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# Analysis

## Introduction

The Rubik’s cube is one of the most well-known puzzles ever created and has intrigued and baffled the minds of children and mathematicians alike for years. It is a 3D, coloured combination puzzle, created in 1974 by Hungarian architecture professor Ernő Rubik, and has gone on to be one of the most best-selling toys in the world, selling over 500 million copies.

The standard Rubik’s cube is a 3x3x3 cube, however, there have been lots of variations made over the years, for example a 4x4x4 cube, a 2x2x2 cube, a mirror cube, which scraps the colours completely and relies on the shape of the cube pieces to be solved, and even a pyramid version of the puzzle named the “pyraminx”. There have also been lots of designs over the years for “speed cubes”. These are cubes designed to turn quicker and smoother, for use in competitive environments where milliseconds can be the difference between winning and losing.

There has been lots of study and research about Rubik’s cubes, and my focus for this project is to create a pathfinding algorithm that will find the most optimal way to solve a Rubik’s cube, by solving it in the least number of moves possible.

## Research

Many mathematicians have studied the Rubik’s cube and lots of research has been conducted on the maths and logic behind the puzzle. Originally the cube was advertised to have ‘over 300 billion combinations!’ however, research has shown that there is in fact over 43 quintillion possible combinations.

Lots of different pathfinding algorithms have been created for Rubik’s cubes, all fairly similar in concept. For example, Thistlethwaite’s algorithm, which focuses on different parts of the cube separately, and then Korf’s algorithm, a variation of ThistleThwaite’s known as an “iterative deepening depth first search”.

While these are both efficient methods to solve a Rubik’s cube, neither of them guarantees the path with the least number of moves. Modern computers simply cannot solve a 3x3x3 cube using a brute force BFS searching algorithm. There are 18 different moves that you can perform on a standard cube, and research has shown that any scrambled state is never more than 20 moves from being solved. This still leaves us with a maximum time complexity of 18 ^ 20, or 1.3x10^25, which is much too large.

Instead, I will create the pathfinding algorithm on a 2x2x2 Rubik’s cube, as there are a significantly smaller number of possible states, as well as less moves.

There is set notation used to describe the movements of a cube:

**U**, **D**, **F**, **B**, L and **R**.

Each of these letters correspond to a face on the cube, and its rotation clockwise.

Each movement also has a corresponding rotation anticlockwise, known as the “prime” movement and indicated as **X’,** bringing the total number of moves to 12.

For example, the rotation **U** refers to the top face of the cube rotating clockwise, and the rotation **U’** refers to the top face moving anticlockwise.

Since there are no middle pieces on the 2x2x2 cube, the number of unique moves totals to 6.

(The clockwise rotations of two opposite faces have the same effect on the cube)