CSE 525 Project Report: Rubik's Cube Solver Robot

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1 Task

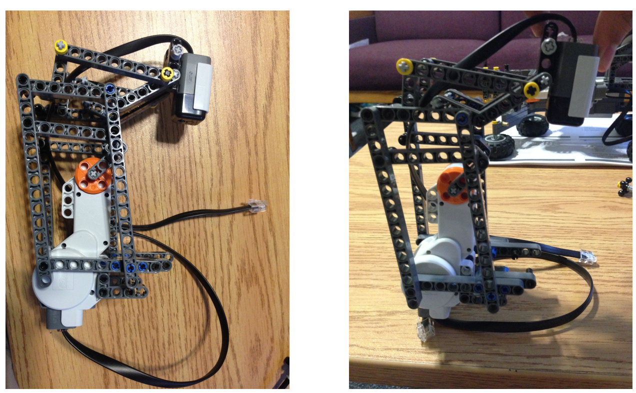
Robot is aimed to solve the famous 3D combination puzzle, Rubik's Cube.

2 Building of the robot

Designing and building of the robot included setting up three main sections and combining them impeccably to get the desired output.

2.1 Arm With Color Sensor

First section involves setting up the arm that holds color sensor to scan each sticker (box/cell) in every faces of the cube. There are 9 stickers in each face and total of 6 faces in the cube. Color sensor initially scans the 54 stickers' color values of the cube placed in square base and records it which later is processed to determine the color to which the values corresponds. Color obtained will be either of 6 colors of the cube which are red, blue, orange, green, yellow and white. This is shown in the Figure 1.

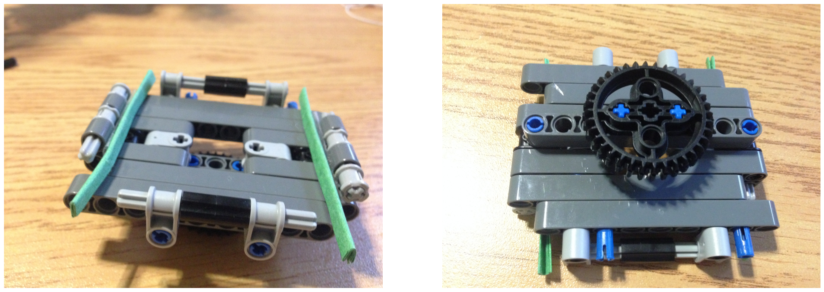


(a) (b)

Figure 1: Arm With Color Sensor

2.2 Square Platform

Second section involves building the square base where cube can be placed. This base is built in such a way that a motor is able to rotate it 45 degrees to scan color values of each sticker in a face and to rotate, 90 degrees to be able to get either of the two currently non accessible faces (Figure 5) of the cube on top and along with the two, 180 degrees to solve the cube based on moves obtained after applying the solving algorithm. This is shown in the Figure 3.



(a) (b)

Figure 2: Square Platform

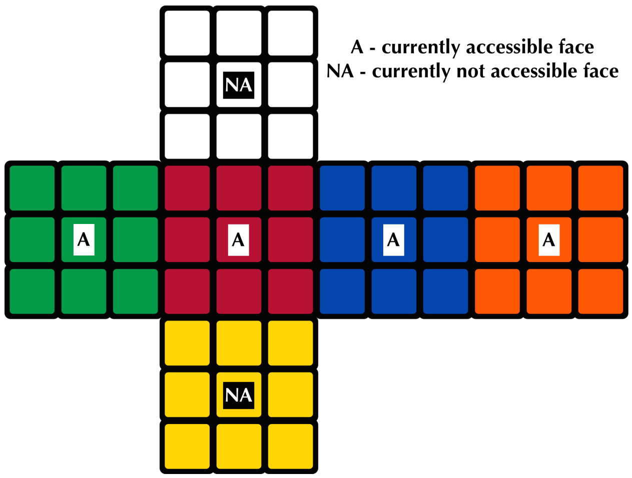
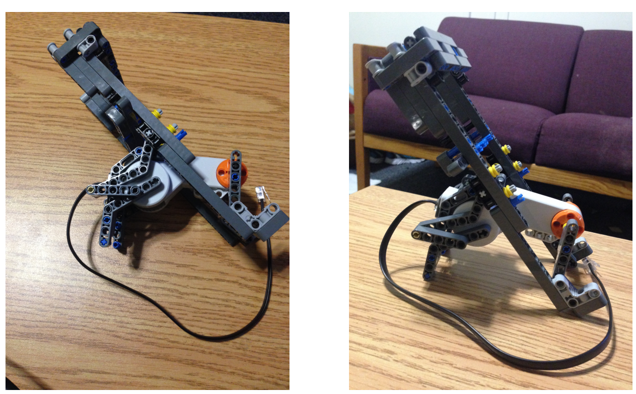


Figure 3: Cube Faces

2.3 Arm To Flip The Cube

Third section involves setting up the arm which can be used to flip the cube to get either of the 3 other currently accessible faces of the cube on top and to solve the cube if returned moves requires flipping of the cube. This is shown in the Figure 4.



(a) (b)

Figure 4: Arm To Flip The Cube

2.4 Base With Controller

Next step involved building a base which sits on a table or any flat surface that holds all three parts mentioned above at appropriate positions along with controller of the robot.

(a) (b)

Figure 5: Square Platform

2.5 Full Robot

The fully assembled robot is shown in the Figure 6.

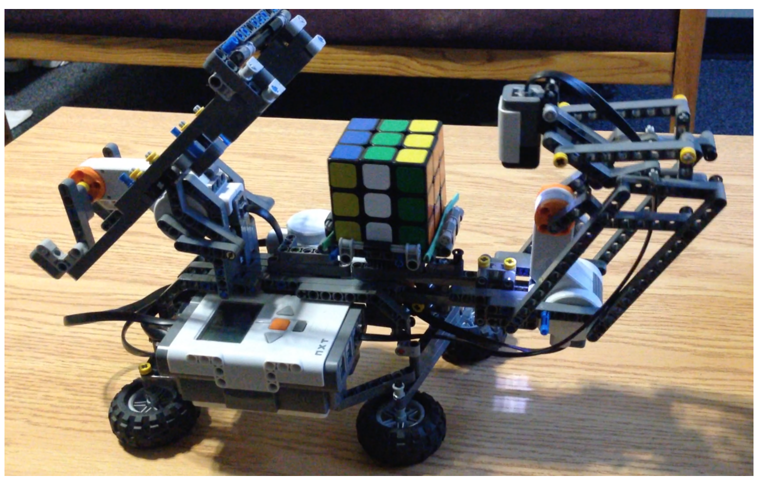


Figure 6: Fully assembled robot

3 Technical Challenges and Solutions

3.1 Hardware

Our hardware is comprised of three major parts.

- Arm with a motor to flip the cube.
- Arm with a motor to scan the cube.
- A motor that rotates the cube.

It was challenging to set up the hardware such that all the parts worked seamlessly. This involved following challenges -

- Taking care of height and orientation of the Hitechnic NXT Color Sensor such that it is at approximately the same height over each of the color blocks of the cubes face and is almost perpendicular to the plane of the cubes face. Missing of a small piece of the hardware lead to reading of incorrect values.
- Building the platform for the cube that exactly holds cube in position by being slightly bigger in dimension than the cubes square base. Also, this platform needed walls all around so that it allows us to rotate just the bottom face of the cube. Extra paper pieces were used to get platform to exact square shape to hold the cube at its place.
- Having the arm that flips the cube by holding the top surface of the cube at correct height. Different trials were run with different size and shape of lego parts to get the arm to stay fix on the cube properly so that it holds the top two layers of the cube still while bottom most face was rotated.

3.2 Software

Moving the motors to exact angles and predefined positions was a challenge. We solved this by first fixing the tachometer count of the extreme possible positions and defining all other positions/ moves relative to this extreme position. Each time the error with respect to required position is measured and motor position is continuously corrected.

Measuring the color of all the color blocks of all the faces was a challenge. This is because with our hardware the cubes center, edges and corner blocks were at a different distance from the color sensor. To solve this, we first adjusted the arm as much as possible to make sure that the color sensor is approximately perpendicular to the cubes surface. After this we empirically measured and fixed thresholds for all the colors. This helped the robot sense color accurately in all kinds lighting conditions without the need for recalibration.

4 Self assessment about the robot

Robot is able to -

- scan values of 54 stickers of the cube and process it into appropriate color and store it in a data structure.
- build the initial state of the cube using the color read. This cube data structure is initialized and maintained such that at any point the entire cube state is valid i.e., there cannot be values which never occurs in the actual cube.
- flip the cube number of times based on the requirement. If it needs the next accessible face on top then it flips once, if it requires the opposite face on top then flips twice and so on.
- rotate the square base effectively depending on the angle.
- solve the Rubik's cube if the initial state of the cube is scrambled in one dimension i.e., when 2 of the 6 faces are not disturbed.

Robot is not able to -

- solve when all the faces of the Rubik's cube are scrambled.

You can find the working of the robot at `https://youtu.be/j-R1wCFLeYM`

5 References

MindCuber - `http://mindcuber.com/`