The Augmented User:
a Wearable Augmented Reality Interface

Francisco GINER, Cristina PORTALÉS
Camino de Vera s/n, Laboratorio de Luz, BB.AA., Univ. Politécnica de Valencia, Spain
fginerm@pin.upv.es, criporri@doctor.upv.es

Abstract. In this paper, 'The Augmented User' project is presented, a new Augmented Reality (AR) system based on the ARToolKit and MRXToolKit technologies. We have developed an innovative system in which the user is visible in the AR scenario and indispensable part of the final result: he/she is in fact the carrier of the markers that are recognized by the system allowing his/her own transformation; this opens the possibilities of the users that are immersed in an AR system, being at the same time the augmented matter and the spectator. We also introduce two interesting applications for our system: the 'changing personalities' game and the 'image carrousel' performance, as simple examples of the multiple applications that our system actually have. The collaborative part is also proposed and presented, which makes the applications even more interesting. Finally, some conclusions are presented and further work is proposed.

1. Introduction

The Augmented User is an AR application based on the well known ARToolKit [2] and MXRToolKit [9] libraries; these libraries are indeed the base of a wide range of AR applications [1, 3, 4, 5, 6, 7, 8, 10, 11, 12]. Most of these applications are applied to visualize elements virtually inserted in a pre-existing physical context. In our system we try to relativize some of the dualities or binary structures that arise in these kinds of applications regarding to the perception, for example:

- Relationship user/object: the user is part of the object[1].
- Inside/out: user incorporation inside the representation space.
- Refers to the 'mirror stage'[2] by changing user identity.

To deal with these dualities, the spatial distribution of some basic elements is inverted:

- Normally the user establishes identification between the display and his/her vision, identification increased by the physical location of the HMD (Head Mounted Display) which is placed at the height of his/her eyes. In our application the mechanical eye, i.e., the camera is far away from the user.
- It is also common that the user equipped with the HMD observes markers (to achieve user pose) as an exterior object. In our case, the markers form part of the user. The user acts, sees, thinks and feels at the same time the AR experience.
- The projected image works as a mirror whose reflex is viewed by the user and others, thus allowing a collaborative experience. Furthermore, within a single AR scenario, several markers wear by different users can be tracked, thus allowing

[1] 'Be-like-object for the Other'. Jean Paul Sartre
[2] 'The stage of the training mirror like of the function of I (je)' [1949] Jacques Lacan (Written 1)

several augmented users that may or may not be together with other non-augmented users.

Our application is generically approximated to the contraposition: ‘to be is to perceive (esse is percipere) / to be is being perceived (esse est percipi)’ [3], affecting also in questions of identity, avatar and playing.

In the following sections, the camera pose, our AR system and the developed marker prototypes are explained. Some examples are shown, including a collaborative AR scenario with multiple users, whose experiences are also collected. Finally, some conclusions are given and further work is proposed.

2. Camera pose tracking

Normally, in AR applications the camera pose (position and orientation) corresponds to user’s head pose, so the camera point of view is considered to coincide with that of the user. In our case, the camera is still and far away from the user.

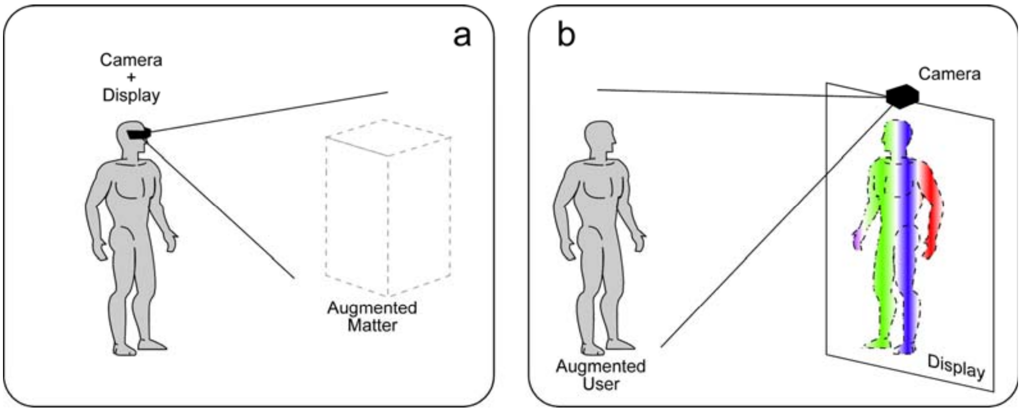

Figure 1. Relation between user and camera:
a) in traditional AR system; b) in the Augmented User system.

Our interest yields in acquiring the relative pose between the markers and the camera. Camera pose tracking is one of the most crucial parts in AR applications [5]. This consists on determining the 6 outer orientation parameters of the camera, i.e., three translations and three rotations. In our application, this task was achieved with the ARToolKit library, which was developed at the HIT Lab of the University of Washington. This technology provides the necessary computer vision techniques required to track some kind of markers, and accurately calculate the camera pose relative to them. Virtual objects are then accurately posed – relative to the markers – in the ‘real’ world. We also used the MXRToolKit developed at the MXR Lab in Singapore, which consists of a library of routines to help with all aspects of building mixed reality applications.

3. System

Our system consists of:

- The physical wearable markers,
- an overhead screen,
- a DV-Camera, connected by an IEEE 1394 cable to the CPU,
- a computer graphics workstation,
- two (or more) potent and controlled focuses,

[3] By G. Berkeley.

- ARToolKit and/or MXRToolkit libraries.

The markers are carried by the user and are linked to some 3D virtual models. The virtual models are in the VRML format and, for some applications, are mapped with images. The overhead screen has a dimension of 2.5x1.5 m, and is made of a translucent white plastic. The dimension of the screen and the distance to the projector should be taken into account in order to achieve a representation scale similar to the real one, thus incrementing the mirror effect. The user is situated within a distance of 1-3 m to the screen and at the same height. The camera is situated at the very top of the screen pointing to the user. Two focuses are needed to properly illuminate the user for the camera to track the markers; the light should be directed in such a way that the screen itself remains in half-light. In the following figure, the spatial situation of all devices and the user can be seen.

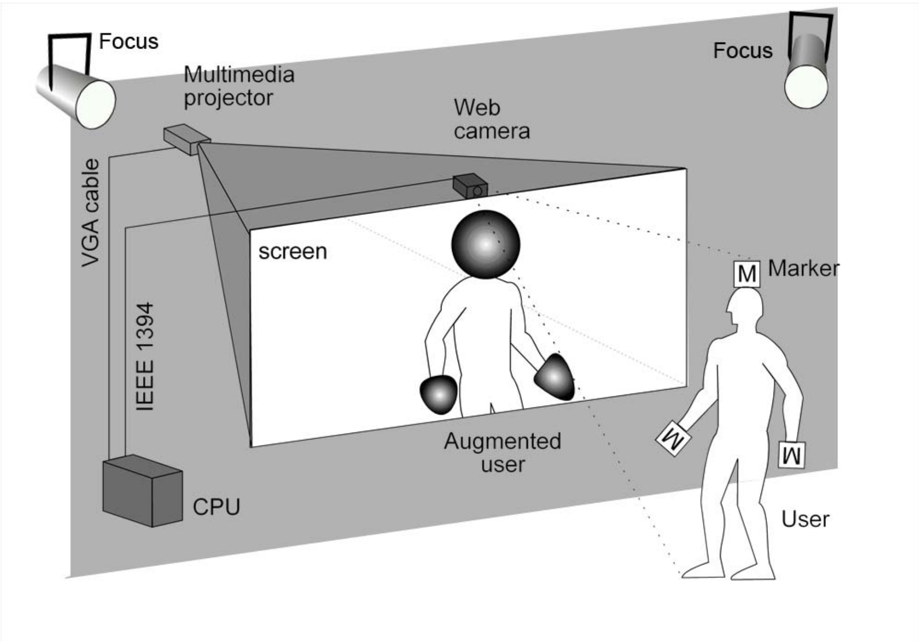

Figure 2. System scheme.

4. Marker Prototypes

Several prototypes were made. At the beginning, basic virtual shapes were tested with the user carrying a simple marker on his/her hands (figure 3).

Figure 3. Simple marker and user as a snowman.

When the user moves with the marker, the virtual object acquires the same movement, thus allowing a playful experience. The first impression acquired by the users was very positive, as they really enjoyed the fact of being transformed into a new character that followed their movements. Nevertheless, the users found that carrying a marker was not comfortable, as they wanted to have their hands free. We found another problem with this system, that the users need to handle the marker at a certain position, neither lower nor higher, for the virtual object to appear in the correct place. We thought about the possibility of doing a vest-marker for the marker to be fixed at a certain location, but somehow we needed several vest-sizes to allow all kind of users to wear it. Another problem found was the fact that, within the natural user's motion sometimes his/her arms partially hided the markers, thus loosing the virtual object at that time. Therefore, the idea of making a vest-marker was abandoned.

After thinking about the best suited place for the user to wear a marker, we concluded that the best one was on his/her head, which is the highest point of the human being, solving the occasional problem of the arms hiding the marker. We decided to make a hat in such a way that it could be wearable by all users. So the hat itself is mainly made of wool, which makes it to be elastic. This hat is composed by a set of three markers, forming a prism with a triangular base in such a way that the virtual object will never be loosed although the user rotates, allowing a more motion freedom.

Figure 4. User wearing the prismatic hat; Man-to-Lady.

A posterior and natural evolution of our hat marker is the hair band marker, with both reduced dimension and weight, and more comfortable for the user to wear. Additionally, we also modelled markers for the user hands, thus allowing the incorporation of new virtual objects for different parts of the user body. Each one of the virtual models is independently animated by the user, thus incrementing gaming possibilities. It should be pointed that reducing the marker dimensions implies the need of both a better camera resolution and illumination, thus marker dimension is always dependent on our system specifications. In the next figures the last prototypes can be seen.

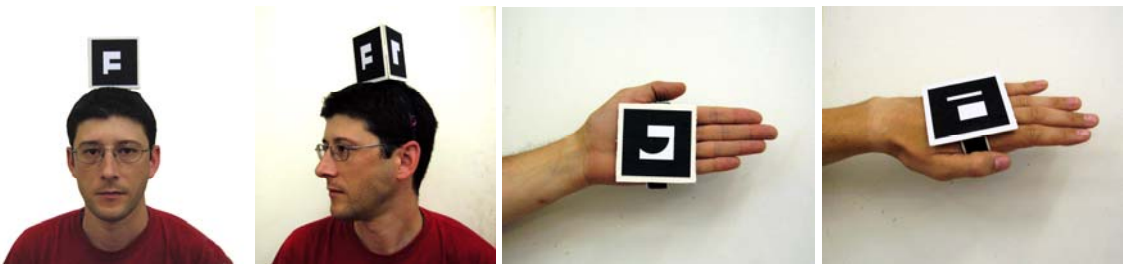

Figure 5. User wearing the hair band marker and the hand markers.

The wearable markers are indeed an inexpensive system for the AR applications. Furthermore, the markers are extremely light to wear. These two facts allow this system to be used by everybody, including children, with no fear to break normally expensive vision interfaces (as HMD, hand-held screens, laptops, etc.) or pose sensors (as inertial sensors, GPS, etc.). In [4] the user wears a glove, with a marker attached; nevertheless, in this case the information acquired from the marker is used to navigate within the virtual world. Therefore, we can say our system is innovative.

5. Changing personalities

For this application we modelled different characters (a lady, a young child, Mr. Potato, etc.) in the VRML format. The users see themselves with the new personality projected into the overhead screen that acts as a mirror. The projected image is rendered in real time, allowing a visual dialog in which the user can be introduced very easily. In the following figures we can see the user transformed in Mr. Potato. He is wearing the hair band marker that is linked to the Mr. Potato's head, and the right and left hand markers that are linked to Mr. Potato's right and left hands, respectively. This makes the user to experience a personality change, which is not only seen by other users, but principally by him/herself from the exterior of his/her own augmented body; the user is an interactive spectator and an indispensable part of the application for being the matter of itself, which is in continuous transformation.

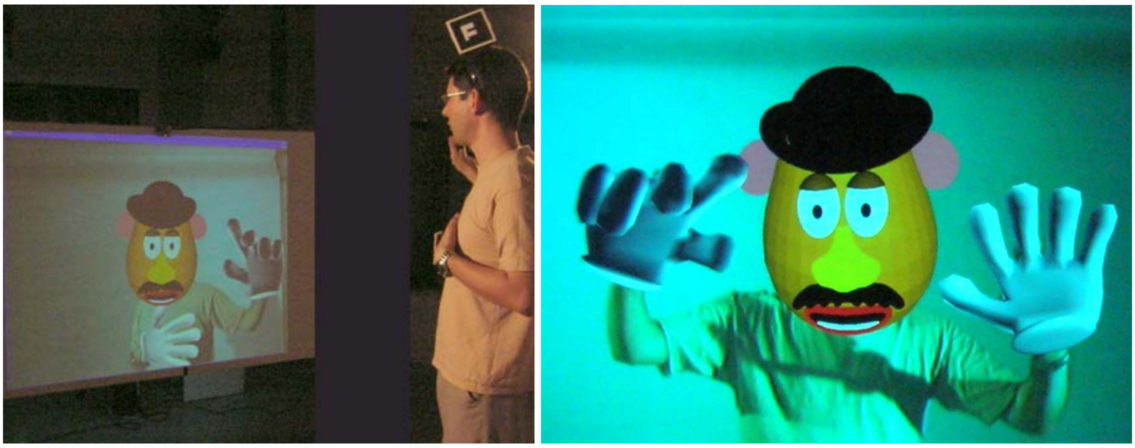

Figure 6. User transformed in Mr. Potato.

It should be pointed that one of the well-known drawbacks of using marker-board tracking is the presence of the marker itself, which tends to look unnatural. In our application this problem disappears, as the markers are always hidden by the virtual objects, thus avoiding them to appear in the projected image. The model scale with respect to the user is exaggerated; therefore the playful and/or cartoon effect is increased.

6. Image carrousel

This application consists of a set of images disposed in several bands that are animated, thus rotating around the user. This virtual model is also in the VRML format and the application runs under the MXRToolKit libraries. The mapped images can show past events, far places, personal and/or private spaces, user's relatives, etc. Therefore, the image content can have a thematic, expositive, narrative and/or random character. We can also establish a relationship between past, present and future, close and far places, known and unknown, etc.
Images are mapped on a VRML animated model consisting of a set of planar surfaces disposed in different bands. These bands can intercept each other at a certain point, showing an interesting visual effect similar to that of a kaleidoscope (figure 7).

The virtual model can be modified by changing its rotation velocity, number of planar surfaces, number and tilting of the bands, intersections, etc. For the same virtual model, different images can be linked. Very interesting is the sum of both model and user movements.

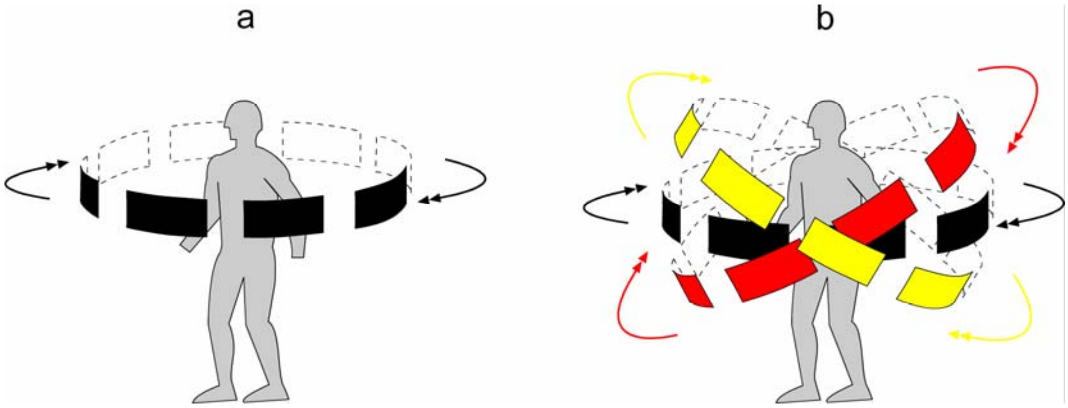

Figure 7. Carrousel model scheme:
a) with only one band; b) with three bands intersecting each other.

In this application we faced the occlusion problem, i.e., the non-desirable effect when a real object (in our case, the user) partially should hide the virtual one. We solved this problem in a very easy way, just giving mapping information to the faces of the planar surfaces that point outwards the user, thus the faces pointing to the user remains transparent, and are not seen in the projected image when being backward to the user. In the next figure, we can see the user with a thematic Image Carrousel application, showing some images of Ghent.

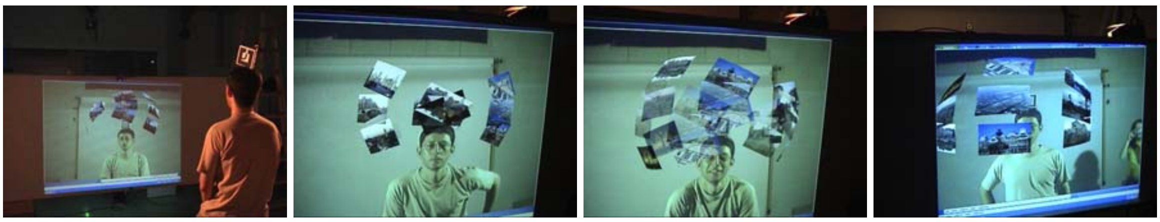

Figure 8. Image Carrousel with images of Ghent (Belgium)

7. Collaborative Scenario

Multiple users can immerse in each one of the applications at the same time. Thus, a collaborative space is created. Within this new space, each one of the users is wearing a set of markers, related to different virtual objects, but with some kind of relation between them. For example, in the 'changing personalities' application, the heads of couples of famous characters were modeled; these models are in fact simple quasi-spherical shapes mapped with images, which are very easily interpreted by the user. This specific application remits to some artistic expressions of Tony Oursler[4], who projects videos of human faces on some kind of heads acting like screens of inanimate dolls in a non habitual positions and scales, adopting finally these pieces a similar aesthetics to ours, and provoking the reflection of the spectator; in our case, the user gives 'live' with his/her own movement to the augmented hybrid in which he/she is converted. We do not discard to map the heads with some videos instead of images, which will allow a major interaction.

To map the models, firstly we focused our attention on legendary Hollywood couples, as Jack Lemmon & Walther Matthau, Spencer Tracy & Katharine Hepburn, C3PO & R2D2 or Fred Aster & Ginger Rogers. Therefore, user 1 could be Fred Aster and user 2 Ginger Rogers. They both could dance as in the legendary *Shall we Dance* movie. We also thought

[4] http://www.tonyoursler.com/

about couples than can never be together or never ever met, but have lot in common, as Isaac Newton & Albert Einstein, Wolfgang Amadeus Mozart & Ludwig van Beethoven, Hergé & Tintin or Dr. Jekyll & Mr. Hyde. Could you imagine Mozart and Beethoven talking about a Symphony?, or Dr. Jekyll facing with Mr. Hyde? What would ask Titin to his creator, Hergé?. In the following figures, two users transformed into Jack Lemmon & Walther Matthau are playing together.

Figure 9. Different users playing with their new identities:
Jack Lemmon & Walther Matthau; Laurel & Hardy; Mr. & Mrs. Potato

For the 'image carrousel', an augmented collaborative application was created in which images from three different spaces were shown. User 1 could see the images from a trip to London (city), user 2 from a trip to Ordesa (field), and user 3 some personal/private (home) images. In the next figure the three different models can be seen.

Figure 10. Different images for a collaborative image carrousel application showing three different spaces: city, field and home

8. User experience

User response with both 'changing personalities' and 'image carrousel' applications has been very positive. A total of 17 men and 17 women ranging from 7 to 60 years old tested our system; after the experience all the users fulfilled a short test. We asked them to score between 1 (bad) and 10 (excellent) a total of 9 different facts of our system. The facts/questions to be scored were:

1. Interaction
2. Fastness of the system (regarding to the user movements)
3. Design and comfort of the wearable marks
4. The idea of the mirror as an interface
5. 3D virtual models
6. Gaming possibilities
7. Learning possibilities
8. Therapeutic possibilities
9. Gallery/Museum possibilities

In figure 11 the mean scores are shown. As it can be seen all the scores are above 6.5 and, in general, women gave better punctuations; the fact that was better scored by women was the question 6 (9.4 points) and by men the questions 4 and 5 (8.1 points).

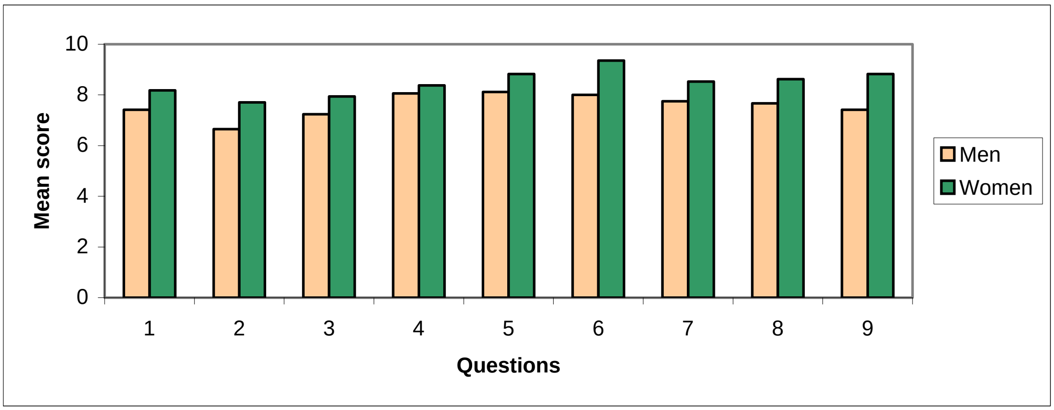

Figure 11. Scores given by the users to 9 different questions about our system

We also asked the users to write a short conclusion about the experience. In general, they empathised the fact of the gaming possibilities, and gave us some new ideas to improve our system or use it in a different scenario. Some of the comments were: “I enjoyed myself very much. It could be interesting to add some kind of music related to the new virtual personality”; “A new virtual scenario could be created”; “Improve the system velocity and use bigger mirrors”; “Add more virtual objects and pay more attention in the learning possibilities”. In general, the applications that people enjoyed the most were the collaborative ones.

9. Conclusion

In this paper we have presented the Augmented User, an innovative AR application were the whole system is inverted: the camera is far from the user who is augmented by some kind of wearable markers. The user interacts with the virtual world with his/her own movements, being at the same time the ‘user’ and/or ‘matter’ of the application and the ‘spectator’, being transformed and acquiring a new identity inside the already-known real space.

The identification of the user with the interface is immediate since he/she recognizes him/herself and realizes about the gaming possibilities, those that permits his/her own body by the movement, since the system does not have physical limitations beyond the space in which is developed, i.e., the prepared AR scenario. The movements of every user are different and particular; the way of reacting when turning into an augmented user is also different depending on the connotations of every transformation and what they mean for every user, making the application to be different, unique and unrepeatable regarding to personal feelings and sensorial perception. The collaborative experiences allow a more playful game and interesting interaction between different augmented users within a shared space.

Regarding to the whole system, it should be pointed that the facility of programming allows changes and variations with very little cost of time and material resources, which makes possible a rapid adequacy and update of the application to new spaces and needs. Moreover, the rapid and easy evolution that we are experimenting makes us think about a very stable system of high interaction in real time, of easy use and with multiple possible ways of development, including different fields of application, from playful to documentary or therapeutic.

10. Further work

We are working in new marker prototypes that are auto illuminated, in such a way that the dependency of external luminous devices disappears. Furthermore, the incorporation of a new camera with more resolution and a greater angular will allow us to decrease the markers dimensions thus allowing the user to experiment a more freedom sensation. A further incorporation of video images to map the models, or even, some kind of in-real-time video, could increase the conceptual potential of our applications.

Finally, in the presented collaborative applications, it could be interesting that users could really face each other, thus allowing an AR face-to-face collaboration [7]. Within our currently interface this is not possible, because both users have to look to the same screen to see the virtual objects. Therefore, we are working in order to enrich our interface. One of our ideas is an interface using three screens placed in orthogonal positions (figure 12), in such a way that the users could always see each other, although they look in different directions.

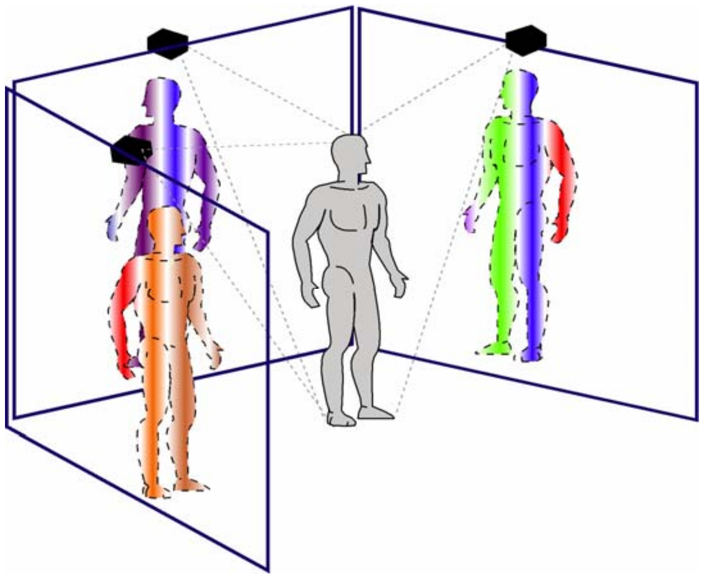

Figure 12. Interface prototype

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