Comprehensive Design Review

Team 5: Helping Hand

Team Members: Corey Ruderman, Dan Travis, Jacob Wyner, Joshua Girard

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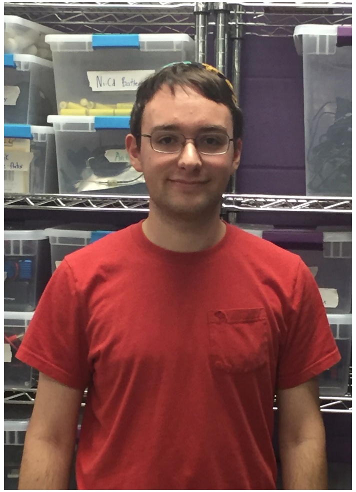
Advisor: Professor Duarte

The Team:



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CSE

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The Problem:

- Robotic arms are used in everything from medical research to construction

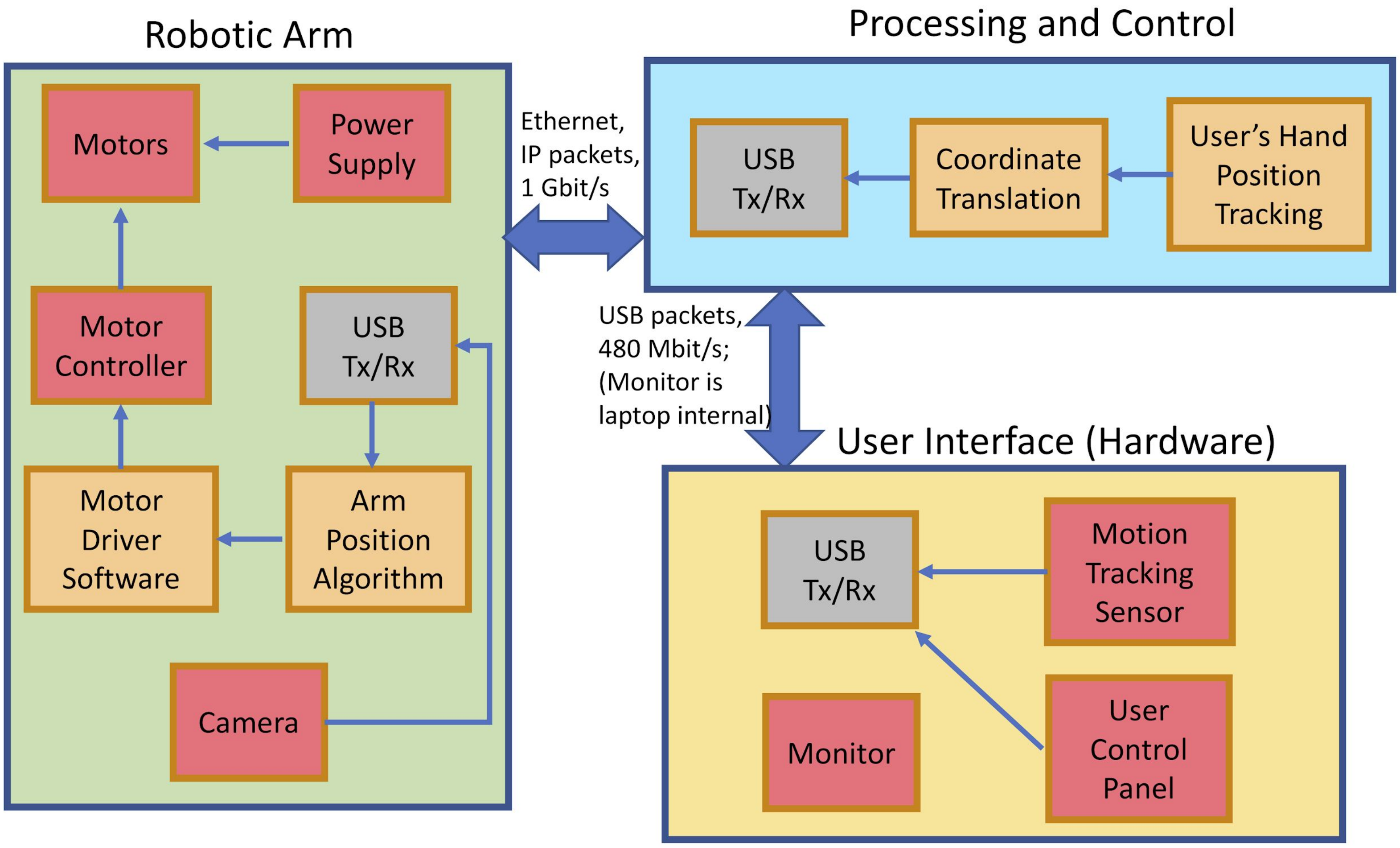
- Remote control of robotic arms is complicated and unintuitive

Arm Requirements and Specifications

- Arm will have a minimum range of motion defined by a rectangular prism 1.5′x1.5′ horizontally and 1′ vertically directly in front of the robot in 4 DOF
- Arm should mimic the user's arm position with <0.25 second latency
- Arm will be able to move at least 5 inches per second in any direction
- Robot will move towards the user's current hand position as fast as possible rather than mimic all movements exactly
- Evaluation metric: Arm will perform the task of moving 5 rocks (approx. size of a ping pong ball) placed randomly within the workspace of the arm into a ~3″ tall bowl of diameter ~8″ within 5 min

User Interface Requirements and Specifications

- Hand tracking -- Intuitive and easy to use
- Fast tracking rate (>20 FPS)
- Accurate tracking (within 1” of actual hand position)
- Adequate range of motion (> 2′x2′x1′ tracking area)
- User Control Board should implement: on/off, emergency stop, pause/resume


Robotic Arm
Processing and Control
User Interface (Hardware)
Motors
Power Supply
Motor Controller
USB Tx/Rx
Motor Driver Software
Arm Position Algorithm
Camera
Ethernet, IP packets, 1 Gbit/s
USB Tx/Rx
Coordinate Translation
User's Hand Position Tracking
USB packets, 480 Mbit/s; (Monitor is laptop internal)
USB Tx/Rx
Motion Tracking Sensor
Monitor
User Control Panel

CDR deliverables

- Integration of base motor into control algorithms to provide positioning in 3DOF
- Integration of gripper into system: Gripper state (open/closed) will be controlled by the user opening and closing their hand
- Implementation of live video feed from arm to user allowing them to use the arm remotely
- Arm will perform task as described in specifications slide within the 5 min timeframe

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Integration of 3rd DOF in Software: Jacob

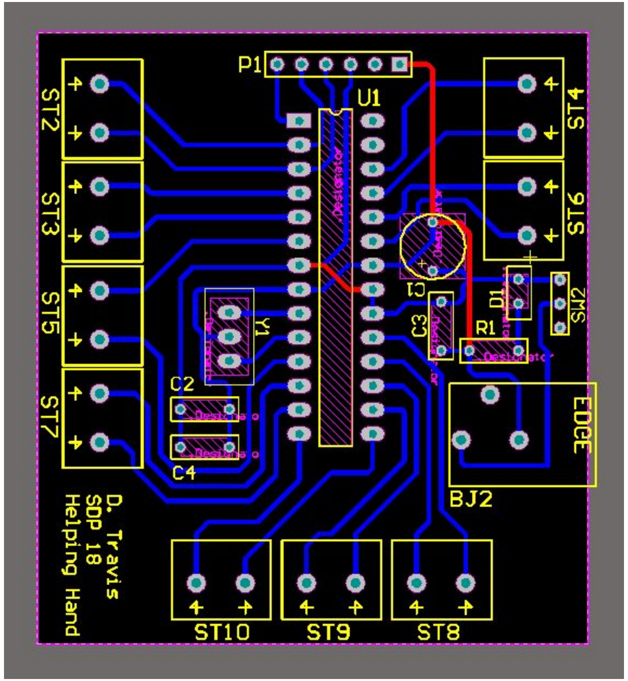
- Inverse kinematics algorithms were altered to incorporate the base rotation
  - Simple trigonometry was used to calculate what angle to set the base
  - Next the x and y values were corrected for the angle of the base and input into the original inverse kinematics equation
- Motor controller algorithm was altered to incorporate the base motor
  - Motor speed was set proportional to the difference between the current position and the goal position
- The stepper motor is controlled using a square wave of varying frequency

Integration of 3rd DOF in Hardware: Dan

- Base motor hardware
  - Stepper motor to control the base rotation
  - Machined an adapter to attach a gearbox to increase torque and lower speed
- Tensioning system
  - Two tracks for the motor to slide into
  - Additional bracket which tensions the chain when screwed from the outside of the box

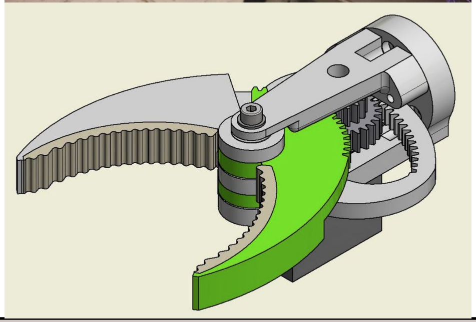
PCB development: Dan

- Designing a board with an ATMEGA328P and several screw terminals
- Two copies of the board will be used throughout the project
- One will interface with the user control board, and the other will interface with the motor control boards
- Planned to cut on Circuit Board Router, but will have to have the board fabricated



Gripper Hardware: Dan

- Open source Mantis Gripper designed by Andreas Hölldorfer
- 3D printed with built in molds to cast silicon claws
- Assembled with ABS printed parts, Vytaflex 30, a servo motor, and several bearings and screws



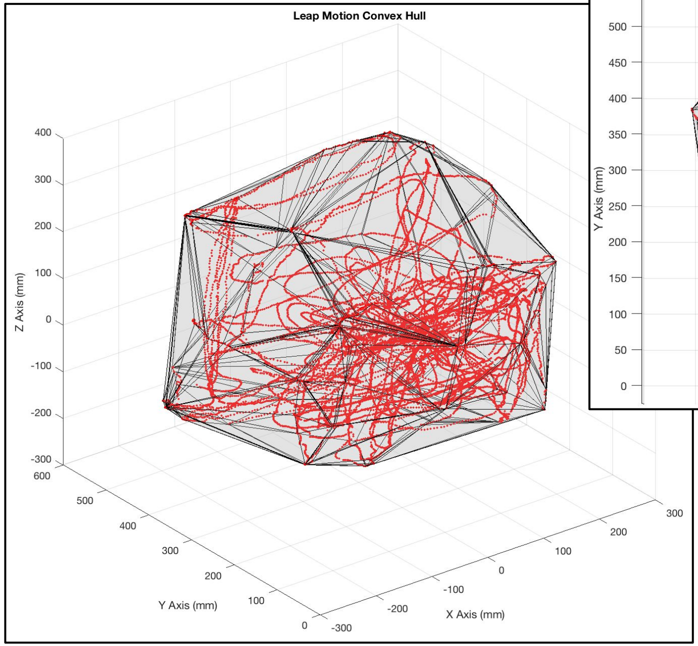
User Control Board: Joshua

- Joshua instead of Dan
- Redesigned User Control Board
- USB connection to user's computer
- Interfaces with the client software
- Features
  - Pause/Resume
  - Potentiometer--either for gripper strength or movement speed or tracking sensitivity
  - Power
  - Emergency Stop

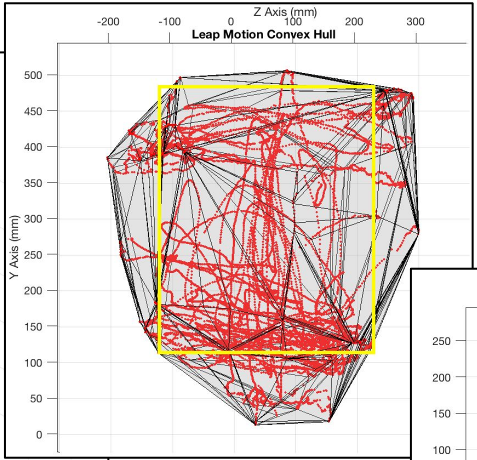
Kinect vs Leap Motion Evaluation: Joshua

- Implemented test software for hand tracking using the Microsoft Kinect 2.0
- Results: Stay with the Leap Motion
  - Kinect does not perform very well for fine motor tracking as it is designed for whole-body tracking
  - Kinect has lots of jitter in tracking accuracy
    - On the order of a few centimeters
    - Leap has almost no jitter
  - Kinect would lose tracking if any part of the arm was occluded

Leap Motion Tracking Volume Analysis: Joshua

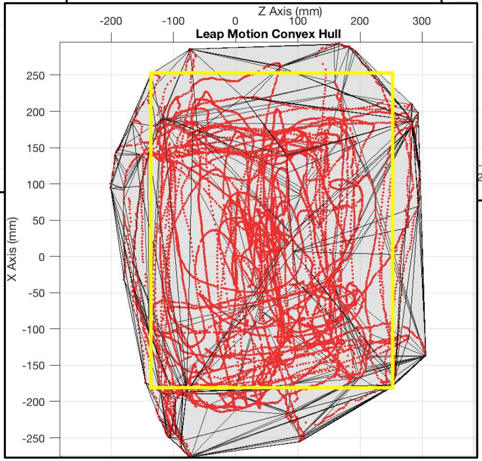


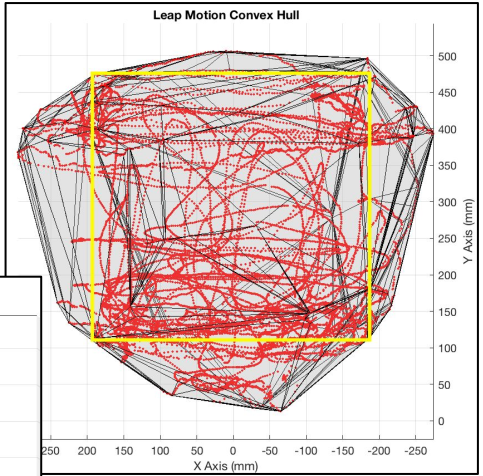
X-Y-Z Axes



Y-Z Axes

X-Z Axes





X-Y Axes

Leap Motion Tracking Volume Analysis: Joshua

- Leap Motion's tracking volume:
  - 430mm x 370mm x 375mm
- Original specification: 2'x1'x2' tracking area
  - ~600mm x 300mm x 600mm
- Falling short in the X and Z dimensions
- A few solutions:
  - Try to implement a second Leap to augment the first
  - Scale the tracking so that smaller hand movements correspond to larger robot movements; ~1.6:1 scaling
  - Accept smaller tracking area if it's sufficiently accurate

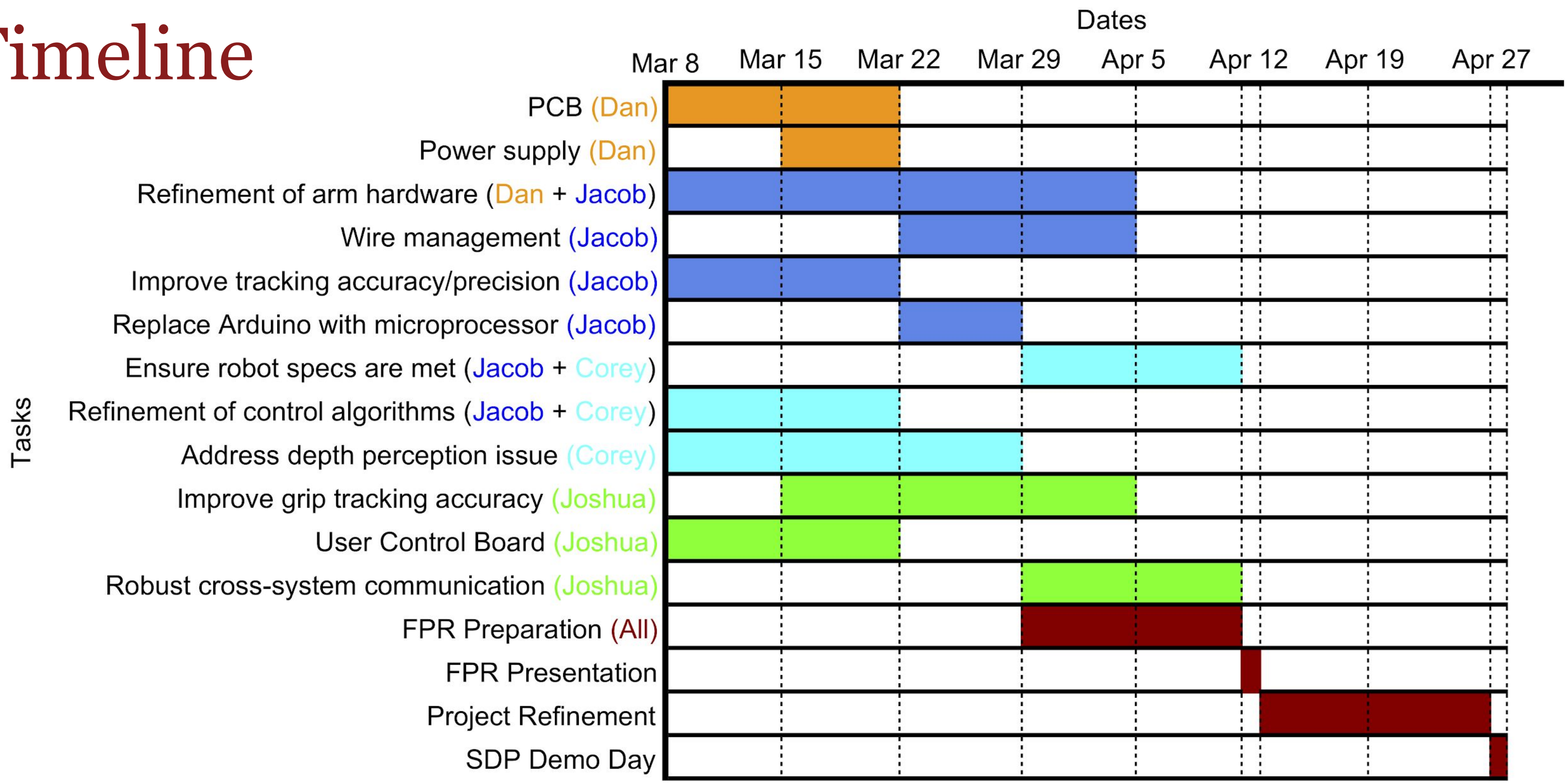
Live Video Implementation: Corey

- Used bidirectional capability of ethernet to stream data over the network
  - 100 Mbps both ways
- Used UDP to read camera stream from Raspberry Pi
  - Specify Raspberry Pi’s ip address and webcam’s port
- Issue: depth perception
  - Solutions:
    - Different camera
    - Additional camera

FPR Goals

- Fully integrate PCB into motor controller circuit (Dan)
- Fully integrate user control board (Joshua)
- Address Leap motion tracking volume issue (Joshua)
- Improve grip tracking accuracy (Joshua)
- Address depth perception issue on video feed (Corey)
- All specs described in slide 4 will be met (Jacob+Corey)
- Improve tracking accuracy/precision (Jacob)
- Wire management (Jacob)

Timeline


Dates
Mar 8
Mar 15
Mar 22
Mar 29
Apr 5
Apr 12
Apr 19
Apr 27
Tasks
PCB (Dan)
Power supply (Dan)
Refinement of arm hardware (Dan + Jacob)
Wire management (Jacob)
Improve tracking accuracy/precision (Jacob)
Replace Arduino with microprocessor (Jacob)
Ensure robot specs are met (Jacob + Corey)
Refinement of control algorithms (Jacob + Corey)
Address depth perception issue (Corey)
Improve grip tracking accuracy (Joshua)
User Control Board (Joshua)
Robust cross-system communication (Joshua)
FPR Preparation (All)
FPR Presentation
Project Refinement
SDP Demo Day

Demo