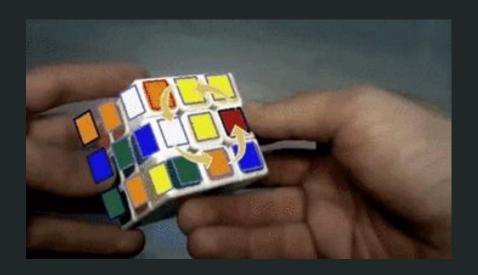
Cubr: Cube Puzzle Solver

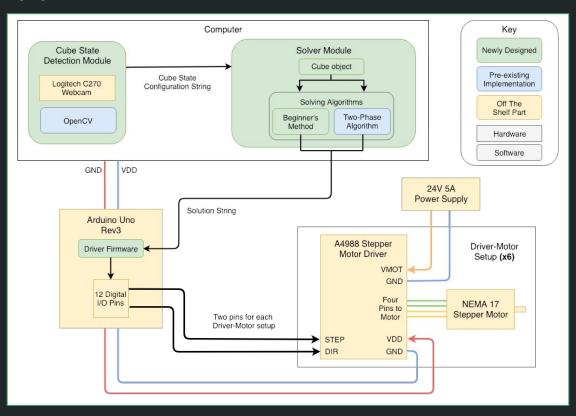
18500 S19 Team D6
Project Proposal
JT Aceron, Lily Chen, Sam Fazel-Sarjui

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

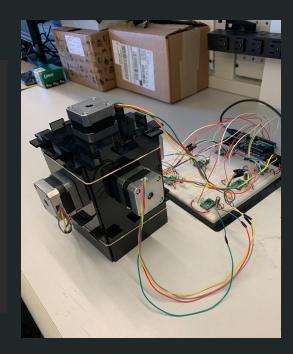




cube solved? True

of moves: 75
solution:

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



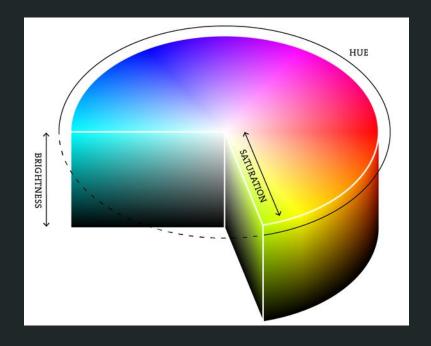


Metrics and Validation

- 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?

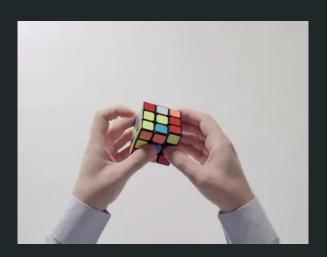
Metrics: Cube State

- 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



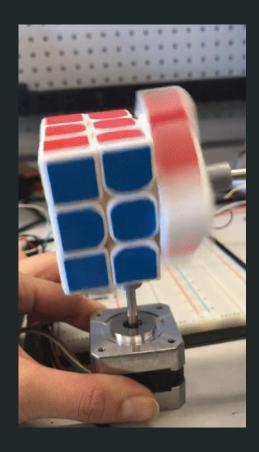
Metrics: Beginner's Method

- 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	\$ 7.8	31	\$ 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	\$ 4.3	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		\$	19.86	\$ -		\$ -	Feb 19	
Lighting Box Tent Kit	https://www.amazon.com/BrightBox-Portable-Photo-Studio- Light/dp/B01N75CIVP		\$	21.99	\$ -		\$ -	Feb 19	
Valk 3	https://www.thecubicle.com/collections/3x3/products/valk-3	2	\$	19.99	\$ 3.5	22	\$ 43.20	Feb 11	Running
Mofang JiaoShi MF3RS2	https://www.thecubicle.com/collections/3x3/products/mofan g-jiaoshi-mf3rs2	2	\$	7.99	\$ 3.5	22	\$ 19.20	Feb 11	
MoYu WeiLong GTS2 M	https://www.thecubicle.com/collections/3x3/products/moyuweilong-gts2-m	1	\$	25.99	\$ 3.5	22	\$ 29.21	Feb 11	Total:
Breadboard-friendly 2.1mm DC barrel jack	https://www.adafruit.com/product/373	3	\$	0.95	\$ 10.	13	\$ 12.98	Feb 11	\$515.59
3D Print Coupling Arms (prelim)		4	\$	0.90	\$ -		\$ 3.60	March 27	Ψ313.33
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	s -		\$ 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_s	1	\$	16.99	\$ -		\$ 16.99	April 24	
Jumper wire kit	https://www.amazon.com/gp/product/B06XRV92ZB/ref=ox_sc_act_title_5?smid=A2QLFR4HNCTTLU&psc=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=AM0JQ074J587C&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=AB9370916I9PH&psc=1	1	\$	8.99	\$ -		\$ 8.99	April 24	

CUBR GANTT CHART				Feb 3-9	Feb 10-16	Feb 17-23	Feb 24 - Mai	Mar 3-9	Mar 10-16	Mar 17-23	Mar 24-30	Mar 31 -	- Apr Apr 7-13	Apr 14-20	Apr 21-27
	START	2000	TEAM	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK		WEEK 11	WEEK 12
TASK NAME	DATE	END DATE	MEMBER	M T W Th	F M T WTh I	M T W Th F	M T WTh F	M T W Th F	M T W Th F	M T W Th F	M T WTh I	MTW	Th F M T W Th F	M T W Th I	M T W Th F
Cube State Detection (CSD) Module				di di di di											
UI: Full Cube Configuration Display	2/3	2/10	Sam												
Color Calculation + Classification	2/3	2/17	Sam												
Color-Agnostic Scanning Orientation	2/10	2/17	Sam												
UI: Live Color Tracker	2/17	3/3	Sam												
Determine Solution to Lighting Variance	3/3	3/17	Sam									4 9 9 9			
Solver Module															
Design OOP Cube Representation	2/3	2/17	Lily												
Implement CSD Mapping Orientation	2/10	2/17	Lily												
OOP Move Definitions	2/17	3/3	Lily												
Implement Beginner's Method Algorithm	3/3	3/17	Lily												
Integrate OOP Design with Two-Phase	3/10	3/20	Lily												
Interface Solver with HW	3/24	4/3	Lily												
Debug and Verify Code			Lily												
Hardware (HW) Module															
Purchase Parts	2/3	2/10	Multiple/All		(Backup part	s)									
Research Stepper Motors + Drivers	2/10	2/24	JT												
Design Motor Master-Slave Setup	2/24	3/10	JT												
Get One Motor Setup Working (FW)	3/6	3/24	Multiple/All												
Design Power Circuit	3/3	3/10	Lily												
Solder Pins to All Drivers	3/6	3/10	Lily	11111											
Circuit Prototyping	3/17	3/24	Sam												
CAD Models: Motor Housing	3/17	3/24	Lily												
CAD Models: Coupling Arms	3/17	3/24	JT												
CAD Models: 3D Print	3/24	3/31	Multiple/All												
Assemble 3D-Printed Housing	3/27	3/31	Multiple/All												
Interface FW with HW	3/6	3/20	JT												
Map moves to Keypresses	3/13	3/24	JT												
Read + Execute Solution String	3/24	3/31	JT												
Debug and Verify Circuit	3/24	3/31	JT												
Integration and Testing		-14										7 7 7			
CSD: Color Accuracy	3/10	3/17	Sam												
CSD: Cube Mapping	3/10	3/17	Sam												
CSD: UI	3/10	3/17	Sam												
Solver: Beginner's Method Efficiency	3/10	3/24	Lily												
Solver: Two-Phase Integration + Efficiency	3/24	3/31	Lily												
HW: Control Single Driver-Motor Setup	3/17	3/24	JT												
HW: Map Moves to Keypresses	3/20	3/27	JT												
HW: Tune stepper motors	3/17	3/31	Multiple/All												
HW: Basic Solution String Execution	3/24	4/3	Multiple/All												
HW: Solver Integration	3/27	4/7	Multiple/All												
Slack Time	4/7	4/28	Multiple/All												

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

