Natural User Interface for Board Games Using Lenticular Display and Leap Motion

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Abstract. Various board games, including chess, are now played on PCs, but they differ from actual board games because a mouse is typically used to move the pieces. Moving a piece by pinching it with one's fingers, as in actual board games, is desirable to increase a player's sense of reality. That the pieces look as if they were floating in the air is desirable so that the players can pinch them easily. Thus, we used an autostereoscopic display in which a lenticular lens is used to cover the liquid crystal display of a PC. As a result, each piece of the board game looks as if it were popping out of the 3D display screen, without the need for the player to wear special glasses. In addition, we use a Leap Motion Controller, a motion-capture device that is particularly suitable for capturing the position and movement of fingers so that a computer can recognize where in the 3D space the fingers are and whether the fingers are pinching a piece or not. Therefore, the user can operate the piece easily and intuitively.

Keywords: Natural user interface · Board game · Lenticular display · Leap motion controller

1 Introduction

Board games, such as chess, have been popular since ancient times. Various board games are now played on PCs, but these games considerably differ from actual board games in the sense that an artificial input device such as a mouse is typically used to move the pieces. Moving a piece by pinching it with fingers, as in actual board games, is an ideal interface to increase the sense of reality of the player. A desirable feature is that the pieces look as if they were floating in the air so that the players can pinch them easily. Thus, we build a new human interface that consists of a Windows PC, an autostereoscopic 3D display, and a leap motion controller [1]; the third device is a 3D motion-capture apparatus specialized for human fingers. A chess player can operate a virtual piece that looks as if it were floating in the air by a gesture of pinch-ing and moving it by hand directly. The configuration of our system is shown in Fig. 1.

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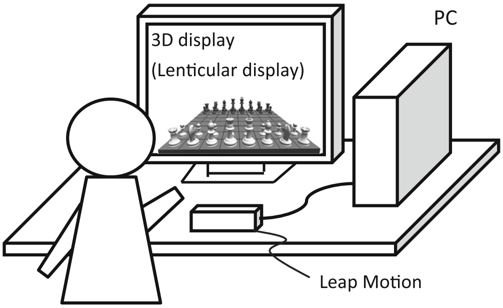
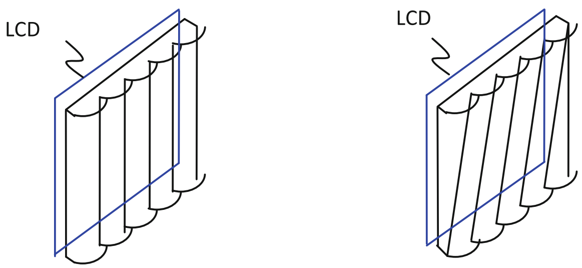


Fig. 1. System configuration

2 3D Display

Using 3D displays is highly effective to improve the usability of 3D games because binocular parallax provides an important clue to obtain depth information.

Stereoscopic image display methods [2] are roughly classified into two. One is the method in which a user wears stereo glasses such as polarized or liquid-crystal shutter glasses. The other is the autostereoscopic method in which a user can see stereo images without needing to wear special glasses. Although the latter method has a limitation in that the image tends to be indistinct when the amount of popping out becomes large, its advantage is that it does not require special glasses. Among various autostereoscopic methods, the lenticular display is adopted in the present study because it displays bright and high-quality 3D images. The simplest lenticular method can be produced by placing a lenticular sheet, which consists of an array of minute semi-cylindrical lenses, on a liquid crystal display (LCD), as shown in Fig. 2(a). How-ever, a moiré pattern is visible. If the lenticular sheet is slightly slanted to the LCD, as shown in Fig. 2(b), the moiré becomes less visible. This condition is known as the slanted lenticular method [3]. In this study, we use a ready-made 24-inch 3D display (Newsight Japan NSJ-MVLL24AD3, 1920 × 1080 pixels) with a built-in slanted lenticular lens.



(a) Normal lenti (b) Slanted lenticular display

Fig. 2. Lenticular displays

Until several years ago, substantial initial cost to manufacture a custom-made lenticular lens was necessary because of the widespread belief that the ratio of the lens pitch and pixel pitch had to be a simple integer ratio. However, using inexpensive ready-made lenticular lenses was enabled by the emergence of the fractional view method [4, 5]. Although the method adopted in this study can also be classified into the fractional view method, our method is slightly different from the original fractional view method in that the lenticular image is synthesized from a finite number (e.g., eight or sixteen) of images rendered from various camera positions.

We use an Open Graphics Library (OpenGL) for the rendering. OpenGL has the function of double buffering to reduce flicker. In our system, this function is used for real-time rendering of multiple-view lenticular images, as shown in Fig. 3. A len-ticular image is synthesized from the images read from the back buffer because the images are composed of pixels. Our method is fast because a time-consuming process such as ray tracing is unnecessary. The obtained lenticular image is displayed on the LCD.

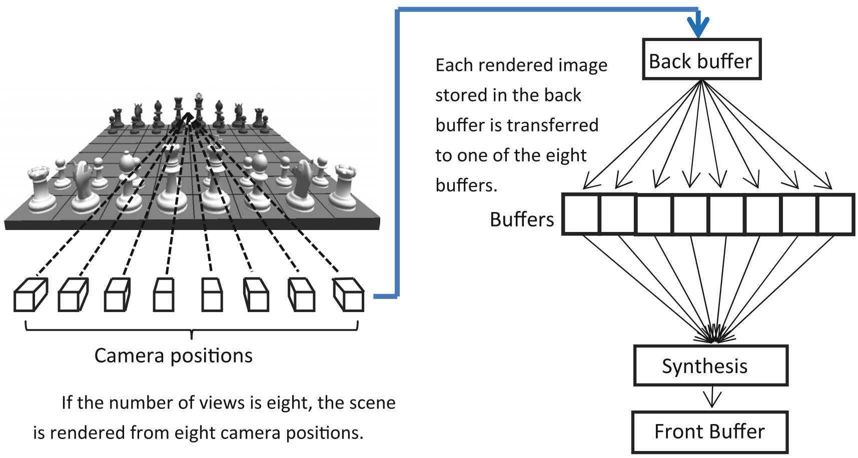


Fig. 3. Real-time rendering of multi-view lenticular image using OpenGL

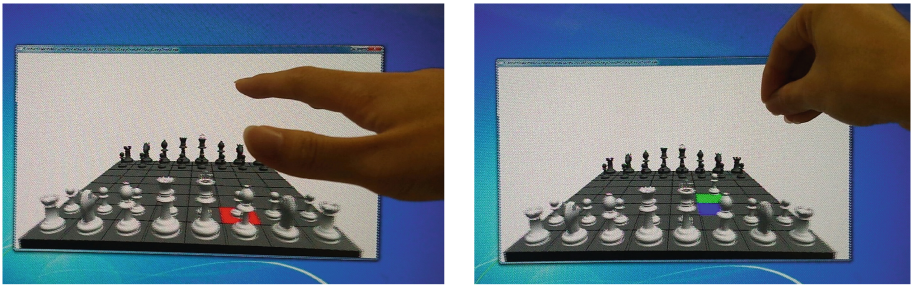
3 Acquisition of Position and Shape of Hand

In addition, the PC has to know where in the 3D space the fingers are and whether the fingers are pinching a displayed piece or not. We use a Leap Motion Controller, a motion-capture device particularly suitable for capturing the position and motion of hands and fingers. Unlike using a mouse, no hand contact or touching is necessary because the 3D position data of the fingers are calculated from two images captured with two monochromatic infrared cameras.

3.1 Display of Hand Position and Grip Decision

Microsoft Visual C ++ and Leap Motion SDK 2.0 were used to develop our appli-cation program. Displaying the current position of the player's hand in a way is nec-essary so that the player can pick up the intended piece among many pieces. In this system, the location of the palm is acquired as the return value of a member function "palmPosition()" of the Hand class. Whether the fingers are grasping a piece or not is determined by acquiring the return value of a member function "pinchStrength()" of the Hand class. The return value expresses the degree of the opening and closing motion of the thumb and index finger.

When a hand is above the board, the square directly below it becomes red, as shown in Fig. 4(a). When the hand is closed to pick up a piece, the square becomes green and the squares of the possible destinations of the piece become blue, as shown in Fig. 4(b). Possible destinations differ depending on the type of piece. However, the actual destination of the piece is not limited to the colored squares so that the player can easily correct any wrong move. Therefore, the user can easily operate the piece.



(a) When the hand is open (b) When the hand is closed

Fig. 4. Coloring of the square directly under the palm

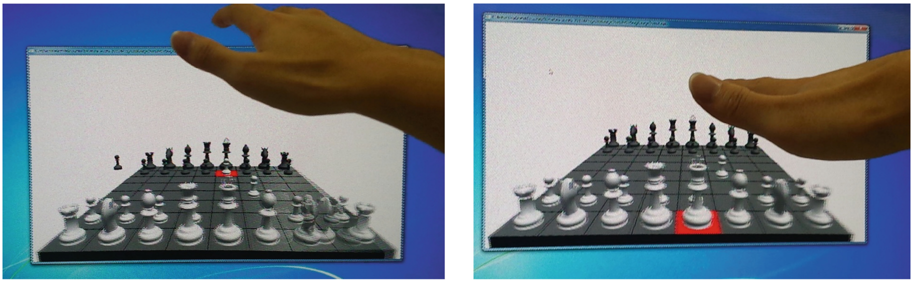
3.2 Processing When a Piece Is Placed on the Board

3.2.1 Adjustment of the Position of the Piece

If the piece is placed away from the center of the square, the player will have difficulty recognizing the square on which the piece is located. Therefore, the piece is automatically moved to the center of the square.

3.2.2 Processing When a Piece is Moved to a Square on Which Another Piece is Placed

If the color (black or white) of the piece moved to the square differs from that of the piece that has been placed on the square, the enemy's piece is moved outside of the board, as shown in Fig. 5(a). If the color of the piece moved to the square is the same as that of the piece that has been placed on the square, the piece moved is automatically returned to the former position, as shown in Fig. 5(b), because such a move is not allowed in chess.



(a) When opponent's piece is taken. (b) Friend's piece cannot be taken.

Fig. 5. When a piece is moved to an occupied place

4 Experimental Results and Discussions

The devices used in the experiment are listed in Table 1.

Table 1. Devices used in the experiment

	Name of device	Developer
CPU	Intel Core i7-3770 Processor	Intel
GPU	GeForce GF-GTX750Ti-EL2GHD	NVIDIA
3D display (lenticular)	NSJ-MVLL24AD3	Newsight Japan
Motion capture device	Leap Motion	Leap Motion

Our experimental system worked as designed. Since the board and pieces were au-tostereoscopic and each piece could be picked and moved with fingers, a high sense of presence was achieved although no force feedback existed. When an external GPU was used, a practically sufficient frame rate was obtained even when the resolution of the image was 720 × 1280, as shown in Table 2.

Table 2. Average frame rate (frames per second)

	HD Graphics 4000		GeForce GTX 750 Ti	
Resolution	8 views	16 views	8 views	16 views
720 × 1280	10.3	6.5	21.6	14.4
360 × 640	27.7	17.3	38.5	30.0

At present, precisely matching the position of a virtual piece displayed on 3D space and the position of the actual human hand is difficult for several reasons. First, the amount of popping out is not large enough because the 3D image is blurred when the popping out becomes large. Therefore, increasing the space where the virtual space and the real space overlap is difficult. Second, the position of the virtual piece changes slightly in the 3D space when the player's viewpoint moves. The probable reason is that the 3D image consists of a finite number of rays emitted from a finite number of LCD pixels, in addition to the problem that the calibration is difficult. Therefore, a 3D display system with a slightly higher density of ray is required. In particular, the vertical displacement seems large because this system does not provide vertical parallax up to now. This problem can be solved if integral imaging, which has not only horizontal but also vertical parallax, is adopted in the future.

5 Conclusion

We have developed a new NUI for digital board games, such as chess, in which a lenticular display and a motion-capture device are combined. To view pieces that have been created with 3DCG and look as if they were floating in the air, players need not wear special stereo glasses because a lenticular display, which is a kind of autostereoscopic display, is used instead. In our system, the position information of the player's fingers is obtained by the 3D motion-capture device called Leap Motion Controller. Whether the fingers are grasping a piece or not is also detected by the device. Therefore, players can move pieces naturally and intuitively with their fingers in the 3D space although no force feedback exists in this system. Therefore, a realistic operation that feels close to that of an analog board game has been achieved.

In the future, when the amount of popping out becomes large and the alignment between the 3D display and motion-capture device becomes more accurate, more natural and intuitive operations of pieces will be possible, and the completeness of the game will increase. The results of this study are considered to be applicable to other board games such as Shogi, Go, and Othello.

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