ELECTRONICALLY ENHANCED BOARD GAMES BY INTEGRATING PHYSICAL AND VIRTUAL SPACES

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Abstract This paper describes an electronically enhanced board called E^2 board. The motivation of our work comes from a traditional board game, which groups of players enjoy in a face-to-face situation by manipulating pieces on a physical board. In order to enhance users' excitement and immersiveness, a physical board and a virtual world created by a computer are linked together with E^2 board. An important function of E^2 board is the rapid recognition of massive numbers of different objects. The authors have developed several applications using E^2 board: not only games, but also systems for supporting group activities. Some of these applications are shown.

Keywords: board game, Radio Frequency Identification (RFID), tangible interface, augmented reality.

1. Introduction

Irrespective of age or sex, people enjoy board games in their daily lives with friends and family. There are various kinds of board games played all over the world, some of which have evolved over thousands of years. For example, *Wei-qi* (*Japanese Go*) was invented in China more than 4,000 years ago; the predecessor of Chess was an Arabic board game called *Shatranj* played about 1,400 years ago; and Backgammon has evolved from an ancient Roman game called *Tabula* [15][2]. Board games have been played since ancient times and are still popular today.

Compared with today's computer games that use sound, graphics and animation, a board game that is composed of a board and pieces uses very simple media. However, people still find traditional board games

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exciting. During a game, various strategies and skills are required for outwitting other players, and participants enjoy face-to-face communication and interaction with each other. In this paper, the authors attempt to enhance traditional board games electronically. One realization of such enhancement is to visualize a board on a computer display, and enable players to manipulate pieces by using a mouse and a keyboard. Such "computer board games" are available through the Internet or in computer game stores. These games not only use images and sound effectively, but also allow players in different locations to enjoy them through a computer network. A critical feature of an original board game is that players can manipulate a physical piece on a physical board. However, this feature is lost in computer board games due to the constraint of a computer display, where visualization is in a two-dimensional space.

On the other hand, we retain the physical feature of a board game for the following two reasons: human beings have become familiar with its play style (we sit around a board, and manipulate a piece with our own hands) over a long period; and it seems to be one of the fruitful ways for supporting group activities in the context of HCI design proposed in [3] (tangible user interfaces). In this paper, we describe a system called E^2 board (Electronically Enhanced board). When a player places or moves a piece on E^2 board, the effect of his or her manipulation is immediately visualized on the board through a LCD projector. Thus, E^2 board allows players to actually manipulate physical pieces on the board (a feature of traditional board games), and also gives them visual and auditory feedback through a virtual world.

In the next section, the configuration of E^2 board is described and games that use E^2 board are shown. The authors have so far developed several board games with E^2 board and one of these, *CatchTheButterfly*, is examined in this paper.

2. System Configuration

2.1. Requirements for E^2 board

Consider a board game like Chess or Go. Players have different types of pieces (rook, bishop), which have different positions on the board. During play, there are many pieces on the board? in the case of Go, more than 300 pieces are possible. Therefore, the following requirements must be satisfied:

- 1 The type of object placed must be recognized automatically.
- 2 The location of a placed object must be detected automatically.

- 3 Large numbers of objects (about 500) must be recognized at the same time.
- 4 The recognition time must be as short as possible (within about 0.1 seconds).

The fourth requirement is especially important. Players will be irritated if they have to wait to receive feedback each time they manipulate a piece. A system called Envision and Discovery Collaboratory (EDC) for supporting collaborative work and learning in urban planning and design has been described in [1]. In EDC, a touch-sensitive projection board is used for object recognition. However, this type of board (for example, *SMART Board*) is a single input device, and is not suitable for applications that are required to recognize multiple objects quickly. Another method for object recognition is to embed resonant circuits whose resonance frequencies are different from each other in different kinds of objects (for example, a commercial toy called *RedBeard Pirates Quest*). However, in order to distinguish between two circuits, the difference of their resonance frequencies must be large, and it is therefore difficult to assign circuits of different frequencies to many kinds of objects (low discrimination power). Moreover, the fact that stable performance for recognizing multiple objects (twenty to thirty objects) is not guaranteed has been found through our experiments. *Sensetable* [11] can electromagnetically track the positions and orientations of multiple objects on a tablet, and is used for chemistry and system dynamics simulations. However, the number of objects it can track is currently less than ten.

2.2. A Method with Image Processing

In image processing approaches, a camera is installed above a board where objects are placed, and images gained by the camera are used for object recognition. A system called *Urp* for urban planning and design has been proposed in [17]. In *Urp*, small color dots are applied to the surface of each object as an optical tag. A two-dimensional matrix code that is also applied to the surface of an object is described in [13]. In these two works, a different pattern of a visual tag is assigned to each object. By recognizing its pattern, the corresponding object is identified. In [5], a system called *Enhanced-Desk*, an electronically enhanced work environment, is proposed. *Enhanced-Desk* integrates object recognition with visual tags proposed in [13] and human hand recognition with an infrared camera that can generate an image based on human body temperature. In an image processing approach, cheap material such as paper or wood can be used for a board. However, this approach is not acceptable for the following reasons:

Figure 1. System Configuration: (a) The sensing board and (b) software architecture

- Recognition is not perfect: During a game, players often cover a part of the board with their hands or heads, and a camera above the board cannot always generate an image where all the objects on it appear whole. In addition, if an image processing method without visual tags is used, correct detection of types and locations of hundreds of pieces based on their color and shape information will be difficult.
- Time-consuming: Due to the remarkable improvement in hardware performance, time needed for image processing has become shorter. However, several researchers have noted that image processing or computer vision technologies are still time-consuming (for example, [4]). Compared with a traditional image processing or computer vision method that uses edge detection or color histogram, a method with visual tags is effective in improving object recognition rate and speed. However, [8] reported that glyph recognition takes at least a few seconds (at worst more than one minute), and object recognition requires a few seconds with a method proposed in [13]. Moreover, visual tags are obtrusive [18], because a visual tag itself is just an implementation matter, and not at all related to users' interests (playing games).

2.3. A Method with RFID

Through these investigations, we decided to use the RFID technology (by OMRON Corporation) to develop the current version of E^2 board. RFID is a non-contact object identification and data transfer technology. The RFID system consists of two components: an antenna (with a transceiver and decoder) and a tag (Figure 1 (a)). An antenna emits

radio signals to activate a tag, and writes data to the tag or reads data from it in the electromagnetic field produced by the antenna. An antenna combined with the transceiver and decoder is called a reader. It decodes data encoded in a tag's integrated circuit (IC) and passes the data to an attached personal computer. The RFID is a reliable and unobtrusive technology: the performance of data transmission between a tag and an antenna is stable, and a tag is small enough to make it invisible by embedding it in a piece. However, the data transmission speed between a reader and a tag is not very fast (10ms to 20ms). This may cause serious communication delays; for example, it will take 1 to 2 seconds to identify a hundred pieces. The authors devised a new method that reduces the processing time for data transmission. In the current implementation, one CPU (Hitachi 16MHz microcomputer unit) is attached to a unit that comprises 10×8 squares as shown in Figure 1(a). When E^2 board receives a command for detecting the arrangement of pieces on it from an attached personal computer, it first sends a read command to all the CPUs simultaneously through the interface CPU. Then, the CPU of each unit sequentially activates and controls 80 antennas in its unit, so that each of them activates a tag and reads its data. Finally, E^2 board sends data about tags from the CPUs through the interface CPU. The architecture of the board enables parallel processing of communication between tags and readers, and makes the communication time theoretically independent of the number of units, or the size of the board. The time taken to acquire the arrangement of pieces on the current version of the board is less than 0.05 second. The merits of this architecture are as follows:

- Users can simultaneously place or move multiple pieces on the board.
- By changing the number of units, the board can be freely extended or reduced without increasing response time.

A grid frame is laid like a checkerboard on the surface of E^2 board. A tag embedded in a piece is placed inside a grid, and a reader is embedded in the board under each grid. A tag must be included in an electromagnetic field produced by a reader just under the tag. If the tag is not placed inside a grid, it will receive interference from electromagnetic fields produced by neighboring readers. This interference will prevent the tag being successfully identified by one reader. Recently, the RFID technology has begun to be used for object recognition in some research projects. In *DataTiles* [14], for example, RFID antennas are laid like a checkerboard on a touch-sensitive display, which is similar to our approach. When a transparent tile that embeds a RFID tag is placed on

the display, related information to the tile appears on the display. However, the maximum number of tiles that a user can place is 12 (3×4), and it is not enough for our purpose. In the current version of E^2 board, there are 20 $\times$ 24 grids with sides of three centimeters. It can be separated into two parts whose weights are about 4kg and 3kg, respectively. E^2 board is not light enough to be portable. However, E^2 board can be sent in advance to the game location, and one person can easily set it up. Setup involves assembling the parts, connecting a personal computer and E^2 board through their RS-232C interfaces, and then E^2 board is ready to start object recognition on its surface. This method avoids laborious work such as calibrating a camera position or adjusting its installation angle, which are necessary if using an image processing approach. This feature is also important when E^2 board is used for supporting collaborative learning at elementary schools where it is not easy to install unfamiliar equipment. This application of E^2 board is described in the next section.

2.4. Software Configuration

Figure 1 (b) shows the software architecture of the applications described in this paper: a board control module, a simulation module and a visualization module. The board control module, which is commonly used in all the applications and implemented as a dynamic link library, accesses E^2 board, controls it (activates or inactivates its sensors). The simulation module, whose implementation is different in each application, then makes a simulation based on the arrangement of pieces acquired through the board control module. The visualization module, which is also implemented differently in each application, receives the simulation results and updates the visualization. All the applications were developed using the C++ programming language and are currently executable on Microsoft Windows98 and Windows2000.

3. An Example of Applications

CatchTheButterfly is categorized as an edutainment application. The system is played by one or two persons. The aim of this system is to support in learning about habitats and features of butterflies in Japan. The system allows players to catch a butterfly with a physical piece with a net (*netpiece*). When a player has successfully caught a butterfly by placing a *netpiece* at the location where the butterfly is hidden, she can gain scores. In a traditional board game, a physical board is static: players always see the same information on the board during a game. On the other hand, this system can change the visual display on the

Figure 2. CatchTheButterfly: (a) A player selects a certain area in Japan and tries to catch a butterfly on the board, and (b) A butterfly appears (left side of the figure), when a player has found it successfully.

board every time a player moves his or her piece. For example, when a player put a *netpiece* on the board and could find a hidden butterfly or failed to do it, an animation shown by the system is changed (Figure 2(a)(b)).

4. Conclusions

This paper describes an electronically enhanced board called E^2 board. In order to realize a function that can quickly recognize different types of numerous objects, the authors used RFID technology and devised a new method for data transmission, by comparison with other technologies. The initial motivation for developing E^2 board was to create a new type of a board game that integrates a physical board and a virtual world created by a computer. While formal users studies on these systems have not been carried out, the authors have received valuable comments from users. Future research will be aimed at improving the systems and exploring the possibilities of new applications.

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