Modular Robotic Arm

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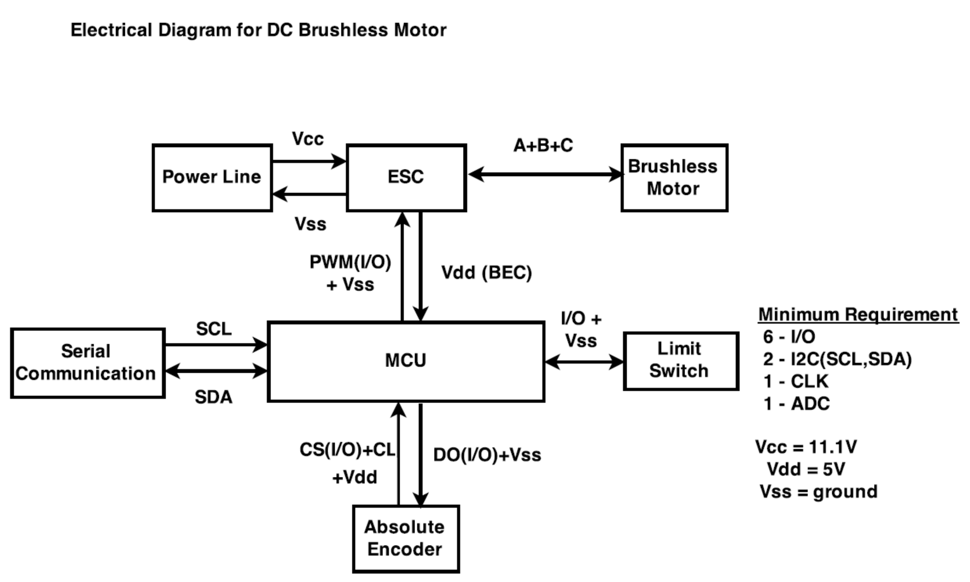
Introduction

A modular robotic arm which is both advanced and relatively inexpensive is currently not available on the market today. A consumer's options choices consist of inexpensive but weak toy arms or commercial grade robotic systems with prices far above the affordability of the average person. The goal of the project is to design and build a controllable modular joint that can be used to assemble a robotic arm. The design and component selection for the joints would allow a relatively inexpensive arm to be assembled while still maintaining precision and accuracy in its movements. The target users of the arm are expected to be hobbyists and students.

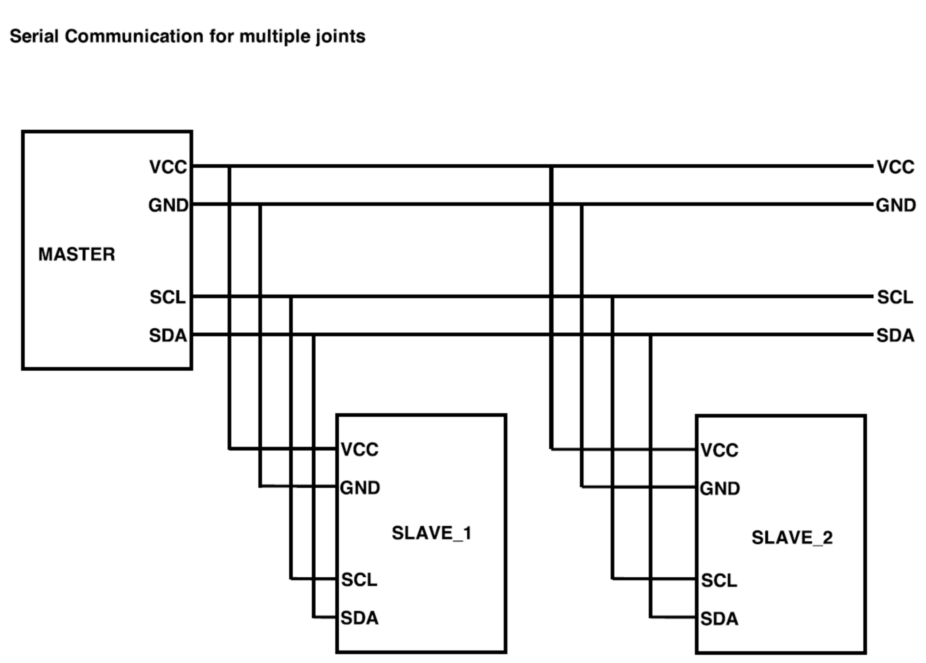
Key System Needs

ID	Need	Description	Reasoning
N 01	Modular Joints	All joints should be able to be used in combination with any other joint(s).	Modularity allows a robot with an arbitrary number of degrees of freedom to be constructed based upon user needs
N 02	Payload	A joint should be able to lift a 1 kg load held at one meter horizontally from the axis of rotation	Without being able to manipulate a payload, a robotic arm would be nearly useless. Defining the payload also defines what applications the arm could be used for
N 08	Cost	The price of materials for each joint should be no more than $150.	This is to keep the cost down for the end users as well as to fit in the market gap.
N 09	Accuracy	Any rotation to a software defined angular position should be within 1% of the full rotation of the joint	Allows arm to move to predictable positions through software commands
N 10	Precision	Any three consecutive rotations to the same software defined angular position should be within 1% of the full rotation of the joint	Allows arm to repeat tasks in a predictable manner
N 11	Maximum Weight	Each joint should not weigh more than 0.5 kg	Motors towards the base of the arm will need to create enough torque to lift the rest of the arm. The lower the weight the lower the necessary torque is.

Electrical Design

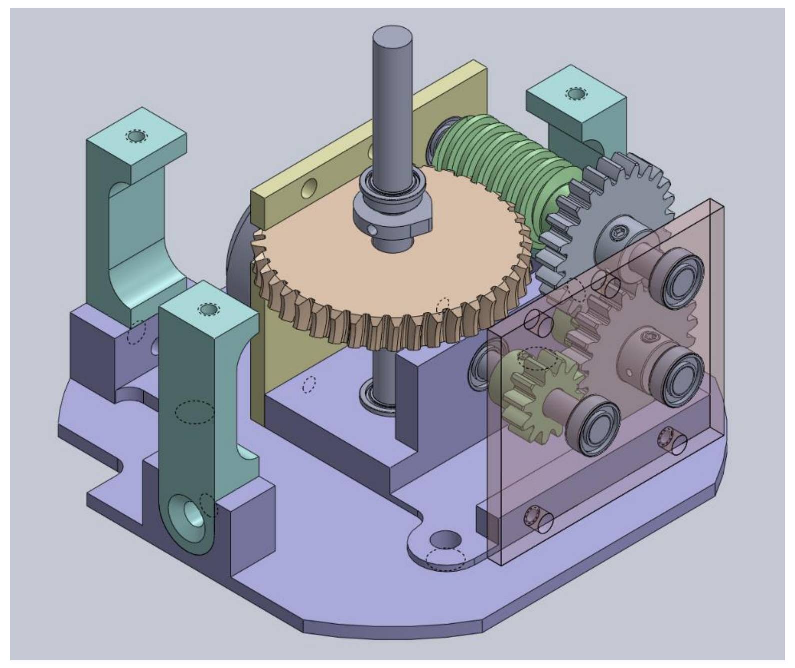


- Design uses a close-loop motor control system for modular robotic joint using an AEAT-6010-A06 10-bits magnetic absolute encoder and limit switch as position feedback
- Uses an RC brushless motor to to achieve high output power with minimum weight
- Arduino Pro Mini board (328 - 5V/16MHz) acts as the control unit for the joint
- Communication between main board and joints uses I2C serial protocol to enable fast data transfer between main controller and multiple joint controllers

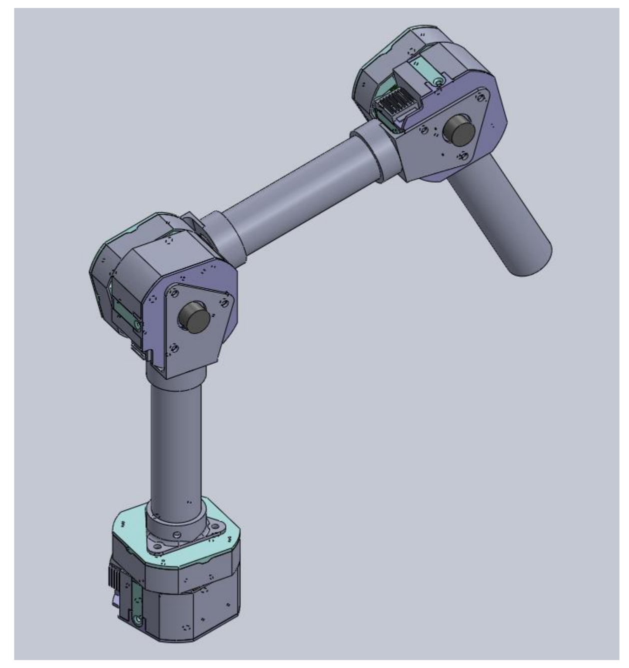


Mechanical Design & Machining

- Adapters are used to achieve different axis of motion from one joint
- Arm segments can be cut from standard SCH80 PVC to create custom length arms
- Worm gear prevents joint from being back driven
- All electronics, hardware and mechanical components are contained within the body of the joint

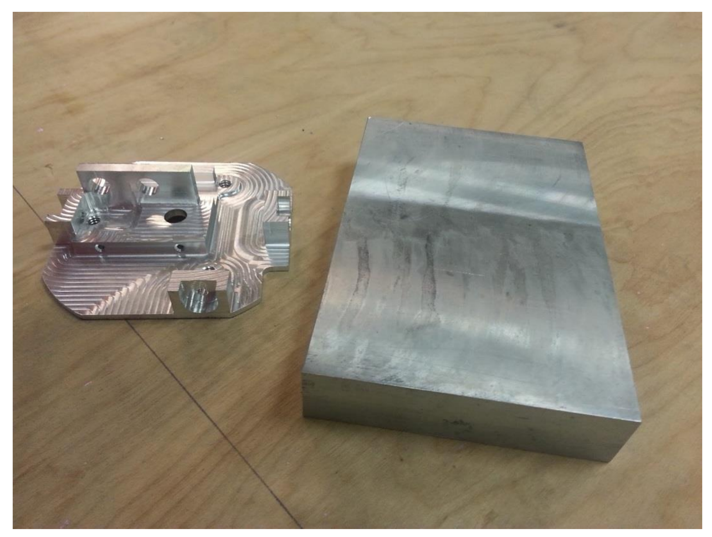


Inner Gear Mechanism



Example of Possible Arm Configuration

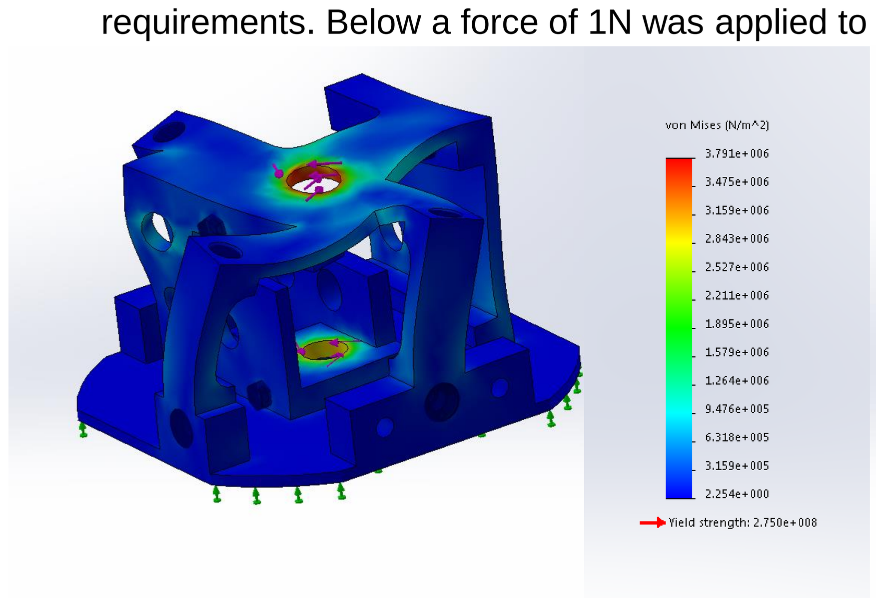
- Structural components were designed to be machined from aluminum
- Outer shell was designed to be 3D printed in order to save weight
- SolidWorks models were imported into Esprit, a program that generates code that runs the Haas MiniMill and VM-2 CNC machines



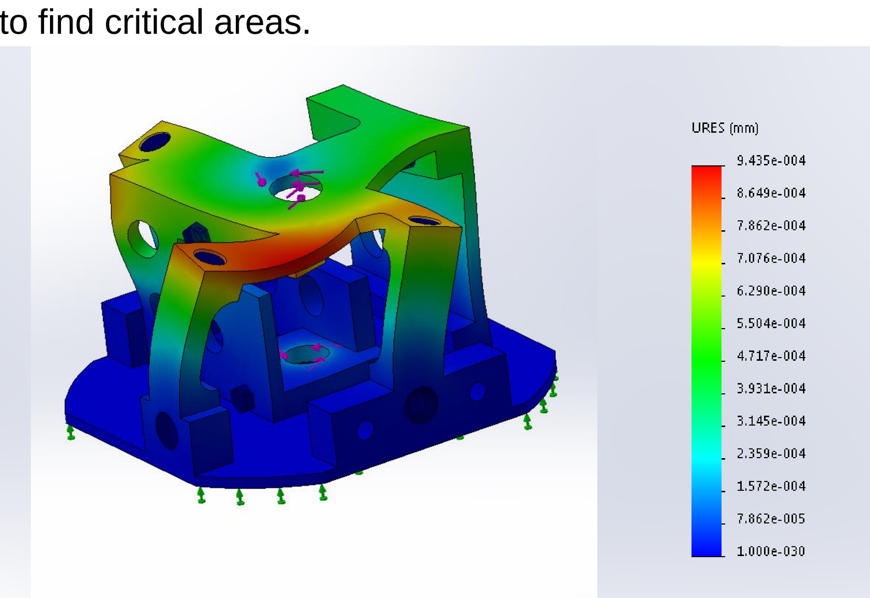
Machined Base Plate and Stock Aluminum

Simulation Analysis

- Stress simulations were run within Solidworks to ensure that designs would meet system requirements. Below a force of 1N was applied to find critical areas.



Stress Simulation

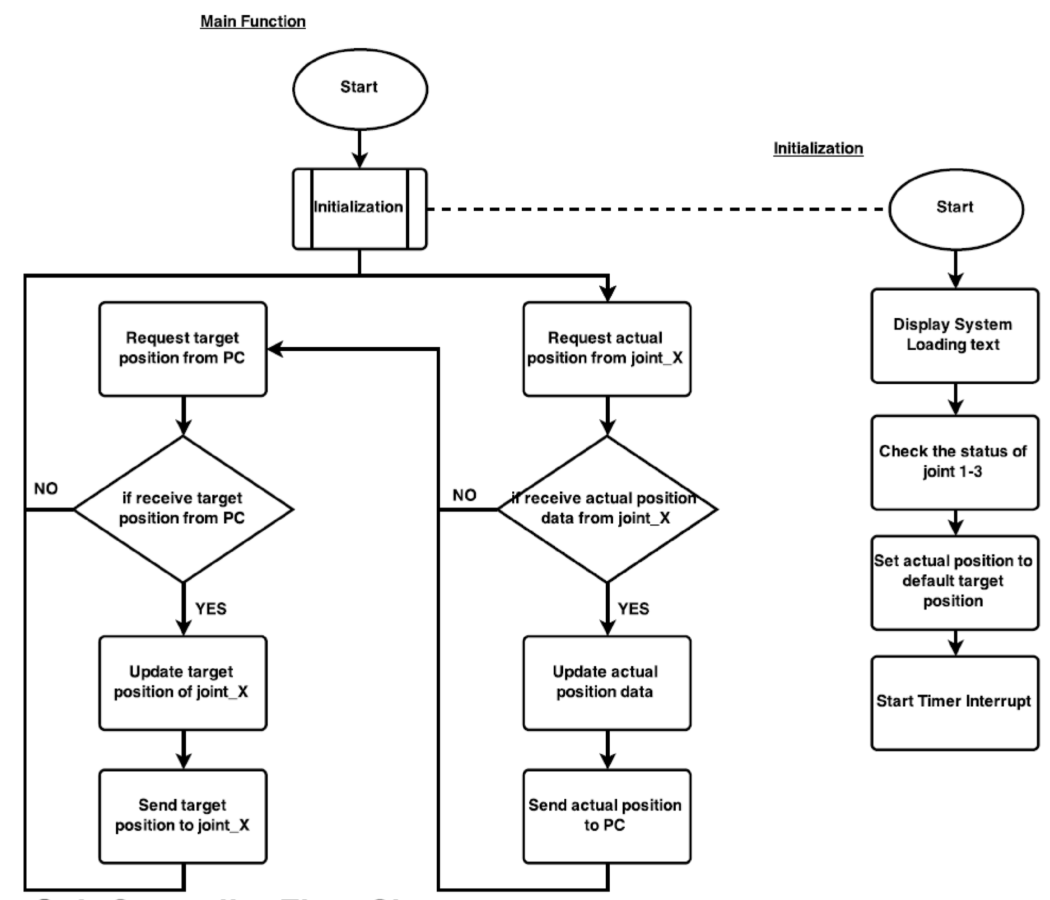


Deflection Simulation

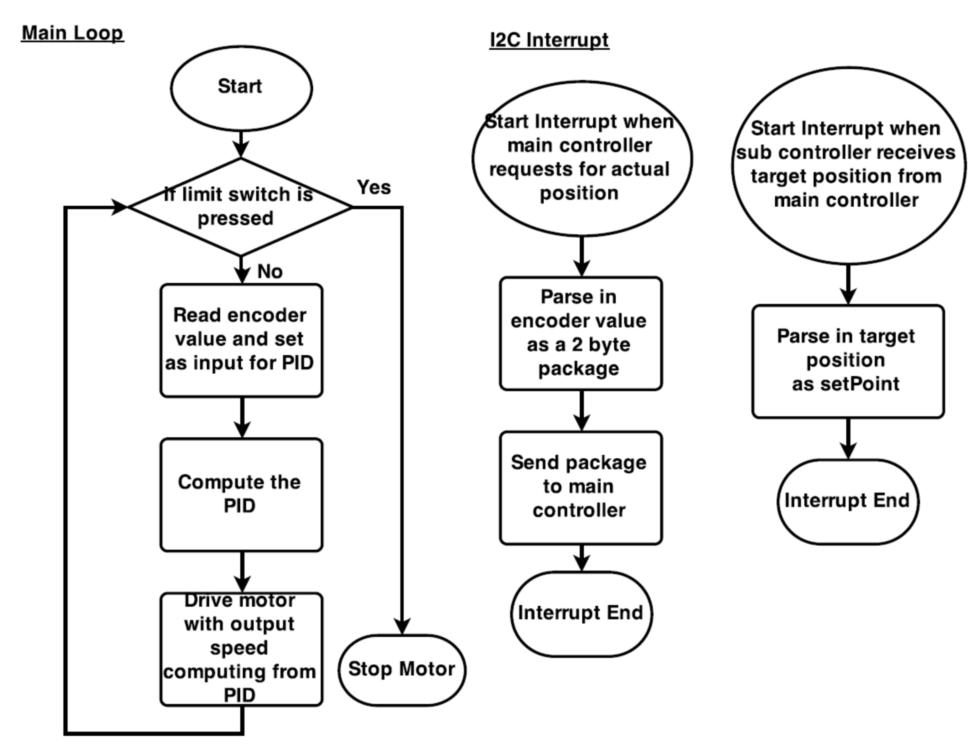
Programming Design

- User is able plug the Arduino Uno board into computer and control the robot arm by sending the target position command.
- The robot is able to automatically rotating and moving to target position

Main Controller Flow Chart



Sub Controller Flow Chart



Summary

Using a systems engineering approach and applying our knowledge gained at WPI, our team was able to design, analyze, build, and program a joint for a modular robotic arm. Beginning with research to discover a market gap, system requirements were agreed upon to create a relatively inexpensive but precise and accurate modular robotic arm. Computer modeling allowed parts to be designed, optimized and simulated to ensure a system which would meet our system requirements.

Acknowledgements

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