Augmented Reality System for the Visualization and Interaction with 3D Digital Models in a Wide Environment

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1. INTRODUCTION

Augmented Reality (AR) applications have demonstrated to be effective in the design review phase, when new products have been designed and require an evaluation [11]. In fact, AR offers the possibility of evaluating 3D virtual models of these products, which can be easily modified, in their real context of use, without the need to produce real prototypes. More-over, AR can be used for presenting and interacting with 3D virtual models also in other fields of appli-cation, as architectural and engineering simulations, stores, museum exhibitions, and so on, for improv-ing and enriching the users' experience. However, the visualization of and the interaction with 3D digital models in an AR environment requires dealing with devices that can be invasive and uncomfortable and, as a consequence, they cannot be used for a long period of time. The selection and the combination of these devices have a significant impact on the perfor-mance of the AR system. The best solution does not exist and usually the final AR system configuration is a compromise among several aspects, such as immer-siveness, user's comfort, complexity, cost and so on.

An example of AR system for design review uses See-Through Head-Mounted Display (ST-HMD) for the visualization, and a remote control for the interaction with the 3D digital model, as described in [3]. This system, while providing a good visualization of 3D digital models merged with and real objects, can strain the user because of the weight of the ST-HMD. Besides, the interaction through a remote control has to be learned by the users. Other traditional design review systems based on projection display, such as PowerWall and Cave [2], do not allow merging 3D digital models with real objects, and are usually expensive and complex to set-up.

The aim of the research, presented in this paper, is to develop a new interactive AR system, which allows the user to comfortably interact with the virtual object, integrated in the real environment, by using a specific projection-based display, without the need to wear cumbersome equipment. The proposed AR system uses the Fog Screen display technology [6] for the visualization and a Microsoft (MS) Kinect [7] to track the user's point of view and his/her gestures. The gesture tracking has been used to provide the user with interaction metaphors. These metaphors are based on the principles of the gesture-based AR interface. The effectiveness and the usability of the AR system in managing three-dimensional virtual objects in the AR environment have been subsequently evaluated by organizing testing sessions with users.

The paper starts by providing information about the Fog Screen technology and the main functioning principles. Then, the architecture, the key features and the development of the new interactive AR system are described. Eventually, the paper presents the testing sessions with the users and a discussion about the derived results.

2. FOG SCREEN DISPLAY TECHNOLOGY

The AR system developed by the authors uses as a projection element a thin layer of fog. This display technology, commercially named FogScreen ® was patented in 2004 [12]. This kind of display system is also called "intangible display" and is produced in different sizes and configurations. The common functioning principle is based on the rear-projection of images on a thin layer of fog. This type of dis-play allows obtaining images that appear floating in mid-air and can be easily crossed by the user's body. The operating principle makes this screen mainly usable in indoor environments (requiring the absence of strong air movements), allowing a good quality of the projected images and a wide viewing angle.

The functioning principle is based on piezoelectric ultrasound transducers. These devices are able to disperse in the air small particles of water by generating a fog classifiable as dry (the diameter of a particle of water is about 10 microns). The dry fog is not able to wet the surfaces with which it comes in contact, is perceived as being dry to the touch, and does not damage clothes or equipment [15]. The dry fog is pushed through a diffuser that distributes it so as to form a thin lamina. This lamina, extremely subject to turbulence, is kept stable by two adja-cent airflows, generated by the presence of numerous fans. The lamina of dry fog acts as a surface on which it is possible to project images, by using reg-ular LCD or DLP projectors. A rear projection turns out to be the best solution, since the creation of the image is due to the diffusion of the light produced by the particles of water spray, making less visible a front projection. The rear projection allows obtain-ing large, high-resolution and with a good brightness images. The projector has to be positioned behind the display to a height such that the projection is suffi-ciently angled with respect to the users' observation point, in order to avoid that the light dazzles them excessively.

Since this technology was introduced, it has been considered very effective for developing Virtual Reality (VR) and AR applications. The reason is that images, while appearing floating in mid-air, induce the sense of a real presence of the virtual object in the real environment. In [4] an interactive system for VR was proposed. This system extended the basic 2D Fog Screen setup with stereoscopic imagery, an optical IR tracking system and several input devices to allow the user to interactively manage the virtual contents. The same system has been subsequently investigated in [14] to propose further 2D and 3D interaction techniques. Nevertheless, the setup of this system is quite complex and implies using several devices for the tracking and the interaction. In [13], a simpler system based on Fog Screen display has been described. The system has been implemented with a low-cost head tracking system based on a webcam placed near the projector behind the screen. This solution is very simple and inexpensive, but it allows tracking only the user's face, and also in a not-really-excellent manner, as admitted by the authors themselves. An attempt to eliminate the head tracking has been proposed, consisting in a system based on cylindrical fog screen and multiple projectors [17]. This system provides the user with multiple images of a virtual object from different viewpoints. Unfortunately, the resulting images are a bit overlapped and the working volume is too small.

To simplify the head and gesture tracking, the pro-posed AR system integrates the MS Kinect. It is a low-cost depth-sensing camera that allows capturing 3D information of the scene in real-time without high computational load. In the AR field, an example of application that uses the MS Kinect is the "Augmented Mirror" [16]. In this application, the Motion Capture functionality of MS Kinect has been used to con-trol a virtual character that, in real-time, talks to an audience through an augmented mirror. In another application, the MS Kinect has been used to develop a curved projection-based AR system [1]. This appli-cation has demonstrated how an AR system can be made interactive by using gesture-based interface via MS Kinect.

The research work presented in this paper aims at using similar gesture-based interaction, developed by using a MS Kinect, to handle the virtual content visualized on the Fog Screen display.

3. THE INTERACTIVE FOG SCREEN AR SYSTEM

In order to develop the Fog Screen AR system, the main requirements have firstly been identified. These requirements are related to the main functions that the system has to provide: firstly, it has to offer a wide working volume in which the virtual content is visualized in stereoscopy; more, users have to be able to look at the virtual content from different points of view, and interact with the virtual content in an easy-to-use and intuitive way. Then, the hardware and software architecture have been designed according to those requirements. In the following, the main requirements of the AR system are listed:

- wide working volume;
- stereoscopic visualization of the digital content for the perception of the depth of the scene;
- tracking of the user's point of view to correct the projected images;

- recognition of some simple user's gestures for interacting with the digital contents;
- easy setup.

3.1. System Architecture

The architecture of the Fog Screen AR system is quite simple, since it is made up of commercial devices that ensure an easy management by means of stable software libraries.

The Fog Screen device, which has been used to implement the system, is made up of a single vertical unit containing the piezoelectric ultrasound transducers and the ventilation system necessary to create the lamina of dry mist. The overall height of the unit is 220 cm and it produces an available display surface of 215×190 cm.

The stereoscopic visualization is provided by a stereoscopic projector and active shutter glasses. The Fog Screen technology allows for a stereoscopic viewing with polarization, shutter glasses or any other stereoscopic method. After conducting some preliminary tests, the shutter glasses solution was preferred. Indeed, thanks to the shutter glasses, it is possible to have brighter and sharper images.

The stereoscopic projector used is the Nec V300X [8], which is empowered by 3000 lumens provides bright and high-contrast images. The shutter glasses used are the 3D Vision kit by Nvidia [9]. The kit allows the development of applications based on Microsoft XNA Framework [5], which have been used to develop the software module that manages the whole AR system. The 3D Vision kit consists of shutter glasses remotely controlled by an IR emitter connected via USB to the computer.

The tracking and the gesture recognition functions are managed by the MS Kinect device. This device does not require setting up the working area, and the user does not have to wear or hold any other device in order to be tracked.

Finally, all the devices are connected to a laptop, which has the following characteristic: CPU Intel Core i5, RAM 4 GB, GPU GeForce GT 330M.

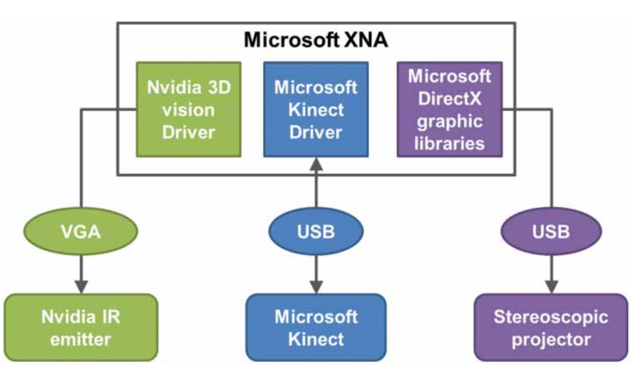

Fig. 1: Hardware and Software architecture of the developed AR system.

The use of these devices makes the setup of the AR system quite easy. In addition, it is worth highlighting that no further calibration is needed when different users use the system. Figure 1 shows the Hardware and Software architecture of the system.

3.2. Software Application

The integration and the management of the hardware selected for the implementation of the Fog Screen AR system have required the development of a specific software application.

Mainly, the software application provides and handles the three-dimensional images used by the Fog Screen AR system. The proper perspective of the images is modified according to the tracking data, which are related to the user's point of view, and are detected by the MS Kinect.

At the same time, the application analyses the movement of the user's hand to allow the user to move the virtual objects within the AR environment. To activate the virtual object handling, the user has to firstly select the object into the scene. The selection of a virtual object is performed by using the ray-casting technique [10]. In the developed system, the ray is cal-culated as the straight line that connects the user's point of view to the position of the user's hand.

The selection functionality can be enabled or disabled by the user through two different modalities. The first one is to hold the hand in front of the selected object for a few moments. The second modal-ity consists in pressing a button on a remote control held in the non-dominant hand of the user. The usability of these two selection modalities has been subsequently investigated and evaluated during the testing sessions, as described in section 4.

3.3. System Setup

The setup of the devices is an important factor in order to ensure the proper functioning of the Fog Screen AR system. The Fog Screen AR system has been placed in a working area of 5×3 m, and in the center of the available space. In front of the display some space has been left free in order to allow the user to move freely. In the remaining space it has been placed a tabletop where the AR environment is presented.

The stereoscopic projector has been placed at a height of 2.3 m, and at a distance from the display surface of 2 m. In this way, it has been possible to completely avoid that the light of the projector dazzles the users while interacting with the system.

The projected image covers an area of 710×945 mm; it has a horizontal orientation, and a res-olution of 1024×768 pixels. Due to the technical limits of the used projector, the image does not cover the entire projection area of the Fog Screen display, but this configuration allows providing an AR area of 150×100 cm.

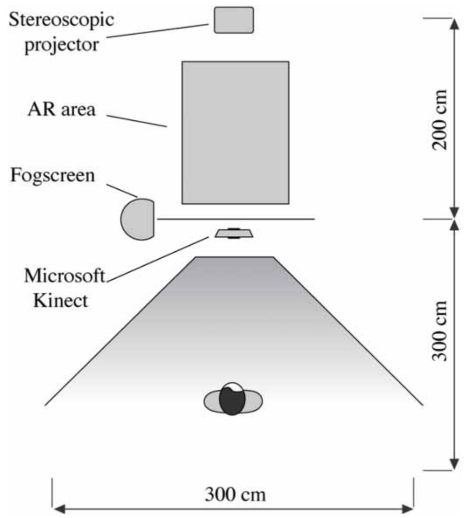

Fig. 2: Setup of the Fog Screen AR system.

For practical reasons, the MS Kinect sensor was positioned in front of the Fog Screen display, so as to easily align it vertically with the center of the projected image. For the correct functioning of the AR system, in fact, it is essential to be able to determine with good accuracy the position of the Kinect sensor with respect to the center of the display. In Figure 2, it is shown the arrangement of the devices, the AR area and the user's working area.

4. TESTING SESSIONS

The operational modalities and effectiveness of the interactive Fog Screen AR system have been validated through two testing sessions. These sessions have been carried out by asking to a group of selected users to remotely manipulate a virtual object. In particular, users were instructed to move, through the developed gestural interaction, a virtual object to specific target positions. The task has been performed in two different modalities: AR and VR. The two modalities have been used to evaluate whether and how much the execution of the task is influenced by the AR visualization.

Figure 3 shows the two different setups used for the testing sessions. The virtual object in both cases consists in a half-length statue, while the targets are real in the AR setup (Figure 3a) and virtual in the VR setup (Figure 3b).

In the AR mode the targets were arranged on a supporting plane to obtain three points in space with different coordinates along the orthogonal axis to the Fog Screen display. In the VR mode the targets are virtually represented in the same layout.

Figure 4 shows the targets layout and the relative distance from the Fog Screen display. Target 0 is the initial position of the virtual object, while the other three targets represent the points where the users have to move the virtual object. The choice of this target layout has been made since usually in AR the visualization of very distant objects can be critical.

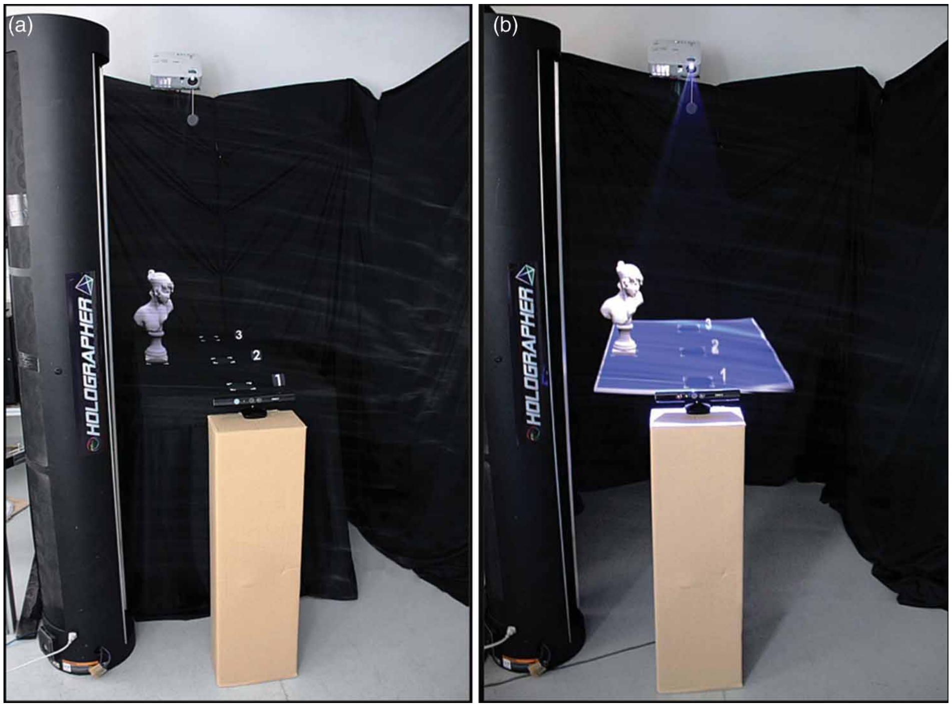

Fig. 3: The two different setups designed for the testing sessions: (a) AR setup, (b) VR setup.

With the increase of the distance, in fact, possible latencies of the tracking system may adversely affect the simulation of the perspective. It is also important to consider that the quality of the display itself may possibly amplify this defect. The instability of the laminar flow of dry fog, in fact, could produce a misalignment between the displayed image and the real context present beyond the projection surface.

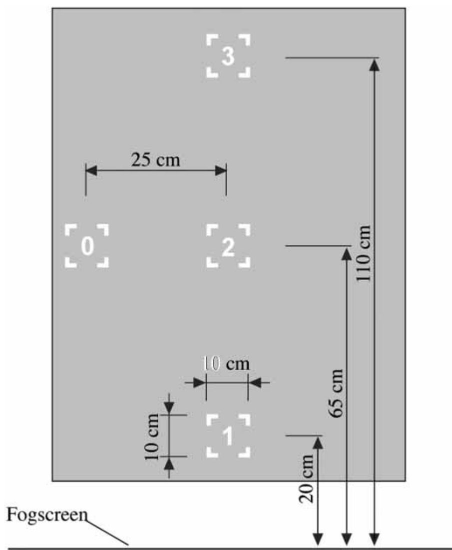

Fig. 4: The targets layout and the relative distance from the FogScreen display.

Forty-four people participated in the testing sessions. The participants were split into two heterogeneous groups. The data collected in the first testing session allowed making some software tuning, and also better defining the rules for the implementation of the second group of testing.

In both testing sessions, users have attended a short presentation of how the system works. Each user has been asked to wear stereoscopic glasses and grab the remote control with his/her non-dominant hand. Before starting the test, it has been indicated the area within which the user was allowed to move, and has been given the opportunity of freely observing the scene from different points of view. Then, users were asked to move the virtual object displayed on the Fog Screen display with reference to the targets set up in the scene. While in the first testing session the users were asked to move the virtual object on the display one time for each of the three target points, in the second testing session the users were asked to move the virtual object 18 times with reference to the three targets. The repetition in the second testing session allows the statistical comparison of the collected data.

In both testing sessions, the execution order of the movement tasks was read by the authors from a list specially randomized. The execution time of each task performed by the users, the coordinates of the obtained displacements, and the number of steps made to reach the target have been recorded. All these quantitative data have been used in the evaluation process of the variants of software application. The sequences of movements have been organized so as not to require consecutive displacements on the same target and have been also randomized to be different for each user. In this way, it was possible to prevent that the activities were subject to an improvement determined by the repetition and this has allowed the authors to analyze the learning activities more objectively.

The test results have been then extensively analyzed. Besides, at the end of the test, each user was asked to fill in a short questionnaire in order to evaluate the usability of the developed system on the basis of both objective and subjective data.

4.1. First Testing Session

The first testing session has been carried out to determine the presence of problems in the interaction with the interactive Fog Screen AR system, mainly related to the used hardware and to some of the functions of the developed software application. The first user group was made up of 24 users, who belong to a heterogeneous group aged between 21 and 38 years old. 4 left-handed users were evenly distributed in the execution of the 4 different versions of the application. In this first testing session 4 different versions of the application were used, each of which has been proposed to 6 users. The 4 versions of the application differ in the following aspects:

- AR-VR

In two versions of the software application, the system uses the AR visualization technique. The virtual object, therefore, is contextualized within the real environment, and the user is instructed to move the 3D object in correspondence of physical targets. In the other two versions of the software application, the VR visualization technique has been used. The task of displacement of the 3D object has been carried out by using virtual targets displayed on the screen instead of the real targets present beyond the fog display. The authors made this distinction in order to evaluate the effectiveness of visualization in AR, by comparing the results obtained in the AR and VR variants.

- Pointing Gesture

The authors made the hypothesis that the pointing gesture performed to trigger the movement of the virtual object in space could be problematic. In fact, it is possible that the user, when pointing the virtual object with his/her right hand, is forced to start the displacement of the 3D object with the fully extended arm. This forces the user to perform at least a step forward in the case where it is required to place the virtual object at the more distant target. This condition may affect the naturalness of the task execution, possibly making it more difficult. Therefore, the authors introduced an alternative movement mode, in which the user can start to move the virtual object in space by simply activating the drag mode by pressing a button on a remote control.

- Head tracking - Fixed camera

The authors also considered appropriate to evaluate the influence of the tracking of the point of view on the interaction with the system. The user's possibility to observe the scene from different camera angles can give a different awareness about the placement of the virtual object. Therefore, a variant of the application that uses a fixed camera for the rendering of the scene has been developed, in order to compare the results with the variant equipped with head tracking.

The variants of the application are summarized in Tab. 1.

4.1.1. Results and analysis

Most of the users have completed the execution of the tasks in less than 3 minutes. Only one user failed to complete the tasks because of a problem of tracking determined by a malfunctioning of the MS Kinect.

First of all, it should be noted that the magnitude of positioning errors committed by the users is proportional to the distance of the target from the display, especially on the Z axis. This error has been found in the testing performance of all the versions of the application. Fig. 5 shows the average error and the standard deviation of the error of each target in the four different test variants.

The average values and the standard deviation (divided by Cartesian axis and displacement targets) demonstrate some differences between the AR and the VR versions of the application. As originally hypothesized, users who participated in the testing of the VR versions have made positioning errors that tend to be lower. The values of the standard deviation, which are lower, report a higher positioning accuracy performed by the users of the VR versions.

Users who have tested the two AR versions made positioning errors that tend to be higher than the VR versions. However, the difference between the sessions is reasonable, because the instability of the projection surface produces an inevitable mismatch between the virtual image and the real objects present in the scene. This misalignment, however, is not present in VR versions, thus allowing for a more precise execution of the task.

The pointing gesture, necessary to trigger the displacement of the virtual object, seems adversely affecting the accuracy of the task. Comparing the results of the AR version with pointing gesture and the AR version without pointing gesture, in fact, it is possible to observe some significant differences. The pointing gesture resulted in a lower naturalness of movement of the users, who encountered more difficulties for completing some tasks. The results obtained show, in fact, an error of magnitude greater

Software version	Visualization	Camera	Movement
AR 1	AR	Head tracking	Free
AR 2	AR	Head tracking	Pointing gesture
VR 1	VR	Head tracking	Pointing gesture
VR 2	VR	Fixed camera	Pointing gesture

Tab. 1: The variants of software application used in the first testing session.

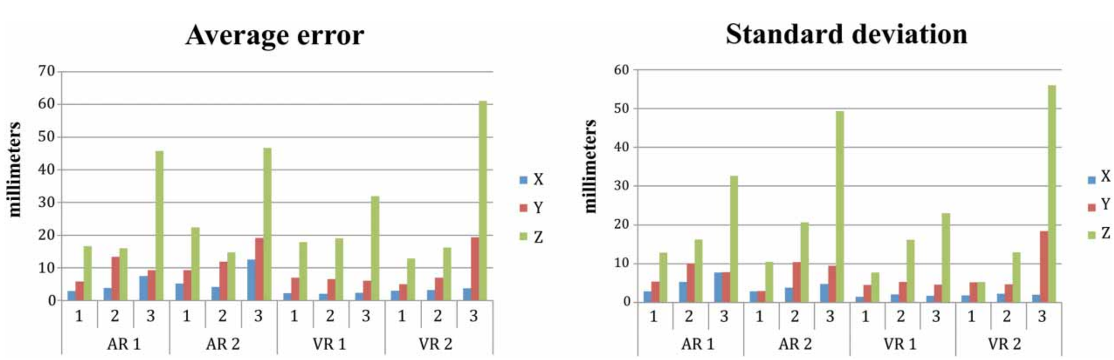

Fig. 5: The average error and the standard deviation of each target (1, 2, 3) in the four different test variants (AR 1, AR 2, VR 1, VR 2).

in the AR with pointing gesture version, especially in relation to the shift in point 3 (the most distant from the display). The durations of the execution are also considerably higher, therefore emphasizing the greater difficulty in execution encountered by the users.

The absence of head tracking in the VR version resulted in a dramatically increased positioning error at the target n°3. It should be noted that the users who have used this version of the application have completed the task in less time. Also, the users themselves have wrongly considered of having correctly positioned the virtual object after just one shift.

At the end of the testing session, users were asked to complete a short questionnaire. The questionnaire has been structured to collect opinions about the usability of the system. It was made up of multiple-choice answers, representing a scale of increasing values (nothing, little, quite, very, very much).

Most of the users of the first session expressed positive opinions about the quality of the displayed image and the consistency of the displayed perspective. This result shows that the head tracking system allows for a convincing simulation perspective. Some users have pointed out that the instability of the display influenced the execution of the task. Nevertheless, the users considered the execution of the required movements as very easy and have argued that the movements of the virtual object were very similar to that of their hand. In few cases, it has been noticed a delay in tracking the user. Consequently, the authors decided to modify the smoothing and the prediction parameters of the MS Kinect to further reduce the possibility that users perceive delay in the movement of the virtual object. Fig. 6 shows the average values collected in the main sections of the questionnaire for the four different test variants.

The results of the first test session allowed the authors to better delineate the objectives and the procedure of the second testing session. Specifically, the pointing system necessary to trigger the movement of the virtual object has been removed, preferring the use of the remote control. Moreover, the tracking of the point of view has been maintained in each variant. The second session of testing, therefore, has been performed with the aim of obtaining a more accurate assessment of the differences between VR and AR. This comparison can be useful in determining how the instability of the immaterial display asset may adversely affect the visualization in AR.

4.2. Second Testing Session

In the second testing session, which required the participation of 20 users, two different versions of the application have been used. Each version has been tested by 10 users, aged between 20 and 28 years. 2 left-handed users were evenly distributed in the test of the 2 different versions of the application. The observation allowed for a more thorough and reliable assessment of the AR visualization. In this case the two versions of the software application dif-fer only for the visualization typology (AR or VR), as summarized in Tab. 2.

Software version	Visualization	Camera	Movement
AR	AR	Head tracking	Free
VR	VR	Head tracking	Free

Tab. 2: The variants of software application used in the second testing session.

4.2.1. *Results and analysis*

All the users have completed the execution of the task in less than 7 minutes. All the users have been able to perform the 18 movements required. Only one user found considerable difficulties in performing the task, due to tracking problems of the Microsoft Kinect.

After the conclusion of the test, the users were invited to fill in a questionnaire, which is useful to obtain remarks regarding various aspects of the interactive Fog Screen AR system, such as the quality of the visualization, any possible annoyance caused by stereoscopic glasses, the consistency of the prospective simulation and the naturalness of interaction.

Even in the second testing session, the users have encountered greater difficulty in placing the virtual object at the target farthest from the plane of the display. The acquired data show, however, small differences between the two versions of the system. The averages of the errors made by the users, in fact, are

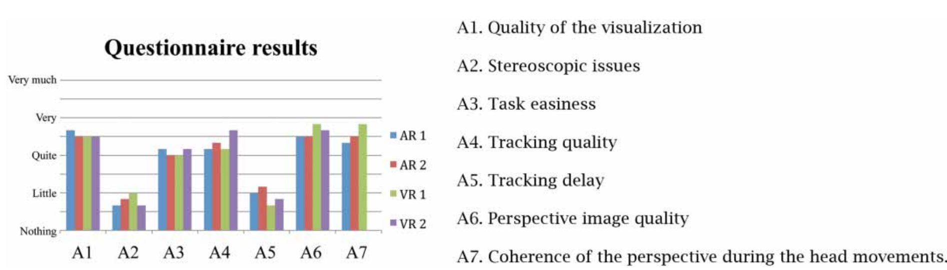

Fig. 6: Average values collected in the main sections of the questionnaire for the four different test variants (AR 1, AR 2, VR 1, VR 2).

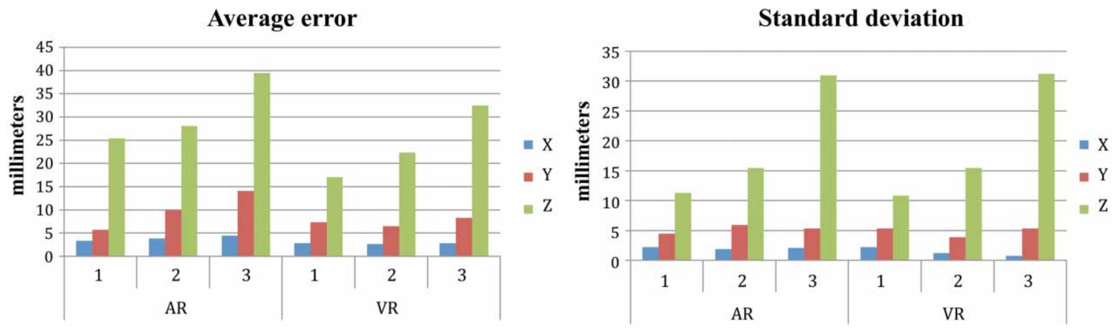

Fig. 7: The average error of each target (1, 2, 3) in the two different test variants (AR and VR).

quite similar, and it is important to emphasize that the standard deviations are almost identical. Fig. 7 shows the average error and the standard deviation of the error of each target (1, 2, 3) in the two different test conditions (AR and VR).

It is important to consider that the average error detected for the AR version could also be influenced by other factors, such as the precision with which the setup has been prepared. In fact, it is possible that the support surface bearing the target n°3 could be not perfectly aligned to the reference system of the virtual software. For this reason, it is necessary to perform a more detailed analysis on the variance of the error made by users in the two versions of the software application.

In order to further investigate the findings from this testing session, it was considered appropriate to rely on the Kruskal-Wallis statistical method. This method is the corresponding of the non-parametric analysis of variance (ANOVA) in which the data are replaced by a ranking. This method has been used because not all the groups of the acquired data follow a normal distribution. Therefore, it is necessary to use a non-parametric test. The Kruskal-Wallis test has been performed by comparing the performance of three tasks in two different versions of the system (AR and VR). The obtained results ($H = 1.851$, $k = 1$, $N = 20$, $p > 0.05$) led to the confirmation of the null hypothesis H0: the different versions of the software application did not significantly affect the execution of the task.

Therefore this result demonstrates that the visualization in AR is well-functioning, because the error made by the users in positioning the virtual object does not appear to be significantly different between the various versions of the system. It is, therefore, very likely that the error made by the users is mainly due to the instability of the laminar flow of the immaterial display and, to a lesser extent, the reliability of the tracking system. Future improvements in the quality of visualization of the immaterial display will definitely ensure visualization in AR even more convincing and effective.

At the end of the testing session, users were asked to complete a short questionnaire. The questionnaire has been structured to collect opinions about the usability of the system. It included multiple-choice answers, representing a scale of increasing values (nothing, little, quite, very, very much). The results of the questionnaires suggest a smooth functioning of the interactive Fog Screen AR system. Users, who participated in the second testing session and have used different versions of the software application, have expressed very similar opinions. The simulation perspective produced by the two different versions is, in fact, convincing in both cases. The visualiza-tion in AR seems, therefore, not being affected by a significant mismatch between the virtual image and the real context beyond the projection surface. The users, in most cases, argued that the instability of the surface of the immaterial display impacts on the image quality. Nevertheless, the quality of the

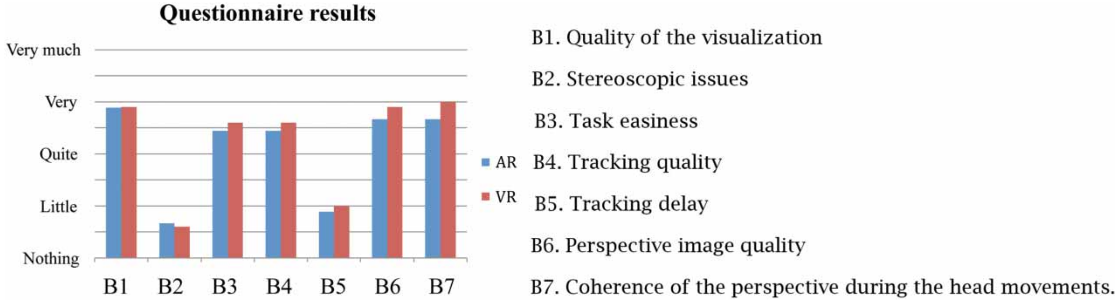

Fig. 8: Average values collected in the main sections of the questionnaire for the two different test variants.

immaterial display was unanimously assessed as very good.

Fig. 8 Shows the average values collected in the main sections of the questionnaire for the two different test conditions (AR and VR).

Even in this second session, users considered the execution of the required movements as very easy and have argued that the movements of the virtual object were very similar to that of their hand. The tracking system did not produce excessive latencies and allowed users to perform all the 18 tasks.

5. CONCLUSION

The research presented in this paper is focused on the development of a new interactive AR system based on the Fog Screen display technology for the visualization, and a MS Kinect device to track the user's point of view and his/her gestures. The AR system allows the user to comfortably interact with the virtual object, integrated in the real environment, by using the movements of his/her body.

Through the use of the Fog Screen display and of a stereoscopic projector, in fact, the virtual object is no longer perceived as lying on a flat display, but it appears immersed in the surrounding reality. The performed testing sessions demonstrated that users are able to easily interact with the virtual object perceived in the AR environment via the movements of their body. Specifically, the results of the two test-ing sessions concerning the various versions of the application show that:

- both the AR and VR visualizations of the virtual object on the Fog Screen display are considered as very convincing by the users;
- the head tracking system allows for a convincing simulation perspective;
- for what concerns the interaction, the users prefer the use of a remote control device in alternative to the pointing gesture;
- the average of the errors made by the users in moving the virtual object is quite similar (and the standard deviations are almost identical) in the VR and AR versions of the application;
- the users considered the execution of the required movements as very easy and have argued that the movements of the virtual object were very similar to that of their hand.

Consequently, the results of the research demonstrate the possibility of turning the Fog Screen display, which at the present moment is used as a technological solution designed to capture the interest of the observer, in an AR effective interactive tool. The authors make the hypothesis that the use of the proposed AR system may be beneficial also for activities such as the exploration of 3D virtual models in architectural and engineering simulation, in military training and surgery, in museum exhibitions, in stores and so on. In fact, the size and the immaterial characteristic of the Fog Screen display allow the representation of large-scale objects within a real context. In addition, the interaction with the virtual objects may be useful for the manipulation of different parts of virtual prototypes, through the possibility of changing, for example, their positions and sizes.

Future works concerning the proposed AR system aim to further improve the visualization quality of the projected virtual object. In fact, some participants considered vaguely annoying the use of active stereoscopic glasses, and the authors are considering the possibility to further investigate the use of alternative stereoscopic display technologies that do not require the use of any auxiliary components, as the stereo glasses. Moreover, another aspect of the AR system that the authors considered as critical is the integration of the MS Kinect device directly into the AR system. This integration, in fact, may reduce the activities necessary for setting up the AR area, and for calibrating the tracking device.

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