



# HERBERT

## AUTONOMOUS RUBIK'S CUBE SOLVER

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# WHAT INSPIRES YOU?

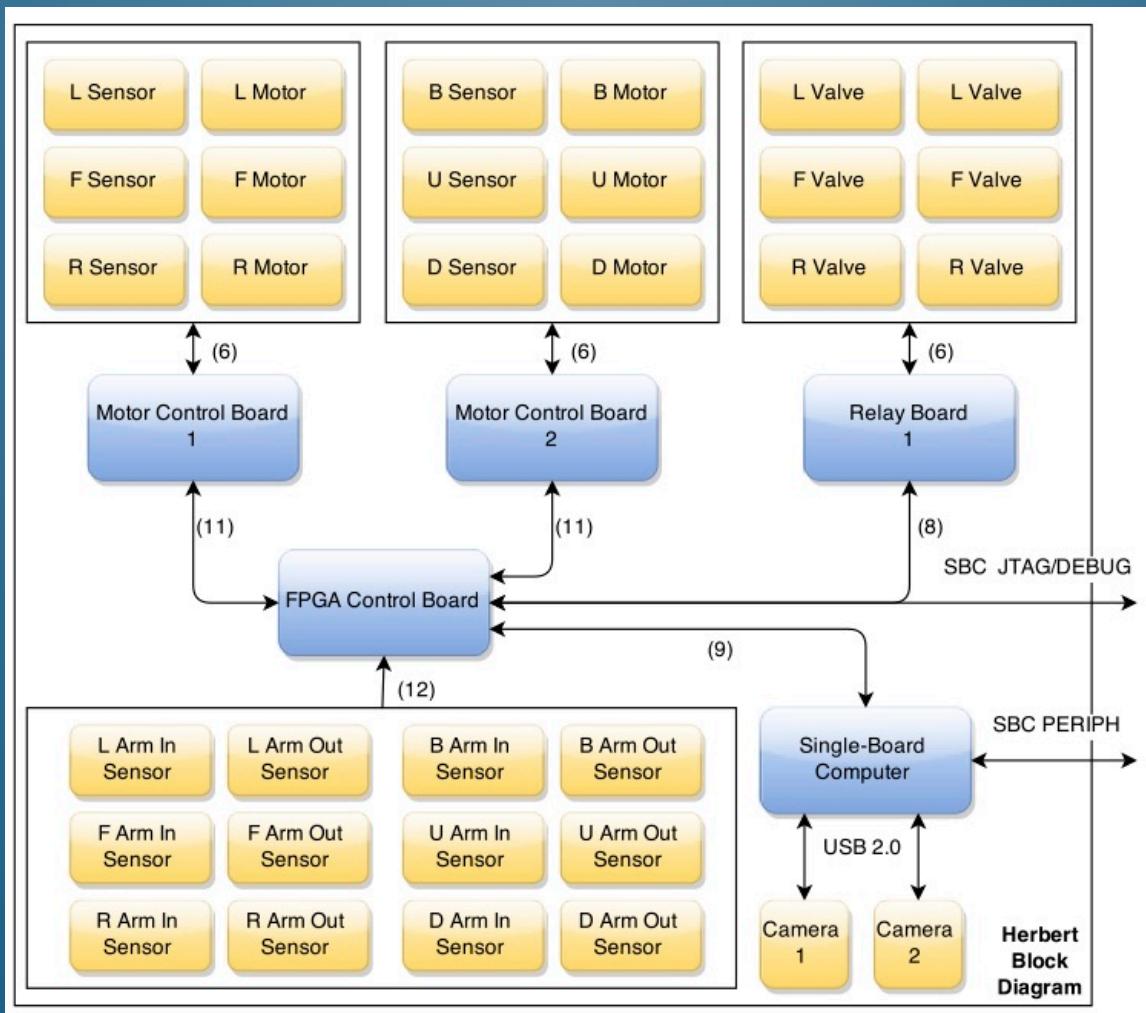
- CubeStormer1 & 3 – Fastest robot to solve a Rubik's Cube (3.253s) [1].  
<https://youtu.be/X0pFZG7j5cE>
- Zackary Gromko – Claims a new record on October 15, 2015 (2.39s) [2].  
<https://youtu.be/bEiQwmEe45s?t=13s>

# INTRODUCTION

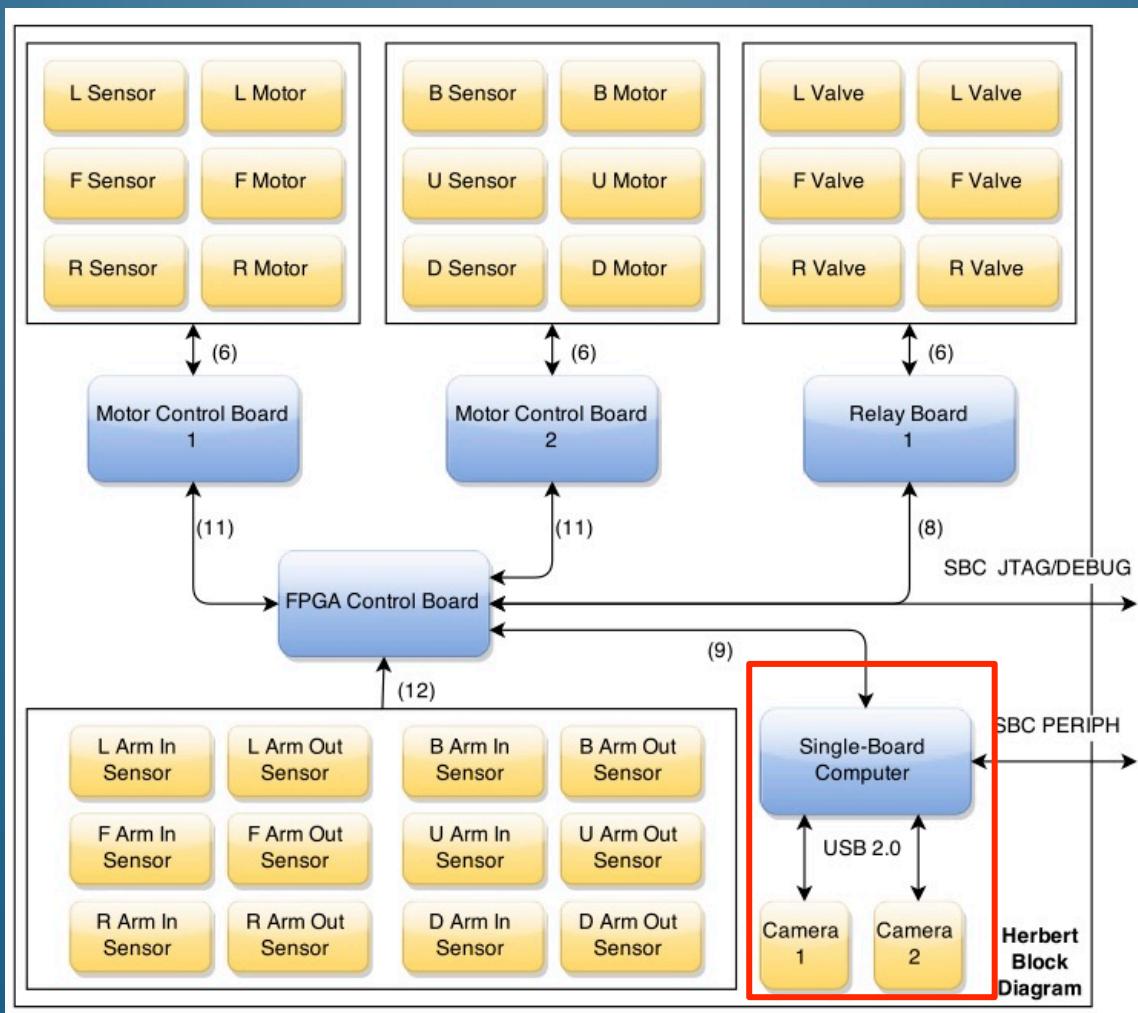
**GOAL:** Create an autonomous robotic Rubik's Cube solver.

- Integrates various technologies
  - Video cameras, stepper motors, mechanical actuators, single-board computer, FPGA
  - Possibly overtake Guinness World Record (3.253s at the time)
  - Optimize mechanical and image processing operations while maintaining the precision needed to solve the cube.

# HIGH LEVEL SYSTEM DIAGRAM



# OPENCV & IMAGE PROCESSING



# OPENCV & IMAGE PROCESSING

## Original Plan

- Two cameras, one for three of the six faces of the cube.
- Grayscale conversion – Convert RGB to pixel intensity for feature filtration [3].
- Canny edge detection - Identify the edges of the cube and the faces [4].
- Contour filtering - Identify cubelets on each face [5].

# OPENCV & IMAGE PROCESSING

## Final Implementation

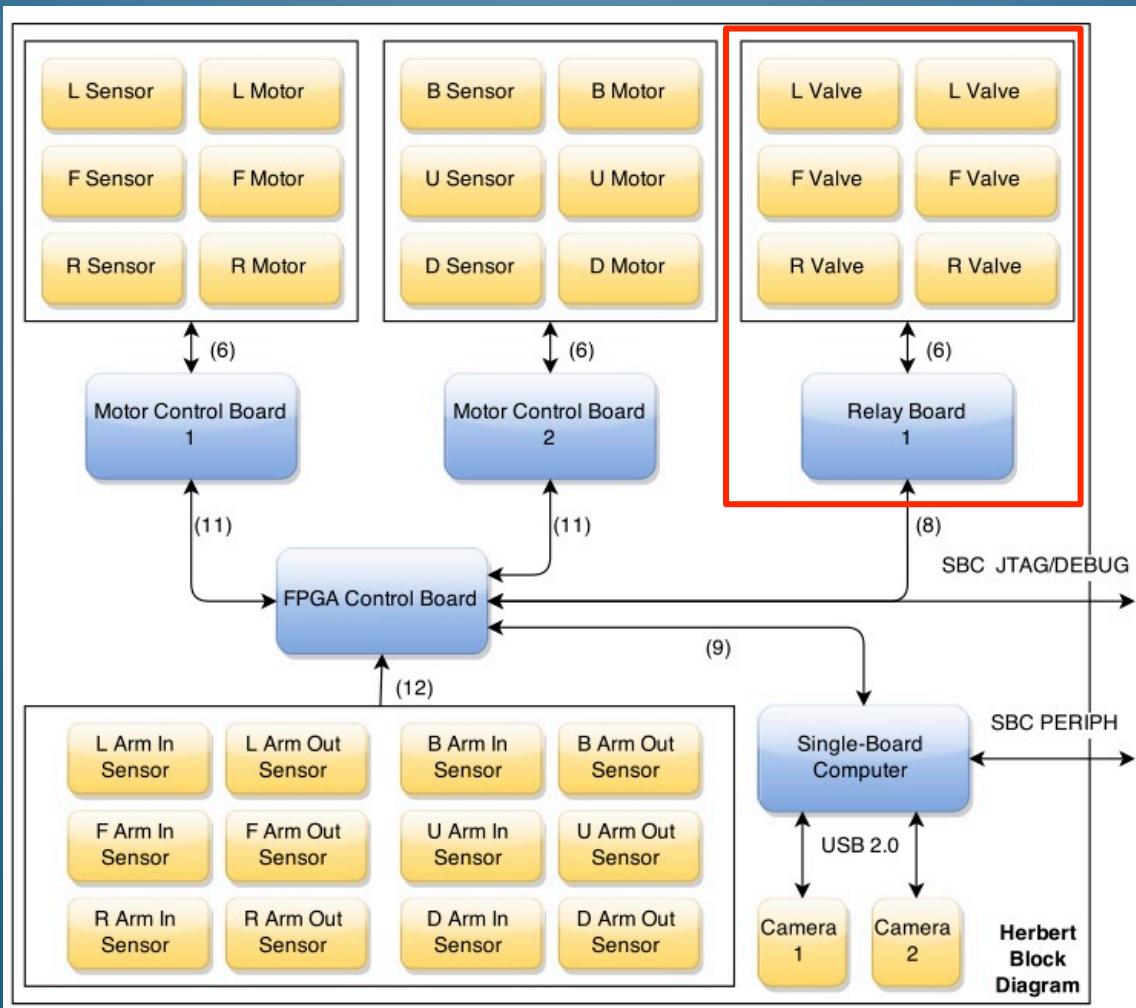
- One camera
- HSV conversion – Convert RGB to HSV [3].
- HSV characterization – Use pixel histogram and bin each facelet (square) [6].

# KCUBE & SOLUTION SEQUENCE

- Cubelets represented with an ASCII character
  - ‘W’, ‘R’, ‘B’, ‘G’, ‘O’, ‘Y’
- Kcube application used to generate the solution sequence [5].
  - Created by Greg Schmidt
  - Utilizes Kociemba’s algorithm

```
Microsoft Windows [ Version X.X. XXX ]  
Copyright (c) 2015 Microsoft Corporation . All rights reserved .  
c:> kcube L: GGWWOWBRB F: GWGBGYWBO U: YOOOWYROY D: ORGWYYRB R: OGBBRYWRR B:  
YBROBGWGR
```

# MECHANICAL ACTUATORS

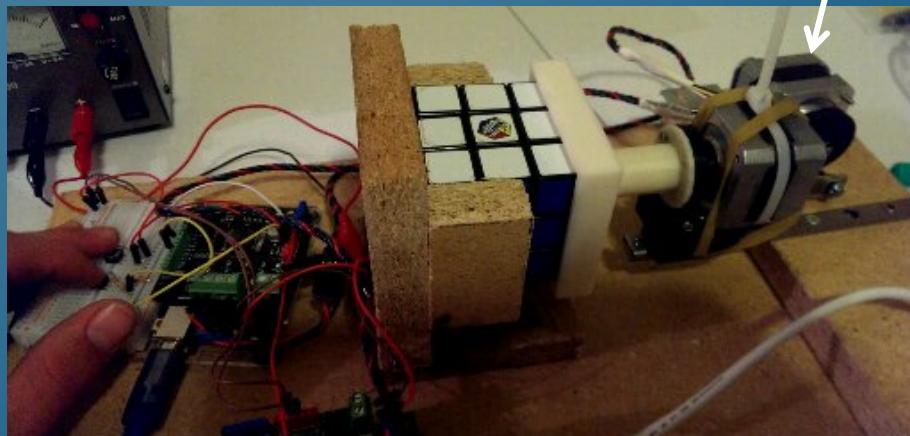


# MECHANICAL ACTUATORS

- One arm for each face
  - Improvement over 4 arms solutions
- Each arm actuates, avoiding contact with the other arms

## Original Ideas

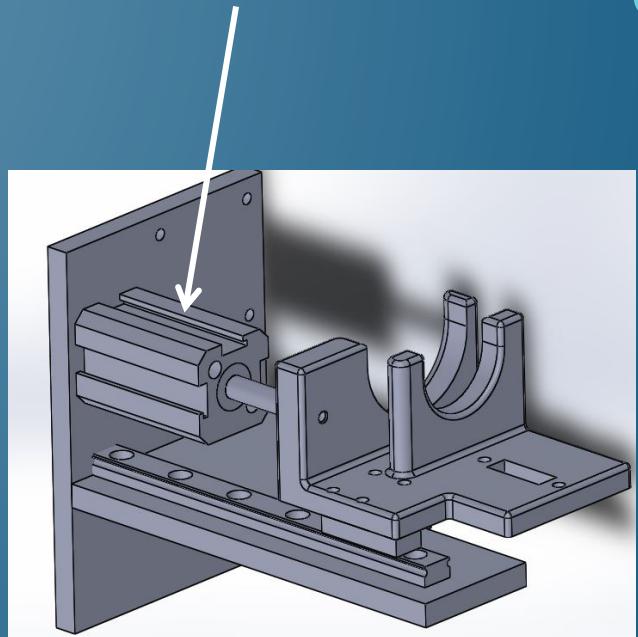
- Rotary → Linear motion
- Linear actuator motor



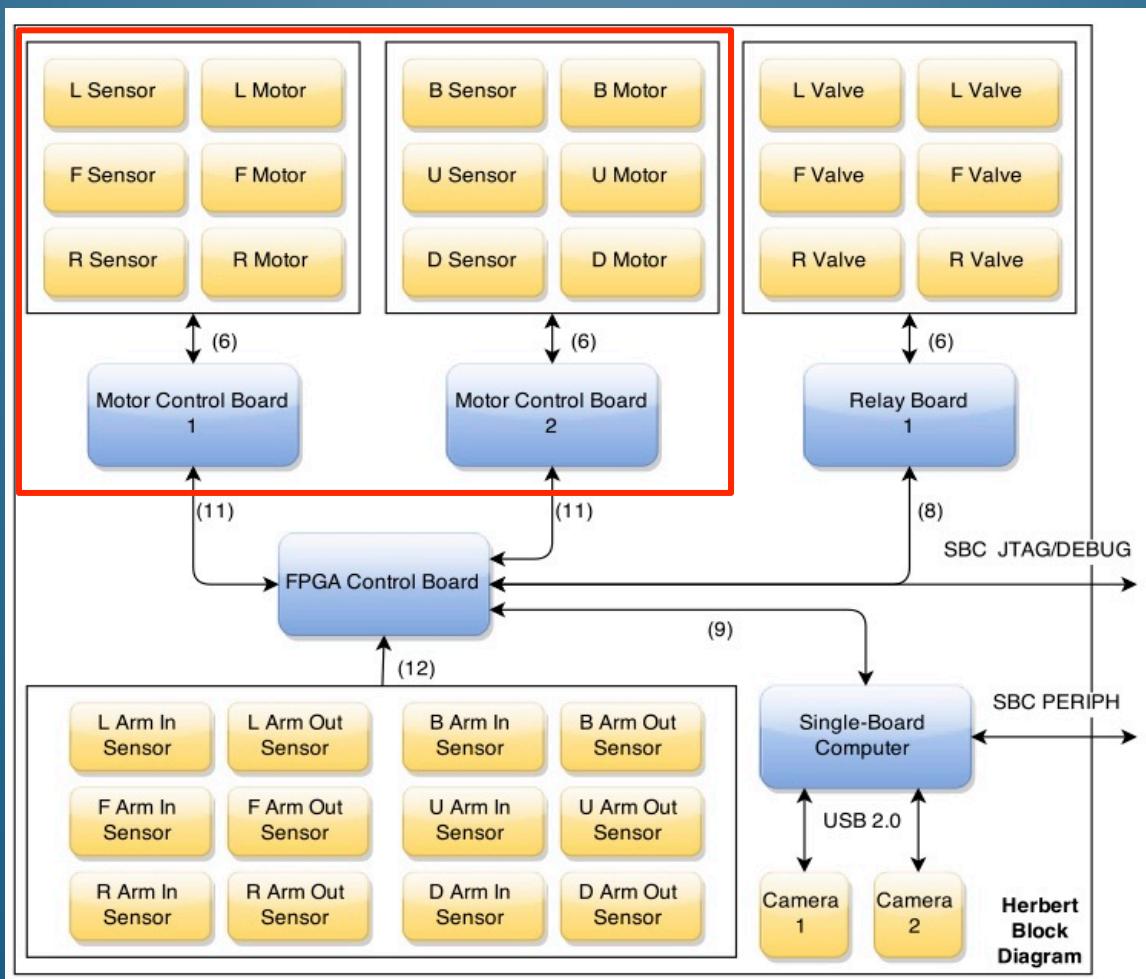
# MECHANICAL ACTUATORS

## Final Implementation

- Double action pneumatic air cylinder
  - High Speed
  - Affordable
  - Small footprint
- Controlled by solenoid valve and a relay board
- Simultaneous coaxial pair motion
- Approximately 40-60psi

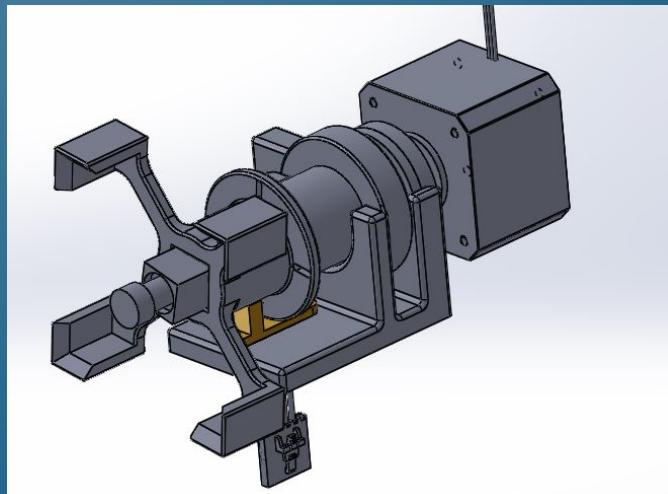


# ELECTRO-MECHANICAL STEPPER MOTORS



# ELECTRO-MECHANICAL STEPPER MOTORS

- Each actuating arm has a stepper motor to rotate each face
- 90/180 degree rotations clockwise or counter-clockwise
- Controlled by an FPGA and proprietary motor control board
- Full steps, no micro-stepping
- Break sensor for 90 degree alignment



# ELECTRO-MECHANICAL STEPPER MOTORS

Progression of Arm Pieces



# CHALLENGES

- Implementing & Synchronizing a system with 6 arm assemblies
- System integration
- Construction & Component acquisition
- Image processing
  - ROI issues
  - Color characterization (lighting)
- Team scheduling

# SUMMARY

- Integrates various technologies and domains of engineering.
  - Computer and Electrical engineering combined with mechatronics and robotics
- Overcame many challenges
- Great application of system integration and teamwork.

# ACKNOWLEDGMENTS

- Point Grey Research
- BioFire Defense
- Futura Industries



# REFERENCES

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