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

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Introduction:
Augmented Reality (AR) applications have demonstrated to be effective in the design review phase, when new products have been designed and require to be evaluated. AR offers the possibility of evaluating 3D virtual models of these products in their real context of use. 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. These devices have to do with the visualization, tracking and interaction: visualization allows the visual merging of virtual objects in the real environment; tracking creates the temporal and the spatial link between real and virtual objects, and interaction handles the communication between users and virtual objects. The selection and the combination of techniques related to these technological aspects have a significant impact on the performance of the AR system.

The aim of the research, presented in this paper, is to develop and evaluate a novel interactive system, which allows the user to comfortably interact with 3D digital models in a wide AR environment by using a specific projection-based display and without the need to wear cumbersome equipment. Starting from these requirements, the authors have developed an AR system based on commercial technologies. After the development activities, the authors evaluated the effectiveness and the usability of the AR system in managing three-dimensional virtual objects in the AR environment through testing sessions with users.

Main idea:
In order to develop the AR system, the authors have firstly identified the main requirements. Then, the hardware and software architecture has been designed according to some of the main requirements, which are listed in the following:

- wide working volume;
- stereoscopic visualization of the digital contents for the perception of the depth of the scene;
- tracking of the user's point of view to correct the projected images; and
- recognition of some simple user's gestures for interacting with the digital content.

According to these features commercial technologies have been selected with the aim to easily handle them through the use of common software libraries. To provide a wide AR working volume it was used a display based on the Fog Screen display technology [1]. This technology, commercially named FogScreen®, was patented in 2004 [5]. It 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 display allows obtaining images that appear floating in mid-air and can be easily crossed by the user's body. These displays are mostly usable indoors (requiring the absence of strong air movements), and allow a good quality of the projected images and a wide viewing

angle. These kinds of displays are rather new and very few applications have been developed mainly for entertainment and advertising. The Fog Screen display used in this work consists of a single vertical layout unit and provides a 215x190 cm display surface.

The Fog Screen technology allows for a stereoscopic viewing by using polarization, shutter glasses or any other stereoscopic method. After performing some preliminary tests, the shutter glasses were preferred: they offer brighter and sharper images.

The tracking of the user's point of view and the gesture recognition functions are managed by the Microsoft (MS) Kinect [4] device. The gesture recognition has been integrated to allow the users to use interaction metaphors, which are based on the principles of the gesture-based AR interface as proposed in [2]. The gesture recognition has been implemented by using the skeleton tracking algorithm provided by the MS Kinect so the user can manipulate a 3D digital model by moving his/her hand within the AR environment after selecting it. The selection is performed with the ray-casting technique [3, 6], where the ray is calculated as the straight line that connects the user's point of view with the position of the user's hand. The selection is confirmed by pressing a button on a remote control held in the non-dominant hand of the user.

The operational modalities and effectiveness of the interactive Fog Screen AR system have been validated through two testing sessions with users. These testing sessions have been carried out by asking to a group of selected users to remotely manipulate a virtual object. In particular, the users were instructed to move a virtual object to specific target positions, by using the developed gestural interaction. This task has been performed by using two different kinds of targets (real and virtual), since the authors made the hypothesis that perceiving the relative position between two virtual objects is simpler than perceiving the relative position between a real and a virtual one. Fig. 1 shows a user interacting with the AR application.

Fig. 1: A user interacting with the Fog Screen AR system.

The results of the testing sessions have demonstrated that the visualization in AR is well-functioning, because the error made by the users in positioning the virtual object does not seem to be significantly different between real and virtual targets. 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.

Conclusions:

The research presented in this paper is focused on the development of a new interactive AR system based on the Fog Screen display and a MS Kinect. The proposed AR system allows the user to comfortably interact with 3D digital models, integrated in the real environment, by using the movements of his/her hands. Through the use of the Fog Screen display and of a stereoscopic projector 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 hands. The

authors make the hypothesis that the use of the proposed AR system may be beneficial for design review activities, and also for activities such as the exploration of virtual models in architectural and engineering simulation, in military training and surgery, 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.

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