in this paper presents four possible using modes, which could be chosen, depending on the intended activity (user x computer, user x user, user x programmed sequence, or user following therapist), categorized in: Game and Therapeutic Modes.

- Game Mode. This mode allows the VI user to dispute matches at home or anywhere, using the system. The matches can be held in two cases: against the computer or against other player. It is important to note that, as the system also provides a visual feedback and both feedbacks (sound and visual) are blended, it also allows non-VI users to participate of the game, turning it an inclusive application and contributing to the socialization of VI users. Schemes of these two cases are illustrated in Figure 9.
- Therapeutic Mode. This mode allows a therapist to introduce a series of exercises to VI users in the activities. This can be achieved by two cases: against a pre-programmed sequence to achieve a desired result, or driven by the therapist, where the position of the sound is chosen by the therapist and one of three speeds can be selected on the fly. Schemes of these two cases are illustrated in Figure 10.

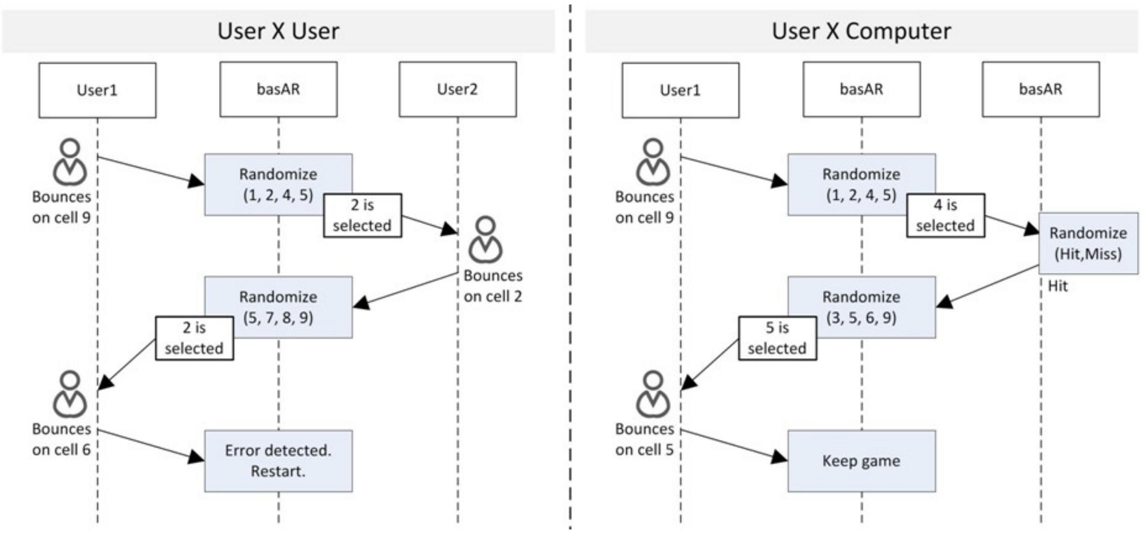

Figure 9. *Game Mode schemes.*

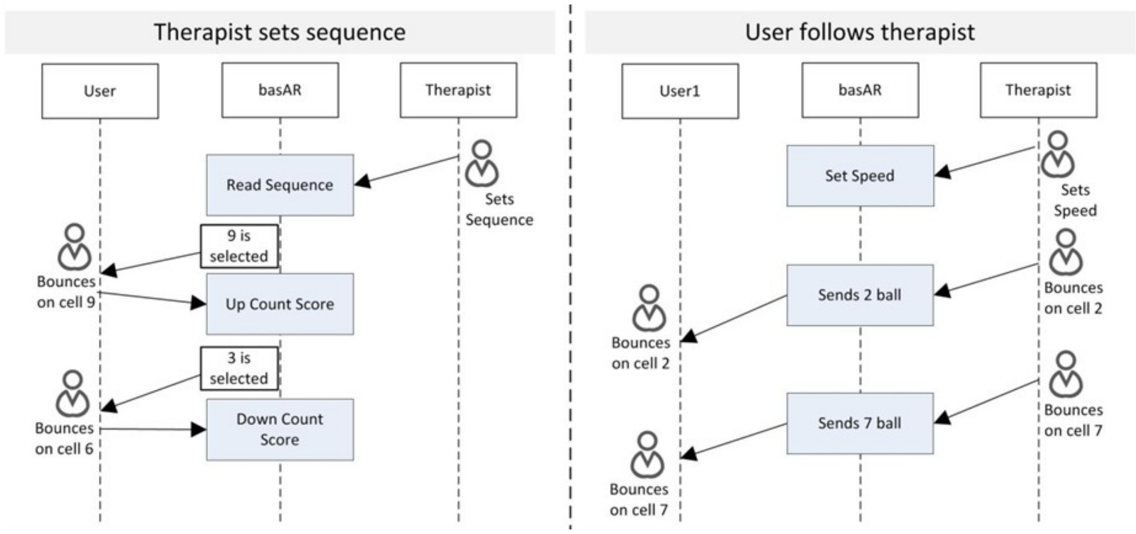

Figure 10. *Therapeutic Mode schemes.*

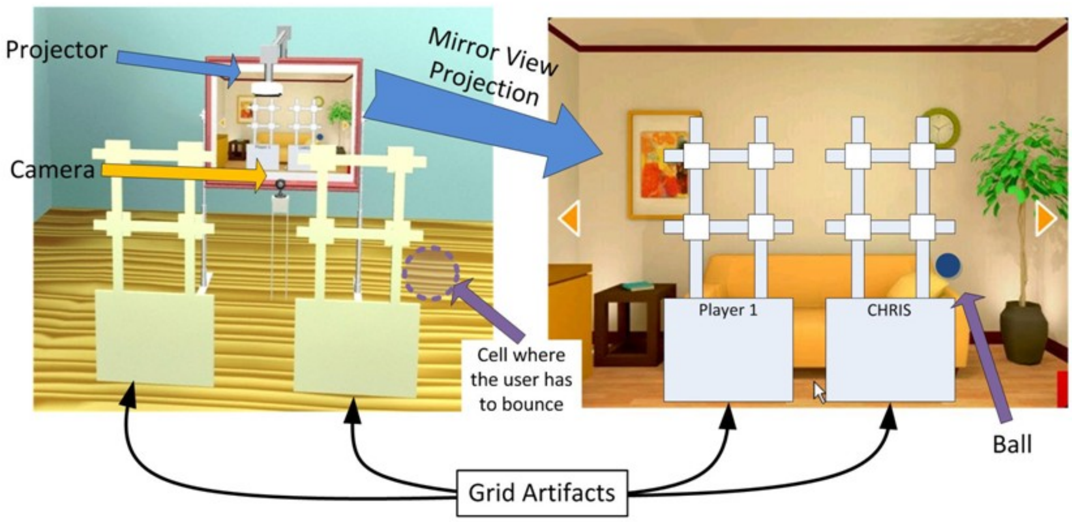

Figure 11. *Game Mode Sketch: User X User.*

Figure 11 presents a sketch of a Game. In it, two artifacts are positioned in front of a camera, which acquires the video and sends it to the projector. The projection shows a mirror view of the users and the augmented layer, showing the virtual blue ball and issuing a sound.

6. CONCLUSION

This paper presented and discussed a low cost, interactive and inclusive application, inspired on the Ping Pong game, which uses a Styrofoam grid artifact to help users to play. The game uses an Augmented Reality environment, implemented with basis on the software basAR, to empower the artifact with virtual properties. The article describes development aspects and some utilization scenarios.

Comparing the presented application with commercially available gaming technologies, it is possible to identify that this system is more affordable, since many users already have computers with cameras. In this sense, it is necessary to build the artifact, which is not a difficult task.

The positive points, observed by some users, were:

- The easiness of acquire the calibration, which is desired in the game-mode, when the user can practice at home.
- Therapists pointed out the inclusive characteristic as an important issue, as some visually impaired children could play with their brothers and friends, making important steps to integrate both worlds.

The identified negative aspects include the fact that a visually impaired user needs help to build the artifact. Besides, the therapists pointed out the difficulty to create the pre-programmed sequences, which could be supported by a future friendly interface.

The application and further information about the implemented augmented reality spatial game are available on Kirner et al (2012b).

In a future version of the application, the negatives aspects will be considered to improve the therapeutic use, such as the inclusion of a burst mode. This will make possible the therapist create a sequence of steps to send to the player. It is being analyzed a development option by means of an ARDUINO hardware.

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