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Rubik's Cube Solver

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Abstract: Rubik's cube is considered to be the most interesting and challenging problem in the world. It is a 3D combination puzzle that was originally called the Magic cube. It has only one correct solution out of the 43quintillion other possibilities. Building an application to solve such a puzzle is a very challenging task. In this paper, the design of such a Rubik's cube solver website using Color Recognition has been discussed. This paper includes the overall process flow for solving the Rubik cube [1]. Our website is designed in such a way that when it will receive a scrambled Rubik's Cube, it will visually evaluate it, will determine how that Rubik's cube can be solved through manipulations and will provide a guide of the solution to the specific user. We have used Color recognition for detecting the initial orientation of the cube. And Segmentation is used to obtain the color pattern of the scrambled cube.

Keywords: Rubik's cube, 43quintillion, Color Recognition, scrambled, Segmentation.

I. INTRODUCTION

Rubik cube is a 3D puzzle that was invented by Hungarian sculptor and professor of architect Ernő Rubik. Originally Rubik cube was referred to as 'Magic cube'[2] and it was licensed by Rubik to be sold by Ideal Toy Corp. in 1980[2]. It is considered as world's best-selling toy all over the world [2].

A Rubik cube has 6 faces and each face has 9 stickers that are one of six colors, (generally red, yellow, blue, green, orange, and white). A pivot mechanism is there in the cube which helps all colors to mix up. And the puzzle will be solved when each face will have only one color. It can take from few seconds to hours to solve the puzzle [3].

A standard Rubik's cube has a 5.7cm (approximately 2¼ inches) size of each face. A Rubik cube is made up of twenty-seven small cubes, also known as "cubelets" or "cubies". Each cubelet consists of an inward extension that helps one cubie to interlock with another which helps in moving the cube to different locations. However, the center cube of each of the six faces is just a square façade; all six are attached to the center mechanism. In total, there are twenty-seven pieces: a single core piece that has three intersecting axes which hold the center square of each face in place and allow them just to rotate, and twenty-six smaller plastic pieces that fit into it to form a Rubik cube [3].

Rubik cube can be solved only by applying a specific algorithm. Many algorithms are present to solve the puzzle but earlier there was a disadvantage that cubist has to remember or memorize the complete steps to solve the cube which was a tedious task [3]. Nowadays, online tutorials for solving a Rubik's cube are given but those online tutorials provide the solution when we reach a particular stage in Rubik's Cube, and steps to reach that particular stage are not given anywhere. A person who is solving Rubik's Cube for the first time may get stuck at any stage and would not know what to do next. One more problem can occur that if any person wants to know that after how many stages, he will be able to solve that puzzle completely then there is no way found till now by which we can get that information. Our website will help a person who is stuck in between to reach the root position and will tell the steps by which we can solve the Rubik's Cube.

Due to advancements in the implementation of image processing and the development of many algorithms, an application could be made to solve it. This paper involves all those steps that were involved in making a website and solving the Rubik cube. Image processing plays a very important role of all, and thus its accuracy was considered very vital. We have used the HSV color range because of its simplicity and accuracy for different colors [4][5]. With the color range defined, each color could be differentiated from the other. The first step is identifying the color of the cubies and the second step is the generation of an algorithm. From a pre-programmed set of possibilities and the corresponding responses are referred to generate the right algorithm [1].

II. RELATED WORK

Due to the unique features of Rubik's cube, it has been used by scholars all over the world for research purposes and has been the subject of keen interest for everyone [6]. Programs that can solve a Rubik cube in the least possible ways were discussed by T. Rokicki and R. E. Korf in [7] and [8]. R. E. Korf proposed an algorithm in [9] that solves the Rubik's cube in an optimal solution length of 18moves using pattern databases. S. Liu and F. Ďurovský have discussed various methods for solving the Rubik cube puzzle in [10] and [11]. In [12] & [13] G. Zhao and R. Higo presented a cube solver robot based on STM 32 and a multi-fingered hand respectively.

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S. L. Lu, M. Huang, and F. R. Kong presented a Rubik's cube solver bot in their paper which was based on a mechatronic system and all its manipulators were driven by pressurized air. The color recognition of the initial state of a cube was done in HSV color space [14].

In [15], a computer vision algorithm for solving the Rubik cube was presented. This paper addressed the problem when a long-term fixed camera-cube position is not possible. For detecting the position of the cube Hough transform and advanced clustering functions were used and for detecting the state of the cube color detection algorithms were used. In [16], the color drifting problem of color recognition of the cube is addressed.

To illustrate the efficiency of the training-based method "Scatter balance and Extreme learning machine" method is proposed. T. Li, W. Xi, M. Fang, J. Xu, and M. Q.-H. Meng presented an interesting approach to solving the 2x2x2 Rubik's cube with a multi-fingered dexterous hand with a 24-DoF. They used the hierarchical deep reinforcement learning method to design a model-based cube solver to find optimal move sequences [17].

III. IMPLEMENTATION

Each cube has six sides: UP, DOWN, RIGHT, LEFT, FACE and BACK. Each side corresponds to one color based on the viewer's perspective that is, generally red, yellow, blue, green, orange, and white as shown in Fig.1. Our work is to solve the Rubik's Cube of the user and to provide him a guide full of instructions so that he can solve it by himself also.

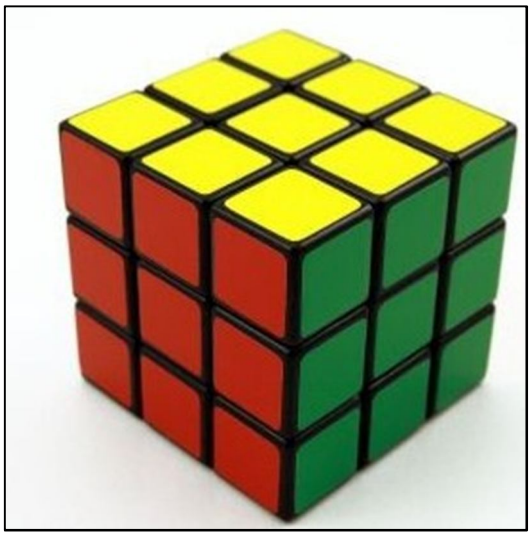


Fig. 1 Unscrambled Cube

The image of the scrambled cube is captured by a camera at first and send website via the drag and drop process as shown in Fig.2 below.



Fig 2 Drag and Drop Process

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The images received by the computer are resized to a square of fixed length and then converted to HSV format. HSV color format is more accurate than RGB color format that's why we have used it. After that segmentation is performed on each image to differentiate the color on each face of the cube. The obtained images are stored for further processing. When the computer will click the picture of Rubik's cube it is possible that in that picture some background things also come. So, our first work is to crop the picture to the edge of the cube to achieve a clear picture of Rubik's Cube containing 9 small cubes. After that, we will break the picture into 3*3 cubes assuming that we are getting the exact picture. But this will be our ideal case.

We may assume the picture to be a square shape but in actual it is rectangular as we are clicking pictures from some distance and the perspective ratio is different. In that case when we will break the picture into 3*3 then one color may mix with another color. To solve this problem, we will take all the cubes one by one and will start moving from the top, bottom, left, and right edge of the cube to the middle of the cube and will make a graph of the color which we will get on that cube. Using SciPy and other libraries we will calculate the color distribution and the distribution of the color which we will get the most will be allotted to that particular cube. The RGB value that we get may be some distance away from the actual color then we will calculate the distance between the received RGB value from the graph and the actual color and the color which is present at a minimum distance from the received RGB value will be allotted to that particular cube.

Fig.3 shows the flow chart of the working of our website.



Fig.3 Flow Chart

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IV. RESULT AND DISCUSSIONS

User has inputted the scrambled cube on our website as shown below in Fig.4.

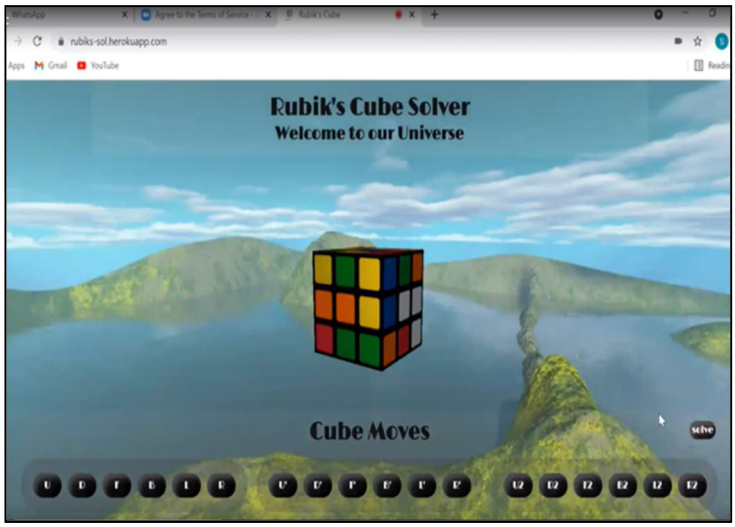


Fig. 4 Scrambled Cube of User

We have used 2-phase Kociemba algorithm to solve the cube.

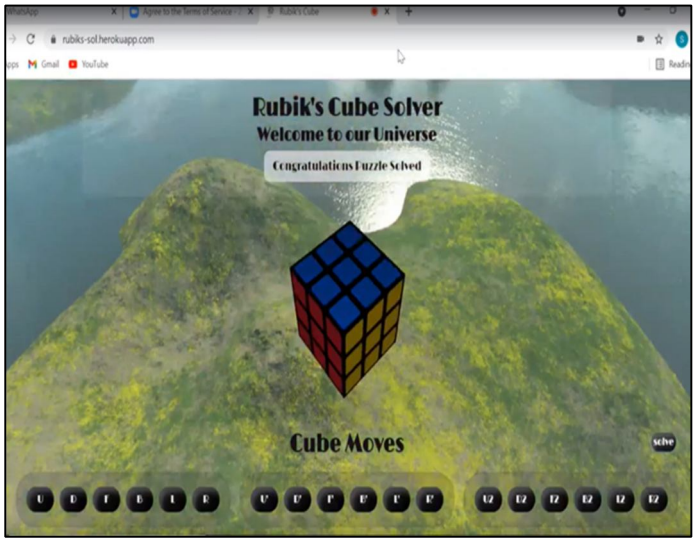


Fig. 5 Solved Cube of the User

Fig. 5 above shows the solved cube of the user.

V. CONCLUSION

The Rubik's cube is still a very difficult puzzle for humans to solve. And it was very challenging to make a website for solving it. With the knowledge of image recognition and image processing we made it possible. Our website will allow the user to scan pictures of unsolved Rubik's cube and will determine the steps to solve that scrambled cube. In addition to this, our website will also serve as a learning tool for beginners to understand the steps to solve the cube.

VI. ACKNOWLEDGEMENT

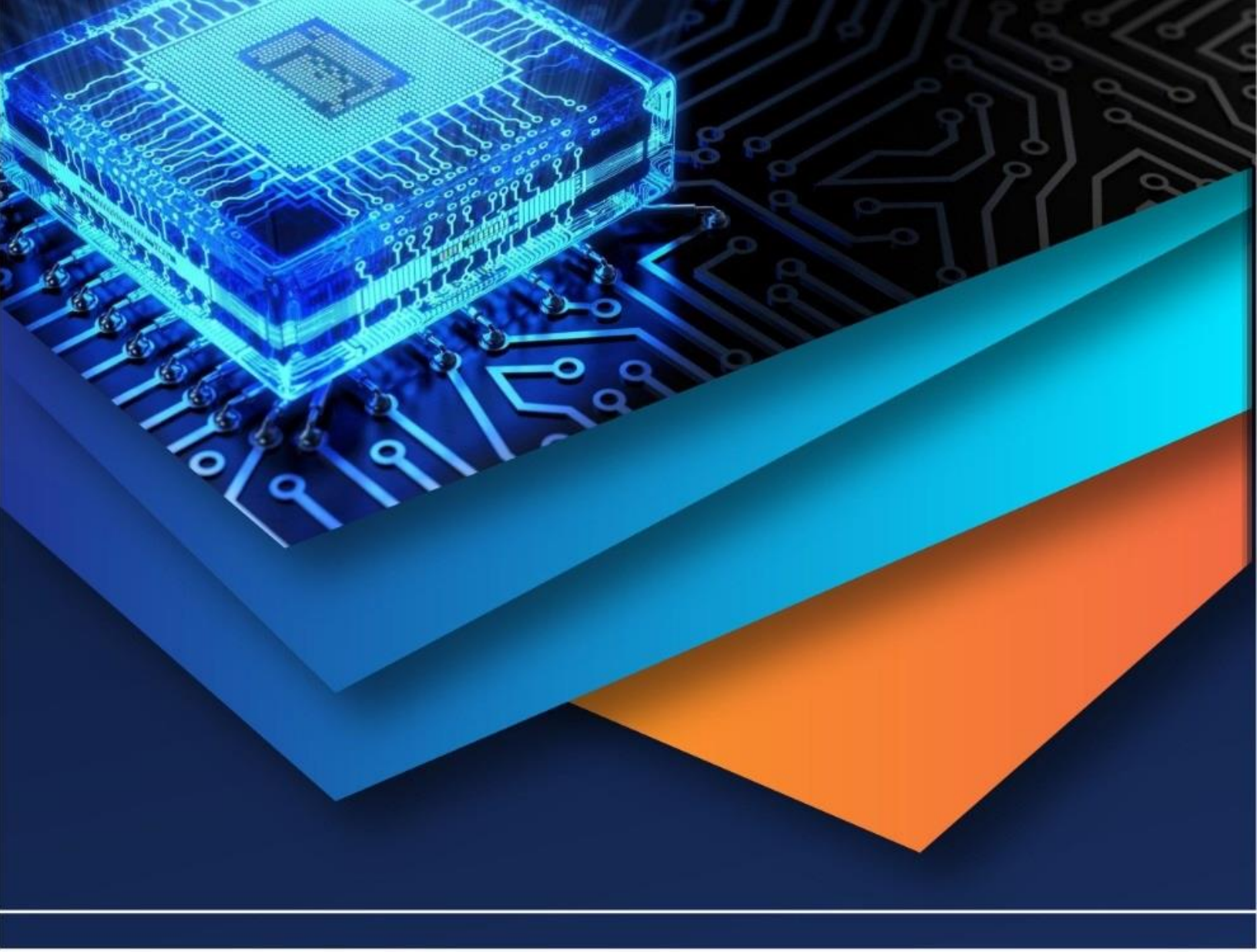
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