Project Name: Rubik's Cube Solver

Team Name: The Decepticons

Team Members:

Tejas Adsul (150100028)
Akhilesh Somani (150100040)
Savyaraj Deshmukh (150100041)
Ritesh Burde (150040028)

Project Description:

We had decided to make a Rubik's cube solving robot as our ITSP. The aim was to solve any scrambled rubik's cube by a bot in the minimum possible time involving the algorithm which takes the least moves to solve the cube. The cube need not be any special cube, any 'ordinary one' would suffice.

Technical Aspects:

The project involved 2 main subtypes:
1.Mechanical Structure
2.Matlab-Arduino based Coding

Mechanical Structure: It was sort of a box except that it had a base on which wooden planks had been arranged as shown in the pic. There were 6 steel rods to hold the cube in position and rotate the 6 faces of the cube. The rods were connected to stepper motors, which in turn were connected to a Arduino Uno.

Matlab: We had decided to use the Thistlethwaite's algorithm to solve the cube. Matlab gave us the moves to solve the cube, which were then fed to Arduino.

Arduino: The stepper motors were controlled by the Arduino based on the input received from Matlab.

The main aim of this project was to make the bot user friendly and reduce the time to solve the cube.
This project gave us a flavour of basic Arduino coding, Matlab programming and introduced us to various electronic components like Stepper motors, stepper drivers, breadboard, etc. It was an excellent platform to learn technical stuff.

Timeline:

➢Phase 1: (20th May to 31st May)

1. Decided all the basic requirements for our project like
: What materials would we be requiring?
: Where to get those those things?
: What would be their approx. price?

2. Which algorithm to use?
: Browsed for the possible algorithms feasible to be used.
: We decided to use the Thistlethwaite algorithm over Korf's algorithm as it was less complex to handle.

3.We finalised our Mechanical model. We created a Solidworks model of our project.

4.How to connect the cube with the motors? We were yet to decide between vacuum cups and steel rods.

This was followed by the 1st review meet.

➢Phase 2: (1st June - 10th June)

1. Bought a stepper motor(4.2 Kg cm torque), an Arduino Uno, jumper wires, a breadboard, a capacitor(100 µF), an A4988 stepper motor driver and a 12V battery to implement a test run of the motor. All these things were bought from shops on the Lamington road.

2. Bought plywood. Wooden planks cut and filed according to measurements. Base for the structure prepared.

3.Started working on Arduino code. Successful in rotating the stepper motor with the help of Arduino.

4.Worked on the problem of attaching the cube with the motors. We decided to use the steel rods.

5. Got a matlab code to implement Thistlethwaite's algorithm.

This was followed by 2nd review meet.

➢Phase 3: (11th June to 20th June)

1.Serial Communication between Matlab and Arduino achieved.

2.Replaced the A4988 motor driver with DRV8825 motor driver.

2.Stepper motor successfully rotated using matlab via arduino. Made changes to our Arduino code to make it more efficient.

3.Mechanical structure assembled and glued together.

4.Bought 5 more stepper motors, 6 DRV8825 motor drivers, 5 more capacitors, another 12V battery and some more Jumper wires.

5. Tried to assemble the complete the circuit by connecting all 6 motors and trying to rotate them.

This was followed by the 3rd review meet.

➢Phase 4: (21th June to 30th June)

1. The major difficulty to be solved was to rotate the Stepper motor. We refined the Arduino code to make it more efficient.

2. Filing of the rods completed so as to ensure no friction while the cube's rotating.

3. Worked on the adhesion of the rods with the cube. Successfully used DST to connect the cube with the rods.

4. Used DST to ensure firm connection of the rods with the motors.

5. Made serial communication more reliant to ensure proper rotation of the motors.

6. A majority of the time was spent to decide the optimum speed of rotation and angle of rotation of the motors.

7. Fixed the motors into the holes in the structure using cello tape.

8. A lot of trial runs were taken before the project was finally completed to achieve the maximum efficiency.

9. Proper organisation of the bills was done.

Detailed Description:

We had initiated an idea. Now was the time to actually implement it.

We scratched our heads to create a suitable model of our project. Taking into considerations everyone's point of view, we created a Solidworks' model of our project. We took care to show every detail of our model like the position of the rods, the dimensions of the box, the position of motors, etc.

The next major task to decide what exactly were we going to use to attach the rods to the cube. We thought of using the vacuum cups. We sticked to this idea for some time until we found out that the cups were both too costly as well as could not provide enough torque to the cube. We had to discard this idea.

The next task was to decide which algorithm we were to use for our project. We googled for various algorithms. We came across Korf's Algorithm and Thistlethwaite Algorithm. We decided to go with Thistlethwaite's algorithm as the Korf's algorithm was a bit complex to understand. We downloaded the in-built library

in Matlab to solve the Rubik's cube. This was an interface in which we had to give the input to Matlab and it solved the cube and gave us the solution steps.

We bought the plywood to start preparing the structure. We cut 10 pieces of planks of varying size according to our Solidworks' model. We then cut a base for our model. We then cut a hole in each of the planks. A hole which was just large enough to fit the stepper motor in it. We then filed the holes properly so as to ensure the proper orientation and fixation of the motors. The holes needed to be made with maximum precision and at particular locations on the planks so that the cube can be fitted in the centre of the box in a proper way with motors attached. The next step was buying the necessary stuff to start the project. We bought a stepper motor, an A4988 driver (which was replaced by a DRV8825 Stepper motor driver), some jumper wires, a breadboard, a 12V battery, an Arduino UNO, a 2 feet long steel rod and a capacitor.

Then we looked for the alternatives for the vacuum cups. We cut the steel rod into 6 small rods. We then tried to bend one end of the rods into a fork like shape to enable it to attach to the centre piece of each face. This took some time to ensure precision. Later, even this was discarded and we decided to use Double sided tape (DST). DST was put at one end of the rod and stuck to the centre piece of each face.

Meanwhile, we also started to learn coding on Arduino and Matlab. The first milestone in our project was the rotation of the stepper motor using Arduino. We successfully wrote a code to enable the rotation of a stepper motor at our will. We could control the speed and angle of rotation of the motor.

The next thing we learned was how to serially connect Matlab and Arduino. We had a little trouble in learning serial communication. We browsed many sites on the net trying to figure this out. Eventually we learned how to turn LEDs on-off using Matlab, etc. This was followed by controlling the stepper motors from Matlab.
We then assembled the structure by glueing it together. Only the top 2 planks were not glued then.

After the success of 1st stepper motor's rotation, we bought 5 more motors, 5 more drivers, jumper wires, 5 capacitors from Lamington road and ordered a Rubik's cube online.

We then tried to rotate all 6 stepper motors together one after another. After a lot of efforts, we were finally able to rotate the motors from Arduino. We were able to control the angle and speed of rotation of each motor specifically. Then we completed the serial communication for all 6 motors. Now we were able to rotate the motors from Matlab. We extracted the solution algorithm in Matlab and fed it as input to Arduino. Arduino was designed to rotate the stepper motors according to the input. We were then in a position to solve the Rubik's cube. We placed all 6 motors in the structure and connected rods to them using DST. We had tried the coupler but did not find a coupler large enough for our rods. Then arrived a major difficulty which we knew would be really difficult to solve. The motors had to be fixed in the holes to ensure no dis-orientation of the cube during rotation of the motor. But at the same time we needed the motors to be removable so that the cube can be taken out of the structure. So we ensured that the motors would 'just'

fit in the holes. So, we could remove the motors with force and remove the cube. This process took us some time because precision was required. The proper alignment of the motors was also to be maintained. The top 2 planks were glued. The rods were filed to reduce friction. A small depression was made on the base of the structure so that the motor on the bottom was held properly in place. The motor on the bottom was then glued to the structure. After many struggles, we finally got the cube to rotate properly inside the structure. We were successfully able to solve the cube in about 30 secs. Our next target was to reduce time taken to solve the cube. We optimised the speed of rotation and the time pause between 2 rotations to reduce the time to just around 3 seconds!! Finally our project was complete!! :D

Things Needed for the Project:

1.Bought from Lamington road (Silikon Electronics):

- **6 Stepper Motors (4.2 Kg cm Torque) (Rs. 4350/-)**
- **6 Stepper Motor drivers: DRV8825 (Rs. 1250/-)**
- **Jumper Wires: Male to Male (Rs. 180/-)**
  :Female to Male (Rs. 60/-)
- **One 12V battery (1.2 Amperes) (Rs. 380/-)**
- **Aluminum Flexible Coupler (Rs. 280/-)**

2. Bought from Mangal Deep (in front of IIT Main Gate):

- **6 capacitors(100 µF) (Rs. 30/-)**
- **A Steel rod (around 2 feet long)**
- **1 Arduino Uno (Rs. 550/-)**
- **1 Breadboard (Rs. 90/-)**
- **3m long Wire (Rs. 15/-)**
- **One 12V battery (1.2 Amperes) (Rs. 400/-)**
- **Jumper wires (Rs. 530/-)**

3. Bought from Swastik Plywood (in front of IIT Main Gate):

- **A 12mm thick 3*3 feet plywood (Rs. 425/-)*incl. of VAT**

4. Bought from Amazon:

- **A 3*3*3 Rubik's Cube (Rs. 599/-)**

***Note: All prices are exclusive of Taxes/VAT.**

Useful Links (Reference Links):

1.https://www.pololu.com/product/2133 : DRV8825 stepper motor driver

2.http://codesforprogram.blogspot.in/2013/08/interfacing-matlab-and-arduino-serial.html : Serial Communication

3.https://www.arduino.cc/en/Tutorial/StepperOneRevolution : Stepper Motors

4.http://www.instructables.com/id/Arduino-and-Matlab-let-them-talk-using-serial-comm/ : Serial Communication

5.https://www.youtube.com/watch?v=89BHS9hfSUk : Setting the Current Limit on Stepper Motor drivers

Links to our Videos :

1. https://www.youtube.com/watch?v=pqKYfS8EI3U (Youtube)

2.https://drive.google.com/open?id=0B7l_gfMtfvPxRUp3NktuOVh3QXc (Google Drive)

3.https://drive.google.com/open?id=0B7l_gfMtfvPxNy1GWXhlUnJDX2s (Google Drive)

Some other important links of our project:

1.https://drive.google.com/open?id=10DbqZiyNtkw5mO3CmNLLCFKGYXDpfRTYAa8_Vqb6-KI : Algorithm Overview

2.https://drive.google.com/open?id=0B8MYXtTrYEnxVHd5M0dCRENEWHc : Circuit Diagram

3.https://drive.google.com/open?id=0B8MYXtTrYEnxdkV5VHZ0MDMxb0k : Solidworks Model's Video

4.https://drive.google.com/open?id=0B7l_gfMtfvPxUmtvSWFydlR6WUk : Pic of the structure