Guidance System Using Augmented Reality for Solving Rubik's Cube

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Abstract. This paper proposes a guidance system to help to solve the Rubik's cube. For the puzzle to be solved, each face must be returned to consisting of one color. But the problem is quite difficult because there are 4.3252x1019 different states that can be reached from any given configuration. Our system use augmented reality technology to recognize the placement of each square and provide intuitive and easily understandable guidance for solving procedure.

Keywords: Rubik's Cube, Guidance System, Augmented Reality, Immersive, Intuitive, Solving Algorithm.

1 Introduction

Rubik's Cube is a 3-D combination puzzle invented in 1974 by Erno Rubik of Hungary. In a classic Rubik's Cube, each of the six faces is covered by nine stickers, each of one of six solid colors. The puzzle is scrambled by making a number of random twists. For the puzzle to be solved, each face must be returned to consisting of one color. There are 4.3252x1019 different states that can be reached from any given configuration[1].

The problem is quite difficult. In Rubik's cubers' parlance, a memorized sequence of moves that has a desired effect on the cube, is called an algorithm. Many algorithms are designed to transform only a small part of the cube without interfering with other parts that have already been solved, so that they can be applied repeatedly to different parts of the cube until the whole is solved. Some algorithms do have a certain desired effect on the cube but may also have the side-effect of changing other parts of the cube[1].

Augmented reality (AR) is a live, copy, view of a physical, real-world environment whose elements are augmented by computer-generated sensory input such as sound, video, graphics or GPS data. A major strength of AR systems is their intuitive depiction of information, where the user perceives virtual and real objects as coexisting in the same space. At a glance, the user naturally recognizes the content of the information (i.e., an object's location, size, shape, color and maybe its movement)[2]. In this paper, a series of solution steps will be provided by using AR technology.

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2 AR-Based Guidance System

In this paper, we propose a guidance system to help to solve the Rubik's cube using augmented reality technology. The system consists of iPad, 2x2x2 cube and iPad Stand. The size of iPad is appropriate considering cube size, camera distance, and arm's length. 2x2x2 cube is used because the size of square is bigger than classic 3x3x3 cube. The size of square is closely related to the recognition rate and speed when augmented reality works. And we need a mount in order to use both hands for manipulating cube.

Fig. 1. System Overview

Table 1. System specifications

Name	*Type*	*Version*	*Usage*
1. iPad2	Hardware		Personal computer
2. i-Cozy	Hardware		iPad Stand
3. 2 x 2 x 2 Cube	Hardware		Rubik's Cube
Unity Engine	Software	4.0	Game Engine
4. Qualcomm 5. Vuforia SDK	SDK	2.5.8	Augmented reality

Our system uses Unity3D as its underlying development platform and rendering engine. Unity3D is a cross-platform game engine with a built-in IDE. It is used to develop video games for web plugins, desktop platforms, consoles and mobile

devices. Unity3d is a very flexible engine that was used for generating and integrating richer 3D graphic.

For augmented reality, we use a Mobile AR SDK called Vuforia developed by Qualcomm that supports iOS, Android and Unity 3D. It uses Computer Vision technology to recognize and track planar images and simple 3D objects, such as boxes, in real-time. The virtual object then tracks the position and orientation of the image in real-time so that the viewer's perspective on the object corresponds with their perspective on the Image Target, so that it appears that the virtual object is a part of the real world scene.

Vuforia provides Application Programming Interfaces (API) in C++, Java, Objective-C, and the .Net languages through an extension to the Unity game engine.[3] In this way, the SDK supports both native development for iOS and Android while also enabling the development of AR applications in Unity that are easily portable to both platforms. The Vuforia AR Extension for Unity enables vision detection and tracking functionality within the Unity IDE and allows developers to create AR applications and games easily. Figure 2 shows how Virtual buttons work only with image targets.

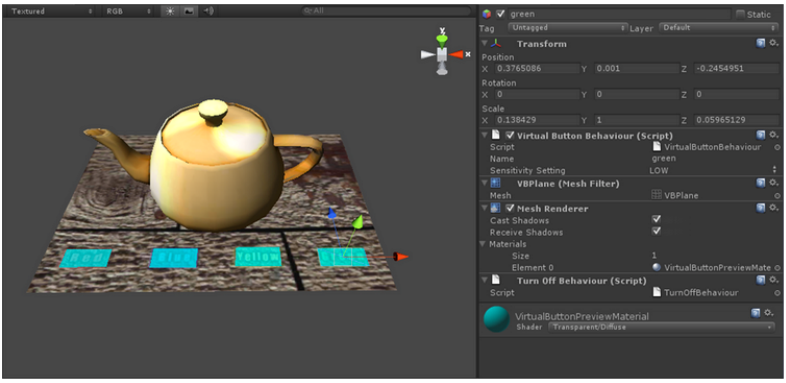

Fig. 2. Vuforia AR Extension for Unity and Virtual Buttons demo

Vuforia uses computer vision technology to recognize 2D and 3D image targets. An image target or 'Trackable" is an image that the Vuforia SDK can detect and track. In the system, a special kind of predefined markers called Frame Markers is used. Vuforia provides 512 predefined Frame Markers where each marker has an unique code of binary pattern around the border of the marker image. Decoding a Frame Marker takes relatively little processing power. In the system, we designed Frame Markers for 24 square with 6 different colors of 2x2x2 cube like the Figure 3.

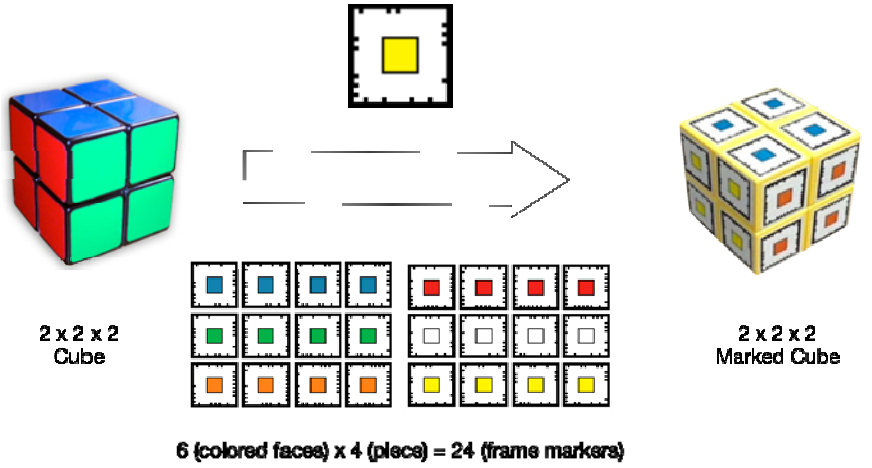

Fig. 3. Frame Markers and 2x2x2 Cube

Our system has three main processes. First, it recognize the placement of each square. If recognition is successes, colored planes are augmented to show the result of recognition. It then figures out the shortest path to solving the puzzle. And, a series of solution steps is provided like the below figure.

Face names are very simple to understand and they let user know which face to turn while reading cube notation. Now if user hold his or her cube strait in front of face, the face of the cube directly in front of user is called the F face, which stands for Front. The cube faces on the right and left side of the cube are the R and L faces. The face on top is U for Up face. The bottom is D for Down face. And the back face is B for Back. Therefore, there are 12 kinds of solution step. These step will be displayed by using AR technology.

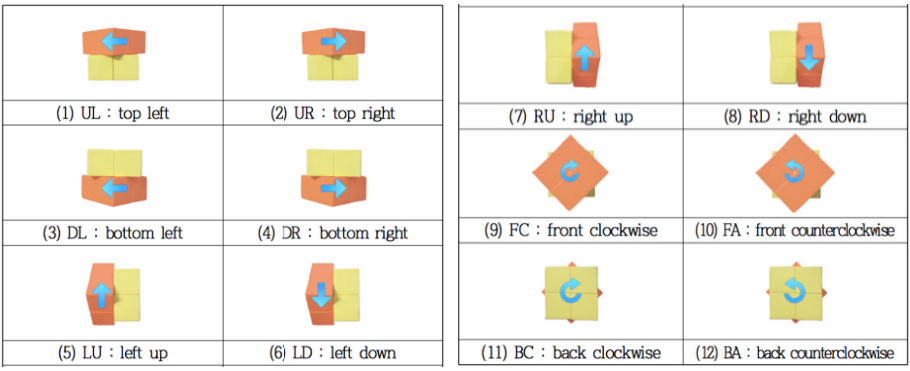

Fig. 4. 12 kinds of solution step

3 Conclusion

In this paper, we proposed a guidance system to help to solve the Rubik's cube. Augmented reality technology is applied to recognize the placement of each square and provide intuitive and easily understandable guidance for solving procedure. Our system has three main processes. First, it recognize the placement of each square. If recognition is successes, colored planes are augmented to show the result of recognition. It then figures out the shortest path to solving the puzzle. And, a series of solution steps is provided like the below figure.

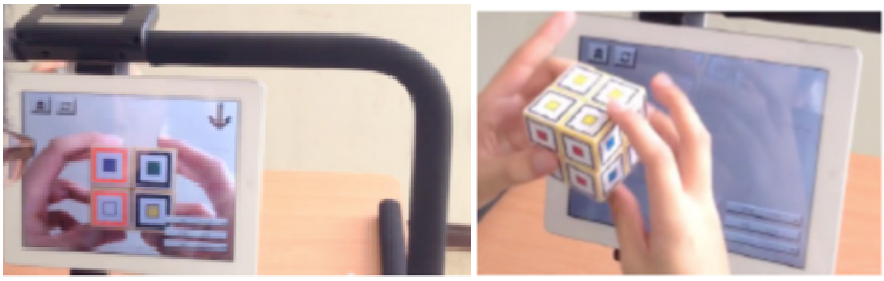

Fig. 5. Display of step-by-step instruction and the result

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