3D Puzzle Guidance in Augmented Reality Environment
Using a 3D Desk Surface Projection
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ABSTRACT
Augmented reality (AR) technology is an intuitive approach in the manufacturing domain. Meanwhile, the use of the technology has been limited until now because AR applications often require special devices, and such systems tend to be expensive generally. In this paper, we propose an AR approach for the 3DUI contest. The highlight of our solution is the deployment of virtual desktop or 3D desktop projection. The virtual desktop consists of real desktop, screen on the desktop and LCD projector over the desk. It is important that our solution uses only commodity hardware and does not request an operator to wear curious goggles or eyeglasses. Assembly procedure is projected to the desktop screen where the puzzle pieces also exist. As the result, the guidance display can be mixed with the real puzzle pieces.

KEYWORDS: Assembly guidance, augmented reality, desktop projection, pattern recognition, heuristic search.

INDEX TERMS: H.5.1 [Multimedia Information Systems] Augmented reality; H.5.2 [User Interfaces]: User-centered design, Graphical user interfaces(GUI); 1.5.4[Pattern Recognition] Implementation;

1 INTRODUCTION
As the progress of display device technology, practical use of augmented reality (AR) and mixed reality (MR) technologies are getting popularity. One of the expected applications of AR is assembly guidance and repair instruction to novice operators or engineers [4]. Similar situation happens in this 3DUI contest where novice player, who have no prior training and instruction, must complete highly intellectual mission.

The use of AR technology for the contest is straight forward and we can employ fruits of previous research works. The most important work to do is combinational implementation of elemental technologies and deployment to complete the given task. The technological components are followings;

• Pattern recognition to detect piece type and position,
• Heuristic search to find the puzzle solution,
• Displaying the guidance information to the player.

We decide to use conventional approach for pattern recognition and heuristic search programs to shorten the time of system development because there are many standard techniques and program libraries are available for these tasks. So, we intensively worked for display system. The display model we choose is so called desk surface projection. This display model is also called as meta-desk or virtual desk [2][3]. In this model, the real desk surface is used as projector screen and we can put puzzle pieces on it. This situation or mixed existence of real object and virtual image at the same time is very common characteristics in AR application.

There are two reasons why we use desk surface projection. One is the radical improvement of commodity projector systems. The brightness of small projector rises so rapidly and we can easily understand information projected on desk surface even in ordinary office illumination condition. The other is the 3D projection function by which the player can see guidance information as stereoscopic image. The puzzle is defined in 3D space, so that stereoscopic display could help the player understanding the guidance.

2 DESIGNING THE SOLUTION
Figure 1 illustrates overall structure of our solution. As described in previous section, the solution consists of three subsystems and the system management subsystem. The contest problem is well defined, and the sequence of instruction is defined at the beginning of the game. It means that the three subsystems are almost running independently and the communications among subsystems are limited.

2.1 Piece Recognition Subsystem
At the beginning of the game, piece recognition subtask capture the desk surface image by using USB camera, which is mounted near the projector. The captured image is passed to pattern recognition program to read the piece type and position of the piece on the desk surface. The contest rule request that all pieces can be placed randomly. Overlapping or stacking of pieces may not be considered to simplify the task.

At this moment of writing this paper, we are assuming the pieces are set to predetermined initial positions since our piece recognition module is under development.
2.2 Heuristic search subsystem
The heuristic search is a program that searches the possible goal that fills 3x3x3 space by puzzle pieces. The search space becomes huge because the puzzle uses 6 or 7 pieces and combination of rotation and offset of pieces. If the shape definitions of puzzle pieces are known apriori, the system can use the pre-computed result. In such case, we need not to use heuristic search program. This program required if the puzzle definition is not given at the start of the game, or the system is requested to understand physical shape itself.

2.3 User Interface subsystem
Our user interface uses 3D projection on to a desk surface. Similar layout have been discussed for 2D information, however, 3D stereoscopic projection has not. In the contest, the puzzle pieces must be displayed as natural 3D objects to help player understand the operation to do. We developed new screen projection model for natural appearance from player’s viewpoint. Figure 2 is a photograph taken from player’s viewpoint and it is clear that the cubic object at the front-right appears as if it is standing upright on the desk surface. Figure 3 is the photograph of experimental setup of the solution proposed.

3 Operation and Performance Evaluation
Before start a game, all puzzle pieces are placed in designated area on the desk. Then, the system starts initialization of internal states. In the phase, the piece recognition subsystem captures the desk surface image and outputs the position and type of each piece. After initialization, the system solves the puzzle by using heuristic search subsystem. Our puzzle solver responds the first solution in few seconds. Then, the result passes to the display subsystem and guidance to the player starts.

During the game, the guidance is shown to the player as arrow-line information that starts from the piece to the place to go. The 3D view of a cube, that is the goal of the game, is displayed in the right of the game fields, and it helps the player understand what is doing at the stage. We performed user evaluation by 5 colleagues and 10 novices. All of them completed the mission without assistance. The worst and best records were 1 min 52 sec and 27 sec, respectively. Average timings were 58.4 sec by 10 novices and 37.8 sec by 5 laboratory members. Figure 4 is a snapshot to show how a player uses the system.

4 Conclusion
Desktop metaphor is well accepted as the basic concept of graphics user interface in personal computer world. It may be connected with our experience of studying at the desk since at the age of kindergarten. The desktop is so familiar to everyone that it is very intuitive and helps a novice player understand the operation. It is important that the desk surface AR can be applicable to practical operation including mechanical assembly, maintenance and repair. We will continue to work on it to increase flexibility and versatility of this solution.

References