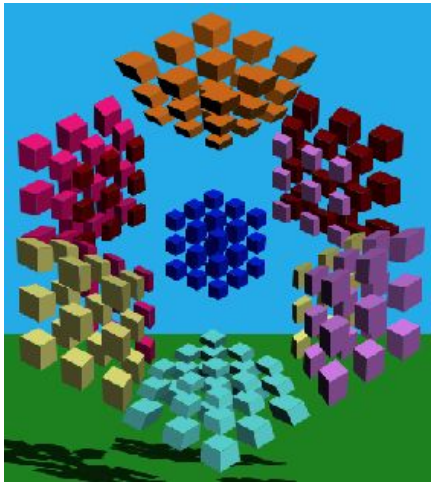
Solving the Rubik’s Cube

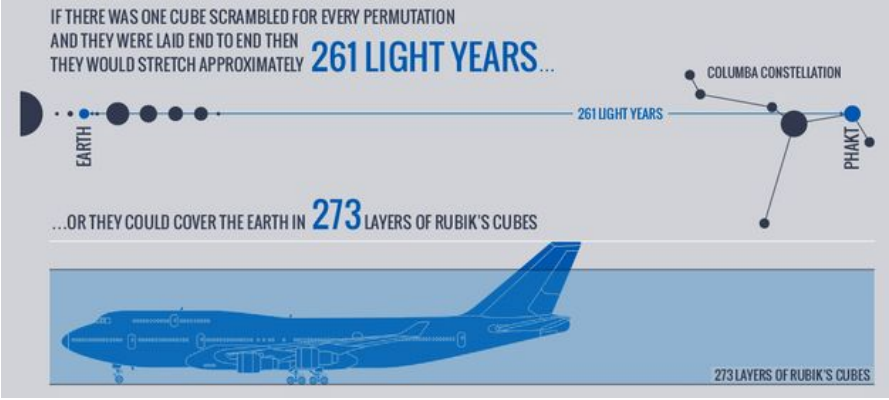
Pax Kulbis

Introduction

- Combination puzzle invented to model 3D geometry in 1974 by Erno Rubik
- Originally created as a 3 by 3 (a cube with each face split into 9 smaller faces), but has many different variations and spinoffs (2 by 2, 7 by 7, Rubik's 360, Gear Cube, Super Square One)
- Is a favored tool for mathematicians due to its simple nature, but deep complexity



Possible Positions



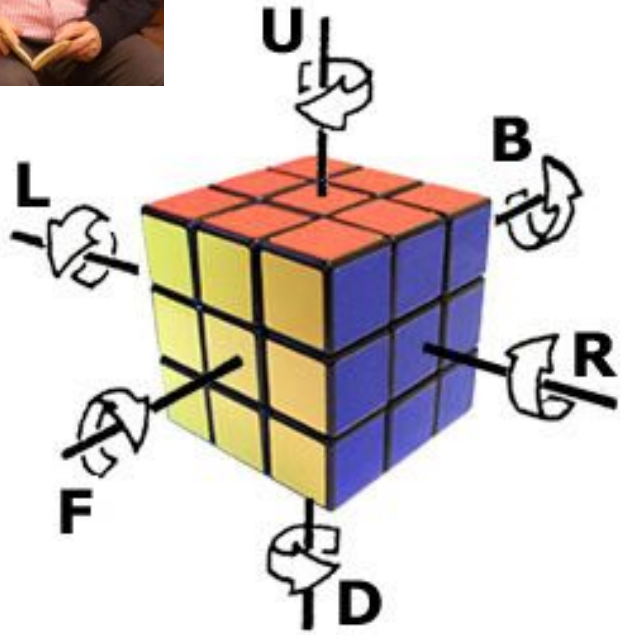
- Although there are 54 cubbies (9x6),

  there are really only 26 pieces
- 8 Corner pieces
  - Can be placed in 8 different positions (8! = 40,320)
  - Can be oriented 3 different ways (3^7 = 2,187)
- 12 edges pieces
  - Can be placed in 12 positions, but restricted as it must be in a permutation (12!/2 = 239,500,800)
  - Can be oriented 2 different ways (2^11 = 2048)
- 6 center pieces
  - Don’t move, only rotate
  - (if the center pieces have to be aligned correctly, another (4^6/2 = 2048)
- If we consider possibilities when we can take apart cube, it’s even more

$$8! \times 3^7 \times (12!/2) \times 2^{11} = 43,252,003,274,489,856,000$$

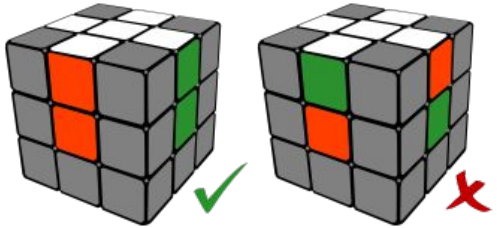
Singmaster Notation

- Standard Rubik’s Cube algorithm notation
- Letter corresponds to a 90 degrees clockwise rotation while looking at the indicated face
  - Faces: Front (F), Back(B), Left(L), Right(R), Up(U), Down(D)
  - An apostrophe (Ex. F’) implies a counter clockwise turn
- All rotations are quarter turns, half turns are just 2 quarter turns (Ex. 2F)



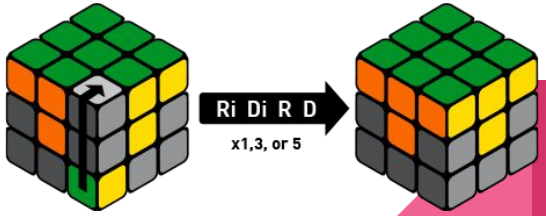
Layer Solving - “Beginner’s Method”

- Uses 7 steps, some human common sense, and a handful of simple algorithms to solve the cube by layers
- Takes more moves, but is easier to remember/understand
- Step 1: White Cross
- Step 2: White Face and 1st layer
- Step 3: Second Layer
- Step 4: Yellow Cross
- Step 5: Yellow Edges
- Step 6: Yellow Corners in their place
- Step 7: Orient Corners



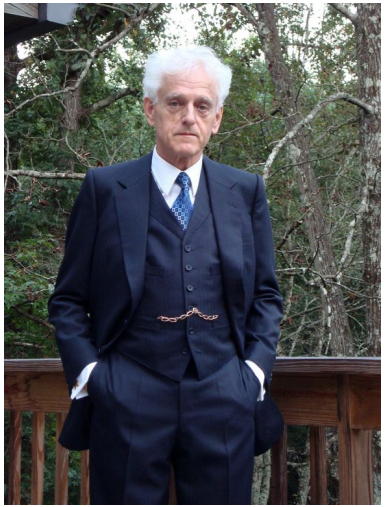
Step 1: White Cross

Step 3: Second Layer



Step 2: White Face and 1st layer

Thistlethwaite's Algorithm



- Thistlethwaite is a mathematician and professor at the University of London. He has a love for problem solving
- His algorithm works on the whole cube at once, instead of working layer by layer.
- Very efficient (can solve any scrambled cube in 52 moves or less) but requires a computer to operate (as it must account for every situation)
- Split the cube into 5 groups
  - G_0 = <L,R,F,B,U,D>
    - All possible positions
  - G_1 = <L,R,F,B,U2,D2>
    - Positions that can be reached (from the solved state) with quarter turns of the L, R, F, and B, but double turns of U and D.
  - G_2 = <L,R,F2,B2,U2,D2>
    - Positions that can be reached with quarter turns of L and R, but double turns of F,B,U,D.
  - G_3 = <L2,R2,F2,B2,U2,D2>
    - Positions that can be reached with double turns of each side
  - G_4 = {I}
    - The solved cube

My Project

- Using a 2D array to represent the cube in Javascript (first array represents faces, second represents location in that face)
  - Then draw it onto the canvas using 3JS
- Will use Layer Solving
  - Might not be the best approach: easy for humans to recognize correct move, but hard for computer because there are so many possible positions
- Animations
  - Future moves will be put into in a queue
  - Program will animate one at a time (through linear interpolation)
- May use Object Oriented approach (pieces represented as objects, several properties) & try to import Thistlethwaite's Algorithm chart