Robotics Engineering

DESIGN AND MANUFACTURING OF A 100G PARALLEL KINEMATIC MANIPULATOR

Spenser Brouwer (ME), John Cushion (ME), Elizabeth De Zulueta (RBE), Joshua Janssen (ME), Sean Townsend (ME)

Advisor: Prof. Stephen S. Nestinger, PhD

PROJECT STATEMENT

The purpose of this project was to develop a Parallel Kinematic Manipulator (PKM) for use within the Industrial Robotics course at WPI. The PKM should be reliable, expandable, and capable of reaching a peak acceleration of 100G.

INVERSE KINEMATICS

- The workspace and torque requirements were calculated using MathCAD
- The method used solves the angular position of the motors by solving two vector solutions for the path from the origin to the end effector

Angular position of motor 1

Position of B_1

$$B_{x11}(g) := (P \cdot \cos(\alpha_1) + l \cdot g \cdot \cos(\alpha_1))$$

$g := 1$

$$B_{y11}(g) := P \cdot \sin(\alpha_1) + l \cdot g \cdot \sin(\alpha_1)$$

Given

$$B_{z11}(g) := -l \cdot \sqrt{1 - g^2}$$

$$(B_{x11}(g)^1 - A_{x1})^2 + (B_{y11}(g)^1 - A_{y1})^2 + (B_{z11}(g)^1 - A_{z1})^2 = L^2$$

$$sol_{11} := Find(g) \qquad sol_{11} = 0.964$$

$$q1 := acos(sol_{11}) = 15.36 \cdot deg$$

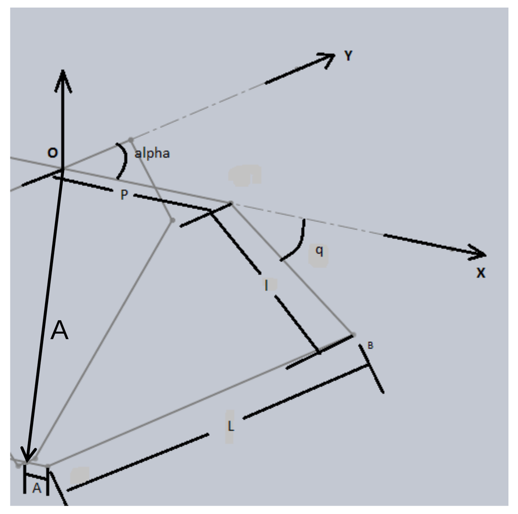

Figure 1: Inverse Kinematic Calculations and simple model

PROTOTYPES

- Two prototypes were constructed out of plastics to determine the pros and cons of 3-arm and 4-arm PKMs.
- These prototypes showed the differences in programming for a 3-arm and a 4-arm PKM
- 4-arm design was selected for full design.
- The 4-arm design was chosen due to programming ease, payload capacity, and 100G capability.

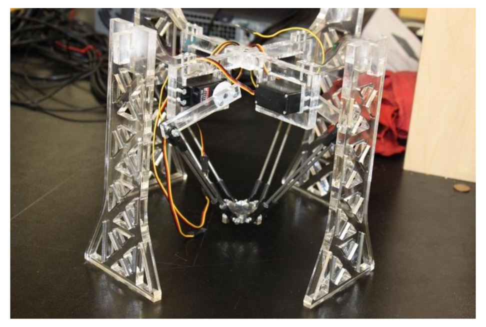

Figure 2: 4-arm prototype

100 G ANALYSIS

- The torque requirements for the 100G goal were calculated using the as designed configuration of the robot.
- Appropriate motors were selected from Maxon Motors USA
- Figure 3 shows the torque required to generate 100G acceleration as a function of vertical position from the origin.

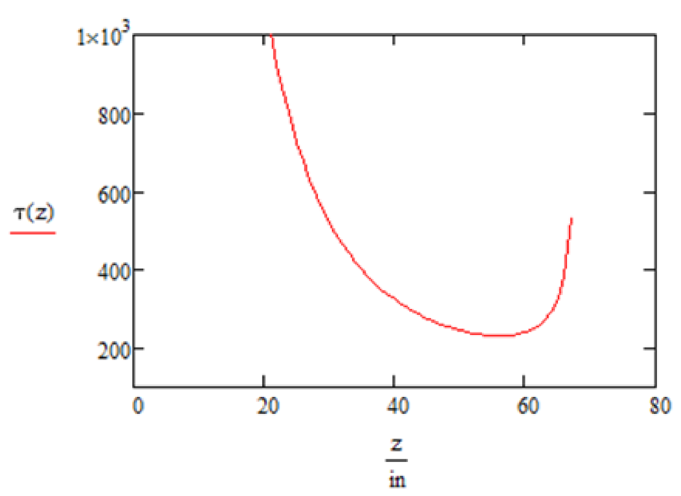

Figure 3: Graph of required torque as a function of position

FINAL DESIGN

- The final robot was constructed out of aluminum and carbon fiber
- A support table was constructed out of steel angle extrusion.

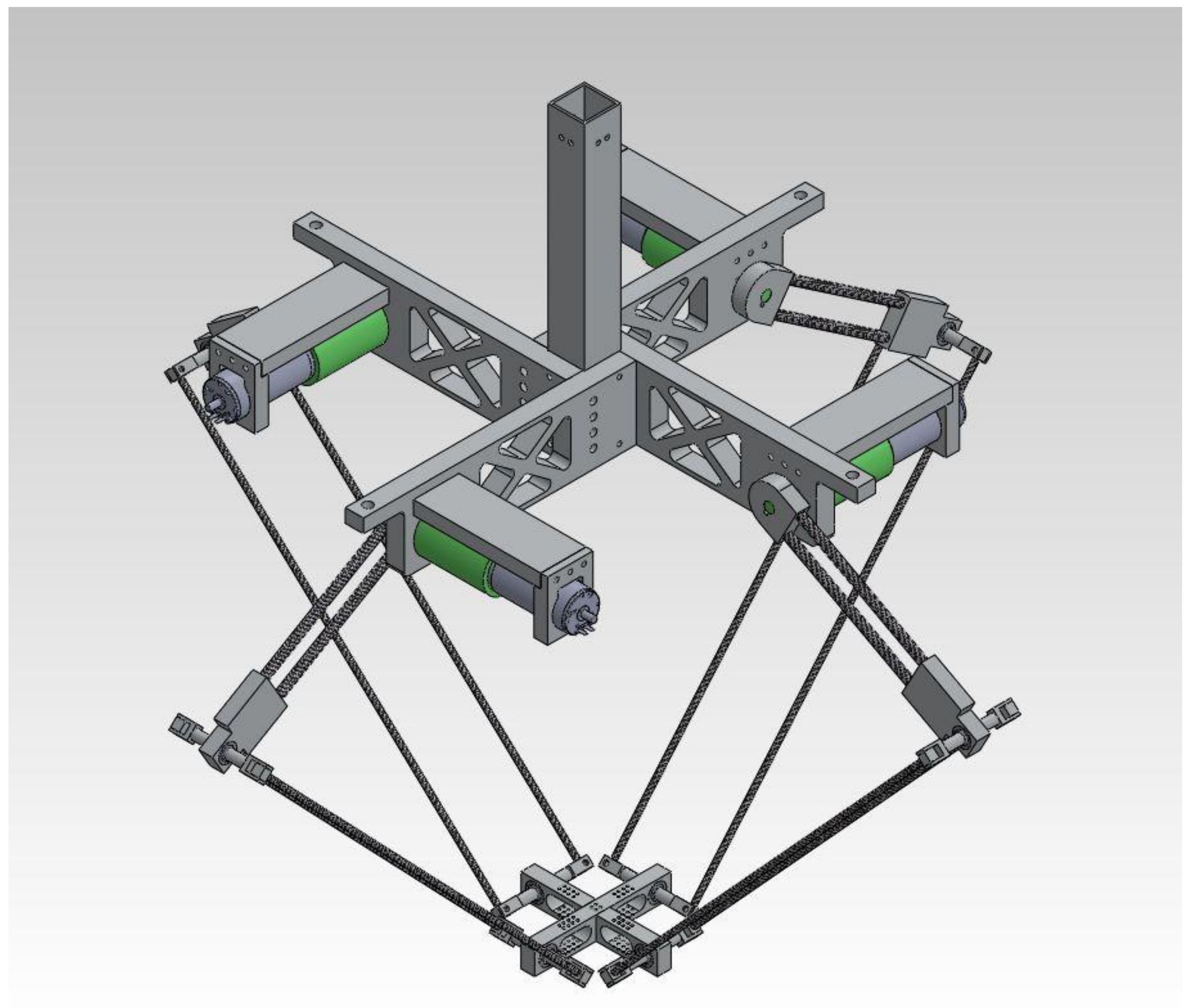

Figure 4: Final Robot Design

CONTROLS AND COMMUNICATIONS

- Master EPOS2 P controller communicates via CAN-bus with slave EPOS2s.
- The CAN-bus ensures coordinated motion of all four motors.
- Each motor has attached encoders to allow for position feedback
- Attached microcontroller to allow for external input/output functionality

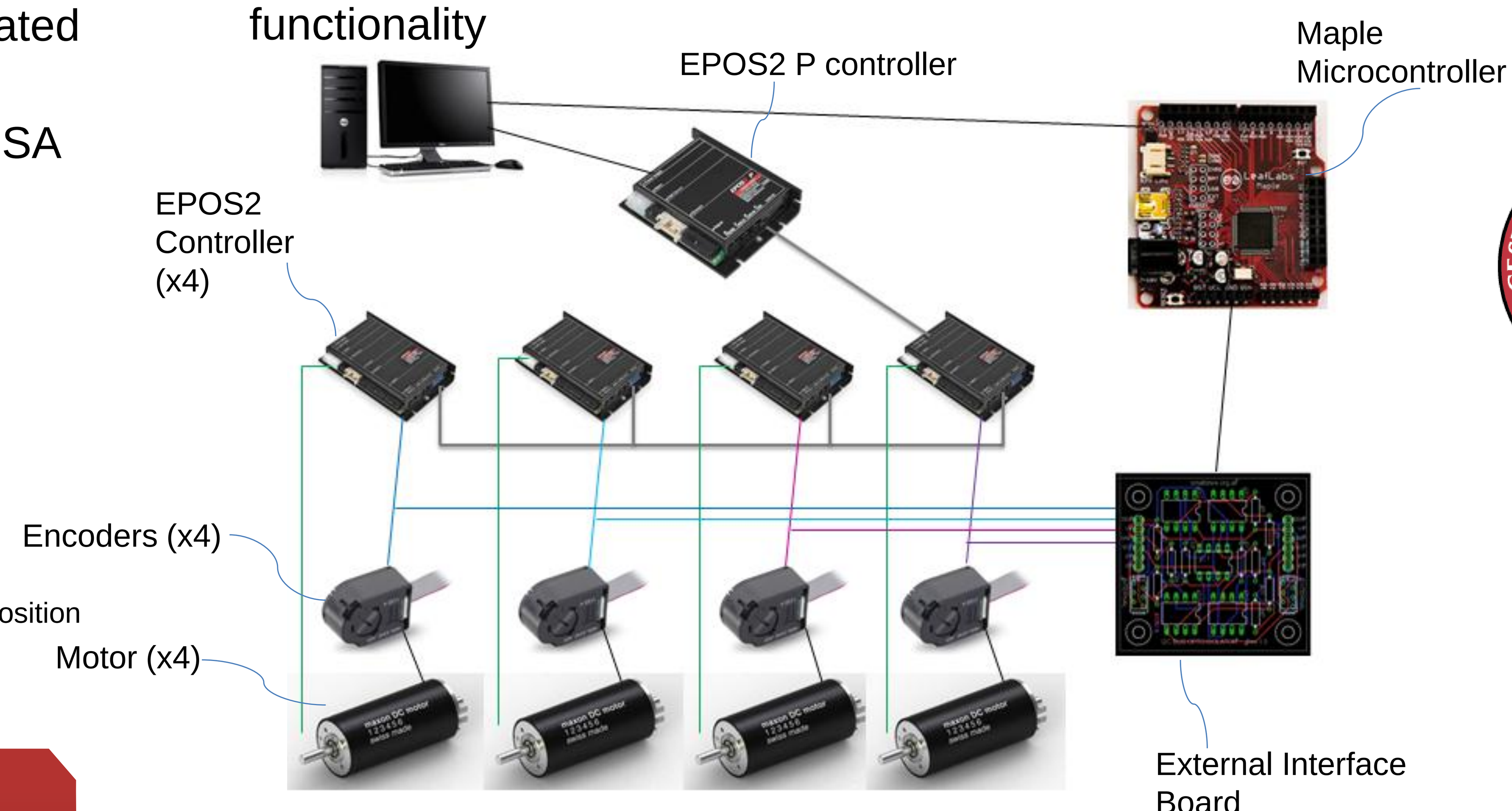

Figure 5: Control Diagram of the Robot

SOFTWARE ARCHITECTURE

- Robot is controlled from a program that communicates directly with the EPOS2 P controller via USB
- Program is written primarily in Java, but uses wrapper classes to communicate with controller in C++
- System requirements were generated through discussion with ME and RBE students and faculty. These requirements were distilled into use cases, which provided the basis for our class diagram and system architecture.
- Users interface with the robot using a touchscreen interface on a standalone PC

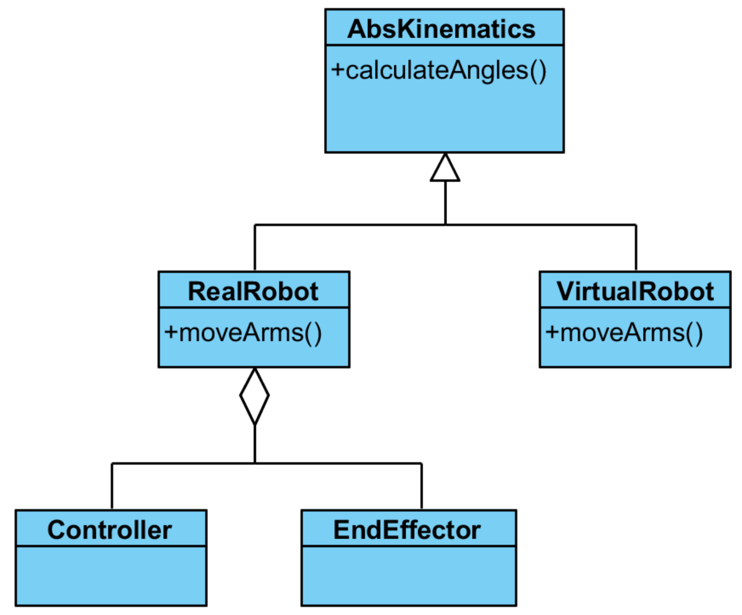

Figure 6: Programming Class Diagram

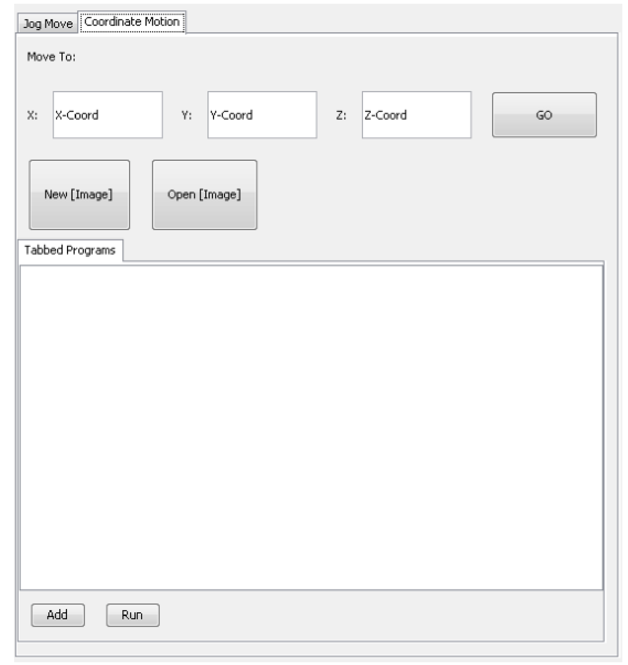

Figure 7: Sample of control program showing coordinate entry and program creation

FUTURE WORK

- Completion of electrical subsystems
- Expansion of GUI capabilities
- Testing of the 100G capability of the robot

SPONSORS

WPI

maxon motor
driven by precision

SPECIAL THANKS

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- Greg Overton
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Stinger Lab
Eclectic Robotics & Automation