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A Proposed Algorithm for Solving Rubik's Cube 3×3×3 Problem by Computer

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ABSTRACT

This paper tackled recruitment of computer to solve Rubik's cube 3×3×3 through a proposed algorithm generate 4 steps (movements) for each face of Rubik's cube's faces resulting from moving second row and second column of center of each face from six faces in original states (configuration) of cube, which represents the row and the column center of each face of the six sides of a cube, which is the color of the face itself. Represent the twenty-four movement generated in the algorithm proposed most of probability positions in correct positions completely to assign correct color of nine cubies for each face of the six sides of a cube and then a solution cube as a whole to make every face of the six of Rubik's cube covered in one color (red, white, blue, orange, green, yellow), and without violating center position ones in original faces (configuration) in Rubik's cube. The experimental results in this paper show a flexible easy to solve the Rubik's cube 3×3×3 to manage without manual dull method (mechanical methods), as well as reducing the search space, which has a huge amount of solutions. A program is written in MATLAB 6.5 language to simulate the proposed algorithm to solve the Rubik's cube3×3×3.

Introduction

Rubik's cube, invented in the late 1970s by Erno Rubik of Hungary, is the most famous combinatorial puzzle of its time [1]. Erno Rubik, a Hungarian architect and professor at the university of Budapest presented the first prototype of Rubik's cube in 1974. Professor Rubik develops the cube as a teaching aid for recognizing three-dimensional spatial relationships. Today, Rubik's cube as discrete optimization problem is a testing ground for scientific questions [2]. When he showed the working prototype to his students, it was an immediate hit. Any 3×3×1 plane of the cube can be rotated or twisted 90, 180, or 270 degrees relative to the rest of the cube. In the goal state, all the squares on each side of the cube are the same color [1]. In fact, there are 4.3252*10 19 different states that can be reached from any given configuration [1,3]. Each side of Rubik's cube contains 9 squares, a total of 54 squares. It has six unique colors on its squares as Blue (B), Green (G), Orange (O), Red (R), White (W), and Yellow (Y). To solve Rubik's cube, one needs set of move sequences, or operations, that correct position individual cubies without violating center position ones in faces and constraints of problem.

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Therefore, it has six unique faces as top face (up), front face, right face, left face, down face (bottom) and back face (beside). The problem of Rubik's cube has been studied and a number of algorithms has been proposed, each of which may find solved. Korf [1] found the first optimal solutions to random instances of Rubik's cube and the median optimal solution length appears to be eighteen moves with IDA* algorithm. Kunkle and Cooperman [4] proven that 26 moves suffice for any state of Rubik's cube solved with three steps. Borschbach and Grelle [2] showed the human strategy based genetic optimizer is a collaboration of human proceeding and genetic optimization techniques. It is applied to the restoration problem of Rubik's cube and successfully solves this task.

This research aims to obtain a solution of Rubik's cube solved by the proposed algorithm can solved any cube in no more than 24 steps (moves). The proposed algorithm moved the second row and second column for each face in Rubik's cube configuration thus generating 4 states (4 new faces) for each face to obtain most of probability positions in correct positions completely and then a solution cube as a whole to make every face of the Rubik's cube covered in one color (red, white, blue, orange, green, yellow) through assigning desired positions from 24 faces to original faces (configuration) in Rubik's cube and without violating center position ones in faces. Also without violating any correct positions in original faces.

The research is organized as follows, besides this introductory section, section 2 presents the structure of Rubik's cube problem and design. Proposed algorithm is described in section 3. Section 4 contains experimental results. Finally, section 5 concludes this research.

Structure of Rubik's cube and Design

One of the most famous combinatorial puzzles of its time [1]. A Rubik's cube is built from 26 cubies, each able to make restricted rotations about a core of Rubik's cube. A face of Rubik's cube is a side. Each face is divided into 9 facelets, where each of the 9 facelets is part of a distinct cubie. A cubie is either an edge cubie (two visible facelets), a corner cubie (three visible facelets), or a center cubie (one visible face, in the center of a side). The facelets are similarly edge facelets, corner facelets, or center facelets. The states of Rubik's cube can be considered as permutations on 48 facelets (the 24 corner facelets and the 24 edge facelets). The center facelets are considered to be fixed, and all rotations of the Rubik's cube are considered to preserve a fixed orientation of the cube in 3 dimensions. The solved position of Rubik's cube is one in which all facelets of a face are the same color [2,3,4]. Below Figure (1) illustrates structure of Rubik's cube 3×3×3.

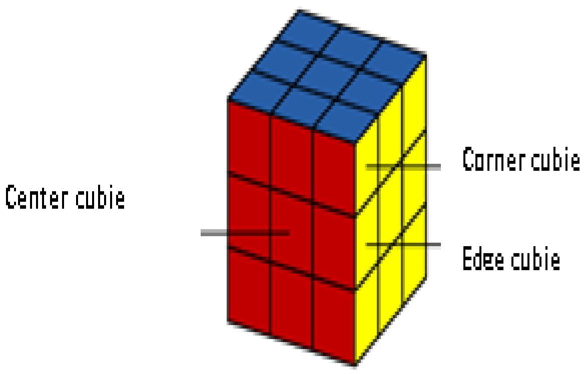

Figure (1) structure of Rubik's cube

In the standard Rubik's cube, the possible colors are white, yellow, orange, red, green and blue, where as distinct center cubie color pairs are always on opposite faces: white and yellow, orange and red as well as green and blue [5]. Each of the 6 faces of the entire cube is made up of nine facelets. Thus, there are 54 facelets on the cube. By rotating different faces of the cube, the cubies can be moved. Each cubie of the turned face, except the center cubie, moves to a location vacated by another cubie. These locations are called cubicles. No matter how faces are rotated, corner cubies always move from one corner cubicle to another corner cubicle. Edge cubie move from one edge cubicle to another edge cubicle. Center cubies have a fixed location relative to the other center cubies. They only can be spun in place [6].

The commercial cube is composed of six fixed cubes, eight movable cubes on the corners and 12 movable cubes on the edges. Each cube is one of six colors. The Rubik's cube has red, yellow, blue, green, white, and orange colors. In its solved state, each color is only one face. When the cube is rotated, the edges and corners move and the cube become scrambled. The challenge of the puzzle is to restore each cube to its original position [1].

The standard Rubik's cube has sides of about 2.2 in (5.7 cm) per square. Various other sizes have also been produced such as a 1.5 in (3.8 cm) mini cube, a 0.8 in (2 cm) key chain micro cube, and a 3.5 in (9 cm) giant cube. While the standard cube is a 3×3×3 segmentation other types have also been introduced. Some of the more interesting ones include the 2×2×2 cube, the 4×4×4 cube (called Rubik's Revenge) and the 5×5×5 cube [2]. Below Figures (2) and (3), illustrate a classic Rubik's cube scrambled and classic Rubik's cube solved.

Figure (2) a classic Rubik's cube scrambled

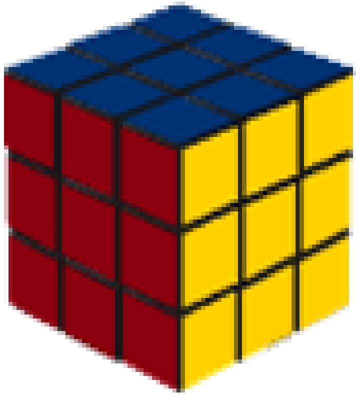

Figure (3) a classic Rubik's cube solved

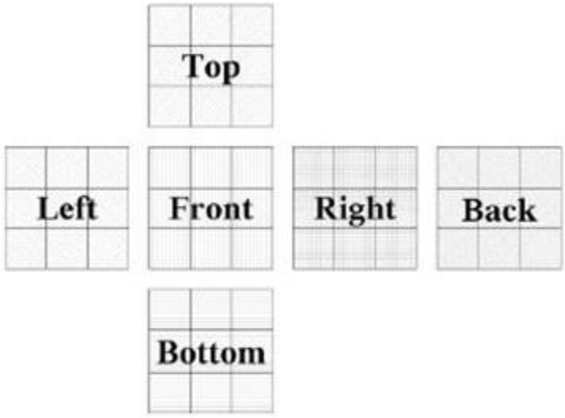

Figure (4) Faces in Rubik's cube graphically

actually the Rubik's cube appears to be made up of 26 smaller cubes. In its solved state, it has six faces, each made up of nine small square faces of the same color. While it appears that all of the small faces can be moved, only the corners and edges can actually move. The center cubes are each fixed and only rotate in place. When the cube is taken a part, it can be seen that the center cubes are each connected by axles to an inner core. The corners and edges are not fixed to anything. This allows them to move around the center cubes.

The cube maintains its shape because the corners and edges hold each other in place and are retained by the center cubes. Each piece has an internal tab that is retained by the center cubes and trapped by the surrounding pieces. These tabs are shaped to fit along a curved track that is created by the backs of the other pieces. The central cubes are fixed with a spring and rivet and retain all the surrounding pieces. The spring exerts just the right pressure to hold all the pieces in place while giving enough flexibility for a smooth and forgiving function [3].

Proposed Algorithm

Preliminary

The orientations for all faces in Rubik's cube illustrated graphically in Figure (4). Single characters in Figure (5) identify the orientations, and one character is given per facelet.

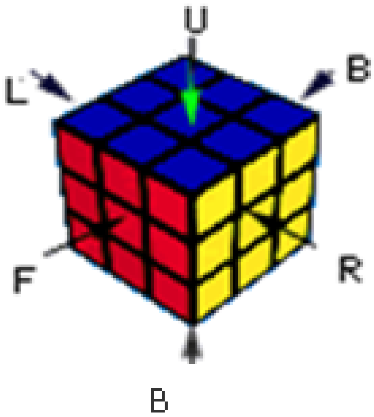

Figure (5) Orientations of Rubik's cube

For starters, when we solve a Rubik’s Cube, we need to know the sides. There is the front (the side facing you) which is called F. There is the up side (the side on top if you are facing the front side) labeled U. There is the left side (the side on the left) labeled L, the right side (the side on the right) labeled R, and the down side (bottom), (the side on the opposite side of the cube from side up) labeled D. There is the back side (beside) (the side on opposite side of the cube from side front) labeled B. The proposed algorithm found feasible solution and translated the mechanical moves in Rubik's cube to manipulate by a computer. The proposed algorithm in this research as follows: Step2: generate 24 moves for all faces (except original face for all orientations) by moving the row and column of center for each face in Rubik's cube.

These operations similar rotates the cube by 90, 180 degrees.

Step2-1: Rotate second row (row of face's center) in original face to become third row.

Step2-2: Rotate third row in (step2-1) to become first row.

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Step2-3: Shift second column (column of face's center) in original face to become third column.

Step2-4: Shift third column in (step2-3) to become first column Step3: while stop criterion isn't satisfied do Begin Search (check) about desired number (desired color) in each moves in step2 and assign desired number (desired color) to original face to obtain Rubik's cube solved. End while

Step4: Print all matrixes (faces) to obtain Rubik's cube solved. Step1: Configuration of all faces for Rubik's cube as front, right, left, top, bottom and back. Each face represented by matrix 3×3 and the program used the numbers from one to six corresponding the six colors.

Experimental Results

Our experimental results have proven that 24 steps (moves) for any state of Rubik's cube to obtain Rubik's cube solved. We generated several solvable of Rubik's cube by proposed algorithm. It determines how the facelets of the entire cube are colored after turning different sides in different directions to one side have the same color. The core of the code programming designed in this research consists of many instructions. The input of program six matrixes 3×3 for each face. Each color represents by number one to six. The final output of the program are a six matrixes to represent all faces (sides) in cube. These faces have six color, while each face has unique color. Each facet is numbered to represent its unique color on the cube. A move relocates eight facets on the cube. In order to replicate this, each facet is given a unique number identifier and is grouped by to generate same color for each faces. The proposed algorithm describes how matrixes is filled with suitable number (suitable color) to obtain the solving of Rubik's cube. Figure (6) illustrated configuration of Rubik's cube of example (1). Figure (7) illustrated numbering configuration to identify the center and all faces for Rubik's cube. Figures (8) illustrated proposed steps (moves) of example (1).Where white is 1, red is 2, green is 3, yellow is 4, blue is 5 and orange is 6.

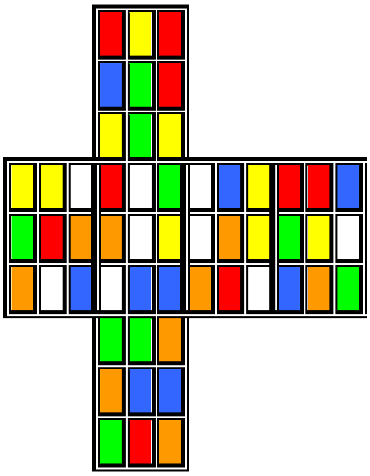

Figure (6) Configuration of Rubik's cube of example (1)

			2	4	2						
			5	3	2						
			4	3	4						
4	4	1	2	1	3	1	5	4	2	2	5
3	2	6	6	1	4	1	6	4	3	4	1
6	1	5	1	5	5	6	2	1	5	6	3
			3	3	6						
			6	5	5						
			3	2	6						

Figure (7) Numbering configuration of Rubik's cube of example (1)

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The proposed steps (moves) illustrated in Figures (8) as follows:

2	1	3	1	5	5	6	1	4	3	2	1	1	3	2
6	1	4	2	1	3	1	5	5	4	6	1	1	4	6
1	5	5	6	1	4	2	1	3	5	1	5	5	5	1

Original front face
Proposed steps (moves) for front face

4	4	1	6	1	5	3	2	6	1	4	4	4	1	4
3	2	6	4	4	1	6	1	5	6	3	2	2	6	3
6	1	5	3	2	6	4	4	1	5	6	1	1	5	6

Original left face
Proposed steps (moves) for left face

2	4	2	4	3	4	5	3	2	2	2	4	4	2	2
5	3	2	2	4	2	4	3	4	2	5	3	3	2	5
4	3	4	5	3	2	2	4	2	4	4	3	3	4	4

Original top face
Proposed steps (moves) for top face

2	2	5	5	6	3	3	4	1	5	2	2	2	5	2
3	4	1	2	2	5	5	6	3	1	3	4	4	1	3
5	6	3	3	4	1	2	2	5	3	5	6	6	3	5

Original back face
Proposed steps (moves) for back face

3	3	6	3	2	6	6	5	5	6	3	3	3	6	3
6	5	5	3	3	6	3	2	6	5	6	5	5	5	6
3	2	6	6	5	5	3	3	6	6	3	2	2	6	3

Original bottom face
Proposed steps (moves) for bottom face

1	5	4	6	2	1	1	6	4	4	1	5	5	4	1
1	6	4	1	5	4	6	2	1	4	1	6	6	4	1
6	2	1	1	6	4	1	5	4	1	6	2	2	1	6

Original right face
Proposed steps (moves) for right face

Figure (8) Proposed 24 steps (moves) of example (1) assign the number of center (center color) for each face in six sides and also assign another number (color) is similar center color as in Figure (9).

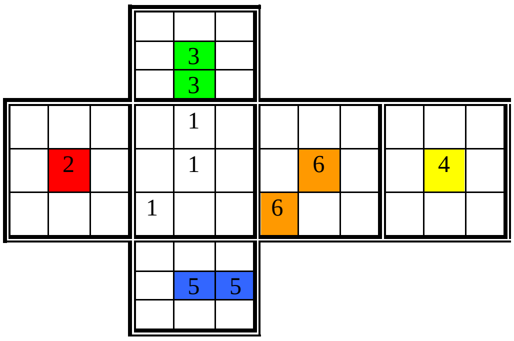

Figure (9) correct positions for numbers (colors) of example (1)

Check the desired number (desired color) in 24 faces in Figure (8) and assign to original faces to complete the solution depending on the color of face's center. Figure (10) illustrated Rubik's cube solved completely of example (1).

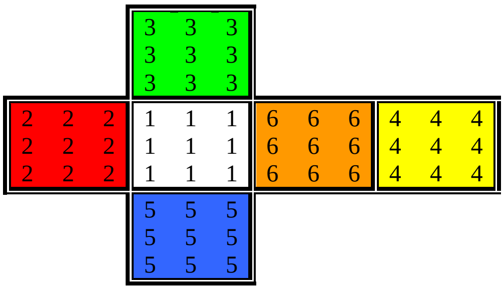

Figure (10) Rubik's cube solved completely of example (1)

For another example, Figure (11) illustrated configuration of Rubik's cube of example (2). Figure (12) illustrated numbering configuration to identify the center and all faces for Rubik's cube. Figures (13) illustrated proposed steps (moves) of example (2).Where orange is 1, red is 2, white is 3, green is 4, yellow is 5 and blue is 6.

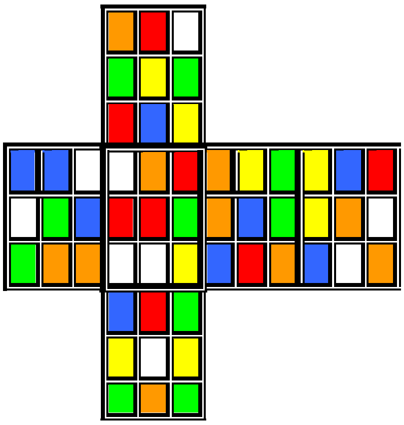

Figure (11) Configuration of Rubik's cube of example (2)

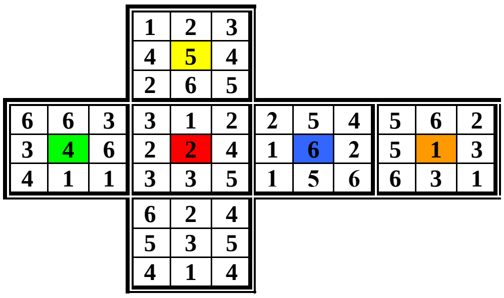

Figure (12) Numbering configuration of example (2)

5	6	2	6	3	1	5	1	3	2	5	6	6	2	5
5	1	3	5	6	2	6	3	1	3	5	1	1	3	5
6	3	1	5	1	3	5	6	2	1	6	3	3	1	6

Original back face — Proposed steps (moves) for back face

3	1	2	3	3	5	2	2	4	2	3	1	1	2	3
2	2	4	3	1	2	3	3	5	4	2	2	2	4	2
3	3	5	2	2	4	3	1	2	5	3	3	3	5	3

Original front face — Proposed steps (moves) for front face

6	2	4	4	1	4	5	3	5	4	6	2	2	4	6
5	3	5	6	2	4	4	1	4	5	5	3	3	5	5
4	1	4	5	3	5	6	2	4	4	4	1	1	4	4

Original bottom face — Proposed steps (moves) for bottom face

6	6	3	4	1	1	3	4	6	3	6	6	6	3	6
3	4	6	6	6	3	4	1	1	6	3	4	4	6	3
4	1	1	3	4	6	6	6	3	1	4	1	1	1	4

Original right face — Proposed steps (moves) for right face

1	2	3	2	6	5	4	5	4	3	1	2	2	3	1
4	5	4	1	2	3	2	6	5	4	4	5	5	4	4
2	6	5	4	5	4	1	2	3	5	2	6	6	5	2

Original top face — Proposed steps (moves) for top face

2	4	5	1	5	6	1	6	2	5	2	4	4	5	2
6			2	1	6	6	2	1						
5			6	1	5	5	6	1						

Original left face — Proposed steps (moves) for left face

Figure (13) Proposed 24 steps (moves) of example (2)

			5	5	5						
			5	5	5						
			5	5	5						
6	6	6	2	2	2	4	4	4	1	1	1
6	6	6	2	2	2	4	4	4	1	1	1
6	6	6	2	2	2	4	4	4	1	1	1
			3	3	3						
			3	3	3						
			3	3	3						

Figure (14) Rubik's cube solved completely of example (2)

The feasible solution of proposed algorithm is found by computer through several operations. The program can instruct a computer to do the steps to solve Rubik's cube 3×3×3. We can work solving the Rubik's cube by manually method that without help, but solving the Rubik's cube could take several months. Manual methods have a large space with timed. The proposed algorithm facilities the difficulty in solving the problem. It is mathematical skill it could find the solving quickly because the problem had many combinations. When solved, every face of Rubik's cube is a solid color. Proposed algorithm is easy to arrange original faces of Rubik's cube. The research is success in twenty-four steps to obtain good solution, while Kunkle and Cooperman, 2007 proven that 26 moves suffice for any state of Rubik's cube solved with three steps.

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خوارزمية مقترحة لحل مسألة مكعب روبك 3×3×3 حاسوبياً

اسراء نذير الكلاك

الخلاصة

يتناول البحث توظيف الحاسوب في حل مسألة مكعب روبك 3×3×3 ، من خلال خوارزمية مقترحة تُولد أربعة خطوات (حركات) لكل وجه من أوجه المكعب الستة ناتجة عن تحريك الصف الثاني والعمود الثاني لكل وجه من الوجوه الستة للحالة الأولية للمكعب، والذي يُمثل صف وعمود مركز كل وجه من الأوجه الستة للمكعب والذي يعدُ لون الوجه ذاته. تُمثل الأربعة والعشرين حركة المتولدة في الخوارزمية المقترحة أغلبية الأحتمالات المتوقعة لمواقع الألوان الصحيحة للكعيبات التسعة في كل وجه من الأوجه الستة للمكعب، ومن ثَمَّ يتم تخصيص اللون الصحيح لكل كعيب من الكعيبات للوصول إلى حل المكعب بأكمله، وجعل كل وجه من أوجه مكعب روبك الستة يغطى بلون واحد (الأحمر، الأبيض، الأزرق، البرتقالي، الأخضر، الأصفر)، مع عدم اختراق لون مركز كل وجه من الأوجه الستة للحالة الأولية للمكعب. أثبتت نتائج البحث التوصل إلى السهولة المرنة في حل مسألة البحث حاسوبياً والأستغناء عن الطرائق الميكانيكية (الحركية) اليدوية المملة، فضلاً عن تقليل فضاء البحث الذي يملك كماً هائلاً من الحلول. أُعد برنامج حاسوبي بلغة ماتلاب 6.5 ليحاكي الخوارزمية المقترحة وذلك لتوليد الحل النهائي لمسألة مكعب روبك 3×3×3.