How to Solve a Rubix Cube

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Introduction

Sometime down the line, I'm going to want to solve a Rubik's cube again, and I'll for sure forget how to do it. So, this document is twofold: to document how to solve a Rubik's cube for myself in the future, and to solidify my own understanding of solving a Rubik's cube through documentation.

I hope that by the end of this document, you will know how to solve a Rubik's cube, using either the beginner method, or the CFOP method.

Notation and Terminology

Before I get started, I'll explain the notation and terminology for Rubik's Cubes. If you're just getting into Cubing, then you're probably not going to want to learn the notation for it. However, when documenting the process, it's imperative that you learn the notation as it's extremely hard to follow since all the explanations and algorithms will be using this notation. In addition, learning the terminology will allow you to understand the algorithms that I explain.

i Notation

Study Figure 1 below to get a good grasp of the notation. It's always good to reference if you get confused on which way to turn.

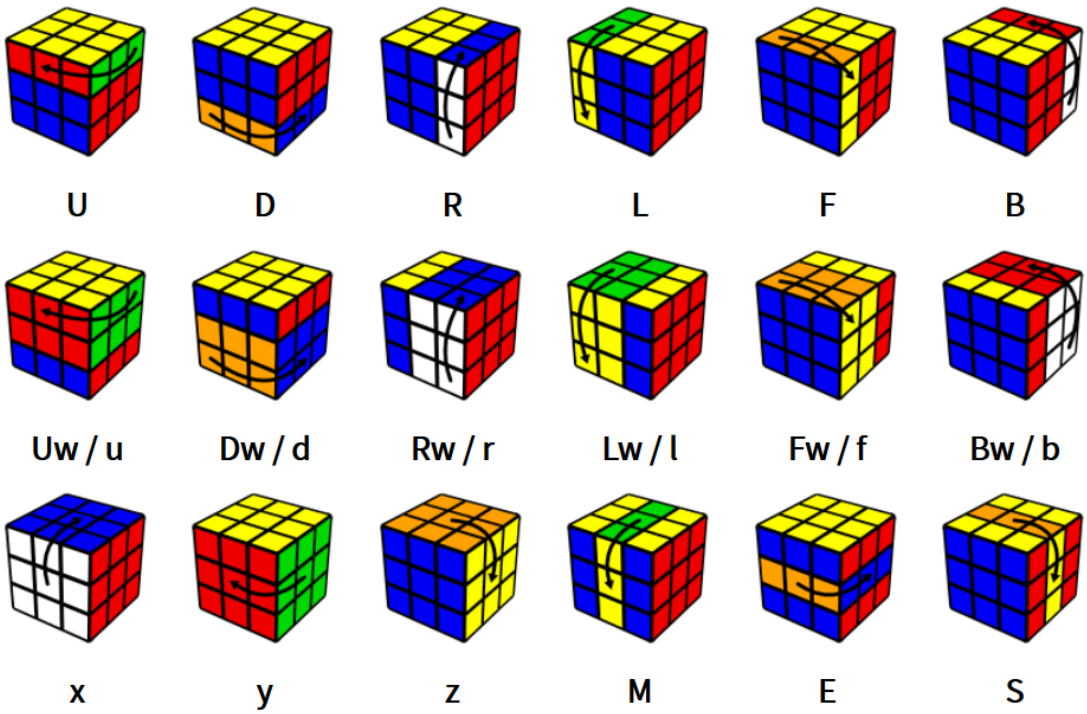

Figure 1: Rubik's Cube Notation

ii Triggers

In addition to standard notation, I'll also introduce a couple of sequences of moves that are commonly used and seen in cubing. These standard sequences of moves are called **triggers**.

1. **Sexy Move:** `R U R' U'` or `L' U' L U`
2. **Inverse Sexy Move:** `U R U' R'`
3. **Sledgehammer:** `R' F R F'`
4. **Su:** `R U R' U`
5. **Ne:** `R U2 R'`
6. **Bring Out Pair:** `R U R'`

iii Terminology

Lastly, I will introduce my specific terminology for Rubik's Cubes. A Rubik's Cube has 6 **faces**. Each face has a center square with a distinct color, that's how you determine which color goes on which face. Every face also has 4 **edges**. If you were to place your finger on a center square of any face, and go immediately up, down, left or right, then you would be on an edge. Similarly, every face also has 4 **corners**. These are the diagonal squares in relation to the center piece.

Beginner Method

This is the method that deals with minimal cases and will solve the Rubik's Cube without having to analyze the cube for certain situations. Because of this feature, this method is a beginner's method and isn't useful for efficiency or speed. However, if you've never learned how to solve a Rubik's Cube before, then this method is a great way to start.

i White Cross

The first step of this method is to create the white cross. The goal is to create a face with all four edges paired with the white center square. In addition, you must pair each of the other four faces adjacent to the white face with the proper edge. For instance, the `red-white` edge will have the white edge on top and the red edge on the side lined up with the red center square. You must do this for the blue, green and orange squares. You may come across a couple cases, and I will detail below how to solve them. For this algorithm, use the `red-white` edge as a concrete example.

1. First, find the edge and locate where it is. If it's on the `U` row, then rotate the top such that the red center is in the front and the edge is directly above or below it.
2. If it slots in perfectly, then you're done. If it's on top though and not in the proper spot, perform this algorithm to realign it:

   `F U' R U`

3. If the edge is in the bottom, then rotate it so that it is now on the top. If it's not in the correct orientation, `red-red, white-white`, then perform `Step 2` to orient the edge correctly.
4. If the edge piece is in the middle layer, then orient the cube so that the white edge is facing you. Then perform this algorithm to get the edge on the bottom, so you can follow from `Step 1`:
   (a) If the edge is on the left of the center square:

   `F' D' F`

   (b) If the edge is on the right of the center square:

   `F D F'`

Verify that the White Cross is done correctly by looking first at the white face. The white center should be connected to white edges in all four perpendicular positions. Additionally, these edges should match with their corresponding center color.

ii Corners for the White Side

Now, turn the cube upside down so that the yellow side is facing up. Once again, noticing the center color square (what determines the face's color) will be important here. Here's the algorithm:

1. Find a corner with white on it. Then identify the other two colors that are on the same corner. It should be one of the four:
   - `White - Green - Red`
   - `White - Red - Blue`
   - `White - Blue - Orange`
   - `White - Orange - Green`
2. You want to position that corner above the position that it would fit in. So the `White - Green - Red` corner would go above the corner that maps to the `White - Green - Red` faces. You can see which corner a corner piece will go to by looking at the center colors.
3. If that corner piece is not in the right position and is in the top layer, perform **Sexy Move** until the corner matches all three sides. This should take a maximum of six tries to get it correct, if done correctly. Reminder, **Sexy Move** is:

   `R U R' U'`

   or

   `L' U' L U`

4. If a corner piece isn't in the top (it's on the bottom but in the incorrect spot), then you can perform the **Bring Out Pair** trigger to get it to the top, then align it over the proper corner.
5. Repeat steps 1-3 for each of the four corners. Once you're done, the "now bottom layer" should be solved.

iii Second Layer Edges

We can now begin to solve the cube at the second layer. Find an edge that's on the yellow layer that should correspond to a side edge in the second layer. Bring that edge over to the centered square that matches the color facing you. So it should be two of the same colors in the middle and directly above it if done correctly. Then notice which side that edge should go, based on the color facing upwards in the yellow face.

1. If it should go right:

$$\boxed{\texttt{U (R U R' U')} \cup \texttt{y(L' U' L U)}}$$

2. If it should go left:

$$\boxed{\texttt{U' (L' U' L U)} \cup \texttt{y'(R U R' U')}}$$

Notice that these are just the left and right versions of **Sexy Move**. You can perform the left and right versions of **Sexy Move** to also remove an edge that's in the wrong spot.

iv Yellow Cross

Now we will solve the yellow cross. There are three cases, but they all revolve around this algorithm:

$$\boxed{\texttt{F (R U R' U') F'}}$$

Once again, notice how prevalent **Sexy Move** is in this algorithm. Here are the three cases:

1. If no edges are on top, perform the above until you get `case 2` or `case 3`.
2. If an L shape appears, rotate the top so that it's in the top left, then perform the algorithm. Then go to `case 3`.
3. If a Line appears, rotate the top so that it's horizontal to your. Then perform the algorithm.

After completion of the above cases, you should have at least four yellow edges creating the yellow cross.

v Align Edges with Center Color

Now we will align the middle edges with the center color of each face. So we will have, for example, the `yellow-yellow, orange-orange` edge align with the proper face. To do this, check if any are already aligned. If they are all aligned, then skip this step. If two are aligned and the faces are adjacent to each other, put them to the back and right. Then perform:

$$\boxed{\texttt{R U R' U R U2 R'}}$$

This is a **Su** and **Ne** combined, more commonly known as a **Sune** trigger. There's the case where two edges align with their center square but they're opposite faces (not adjacent). Then just repeat the above algorithm twice, and after the first one, ensuring the two adjacent faces are in the back right.

vi Ensure Corners are Aligned

Now that the edges are aligned, we need to solve the corners. Similar to how we did the corners for the white, check if the corners match their spots. All three colors of a corner should match all three center colors of the faces their touching. If one matches, rotate the whole cube so that it's at the front right. Then perform this algorithm until all corners are oriented in the correct position (this might not look solved yet). You can also do this algorithm if none are oriented correct. Just make sure to put one correct one at the front right once you've done it.

$$\boxed{\texttt{U R U' L' U R' U' L}}$$

vii Solve the Cube

Finally, flip the cube so that the white side is facing up again. Then perform **Sexy Move** on any corner that isn't already in the correct permutation. Once it's done, rotate the bottom layer (do not move the whole cube) until another incorrect permutation of a corner is at the bottom right. Then do **Sexy Move** repetitively until it's solved. Repeat this for each corner.

Congratulations, you have now solved your Rubik's Cube!

CFOP Method

We just learned the *beginner* method, which is great for someone that just wanted to learn how to solve the cube. However, the limitations using this method are speed and efficiency. That's where the CFOP method comes in, otherwise known as `Cross, First Two Layers, Orientation of the Last Layer, Permutation of the Last Layer`.

i White Cross

Similar to the beginner method, the first step of the CFOP method is to create the white cross.

ii First Two Layers (F2L)

This is one of the hardest steps CFOP because it relies a lot upon intuition.

iii Orientation of the Last Layer (OLL)

Once we've solved the first two layers, we can begin the orientation of the last layer. This is the "yellow" side if you made a white cross. This step is designed to make a complete "yellow face". There are two versions of OLL. One where there are 57 algorithms, and a second version called 2-look OLL where there are just 10 algorithms. This tutorial will cover two-look OLL, a more beginner friendly version. The 2-look OLL is broken into two parts, solving the edges (yellow cross) and then solving the corners.

1. **Edges - Yellow Cross:** There are three cases depending on how the top layer is oriented.

   (a) *A Straight Line:* Orient the straight line so that it's horizontal from the front. Then, perform this algorithm:

   `F (R U R' U') F'`

   (b) *An L Shape:* Orient the L such that it's to the front right. The correct edges should be on the front and on the right. Recall from the earlier notation image that `f` is moving the first two layers forward instead of a single one. Perform this algorithm once you've situated the L correctly:

   `f (R U R' U') f'`

   (c) *A Dot:* When a single edge piece is next to the center, or if it's just the center, then you can perform this algorithm:

   `F (R U R' U') F' ∪ f (R U R' U') f'`

   Note that this algorithm is actually a combination of `case (a)` and `case (b)`.

   Once again, if you notice all three of these algorithms implement the trigger **Sexy Move**, which can make remembering these algorithms a lot easier. You know that you've completed the first look of OLL when you have a yellow cross completed.

2. **Corners:** Once the yellow cross has been solved, we now move to the second look of OLL. The goal is to complete what we started in the first look, and to have all the corners facing up in the correct orientation, but not necessarily the correct spot. There are three specific cases after the first look of OLL.

   (a) *One Color Facing Up:* If there is only one corner facing up, then you will need to move it to the front. However, you move it to the front such that you can also see another yellow facing towards you in the front. Once you have done that, then:

   i. If the yellow face that is facing towards you is on the RIGHT, perform:

   `R U R' U R U2 R'`

   ii. If the yellow face that is facing towards you is one the LEFT, perform:

   `L' U' L U' L' U2 L`

   Notice that for the RIGHT version, it's just a combination of the triggers **Su** and **Ne**, which is commonly referred to as a **Sune** trigger.

   (b) *Zero Colors Facing Up:* If no colors are facing up, then we have two cases.

   i. Yellow is on Two Sides: This case is called the "H" case and it occurs when you have two sides with yellow, and two sides without. They should be on opposite faces of each other. Orient the top so that you have two yellows facing towards you (and thus also having two facing away from you), then perform:

   `F (R U R' U')3 F'`

   Notice again, that we're simply performing **Sexy Move** three times.

   ii. Yellow is on Three Sides: This case is called the "Pi" case. You should have the yellow on three sides, and one side should have two yellows. The other two yellows are on opposite faces. Orient the top so that the two opposing yellows are on the right (and the two yellows on the same side are on the left). Perform:

   `R U2 (R2 U' R2 U' R2) U2 R`

   (c) *Two Colors Facing Up:* The last case is when there are two colors facing up. We can split this case into two separate cases as well. One where the two solved yellows are diagonal from each other and one where the two solved yellows are adjacent.

   i. *Diagonal Case:* Before performing the algorithm, we must orient the top so that one correct upward facing yellow is in the top right. However, you need to choose the correct yellow corner, and you can do that by ensuring you can see both of the yellow corners that aren't on top. Also note that `x` is in `Figure 1`, but you essentially make it so that the white face is now front. Then you can perform:

   `x (R' U R D') ∪ (R' U' R D)`

ii. *Adjacent Case:* There are two cases for when the solved corners are next to each other. Take notice of the two yellow corners that aren't facing upward.

A. If they're on faces opposite each other then rotate the top so that they're on the left. This should also orient the top so that the block of six yellows are on the right. Once this is done, perform:

`x (L U R' U') ∪ (L' U R U')`

B. If they're on the same face then orient the top so it's facing towards you. This should also orient the top so that the block of six yellows is in the back. Once this is done, perform:

`R2 D (R' U2 R) D' (R' U2 R')`

We have now completed the second look of OLL. Once you have done one of these 7 algorithms, then the top side should be solved. This completes the second look of OLL.

iv Permutation of the Last Layer (PLL)

Similar to OLL, PLL has a more advanced version of 21 algorithms, compared to 2-Look PLL that has 6 algorithms. Like OLL, we break PLL into two looks, one for solving the corners, and then one for solving the edges. Except unlike in OLL, we solve the corners first, then the edges.

1. **Corners:** Check the corners to see if they match. More specifically, rotate the cube and see if any of the sides have corner faces that are the same.

   (a) All Different: This is the case where all the corners are completely different and don't match the same side. This means that we need to do a diagonal swap, since two corners are in the correct permutation, and two aren't (they need to be swapped diagonally). Perform this algorithm:

   `(F R U' R' U' R U R' F') ∪ (R U R' U' R' F R F')`

   Notice that the second component of the algorithm is just a combination of **Sexy Move** and a **Sledgehammer**.

   (b) One Corner Matches: In this case, we just need to swap an adjacent corner pair. Rotate the top so that the side with matching colors is paired with its correct face. Then rotate the cube in your hand so that the two unsolved corners are on the right. Then perform:

   `R U R' U' R' F R2 U' R' U' R U R' F'`

   Notice that the above also implements **Sexy Move** and a large sub string of the first component of `case a`.

   After completion of either of these two algorithms, all the corners should be in the correct orientation and permutation, otherwise known as solved.

2. **Edges:** We now will solve the edges, which has two cases.

   (a) *One Edge is Solved:* If one edge is solved, put it in the back. We now have two more cases.

   i. If the right edge has to go into the left face, then perform this algorithm:

   `R U' (R U R U) R U' R' U' R2`

   ii. If the left edge has to go into the right face, then perform this algorithm:

   `R2 U R U R' U' R' U' R' U R'`

   (b) *No Edge is Solved:* Again, we have two cases.

   i. Opposite Edge Swap: This is the case where the edges just need to swap directly across from each other. On your cube that means green and blue swap, and orange and red swap. Perform this algorithm:

   `M2 U' M2 U2 M2 U' M2`

   ii. Adjacent Edge Swap: This is the case where the edges next to each other must be swapped. Perform this algorithm:

   `M' U' M2 U' M2 U' M' U2 M2 U`

   Once you've done one of these 4 algorithms, the cube should be solved.

Congratulations, you have now solved the Rubik's Cube using the CFOP method!

Practice

Now that you've learned how to solve a Rubik's cube, the next best thing is to practice! Below are some helpful websites that can make your practice more intentional and worthwhile.

1. J Perm — Great instructional YouTuber.