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HIGH PERFORMANCE ALGORITHM TO SOLVE RUBIK'S CUBE PROBLEM

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Abstract—

The Rubik's Cube was invented by Erno Rubik in the year 1974. The cube has 6 different colored faces with 9 squares on each face. Every cube face can be rotated which generates a state of the cube. There can be as many as 901 quadrillion states from which a Rubik's Cube can be rotated back to original state. The goal of this research paper is to create a data structure which stores a Rubik's Cube[1] in a computer system, define the methods which perform rotations on the data structure and apply Rubik's Cube solving algorithms to solve the Rubik's Cube back to its original state.

Keywords- Cube, Rotations, Corner, Edge.

I. INTRODUCTION

The Rubik's Cube in general consists of three types of pieces:

- Edge – there are 12 edge pieces, each having 2 sides.
- Corner –there are 8 corner pieces, each having 3 sides.
- Center–there are 6 center pieces, each having 1 side.

Edge and Corner pieces are movable whereas Center pieces are immovable.

Representation in the Computer System:

Data Structure:

The data structure [2] used for a cube must be easily understandable and should be able to perform rotations of its faces. Thus there are some pre-requisites for the cube which are:

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- Face-each cube must have 6 faces and each face must have 9 cubies.
- Cubie-each cubie has one color it represents.

There are 6 colors in the Rubik's cube which are:

- Blue (represented by 1)
- Red (represented by 2)
- Green (represented by 3)
- Orange (represented by 4)
- Yellow (represented by 5)
- White (represented by 6)

A cube can be oriented to any position but for simplicity we always consider:

- Blue face as front. (face with blue in middle)
- White face as bottom. (face with white in middle)
- Yellow face as top. (face with yellow in middle)

Previous propositions orient the cube before rotations so it's more confusing for the programmer to code and for the solver to solve.

The solver must hold the cube as above while solving and the programmer must write his rotations as above orientation of the cube.

Each face has 9 cubies which have nomenclature as:

- tl-top left
- tm-top middle
- tr-top right
- ml-middle left
- mm-middle middle
- bl-bottom left
- bm-bottom middle
- br-bottom right

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TL	TM	TR
ML	MM	MR
BL	BM	BR

Fig. 1 - 9 cubbies which have nomenclature

Behavior of the data structure:

Rotations-rotations [3] can be performed by a programmer on the data structure defined above by swapping the values of the cubies that are affected by the rotation.

Basic rotations of one face movement at time are:

- Clockwise or Anti-Clockwise Right
- Clockwise or Anti-Clockwise Left
- Clockwise or Anti-Clockwise Front
- Clockwise or Anti-Clockwise Back
- Clockwise or Anti-Clockwise Down
- Clockwise or Anti-Clockwise Up

II. SOLVING RUBIK'S CUBE

A programmer can apply any Rubik's cube [4] algorithm to solve the cube. This research paper applies Fridrich method of solving Rubik's cube to the above explained data structure.

All the rotations that are applied to the cube are either programmer's perspective (in case of white cross) or the rotations defined by Jessica Fridrich[5] in her Rubik's Cube Solving algorithm.

The Rubik's cube will be solved in 6 different phases:-

- White Cross
- White Corners

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- Edges
- Yellow Cross
- Yellow Corners
- Correcting the Corners and Completing the cube

1. White Cross

Objective:

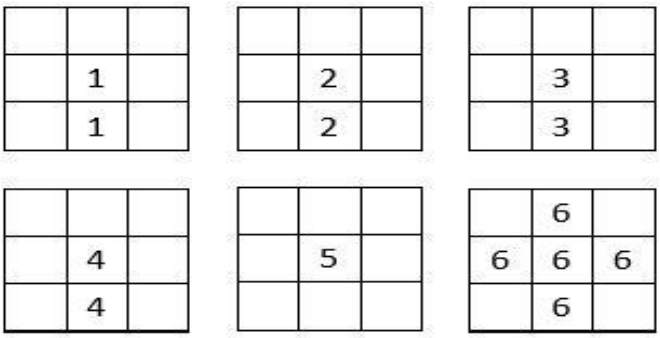

Fig. 2- White Cross

This phase gets a white cross at the bottom of the cube.

Algorithm:

1. Check every white edge (edge with one white color). If a white edge is at its correct position then its true otherwise false[6].
2. Check every white edge (edge with one white color). If all edges are in correct position then go to step 7.
3. Check every face's edge pieces for a white color (6). If white color is found get it to the right place by rotations.
4. If any white edge which was true is affected then return it to its original place by rotation.
5. Give white edge corrected in step 4 true. Go to step 2.
6. Stop. White cross is complete.

Explanation:

Consider following cube:

Notice the white edge piece on the TM or Top Middle of blue face.

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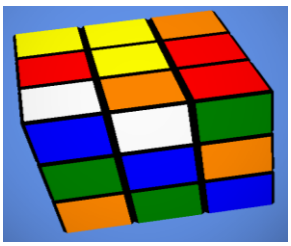

Fig. 3- White edge piece on the TM or Top Middle of blue face

While scanning the white edges this would be the first edge to be encountered by the computer system.

The white edge has an orange neighbor in the yellow face on top[7].

Thus the rotation for placing the orange-white edge to its correct place would be:

1. Anti-Clockwise Front

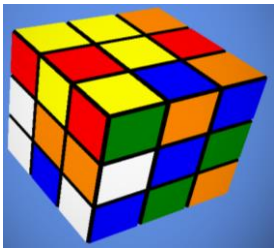

Fig. 4- Anti-Clockwise Front

2. Clockwise Left

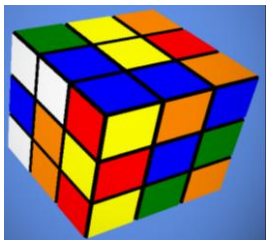

Fig. 5- Clockwise Left

We make the edge orange-white true after the rotations and start scanning the cube for other white edges again according to the algorithm.

2. White Corners

Objective:

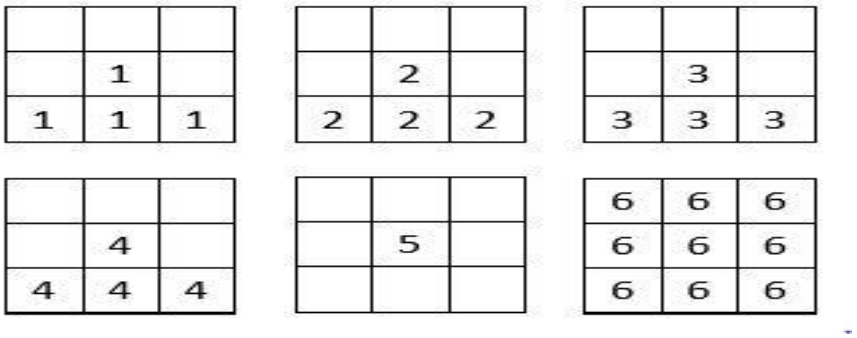

Fig. 6 - White Corners

This phase gets all white corners to their correct position.

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Algorithm:

1. Give every white corner a false.
2. Check every white corner if it is in the right position. If all white corners are in right position then go to step 7.
3. Check every face corners for a white color.
4. If white color (6) is found at the bottom layer bring it to the top by performing rotations.
5. If white color (6) is found at the top layer bring the corner to its right position by performing the rotations according to the neighbor.
6. Give white corner corrected in step 5 true. Go to step 2.
7. Stop. White corner is completed.

Explanation:

Consider the following cube:

Notice the corner piece [8] with white, red and blue color.

Fig. 7 - Corner piece with white, red and blue color

While scanning for white color corner piece computer system encounters white color on the TL or Top Left of red face.

According to the neighbor blue face TR or top right we get the color blue (1) and perform the following rotations to get the corner to its correct position.

1. Clockwise Right

2. Clockwise Up

Fig. 8 - Clockwise Right & Clockwise Up

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3. **Anti-Clockwise Right**

We make the corner piece with blue, red and white true after these rotations as it is in its correct position and then start scanning for the white color on the corner pieces again.

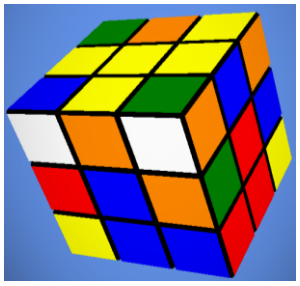

Fig. 9 - Anti-Clockwise Right

3. Edges

Objective:

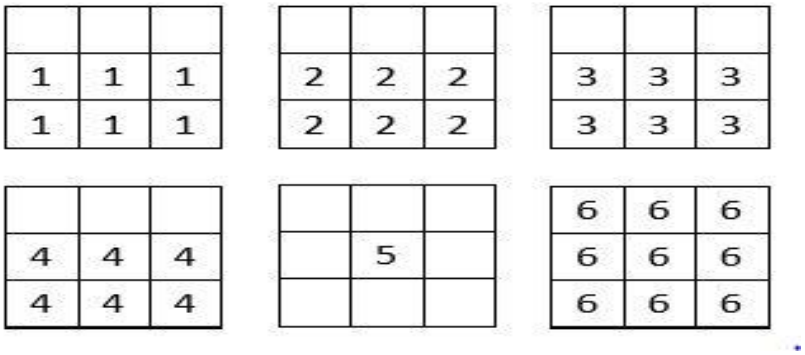

Fig. 10 - Edges

This phase gets all the edges with color blue, red, green or orange to their correct position [9] in the cube.

Algorithm:

1. Give every edge associated with blue, orange, red and green color a false.
2. Check every edge associated with blue, orange, red and green color. If all the edge is in the right position in the cube go to step 6.
3. Check TM or top middle of every face and its neighbor in the yellow face accordingly. If the TM is any other color than the color of the face then do rotations to move the edge to the face where its color matches the face.

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4. If TM is the same color as the face then check neighbor color. If neighbor color in yellow face is not yellow then do the rotations according to the neighbor color.
5. Give edge corrected in step 4 true. Go to step 2.
6. The Edge phase is complete. Stop.

Explanation:

Consider the following cube:

Notice the blue-red edge in the TM or top middle of the blue face.

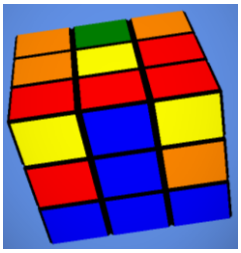
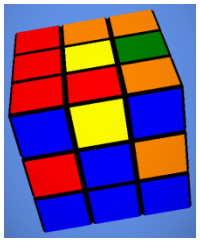


Fig. 11- Blue-red edge in the TM or top middle of the blue face

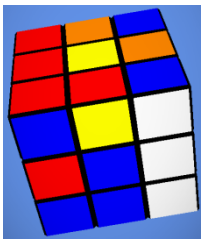
While scanning the TM of blue face computer system encounters the blue color on the TM. As the color of the face and TM are same it then views its neighbor in the yellow BM.

According to color of the neighbor which is red in this case we perform the following rotations to get the edge to its correct position.

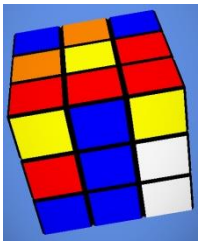
1. Clockwise Up



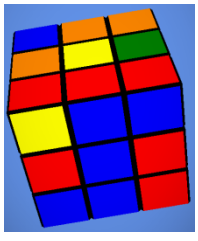
2. Clockwise Right



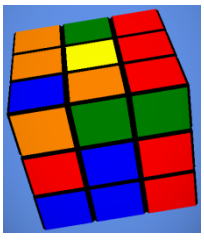
3. Anti-Clockwise Up



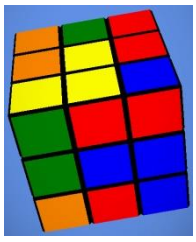
4. Anti-Clockwise Right



5.Anti-Clockwise Up



6.Anti-Clockwise Front



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7. Clockwise Up 8. Clockwise Front

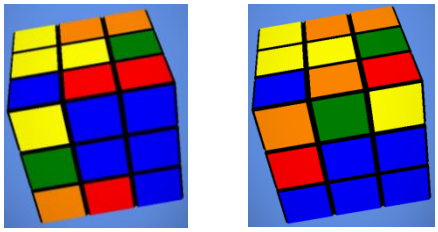

Fig. 12- Eight Phases

We make the edge piece red-blue true after the rotations as it is in the correct position and then start scanning for the TM or top middle of every face once again.

4. Yellow Cross

Objective:

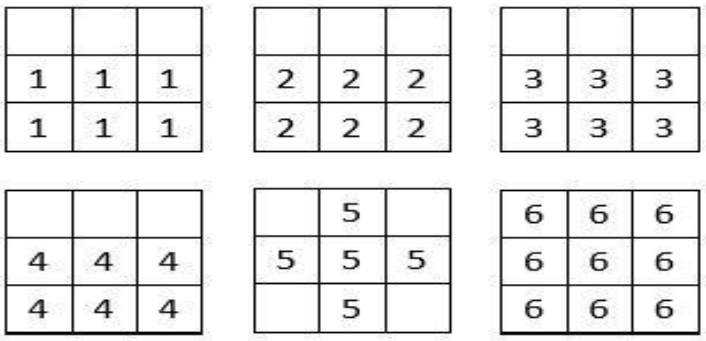

Fig. 13- Yellow Cross

This phase gets a yellow cross on top of the cube.

Algorithm:

1. Give TM (Top Middle), MR (Middle Right), ML (Middle Left) and BM (Bottom Middle) of yellow face a false.
2. If TM, MR, ML and BM of yellow face are yellow then go to step 3 else check which of the piece are yellow and perform the rotations accordingly.
3. Do the rotations over and over again until a yellow cross is obtained.
4. Yellow Cross is complete. Stop.

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Explanation:

Notice that the MR and ML of the yellow face are yellow in color. Thus the rotations to get yellow cross on top of the cube are:

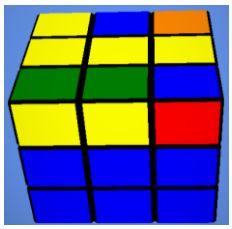
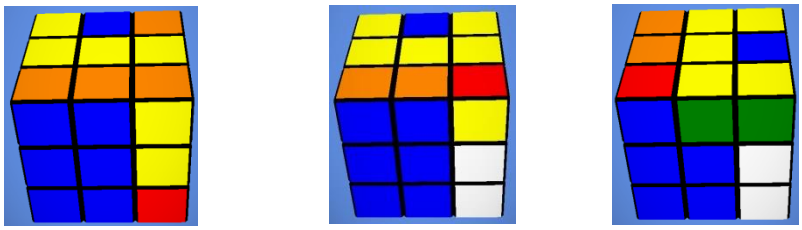


Fig. 14- MR and ML of the yellow face are yellow in color

1. Clockwise Front 2. Clockwise Right 3. Clockwise Up



4. Anti-Clockwise Right 5. Anti-Clockwise Up 6. Anti-Clockwise Front

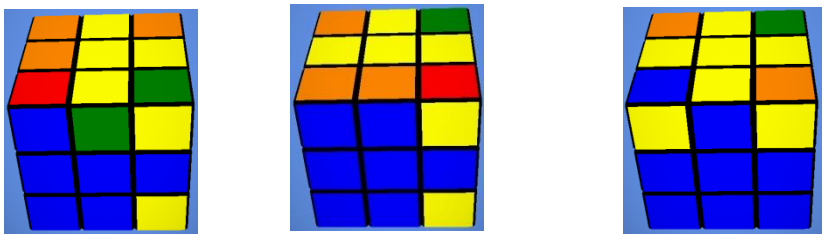


Fig. 15- Six Phases

5. Yellow Corners

Objective:

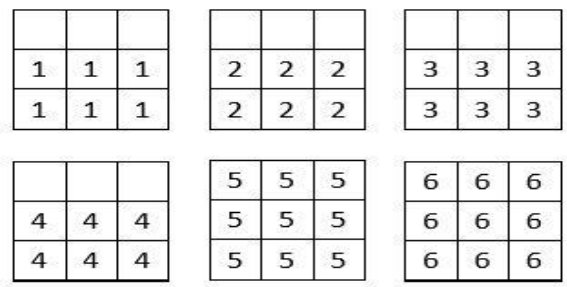


Fig. 16- Yellow Corners

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This phase gets all the yellow corners to the top of the cube.

Algorithm:

1. Give TR (Top Right), BR (Bottom Right), BL (Bottom Left) and TL (Top Left) of yellow face a false.
2. If TR, TL, BR and BL of yellow face are yellow then go to step 3 else check which of the piece are yellow and perform the rotations accordingly.
3. Do the rotations over and over again until all the yellow face is yellow in color is obtained.
4. Yellow Corners are complete. Stop.

6. Correcting and Completing the Cube

This is the time when we have a cube with wrongly placed yellow corners and edges. Thus in this two phase step we first strictly follow the rotations in the Fridrich method[10] to get the corners to their correct position then in the second phase we use set of defined rotations again from Fridrich method to complete the cube[11].

III. CONCLUSION AND FUTURE SCOPE

In this paper we discussed about the Rubik's cube data structure, rotations to be performed on the data structure and solving a Rubik's cube[12] to its original state from a scrambled state. The rotations performed on the Rubik's cube are derived from the algorithm given by Jessica Fridrich. This paper uses simple algorithm to solve the cube which can be understood easily. The algorithm takes 120-150 average one move steps to solve the cube. One obvious future scope of the paper lies in the application of an original algorithm not developed earlier to solve the Rubik's cube faster or in fewer steps[13].

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