The Cube of Doom: a Bimanual Perceptual User Experience

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ABSTRACT
This paper presents a 3D user interface to solve a three-dimensional wooden blocks puzzle. Such interface aims at reproducing the real scenario of puzzle solving using involving devices and techniques for interaction and visualization which include a mobile device, haptics and enhanced stereo vision. The paper describes our interaction approach, the system implementation and user experiments.

Index Terms: H.5.2 User Interfaces [Input devices and strategies]: 3D Interaction—

1 INTRODUCTION
Simple three-dimensional tasks of the real world, as playing with wooden blocks, may become very hard when performed within a virtual environment with virtual blocks. While in the real world a person can benefit from the complete set of human sensory and motor skills to deal with the problem, a suitable human-computer interface must be developed to make the task even feasible in a VE.

This paper presents a 3D user interface to solve a three-dimensional wooden blocks puzzle. The puzzle problem is defined as a virtual environment showing a free area like a tabletop, where all puzzle pieces are equally selectable. The user is able to select any piece and move it to a working area where the final composition is assembled. The system identifies when the solution is achieved and shows the time for completion.

In the remaining of the paper we describe our interaction approach, the system implementation and user experiments performed with a magic cube puzzle.

2 SYSTEM OVERVIEW
Three-dimensional puzzles have the particularity that part of the problem to be solved is hidden from the user view. Thus, we wanted to conceive a system which allowed great mobility for easily turning and inspecting all sides of the objects. Our system consists of an interaction and control model which is similar to the real world object manipulation of such 3D puzzles. It integrates bimanual manipulation, haptic feedback, stereoscopy and head tracking.

For more than a decade, bimanual manipulation has proven to be effective [2]. In our system it occurs with the user’s primary hand being used to select, translate and rotate objects, while the user’s secondary hand rotates a three-dimensional working area. The primary hand controls a 3D cursor with 6 dof (degrees of freedom). The cursor is used to pick, move and orient objects – virtual wooden blocks for instance. At the same time, the secondary hand holds a mobile device with 3 dof tracking capability. With this hand, the user controls the orientation – position is fixed – of a working area which has the shape of the final object of the puzzle. As the blocks are placed into this area, they become part of the solution and start to be controlled by the secondary hand, leaving the primary hand free to pick another block. This allows for quickly inspecting the status of the partial solution.

The primary hand is also stimulated by haptic information in the form of force feedback. Information as weight, collision and impingement are rendered to the user through a haptic device. Force feedback also aids in reinforcing the positioning rules of the environment. For example, collision forces will avoid that the user’s hand proceed on a trajectory which would otherwise take a block to a portion of the space already occupied by another block in the working area or in the free area.

Besides selection and manipulation, another difficulty in 3D interaction is visualization. More specifically, depth information is difficult to obtain. To help the user in acquiring more accurate depth information, in our system we provided two additional features: stereoscopy and parallax effect [1]. While stereoscopy is widely known and understood, the parallax effect is less explored. Parallax occurs when, as the user moves their head to the sides, nearer objects appear to move faster than farther objects. A positive side effect of parallax is that very close objects can be viewed through a variety of different angles simply moving the user’s head. We use parallax in our system by tracking the user’s head and updating the virtual camera position accordingly.
### 3 Implementation

The system has been implemented in C++ based on the Ogre3D library for graphics and using the following hardware: Phantom Omni; iPod Touch; stereo shutter glasses; 120Hz monitor; Wii remote and infra-red LEDs. Also, physics-simulation of rigid bodies has been implemented using the NVIDIA PhysX library [3].

The primary hand uses a Phantom Omni to interact with 6 df of input and 3 df of force output. The asynchronous HD API of the OpenHaptics library has been used to implement the communication with the Omni. Collision detection is calculated by PhysX between objects, and feedback force is calculated following the god object approach using a penalty force.

An Apple iPod Touch is the mobile device held by the secondary hand. This type of device is becoming ubiquitous as we believe in its potential as a 3D interaction device as it offers a number of integrated motion sensors. In our system we use the gyroscope and the accelerometers to provide three accurate rotational degrees of freedom. The working area is then rotated using this information in such a way that it mimics the iPod orientation. iPod to system communication is implemented through WiFi network using UDP.

Stereoscopy is obtained with an NVIDIA 3D vision kit of shutter glasses and driver, coupled with a 120Hz LCD monitor. The parallax depth clue is produced by tracking a couple of IR LEDs we placed at the sides of the shutter glasses. We use the IR sensor of a Wii remote for tracking the user head position. The complete system setup can be seen in Figure 1.

### 4 User Tests

A user study was performed according to the following protocol. We considered two groups of subjects – novice and experts – that were firstly invited to fill a pre-test form that characterizes their profile. Then, they received a short introduction to the interface and the task to be accomplished. Novices also had a practice session of about 1 minute. After that, they started the test without any other guidance. Novices solved the virtual puzzle only once, while experts had to solve the same puzzle three times in a row. Finally, subjects had also solved a real wood puzzle (equal to the virtual one) and filled a post-test form rating satisfaction and fun.

Along the tests, we logged a whole set of dependent variables for each subject which we are not detailing here for lack of space. The ones we analyze in section 5 are the time form completion and completed or not. Fifteen subjects took part in the test, all of them right-handed, male and with a background in Computer Science (professors at the Department, undergraduate and graduate students, most of them on Computer Graphics), with a mean age of 30 years old (standard deviation of 11). Ten subjects were novices and five experts.

### 5 Results

Analyzing the data acquired during the tests of the novices, we notice that 3 subjects did not complete the puzzle using our system, and 3 out of these 5 did not complete the wooden puzzle neither. This indicates that their main difficulty is with puzzles and not 3D interfaces. Considering only the subjects that have completed the task, the minimum and maximum time spent was respectively 340 and 1,551 seconds. The mean time was 945s with a standard deviation of 442s (considering all of the 15 tries). In Figure 3 you can observe the learning curve of the 5 subjects involved in this user study.

Concerning the experts, all subjects completed the virtual puzzle three times, and only one did not complete the wooden puzzle. The minimum and maximum times spent were respectively 130 and 2,074s. The mean time was 625s with a standard deviation of 442s (considering all of the 15 tries). For each subject we measured the time for completion in his first try.

The subjective data captured with the post-test questionnaire indicate that 12 participants are satisfied or very satisfied with the experiment. In their comments, subjects mentioned that, even if they are satisfied, the experiment is very long and involves two different and difficult cognitive tasks: the use of a new two-hands 3D interface, and the solution of a complex puzzle.

### 6 Final Comments

We presented an involving and robust solution for complex manipulations of objects in a 3D virtual environment. Our solution proposes a user experience with two hands and the head movement in a natural way, and was well accepted by the most part of the users. As future work, we are planning further user tests with simpler objects to reduce the cognitive load imposed by the puzzle to a minimum and focusing only on the interaction issue. Also, a greater number of subjects should allow for statistical analysis of the data.

### Acknowledgements

Thanks are due to the volunteers, CAPES and CNPq for grants PIBIC, 481762/2008-6, 309092/2008-6, 509160/2010-7, 483814/2010-5, 483947/2010-5 and 302679/2009-0.

### References

