Mid-year Design Review

Team 5: Helping Hand

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

Advisor: Professor Duarte
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
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System Topology

User Interface

Processing and Control

Robotic Arm
MDR Deliverables

- Arm movement in 3 DOF (base + shoulder + elbow) (Jacob + Dan)
- Arm’s vertical movement controlled by integration of all major systems (All)
- Raw user input data is successfully received and processed (Joshua)
- User control board prototype complete (Dan)
Arm movement in 3 DOF (base + shoulder + elbow) (Jacob + Dan)

Arm’s vertical movement controlled by integration of all major systems (All)

Raw user input data is successfully received and processed (Joshua)

User control board prototype complete (Dan)
Motion Tracking: Joshua

- **Leap Motion Controller sensor**
  - Effective range: 25 to 600 millimeters above the device (1 inch to 2 feet)
  - Field of view: ~150 degrees

- **Mapping of user-space to robot-space coordinates**
  - 1.07 : 1 ratio

- **Tracking speed**
  - ~100 FPS
  - Every 5 samples averaged
  - Transmitting latest coordinates to Raspberry Pi every 50 milliseconds (20x per second)

Design Specification: >20 FPS tracking

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Leap Motion Tracking Area

- **Tracking Area**
  - 2 feet above controller
  - 2 feet wide on each side (150° angle)
  - 2 feet deep on each side (120° angle)

- **Design Specification:**
  - > 2’x2’x1’ tracking area
  - Tracking area of Leap Motion is not a prism so corners are not within the tracked area

- Exploring Kinect tracking in Spring
Intersystem Communication

- Computer to Raspberry Pi
  - Ethernet: 100 Mbps
  - Client Server Model and TCP protocol

- Raspberry Pi to Microcontroller
  - Serial UART: 9600 bps
Arm Electronic Hardware: Jacob

- Raspberry Pi Model 3
  - Connected to Arduino Uno via Serial UART connection
- Atmega328P microcontroller
  - Controls motor controller using PWM signals
- MDD10A NMOS Dual Channel H-bridge
  - Supports 5V-30V
  - Max continuous current: 10A
  - Peak current: 30A
- Feedback sensors feed into 15-pin VGA cable
- Enclosure contains microcontroller, H-bridge, emergency stop
Arm Control Algorithms: Corey and Jacob

- **2 DOF inverse kinematics algorithm**
  - Options: algebraic, iterative, inverse Jacobian
  - We chose to use algebraic method
  - Specific equation is from CS545 at USC

\[
l = \sqrt{x^2 + y^2}
\]
\[
l_2^2 = l_1^2 + l^2 - 2l_1l \cos \gamma
\]
\[
\Rightarrow \gamma = \arccos \left( \frac{l^2 + l_1^2 - l_2^2}{2l_1l} \right)
\]
\[
\frac{y}{x} = \tan \epsilon \quad \Rightarrow \quad \theta_1 = \arctan \frac{y}{x} - \gamma
\]
\[
\theta_2 = \arctan \left( \frac{y - l_1 \sin \theta}{x - l_1 \cos \theta_1} \right) - \theta_1
\]

- **Mapping algorithm**
  - Angle is input, sensor value is output so that arm can move to that point in it’s linear workspace
  - Calibrated using min/max position of arm
Physical Arm Construction: Dan

- Implemented arm design v1:
  - Used 8020 aluminum frame
  - Two linear actuators
  - One DC motor with gearbox
  - Chain drive for base rotation
  - Wooden Enclosure and base
User Control Panel PCB: Dan

- Simple interface to give more control options to the user
- Power On/Off
- Emergency Stop
- Pause and Resume motion of the arm
- Will add additional functionality as needed
- Interfaces with the Raspberry Pi via serial
Proposed: 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
UMassAmherst

Gantt chart

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Demo
Questions