MagicPad: A Projection Based 3D User Interface

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ABSTRACT
In this paper we first describe the novel implementation of a tangible user interface framework, namely the MagicPad. The MagicPad is inspired by the concept of Spatial Augmented Reality. By using an Infrared pen with any flat surface, such as a paper pad that receives projected images from a projector, a user is able to perform a variety of interactive visualization and manipulation in the 3D space. Then we describe the concept of improving the MagicPad by using a pico projector to replace the infrared pen.

Author Keywords
3D user interface, spatial augmented reality, virtual reality, projector.

INTRODUCTION
With the reduction of the cost of computer hardware and the rapid development of PC based graphics processors, the Virtual Reality environment is becoming more affordable and popular. Large high-resolution displays have been widely applied in various domains [1]. These Virtual Reality systems give the user the immersive experience of entering a computer generated virtual world. Augmented Reality (AR), on the other hand, rather than immersing a person into a completely synthetic world, it attempts to embed synthetic supplements into the real environment [2]. Augmented Reality also opens up a new area of user interface design since all real and tangible objects with embedded virtual entities can be treated as a tool or interface to navigate around and manipulate the objects in the virtual world. A number of studies have been done to investigate the possibility of using AR to improve the user interface inside a virtual environment. For example, some researchers [3] have developed a variety of tangible user interfaces using ARToolKit [4].

Spatial Augmented Reality, unlike traditional AR which requires a head mounted display or external display to see the augmented image, the user's physical environment is augmented with images that are integrated directly in the user's environment [5]. The images are generated from the surrounding digital projectors. The user and the augmented physics objects co-exist in the same 3D virtual environment. Naturally, the augmented objects have great potential to be the ideal interface between the user and the virtual environment [6]. A number of attempts are made to realize such concept, for example, the spatially augmented 3D Painting[7], the PaperLens[8, 9] and the MagicPad[10, 11]. With the recent emerging of pico projectors, the mobility of the image source has been greatly enhanced. This also opens up a new dimension of user interface design, as shown in the systems developed by some researchers[12, 13].

The development of the MagicPad user interface is inspired by the Projection-Based Spatial Augmented Reality. In this paper, we descript the design of the MagicPad user interface framework, and the concept of introducing a pico projector to enhance the interface.

DESIGN CONCEPT

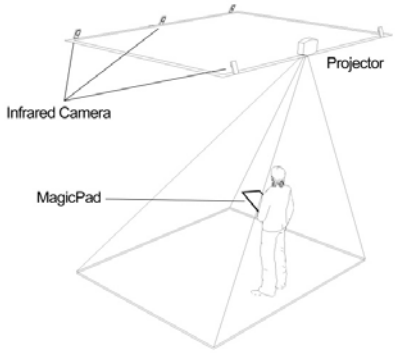

Figure 1: The design concept and hardware configuration of the MagicPad Interface.

The MagicPad interface mainly consists of one or more flat surfaces, which can be a white cardboard or sketch book pages. The white surface (MagicPad) acts as a display to receive the image from the ceiling mounted projector (Figure 1). The position and orientation of the MagicPad are tracked by an optical tracking system. When the MagicPad moves, the image projected by the projector will be updated to match the motion of the MagicPad. This results in the illusion that the image is glued onto the MagicPad's surface without relative movement. In addition, the user can use an infrared pen, which is also being tracked, to interact with the MagicPad. Since the MagicPad and the infrared pen are light weight devices, the user can easily hold them with his/her hands and perform a series of 3D interactions with the virtual environment. In fact, the original innovation of the MagicPad is aimed to provide the similar experience of using a pen and paper. With this

familiar interface tools, we target to allow a layman user, even without prior experience in using VR interfaces, to be able to use the MagicPad right away without much training.

Figure 2: The MagicPad and its accessories.

Figure 3 shows the snapshots of the implementation of the MagicPad interface in a CAVE-like virtual reality system. The user is able to examine and navigate inside the virtual environment by using the MagicPad interface. Full implementation details can be found in related papers[10, 11].

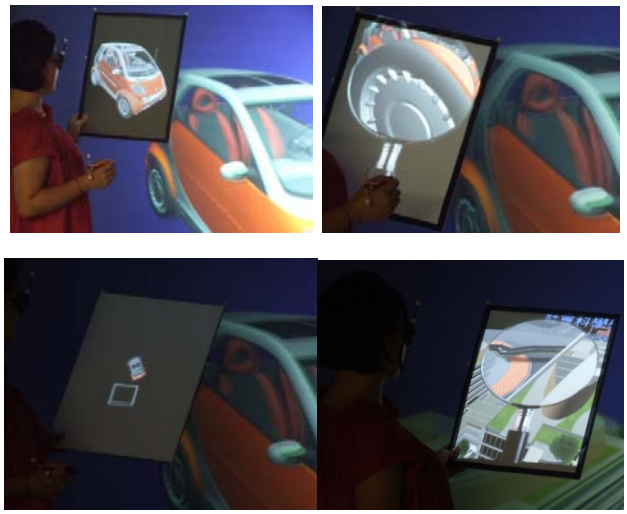

Figure 3. Examination of a car model and navigation within a virtual campus using the MagicPad Interface inside the imseCAVE.

ADVANTAGES AND LIMITATIONS

The MagicPad interface is designed and developed based on the Projector-based Spatial Augmented Reality and therefore shares similar benefits of spatially immersive displays [14]. The key benefit of the MagicPad is that a user does not need to wear a head-mount display or use a monitor to see the augmented images. In addition, the lightweight MagicPad provides a tangible, familiar and natural user interface between the user and the computer system. Our preliminary subject test also shows that users were able to discover and master the different operations supported by the interface within a short period of time without detail initial explanation of its usage. On the other hand, the MagicPad interface also inherits the technical limitations of Spatial Augmented Reality including limited resolution and depth of field of the projector, problems of casting shadow and poor image formation when the projection angle is too steep.

PROPOSED ENHANCEMENT

One of the major limitations of the MagicPad interface is the image resolution on the projected surface. Since only a single projector covers the whole range of movement, only a fraction of pixels is really casted on the MagicPad and contribute to the effective image. In view of this, we propose to use a laser pico projector to replace the infrared pen as the input tool. Using the laser pico projector shows clear advantage of providing a focus free projection, especially when the projector is in motion. As illustrated in Figure 4, the image projected from the pico projector is concentrated in a small area and therefore it can provide an ultra-fine image. By tracking the position and orientation of the pico projector and applying appropriate transformation algorithm, the image from the pico projector can be exactly overlaid on the MagicPad with the same content but with a much higher resolution. Depending on the application, the projected image can also have different rendering modes or be overlaid with text and symbols. A button should be attached on the pico projector so that it can interact with the MagicPad to provide operations such as translation, rotation and scaling. The project image from the pico projector can serve as the instinct visual feedback for enhancing the interactions (Figure 5). For example, for the scaling operation, the pico projector projects an icon representing scaling. The size of the projected icon changes when the user moves the pico projector back and forth to adjust the scaling factor.

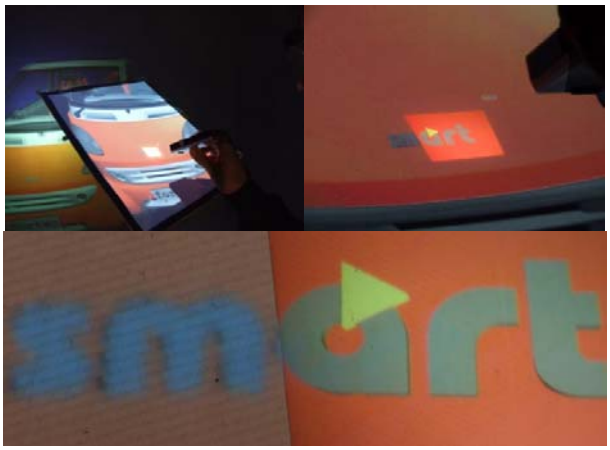

Figure 4. Higher resolution image from the pico projector being overlaid on the MagicPad.

Despite the benefit of introducing pico projector, it comes with some limitations. Although the projector fits in a user's palm, it is less comfortable than holding a pen, especially when a cable is attached for feeding the video signal. Moreover, as the projected area is relatively small, an accurate motion tracking system is needed to ensure the perfect alignment of the images from different sources,

including projectors for imseCAVE, MagicPad and the pico projector. The brightness of the pico projector may need to be adjusted dynamically to avoid casting over bright image when the projector is very close to the MagicPad. It is also an issue whether a user is comfortable to cope with so many images projected from different projectors.

Figure 5. Visual feedback for scaling and rotation from the pico projector

CONCLUSION

In this paper, we have described the design and architecture of the MagicPad framework. The concept of using a pico projector as the input device has been proposed. Although further user studies have to be done to investigate the capability of the MagicPad interface as well as the benefit of introducing a pico projector, preliminary evaluations have shown that this interface enriches the user experience and enhances the effectiveness of human-computer interface. With the declining price of projection and optical tracking systems, spatial augmented reality tools and applications are more easily reaching the general public, and hence starting to reveal its potential in a variety of application domains, including art, design, entertainment and engineering.

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