On the Use of Augmented Reality Technology for Creating Interactive Computer Games

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Abstract. In this paper, we design interactive games systems that adopt augmented reality (AR) technology. By virtue of a conventional webcam for capturing source images, we develop real-time visual tracking techniques based on edge detection and make 3D virtual objects display on our defined markers that are within the source images in the field of view (FOV) of the webcam. Two kinds of gaming interfaces are created for example: one is an AR based Monopoly game, and the other is an AR based fighting game. There are five classic human computer interface design methods considered to create the above AR based game systems. In the example of Monopoly games, we demonstrate how a traditional table game can be turned into an interactive computer game using the AR technology. We also list the advantages of a marker based approach and state why it is suitable for the interactive computer game. Further, the existing popular game consoles with different gaming interfaces are compared to the two AR based game systems. The comparison results reveal that our proposed AR based game systems are lower in cost and better in extensibility.

Keywords: Augmented reality, human computer interface, AR based game system, interactive computer game, marker recognition.

1 Introduction

AR is an interaction technology which combines the real world and virtual objects in the FOV of a camera, as shown in Figure 1. Because of the combination of real and virtual worlds, it is ideal for entertainment, medical science, education, human-robotic system, and so on. Currently, most of AR interfaces are only based on cameras. Previous literatures usually focused on improving the accuracy of object detection, but entire user interfaces are ignored.

AR is realized by the technology of computer vision and computer graphics. In the computer vision, there are three phases, including object detection, tracking, and recognition. In the detection phase, we detect the regions in which objects are located. Second, we track each of the objects using spatial temporal relations. Third, we recognize each of them by means of a classifier. In the computer graphics, we apply the geometry transformation by the relation of a detected object (in the 3D marker

R. Shumaker (Ed.): VAMR/HCII 2013, Part II, LNCS 8022, pp. 353–362, 2013.

coordinate system), the FOV of a camera (in the 2D screen coordinate system), and the camera (in the 3D camera coordinate system), as Figure 2 shows. After the transformation, a 3D virtual model will be displayed at the position of the detected object (the marker) in the FOV.

Fig. 1. Illustration of AR based interaction technology [1]

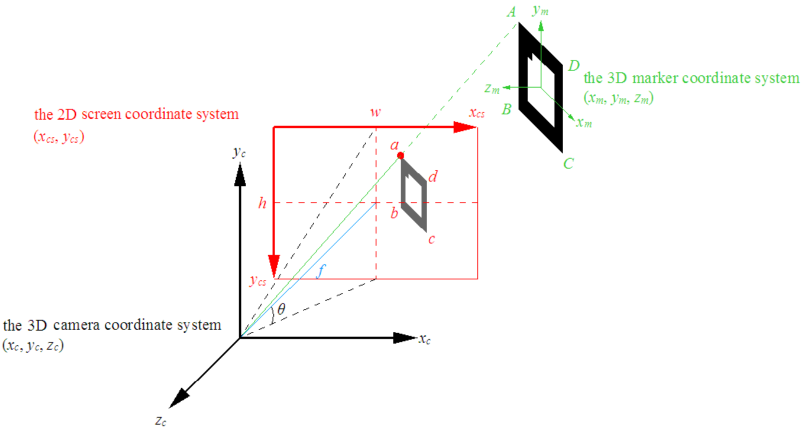

Fig. 2. The relation among the 3D camera coordinate system, the 2D screen coordinate system, and the 3D marker coordinate system

There are two categories of AR technology: marker based and markless based approaches. In the marker based approach [2], we need to design binary patterns for identification. Of such a binary pattern, the corner feature is clear because only black and white colors exist. In the markless approach, we need not design binary patterns for identification, but the computation cost is very high. Usually the algorithm is more difficult to design, and the accuracy is lower in most cases, especially influenced by the variation of the environment lighting conditions. In our proposed AR based game systems, real-time processing is an important factor, and the binary patterns can be regarded as game cards. Therefore, we choose the marker based approach, and design some markers, each of which is associated with a binary pattern printed on a game card for identification. Our design method can provide more than sixty thousand identities that give a good variety of markers for users to apply them. An example of the marker based AR technology is shown in Figure 3.

(a)

(b)

Fig. 3. An example of the marker based AR technology: (a) distinguish binary patterns printed on different game cards in our proposed system; (b) the corresponding 3D virtual model appears on the binary pattern of a game card.

In this paper, two computer game scenarios based on different user interfaces are developed for the AR based environment. We create an easy-to-use interface that is a graphical human interface developed through cross-platform APIs. In our game systems, users can interact with computers via a very intuitive way. Our proposed method enables computers to sense multiple markers in the sight of a camera, and which identity associated with a marker possessing the type, position, and pose is identified. With this information, computers can superimpose 3D virtual models on the specific markers respectively, so that users can interact with the 3D virtual models simultaneously through the markers.

2 Designing AR Based Gaming Interfaces

There are five classic methods to design man-machine interfaces called heuristic evaluation, observation, interviews and questionnaires, logging actual use of users, and user feedback [3],[4]. What follows introduces the details of these five design methods and how they are applied to AR based game systems.

1. Heuristic evaluation:
   Heuristic evaluation can make the research and development team quickly and easily identify usability problems in the man-machine interface products. In the process of heuristic evaluation, based on the control list of usability

guidelines provided by researchers, the evaluators check whether the form of man-machine interface products is right, and identify which items violate usability guidelines. The advantage is that the individual usage problems can be found and the needs of expert users can be listed. The disadvantage is that because the real thoughts of users are not included, unexpected demands of experts cannot be found.

2. Observation:
   Observation is employed to analyze and inquire the actions of users in the study phase, which usually requires three or more users. The advantage is to possess ecology force and to indicate users' work clearly. The disadvantage is that without participant control, the result will be hard to handle.
3. Interviews and questionnaires:
   An interview is used to the analysis phase of operation. In general, it needs five people to participate in. The advantage is that flexible and thorough point of view together with investigation experiences can be required. The disadvantages are that it takes quite a long time and the results are difficult to analyze. Questionnaire is applied to operational analysis and reviews of researches. At least thirty people are required. The advantages are that subjective preference of users can be found. Besides, repeating the whole process is easy. The disadvantage is that in order to avoid misunderstanding, a previous test is needed.
4. Logging actual use of users:
   The method needs more than twenty participants to keep track of full results, like link analysis, layout analysis, and hierarchical task analysis methods. The advantage is the patterns of high usage or less usage can be found. The disadvantage is that it requires a lot of data to analyze contents, which may violate users' privacy.
5. User feedback:
   The method needs hundreds of participants to join in for a long period of time. It is applied to research reviews. The advantage is that it can continuously track whether requests and viewpoints of users are changed. The disadvantage is that it needs stable implementation according to the questions from a specific organization, data retrieval, and so on.

In the following, we create two AR based game systems. Three design methods are chosen to implement them, including observation, interviews and questionnaires, and user feedback.

3 The Design Flow of AR Based Game Systems

In this section, we will elaborate the design flow of the two AR based game systems. One is an AR based Monopoly game, which is a static table game. The other is a joystick controlled AR based fighting game, where the user input is intensive. Because the characteristic of the two games is not the same, the design flow of each of them will be depicted separately as follows.

3.1 An AR Based Monopoly Game

The main inputs of the AR based Monopoly game are different kinds of markers. Figure 4 illustrates the architecture of this game system, and Figure 5 shows a screen-shot of the system where many 3D virtual models are located in a real world. There are three input modes in this game. The first one is a marker dice, which is a replacement for real dices used in the traditional Monopoly table game. The second one is a marker cover, which is used for selecting items. As for miscellaneous operations, mouse and keyboard are employed.

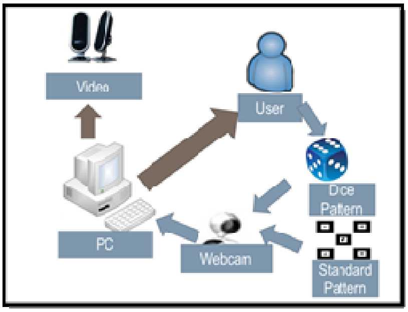

Fig. 4. The architecture of our proposed AR based Monopoly game

Fig. 5. A screenshot of our proposed AR based Monopoly game

Marker Dice

Throwing a dice is an important action in a Monopoly game; therefore, the interface of manipulating this action needs to be designed carefully. To accomplish it, we choose the "interviews and questionnaires" design method depicted in Section 2. Five members are assigned to carry out interviews and questionnaires with thirty people. These thirty people have experiences in playing table games. Several requirements are that not only the dice must be touchable and able to throw, but also the rolling process must be visible in monitors. In [5], it provides an idea for a marker dice, which is in form of a cube with a marker on each side. We adopt such a marker dice in our proposed AR based Monopoly game, where the stop rolling detection of the dice is essential, as shown in Figure 6. The main algorithm of this detection is based on determining whether the parallelism between the orientations of two markers occurs. If the marker on the top side of the dice is parallel to the marker on the table, the marker dice will stop rolling.

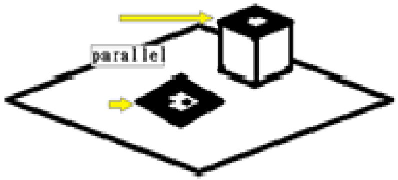

Fig. 6. Stop rolling detection of a dice by checking the parallelism between the orientations of two markers

Marker Cover

There are many conditions that we need to do “select” actions in a Monopoly game, such as deciding which land to buy and determining where to build a house. The design of this interaction is on the basis of user feedback. First, some prototypes of the system are made, and we ask one hundred players to try each of them. After the trials, players send their feelings and suggestions back, and gradually finish the overall system.

The marker cover is the solution to accomplishing a “select” action. The marker cover mechanism is realized using a two-phase approach. In the first phase, when a player wants to choose an item on the table, he or she applies the marker cover to mask an item. In the second phase, to prevent a wrong selection, the action in the previous phase must be confirmed. Users must employ another marker cover to mask the previous cover again. There are two kinds of this cover: one is a “confirm” cover, and the other is a “cancel” cover.

3.2 An AR Based Fighting Game

Generally, the inputs to the system are very intensive in a fighting game, so they are not possible to adopt markers to control the game. The marker here is used to identify the orientations of 3D virtual models. Figure 7 illustrates the architecture of such a fighting game system and Figure 8 shows a screenshot of the system, which is extended from the traditional fighting game scenario. In the AR based game system, users can have their virtual characters displayed in a real world, not limited to a pre-designed virtual background. In addition, the virtual characters are attainable to interact with a real background.

When playing the AR based fighting game, a marker is put in the FOV of the camera. The virtual characters are shown at the related positions to the marker. According to both the “heuristic evaluation” and “interviews and questionnaires” design methods described in Section 2, users tend to play fighting games using joysticks. This is because button-based peripherals are the most responsive input devices, which coincides with the requirement for the characteristic of fighting games.

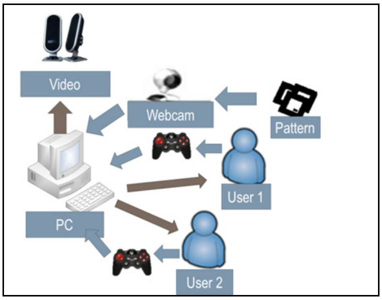

Fig. 7. The architecture of our proposed AR based fighting game integrated with joysticks

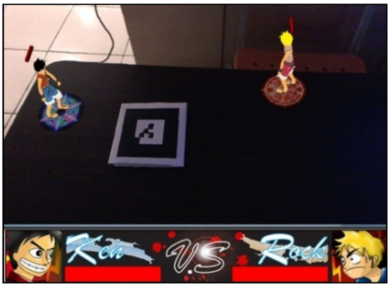

Fig. 8. A screenshot of our proposed AR based fighting game

4 Comparisons of the Existing PC Gaming Interfaces

In this section, our proposed AR based game systems are compared to the existing popular game consoles with different gaming interfaces. The first proposed system is an AR based Monopoly game, and the comparison result between the AR based and traditional Monopoly games whose respect scenarios are shown in Figure 9 is stated below.

(a) (b) (c)

Fig. 9. Three types of Monopoly games created by different technologies: (a) a traditional Monopoly table game; (b) a traditional Monopoly computer game; (c) our proposed AR based Monopoly game.

The traditional Monopoly game on PCs has been popular because the computer treats most trivial and boring parts of the game where users can focus on their strategies to win the game. However, this traditional Monopoly game deprives of the real interactions in a table game. By virtue of the AR technology, our proposed game system still keeps real interactions, when users assign the trivial and boring parts of the game to a computer. The detailed comparison of the three types of Monopoly games is listed in Table 1.

Table 1. Comparison of Monopoly Games Created by Different Technologies

Item compared \ Game type	Traditional Monopoly table game	Traditional Monopoly computer game	Our proposed AR based Monopoly game
Process controlled by a computer	No	Yes	Yes
Interaction on a table	Yes	No	Yes
Interface	Dice	Keyboard & Mouse	Printed patterns
Equipment	Card	PC	PC & Webcam
Viewpoint	Not adjustable	Not adjustable	Adjustable
Resume function	No	Yes	Yes
Multiple players	Yes	Yes	Yes

Next, our proposed AR based fighting game is compared to the existing ones, such as traditional 2D and 3D fighting computer games. The screenshot of each type of fighting games mentioned above is illustrated in Figure 10.

(a) (b) (c)

Fig. 10. Three types of fighting games created by different technologies: (a) traditional 2D fighting computer game; (b) traditional 3D fighting computer game; (c) AR based 3D fighting game

In traditional 2D fighting computer games, users can move the characters only in four directions: up (jump), down (squat), left, and right. In the traditional 3D fighting computer games, users can move the characters freely in a 3D space. In this situation, besides both jump and squat actions, users can move the characters in a 2D space on the ground; thus, the users have more moving strategies to adopt. However, in either the traditional 2D or 3D fighting computer games, their gaming backgrounds are pre-designed. Users can only choose limited scenes in these types of computer games. But, in the AR based fighting game, users need not choose which scene to play in; they simply select a real world as a gaming background arbitrarily. Moreover, it is possible for the characters appearing in the game to interact with the real world, such as the cups colliding with each other on a desk and falling from the edges of a table. Therefore, the extensibility of our proposed AR based fighting game is higher than those of traditional 2D or 3D fighting computer games. Table 2 lists the overall comparisons between our proposed AR based fighting game and the two traditional ones.

Table 2. Comparison of Fighting Games Created by Different Technologies

Item compared \ Game type	Traditional 2D fighting computer game	Traditional 3D fighting computer game	Our proposed AR based fighting game
Game scenes	Limited (Usually 8~20)	Limited (Usually 8~20)	Infinite
Interface	Joystick	Joystick	Joystick
Degrees of freedom	Two	Three	Three
Game extensibility	Normal	Normal	High
Interaction with the real world	No	No	Yes
Object render type	2D image	3D virtual model	Adaptive 3D virtual model
Viewpoint	Fixed	Changeable	Changeable

Finally, two major game consoles, Kinect and Wii, are compared with our system. Both of them have special gaming interfaces. The Kinect exploits a depth sensor to capture the body motions of users; however, the cost of the depth sensor is relatively high [6]. The Wii takes a gyroscope and an accelerator to sense the moving trajectory of the controller. In contrast to the Kinect, the computational cost of the Wii is lower and the hardware cost is cheaper, but the Wii lacks of an AR support [7]. Our proposed game system is based on the AR technology, and its main equipment is a webcam that captures the scenes of a real world into games. Compared to the Wii and Kinect, the price of our proposed AR game system is the cheapest. The computational cost is also lower since we adopt markers as game cards in our proposed system, which are apt to identify the virtual characters and fighting weapons. The comparison result is listed in Table 3.

Table 3. Comparison of the Kinect, Wii, and Our Proposed System

Items compared \ Platform	Kinect	Wii	Our Proposed System
Peripherals	Depth sensor	Sensor and keypad	Camera and joysticks
Equipment cost	Highest	Medium	Low
Interface	Kinect sensors	Wii remotes	Webcam and joysticks
Object render type	3D Virtual model	3D Virtual model	3D Virtual model and real world
Interaction mode	Body motions	Wii remote motions	Moving game cards

5 Conclusions and Future Works

In this paper, an AR based game design flow is presented, and the comparison among different platforms is also made. First, in developing the AR based Monopoly system, we evaluate many user interface design methods. The design of the marker dice is according to the outcome of interviews and questionnaires, and the design of the marker cover is based on the result of user feedback. Second, in the AR based fighting game, the virtual characters are put into the real world by the aid of the marker. Third, the comparison results reveal that our proposed AR based game systems are better than the traditional ones in many aspects. Additionally, the cost and the extensibility of the former systems are lower and higher than other popular gaming interfaces used in the Kinect and Wii.

If the performance of the collision detector for finding virtual characters colliding with real objects can be increased, the extensibility of our proposed AR based game systems can be enhanced. In the future, a framework for such a collision detector will be proposed. This can be a solution to simplifying the applications in most of the AR based systems.

Acknowledgement. The authors thank the National Science Council of Taiwan for supporting this work in part under Grant NSC101-2221-E-011-140-MY2.

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