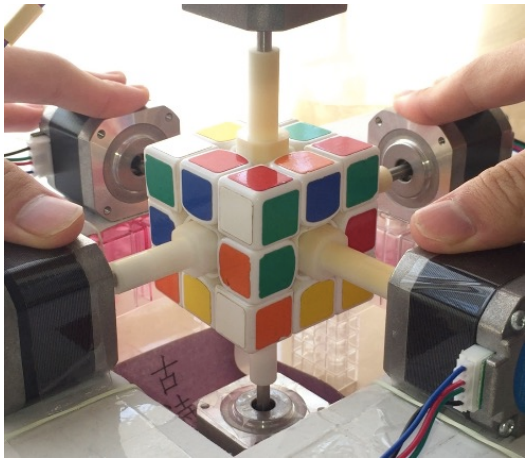
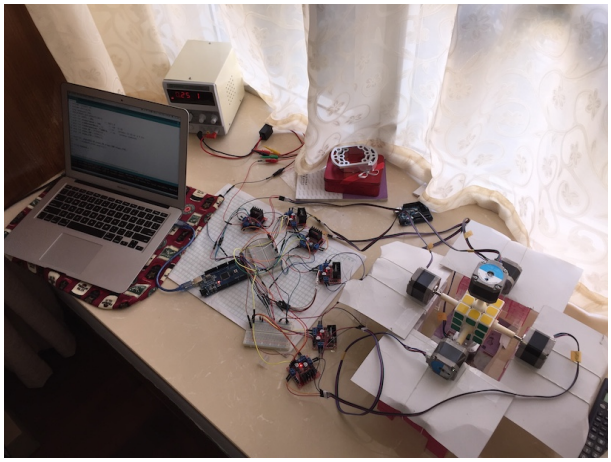
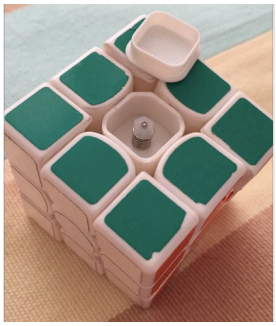
Cubot





I came up with an idea to build a robot to solve the Rubik's Cube during my sophomore year. As a participant in EECS extracurricular introductory courses, a member of the cube association, and a kid growing up showing great interest in machinery and models, I somehow wanted to combine my knowledge and interest to create something fun. Talk is cheap while practice is valuable. I started to build this machine from scratch, only having a rudimentary MCU and a Rubik's Cube, but as well as infinite passion and persistence.

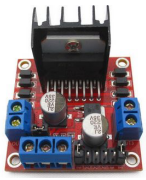


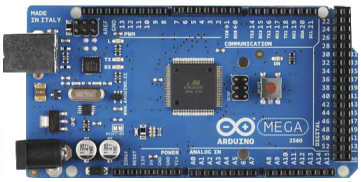
I immediately came up with a general design that motors should be embedded directly in the central block of each face of the cube by 3D-printed components, because the other common design, which uses mechanical arms to rotate the face and turn the cube, is greatly inferior in speed. Therefore, outside the motors and the cube should be a supporting structure, while inside the machine should be two parts of programs, one of which takes in the colors on each face and gives out the solution, while the other controls the motors to execute the solution. Subsequently, I summarized my ideas, listed items needed, and purchased them one by one online.

The first major predicament was how to code a program to solve the Rubik's Cube. I searched online for algorithms. I found out that the method designed for computers takes great advantage of their speciality in computing and orderliness. It is derived from group theory, thus extremely abstract and unapproachable compared with human's method which solves by layers. However, everything I found was describing, or explaining the math behind this algorithm. I spent months, off and on, finding pieces of code, putting them together, and correcting the incompatibility between them. Sometimes I really wanted to quit (and actually I did), because I couldn't find any clue on the essence of this algorithm, let alone its realization. When a new idea, or a different perspective on this problem came to me some time later, however, I would pick it up to give it a try and fail once again.

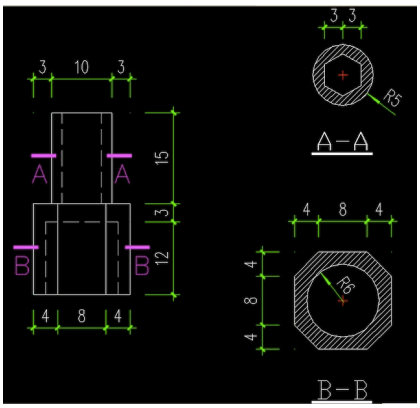
It was not until the end of the summer break in 2016 did I finished debugging. The code could take in preprocessed cube state and solve the cube, which arose a new task to convert the state of colors in humans' eyes to an intermediate state of orientations and permutations that takes effect in computers. If last time I could refer to code and explanations online very often, I worked this out on my own this time. I tried to translate the cube state by myself, and to observe how colors on each block correspond to its relative position; therefore I can know how to determine its relative position and orientation according to its color. After trying and experiencing, I simulated this conversion in programing language and cracked this task.

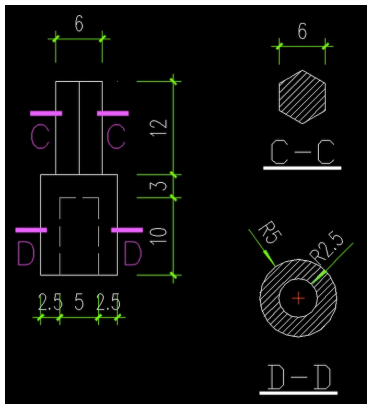
Next to finish is the code in Arduino, while experimenting at the same time was the wiring between all six steppers and drivers and the power source. The code will read the solution and control the steppers only if the wiring corresponds with it. I looked up and official documentation and stepper library source code for guidance. I had to learn about the fundamentals of electronics, so that I can understand the function of each components and connect them perfectly. I kept making mistakes. I knew it each time my power source sent a ‘beep’, indicating a short circuit, or my steppers kept shaking instead of rotating a specific angle in a specific direction.

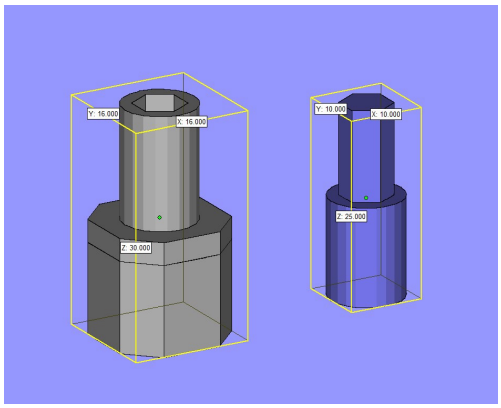




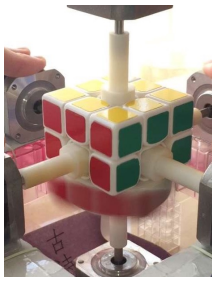
The logic in the code is simple, but a list of parameters wait to be determined according to many real-life engineering problems. For instance, how do I set appropriate speed and steps, so that they can overcome the friction and rotate the cube precisely as fast as possible; how do I adjust input voltage so that it isn’t too large, but meanwhile satisfies the torque to rotate; and whether to rotate 90 degrees counterclockwise or 270 clockwise, since the former charges the direction, losing accuracy and the latter loses speed. Sometimes I sacrifices quickness for robustness, while sometimes I overpower the steppers to increase speed.







Although adjusting and debugging was not finished until my senior year, designing and 3D-printing the connectors was done at the end of my junior year. I was inspired by the design of multi-head screwdriver, so my connectors are easy to attach to and detach from the cube. I did the measurement very carefully using vernier calipers and drew a diagram for it. I even learnt how to do a simple Computer Aided Design since a formal diagram of mechanical components was needed for 3D-modeling and printing, which were later handed to professional companies.



Altogether, they made my Cubot whole. When all the parameters were settled and my machine finally solved a scrambled cube, I could not withhold my bliss dancing in my heart. Although there are improvements, including a more stable and formal structure and color recognition, yet to make, I was still immersed in an unparalleled sense of accomplishment.

Looking back, I spent nearly two years to extend my idea to a real machine. So many difficulties each put a pause to it, some for weeks, some for months, but I am proud that I pressed ‘resume’ sooner or later for each ‘pause’. They are less burdensome when my inclination and capabilities are combined.

Postscript

I summarized this project and put it onto the largest online forum for single chip computer discussion in China immediately after its completion. My project earned recognition from both the

administrator and the folks. It was also recommended to participate in an online engineering competition. This project earned many votes and ended up a top 10% ranking.

After the competition, I was informed that my Cubot attracted interest from a reputed magazine in this field. I was asked to send a copy of my code, instructions, and explanations and to wait for publishing, after which I would be paid a decent contribution fee.

Even more exciting was that a teacher from a maker education organization contacted me through my personal website, consulting me for advice on building a machine to solve cubes. I was really honored to offer help and share my knowledge and experience to more teenagers who are interested in creating fun.

I expected none of these when I started my project because I was driven by nothing except my passion. It is the first time that I have made such a great impact, from friends and teachers around me, to kids and professionals from around China. They all motivated me to further stick to my inspiration, turn it into reality, and enjoy the fun created.