AR Pueblo Board Game

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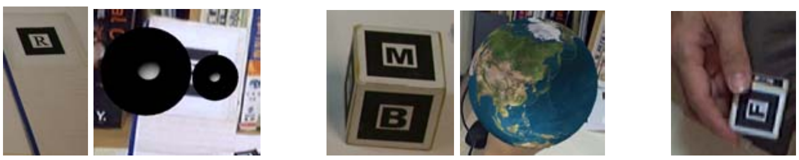
Abstract. This paper considers a new tangible interface for vision-based Augmented Reality (AR) systems. Tangible AR interfaces provide users seamless interaction with virtual objects in AR systems but with the restriction of user's motions. A new tangible AR interface is designed to overcome this limitation. Two hexahedral objects are attached together to create the new tangible AR interface. The shape of the new tangible AR interface removes the restriction of user's motions in existing tangible AR interfaces. Users can move and rotate the new interface freely to manipulate virtual objects in AR environment. This improvement is useful for applications that require unrestricted rotation motions of virtual objects. The Pueblo board game is developed to demonstrate the usability of the new tangible AR interface.

1 Introduction

Augmented Reality (AR) merges real and virtual worlds to provide users useful information that cannot be achieved by users own senses. From the end of the last decade, AR gains much interest from researchers in various fields (i.e., computer science, architecture, industry design, and psychology), and they develop applications in diverse areas (i.e., industry, medical, mobile, and entertainment). Although many researchers have explored AR, the interface design has not been actively studied. General AR applications mainly provide users limited viewing or browsing of augmented information.

This paper considers an interface technique that provides users natural interaction with vision-based AR systems through a tangible 3D object. Recently, researchers apply the tangible user interface [1] to AR systems and develop tangible AR



(a) (b) (c)

Figure 1. Tangible AR interface and occlusion problems (a) Board interface (b) Cube interface (c) Occlusion problems

interfaces. Generally, these interfaces are composed with a real object and markers. One or more markers are attached on the real object as shown in Figure 1, and the pose of the interface is computed based on these markers and used to manipulate virtual objects.

Many researchers use a flat board with a marker (a Board interface) as a tangible interface for their AR systems, Figure 1(a). The Board interface is used to manipulate corresponding virtual objects [3], [4], [5]. Frequently, the Board interface is attached on a real object such as a paddle [3], and a cup [5]. A cube can be used instead of a flat board. More than one marker are attached on sides of the cube, and users can manipulate this Cube interface to interact with AR systems [2], [6], Figure 1(b). The main advantage of using these tangible AR interfaces is that users interact with virtual objects as they do with real objects. The tangible AR interfaces provide users more realistic interaction than using special-purpose input devices, which cause interaction discontinuity [4]. However, the current tangible AR interface has limitations.

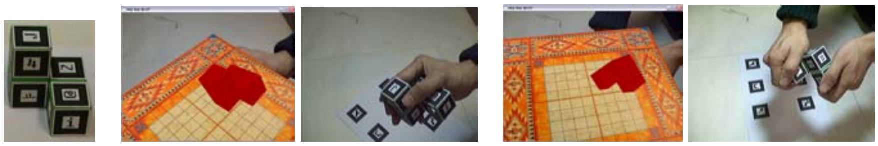
The current tangible AR interface cannot be rotated freely to interact with virtual objects because a marker on the tangible AR interfaces is not always viewable to the camera in AR systems. Users can rotate the Board interface along the up axis, but users cannot rotate it along other axes. The marker on the Board interface is not viewable to the camera for these rotation motions. For the Cube interface, users can rotate it along any axes, but users have to place their hand(s) in special locations of the interface (i.e., corners of the Cube). If users were not careful, user's hand(s) would occlude markers partially or entirely as shown in Figure 1(c) and result the failure of pose estimation. This requirement causes uncomfortable interaction with virtual objects.

This restricted motion is critical for applications that require varied rotation motions. To overcome this limitation, a new design of the tangible AR interface is presented in this paper. Two hexahedral objects are attached together to create the new tangible AR interface as shown in Figure 2(a). We call this interface as the Pueblo interface because the shape is similar to the building blocks of the Pueblo board game.

In the next section, the key aspects of the Pueblo interface are introduced, and the pilot application, AR Pueblo board game, is presented in section 3. The conclusion will follow the description of the pilot application.

2 Pueblo Interface

This section discusses key aspects of the new 3D tangible interface, i.e., basic design, tracking, and interaction. We designed the Pueblo interface considering one aspect of



(a) (b) (c)

Figure 2. Pueblo interface (a) Shape of the interface (b) Visible markers at varying positions (c) Two-hand interaction

interface principles, seamless interaction with an AR system.

The Pueblo interface is an object that is created by aligning two hexahedral objects as shown in Figure 2(a) with markers. Eighteen distinguishable markers are attached to the Pueblo interface, so it can be viewable from the camera of AR systems at any orientation as long as the interface is located inside the viewing area of the camera.

The pose of the Pueblo interface is estimated using the vision-based AR library, ARToolKit [7]. The camera views the Pueblo interface, and the AR system detects markers on the Pueblo interface and estimates pose of the Pueblo interface using the detected markers.

The Pueblo interface provides natural interaction to users. Users hold the Pueblo interface and move or rotate it freely to manipulate the corresponding virtual object. At least one marker of the Pueblo interface is always visible to the camera as long as the interface is viewed by the camera, Figure 2 (b). Users can also hold the Pueblo interface with one or two hands not occluding all markers on the Pueblo interface, Figure 2(c).

3 Pilot Application: AR Pueblo Board Game

The main application of the Pueblo interface is 3D AR board games. One of the popular board games is the Pueblo shown in Figure 3, and we implemented it to demonstrate the capability of the Pueblo interface. The game requires complex 3D manipulations of building blocks to play it. Players have to rotate and move their building blocks to build a large pueblo on a game board.

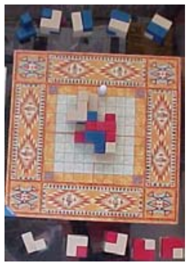
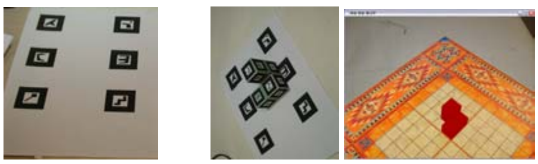


Figure 3. Pueblo board game

The AR Pueblo board game consists of four components, a main board, building blocks, a camera, and a display. The main board is used to place and to manipulate a virtual Pueblo board, and it is the main coordinate of the system, Figure 4(a). Every virtual object on the system will be located relative to the origin of the main board.

The building blocks are manipulated by the Pueblo interface. Users interact with the Pueblo interface to locate their building blocks on the virtual board to build a virtual pueblo. While users are manipulating the Pueblo interface, the camera is used to track the pose of the Pueblo interface, and the system locates the corresponding virtual building blocks in the AR environment.



(a) (b)

Figure 4. AR Pueblo board game (a) Main board (b) Rotate the main board to view at varying locations

HMD and a desktop monitor can be used as a display of the game. When HMD is used, the camera is attached on the front side of the HMD. Players can move their heads to view the game in various locations. When a desktop monitor is used, the camera is attached on the top of the monitor. Players can rotate the main board to view the other side of the game, Figure 4(b). Each display has its own advantages. Players wearing HMD could view the game freely and realistically. When a desktop monitor is used as the display, players are free from wearing a cumbersome HMD, so they can play the game longer than players wearing a HMD.

Using these elements, up to 3 players can play the AR Pueblo game. After selecting the appropriate building block, the player manipulates the Pueblo interface to interact with the selected building block. The player can rotate the Pueblo interface freely as he/she does with a real building block used in the real Pueblo board game.

4 Conclusion

This paper introduces the new tangible AR interface called the Pueblo interface. The Pueblo interface is built by attaching two hexahedral objects, so users can move and rotate the Pueblo interface freely to manipulate 3D virtual objects. This freedom is the main advantage of the new interface over existing tangible AR interface, the Board and the Cube interfaces. By improving the freedom of the interface motions, the Pueblo interface provides natural interaction with AR applications that require unrestricted motions of virtual objects.

Currently, the Pueblo interface is only tested empirically to demonstrate that the interface can provide users natural 3D interactions. The Pueblo interface has not been proven as the optimal interface that provides unrestricted 3D motions to users. The way to design the optimal Pueblo interface is left for the future work.

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