

Cubr: Cube Puzzle Solver

18500 S19 Team D6

Project Proposal

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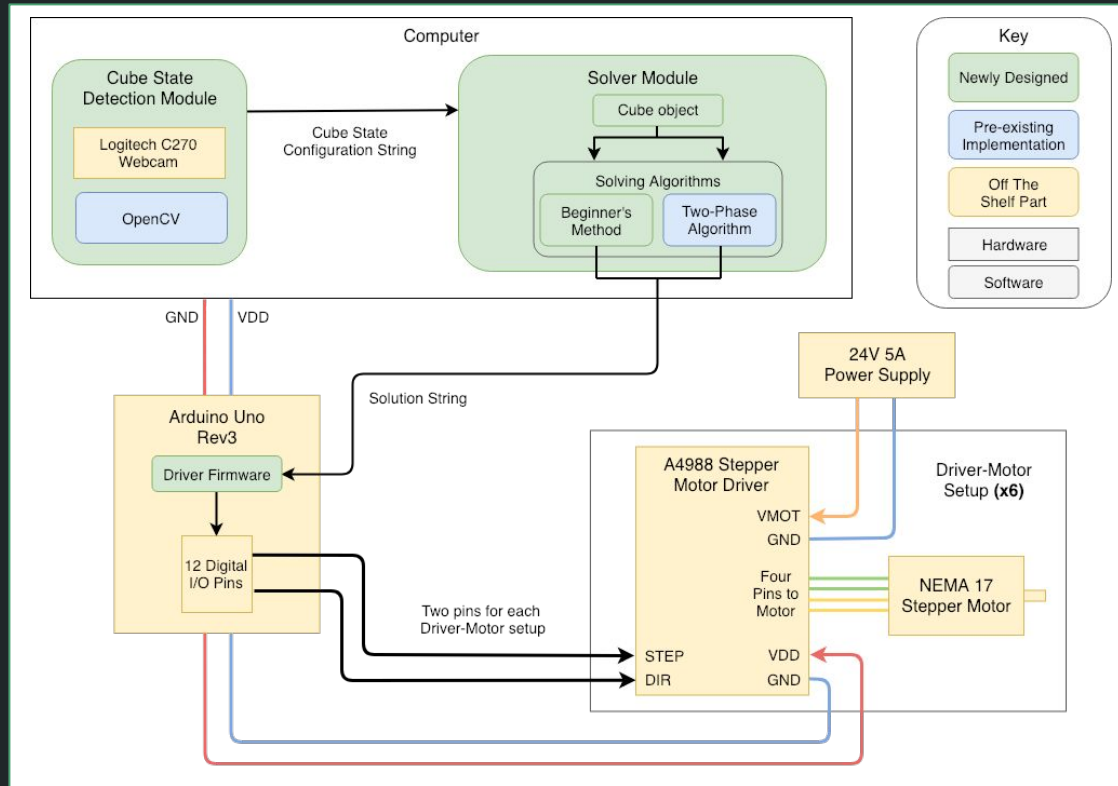
Background and Application Area

- 3x3x3 Rubik's Cube
- 43,252,003,274,489,856,000 unique cube states
- World record time set by Feliks Zemdegs: 4.22

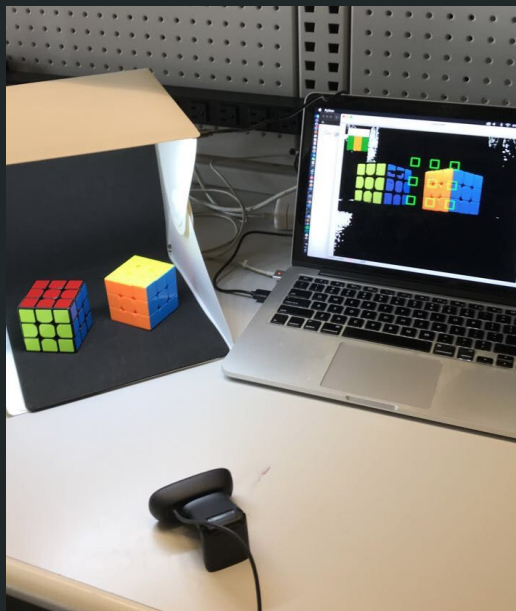
- Software
 - Computer Vision
 - Software Design
- Hardware/Robotics
 - Firmware
 - Circuits



Solution Approach



Demonstration Procedure

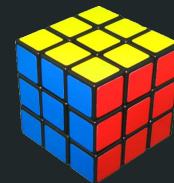
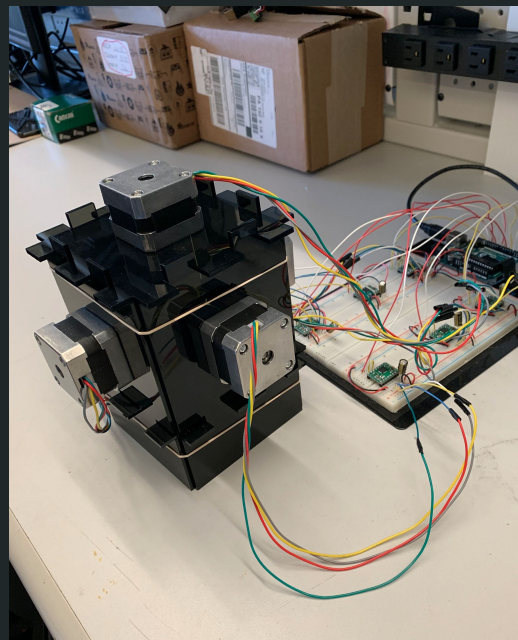


cube solved? True

of moves: 75

solution:

```
D2 U1 L2 B3 R1 R1 U2
R3 U1 R1 U3 R3 B3 U1
B1 U3 B3 U1 B1 B1 U1
B3 U1 B1 U3 B3 U2 L3
U1 L1 U1 F1 U3 F3 U1
F3 U1 F1 U1 R1 U3 R3
L1 U3 L3 U3 B3 U1 B1
B1 U3 B3 U3 R3 U1 R1
U1 F3 U3 L3 U1 L1 F1
L3 U3 L1 F2 D1 R3 U1
R1 U3 R1 D3 F2
```

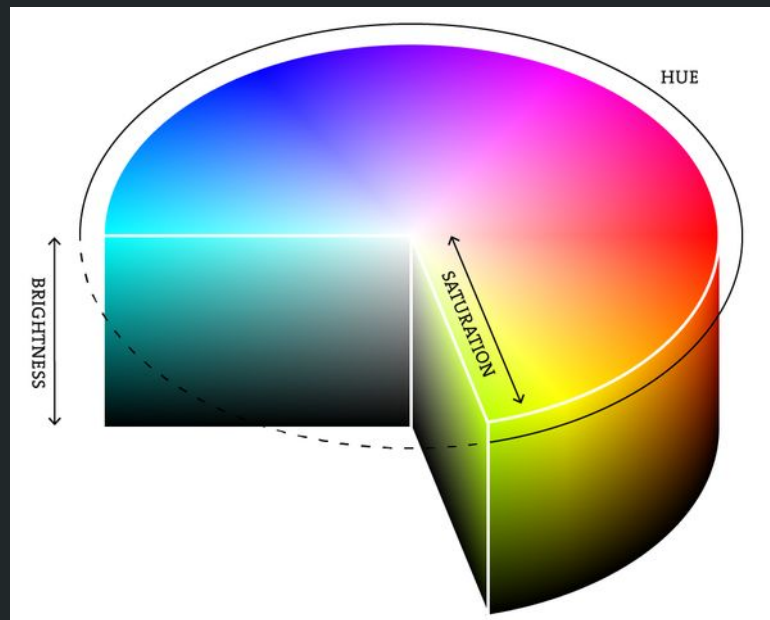


Metrics and Validation

- Cube state detection
 - Live color tracking accuracy
- Algorithm efficiency
 - Number of cube movements to solve the cube
 - Was a solution found?
- Stepper motor precision & timing
 - Verify correct movements are made for any given input
 - How fast to execute a solution string (Baseline 20 moves)
- Is the cube physically solved?

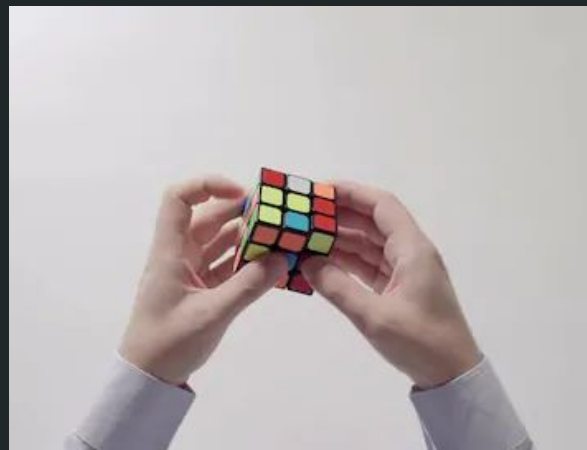
Metrics: Cube State

- Each cube has 54 cube pieces
 - Out of 10 unique cubes, on average 3-4 incorrectly scanned cube pieces
 - Red and orange not 100% differentiable
 - Completely dependent on lighting
- Repositioning
 - How we obtain 100% accuracy
 - Adjusts lighting on cube pieces
- Live color tracking
 - Allows us to see if we are tracking colors correctly



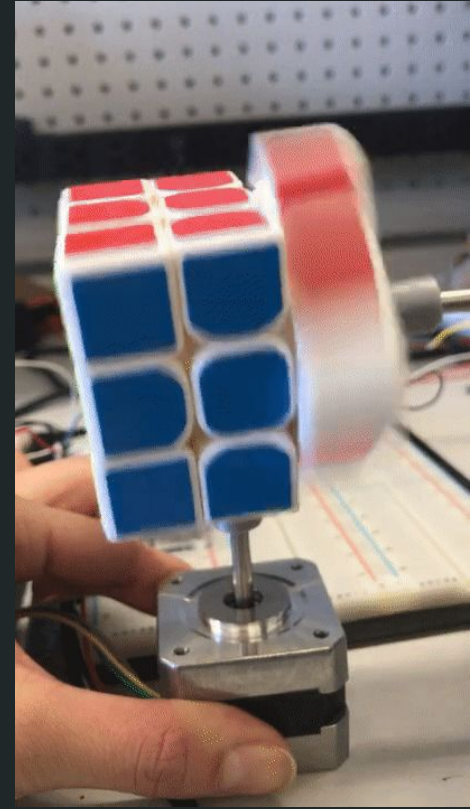
Metrics: Beginner's Method

- Naive Beginner's Method (via Sam): ~120 moves
- CFOP Method (via JT): ~87 moves
- **Our implementation:** 84.4 moves
 - Based on CFOP algorithms
 - Layer 1: 22.6 moves
 - Layer 2: 36.4 moves
 - Layer 3: 25.4 moves
 - Was a solution found?
 - 19/20 different cube state cases



Metrics: Hardware

- TurnSpeed
 - Delay between microsteps: 2 millisecond
 - 0.1 seconds to turn 90 degrees
 - 0.2 seconds to turn 180 degrees
- TurnDelay
 - Delay between each function: 1.5 seconds
- Voltage Reference: 0.5 mV
- Current: 0.5 A



Overall Specifications and Performance

	Color Classification & Thresholding	Naive Beginner's Method	CFOP Method	Our Beginner's Method	Two-Phase Algorithm	Turn Speed	Turn Delay
Expected Performance	100% success	150 moves	57 moves	100-200 moves	≤ 20 moves	1 sec	2 sec
Actual (Average) Performance	95% success	120 moves	87 moves	84.4 moves	≤ 20 moves	0.1-0.2 sec	1.5 sec

Product	Where to buy	Quantity	Price per unit	Shipping fee	Total Price	Purchase Date
NEMA 17 Stepper Motors	https://www.adafruit.com/product/324	12	\$ 12.60	\$ 7.81	\$ 159.01	Feb 11
A4988 Stepper Motor Driver	https://solarbotics.com/product/51090/	12	\$ 6.49	\$ 19.14	\$ 97.02	Feb 11
12V 2A Power Supply Adaptor	https://www.amazon.com/TMEZON-Power-Adapter-Supply-2-1mm/dp/B00Q2E5IXW	1	\$ 7.99	\$ -	\$ 7.99	Feb 11
Arduino Uno Rev3	https://store.arduino.cc/usa/arduino-uno-rev3	1	\$ 22.00	\$ 4.37	\$ 26.37	Feb 11
24V 5A Power Supply Adaptor (alternative)	https://www.amazon.com/ALITOVE-100-240V-Adapter-Converter-5-5x2-1mm/dp/B01GC6VS8I/ref=sr_1_17?keywords	1	\$ 19.99	\$ -	\$ 19.99	Feb 20
Logitech - C270 (Cheap webcam alternative)	https://www.amazon.com/Logitech-Widescreen-designed-Calling-Recording/dp/B004FH05Y6/ref=pd_lpo_vtph_147_b	0	\$ 19.86	\$ -	\$ -	Feb 19
Lighting Box Tent Kit	https://www.amazon.com/BrightBox-Portable-Photo-Studio-Light/dp/B01N75CIVP	0	\$ 21.99	\$ -	\$ -	Feb 19
Valk 3	https://www.thecubicle.com/collections/3x3/products/valk-3	2	\$ 19.99	\$ 3.22	\$ 43.20	Feb 11
Mofang JiaoShi MF3RS2	https://www.thecubicle.com/collections/3x3/products/mofang-jiaoshi-mf3rs2	2	\$ 7.99	\$ 3.22	\$ 19.20	Feb 11
MoYu WeiLong GTS2 M	https://www.thecubicle.com/collections/3x3/products/moyu-weilong-gts2-m	1	\$ 25.99	\$ 3.22	\$ 29.21	Feb 11
Breadboard-friendly 2.1mm DC barrel jack	https://www.adafruit.com/product/373	3	\$ 0.95	\$ 10.13	\$ 12.98	Feb 11
3D Print Coupling Arms (prelim)		4	\$ 0.90	\$ -	\$ 3.60	March 27
3D Print Coupling Arms (final)		5	\$ 0.90	\$ -	\$ 4.50	April 8
3D Print Coupling Arms (final)		4	\$ 0.90	\$ -	\$ 3.60	April 10
VACASSO Acrylic Paint Set (12 Vivid Colors)	https://www.amazon.com/dp/B07FVVG29K/ref=cm_sw_em_r_mt_dp_U_80jTCbRFX3G3N	1	\$ 8.99	\$ -	\$ 8.99	April 15
12x24x1/8" Acrylic Sheets	from Makerspace	2	\$ 8.00	\$ -	\$ 16.00	April 20 & 24
18 Gauge Wire	https://www.amazon.com/gp/product/B01LH1FQJ0/ref=ox_sc_act_title_5?smid=A2QLFR4HNCCTLU&psc=1	1	\$ 16.99	\$ -	\$ 16.99	April 24
Jumper wire kit	https://www.amazon.com/gp/product/B06XRV9Z7B/ref=ox_sc_act_title_5?smid=A2QLFR4HNCCTLU&psc=1	1	\$ 7.49	\$ -	\$ 7.49	April 24
Cable sleeves	https://www.amazon.com/gp/product/B07JJCLJ1Q/ref=ox_sc_act_title_4?smid=A2GQEFKYWQUJT0&psc=1	1	\$ 6.95	\$ -	\$ 6.95	April 24
Wire pins	https://www.amazon.com/gp/product/B0774NMT1S/ref=ox_sc_act_title_3?smid=A1SFG00GMDVKI5&psc=1	1	\$ 9.99	\$ -	\$ 9.99	April 24
Protoboards	https://www.amazon.com/gp/product/B00SK8QR8S/ref=ox_sc_act_title_2?smid=AM0JQO74J587C&psc=1	1	\$ 13.52	\$ -	\$ 13.52	April 24
Screw terminal	https://www.amazon.com/gp/product/B071DN7GQ5/ref=ox_sc_act_title_1?smid=AB937091619PH&psc=1	1	\$ 8.99	\$ -	\$ 8.99	April 24

Running
Total:
\$515.59

Lessons Learned

- Solderless breadboards are not meant for large power supplies
- Careful, organized software design is imperative
- If it's outside your area of expertise, don't be afraid to ask for help sooner
- Head your professors warnings

