HIPSTER

Autonomous Reaming for Total Hip Replacement (ARTHuR)

Progress Review - 8

Team C: Kaushik Balasundar, Parker Hill, Anthony Kyu, Sundaram Seivur, Gunjan Sethi

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Progress Review #8 Goals & Tests

Goals:

- 3D printed linear actuated design
- Source PCB components
- Implement basic velocity control on real arm
- Basic task-prioritization framework
- UI Wireframe

Tests:

- Test 1
- Test 2

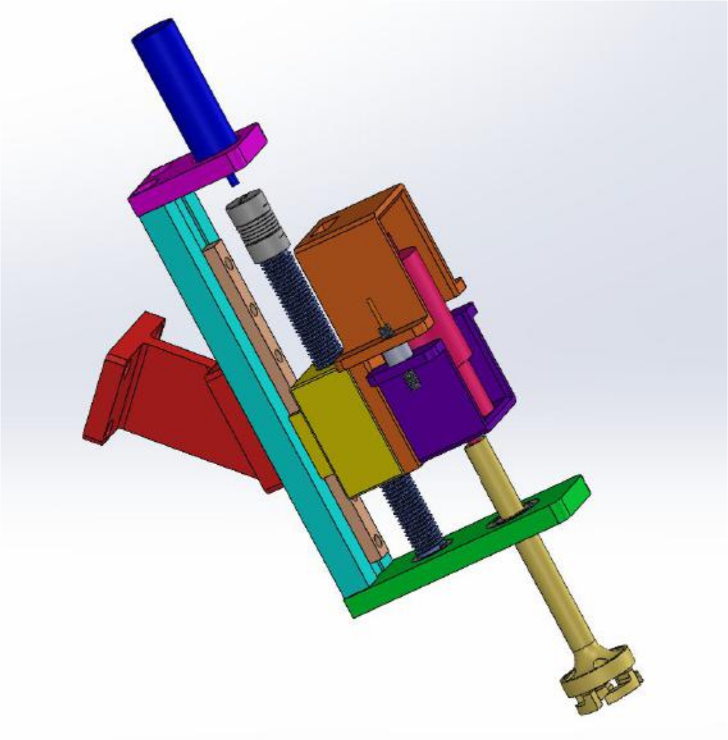
Progress and Challenges

3D Printed End-Effector Design

Objective	
Verify that the 3D-printed linearly actuating end-effector is firmly assembled and can actuate as necessary for the system	
Equipment	Desktop workstation, Robot arm, 3D-printed end-effector, Dial calipers
Elements	Hardware unit: reaming end-effector
Personnel	2 people necessary, one to monitor and evaluate the end-effector, and one to control the motion of the robot arm from ROS
Location	NSH B512
Procedure	
1. Assemble 3D-printed linearly actuated end-effector and verify that all parts are firmly connected 2. Using a dial caliper, measure the distance the reaming motor and reaming handle can travel while actuating the ballscrew by hand 3. Attach the end-effector to the end of the Kinova Gen-3 arm 4. Using admittance mode, move the robot arm through the work area and verify performance and attachment of the end-effector when the arm is at singularity, at joint limits, and when inverted 5. Using dynamic compensation mode, move the pelvis throughout space and verify the end-effector remains rigidly attached and does not exhibit excessive vibrations	
Validation	
1. Ballscrew is capable of actuating reamer motor and reaming handle > 50 millimeters 2. The end-effector remains attached to the arm and is capable of actuating in any position/orientation 3. The end-effector's vibrations are minimal during dynamic compensation	

3D Printed End-Effector Design

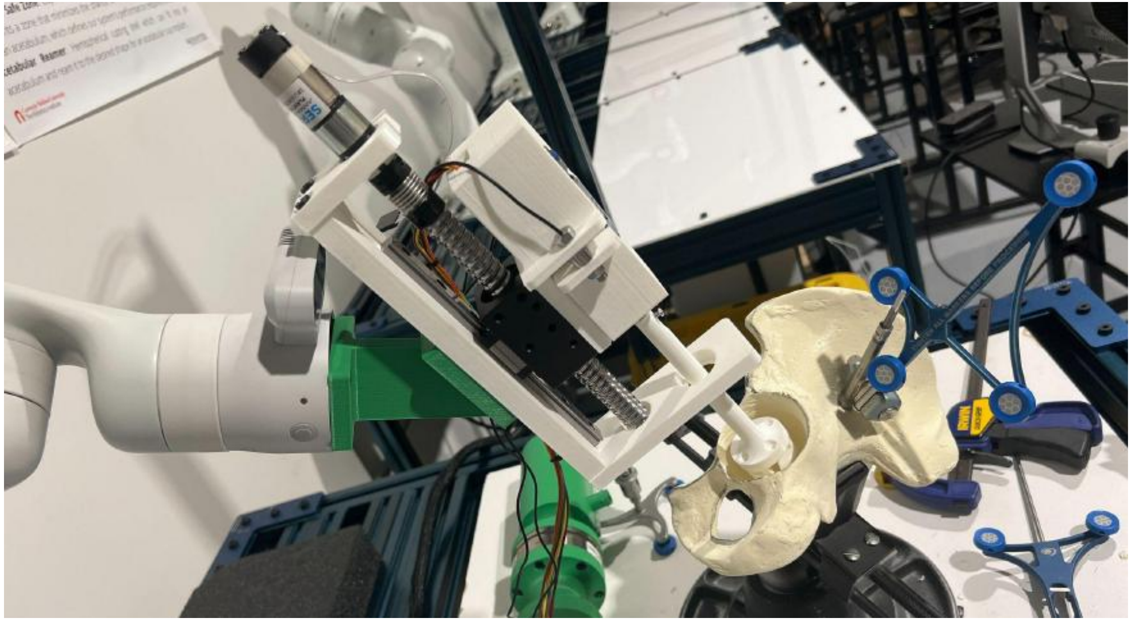
- V1 of end-effector design
- Uses ballscrew + motor as linear actuator for moving assembly
- Force sensing:
  - Can either use ATO force sensors or current sensing
- Need to implement limit switches still
- Also need to design for added marker geometry and covers



Current 3D-Printed Design

Validation Criteria:

- > 50 mm actuation range
- Parts attach to the arm and remain attached
- Vibrations could not be tested as some parts are still loose (no bearings + bad fits)

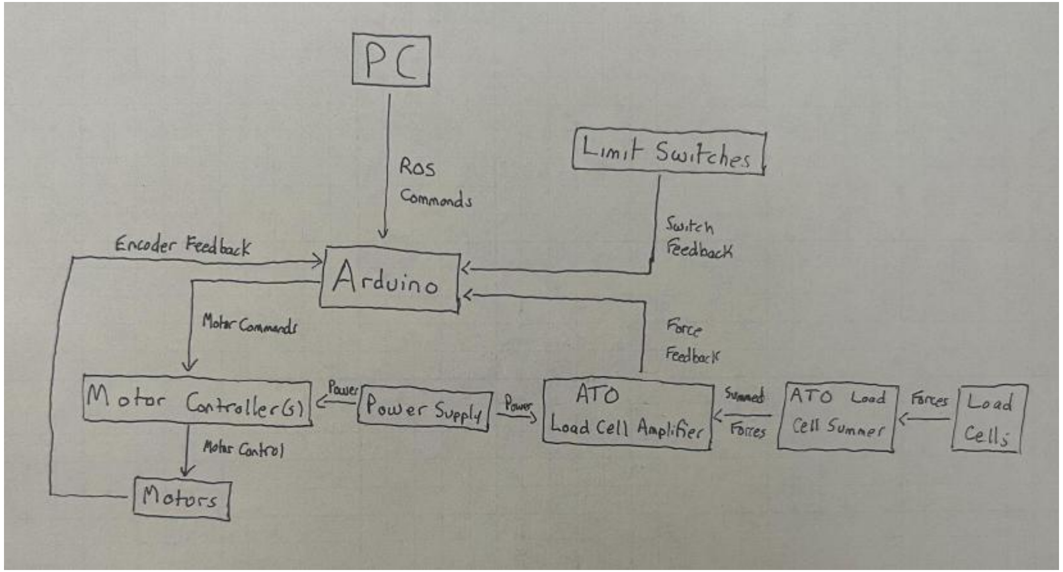


Test 1 Challenges:

- Component dimensions:
  - Linear actuator we bought has weird dimensions that were hard to design around and let to several reprints for improved fits
- Hole sizing:
  - Some mistakes made with hole sizing, leading to necessary reprints
- Difficult to find way to integrate force sensors without them being in line with shaft
- Bearings need to be press-fit into the housing, but don’t want to do that yet as we may need to reprint components in the future

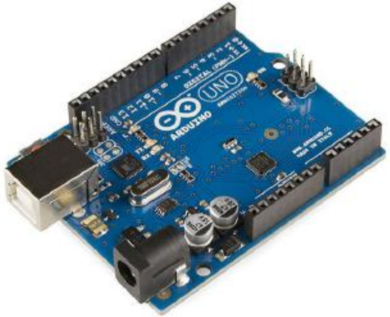
Electrical Subsystem

- Necessary Components:
  - Microcontroller
  - Motor Controller
  - Motors
  - Encoders
  - Force Sensors
    - ATO Load Cells
    - Current Sensing
  - Limit Switches
  - Power Supply



Electrical Subsystem

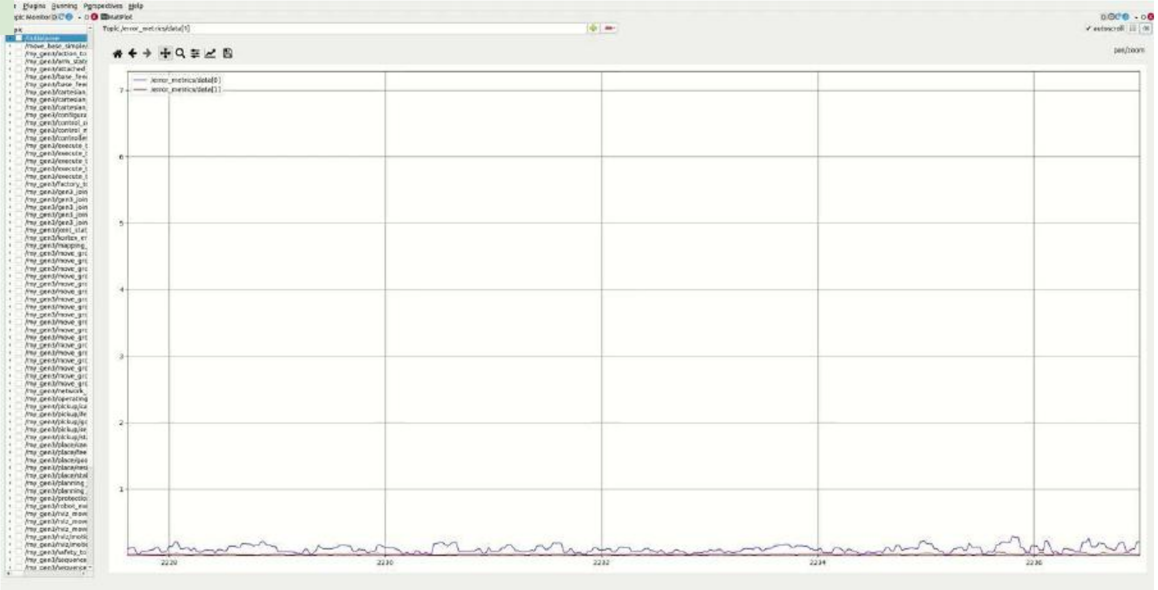
- Already have force sensors, motors + encoders and power supply
- Need a microcontroller, motor controller, and limit switches
- Can use Arduino Uno from inventory as microcontroller
- Can either use a second Cytron microcontroller from inventory (what we're already using) or order a motor shield from Pololu
- Planning on using from inventory for now

Test 2: Basic Tracking Velocity Controller

Objective	
Test the ability of the velocity controller to track a moving frame	
Equipment	Desktop workstation, Robot arm with reaming end effector
Elements	Controls sub-system
Personnel	Two people needed - one to operate and monitor the system, and another to move the pelvis frame.
Location	NSH B512
Procedure	
1. Mount a tracking marker to the Illiac Crest of the pelvis and ensure it is visible to the camera. 2. Perform extrinsic calibration to determine the transformation between the camera and the robot frame. 3. Move the robot arm to its home position. 4. Run the controller script to track the pelvis marker frame with a predetermined offset. 5. Translate and rotate the pelvis within the workspace of the robot to allow the robot arm to track it.	
Validation	
1. The robot arm's velocity controller is able to consistently track the position and orientation of the pelvis marker frame at 40 Hz. 2. The robot arm is able to achieve a position error of < 2mm and an orientation error of <=1.5 degrees when the frame remains stationary.	

Test 2: Results

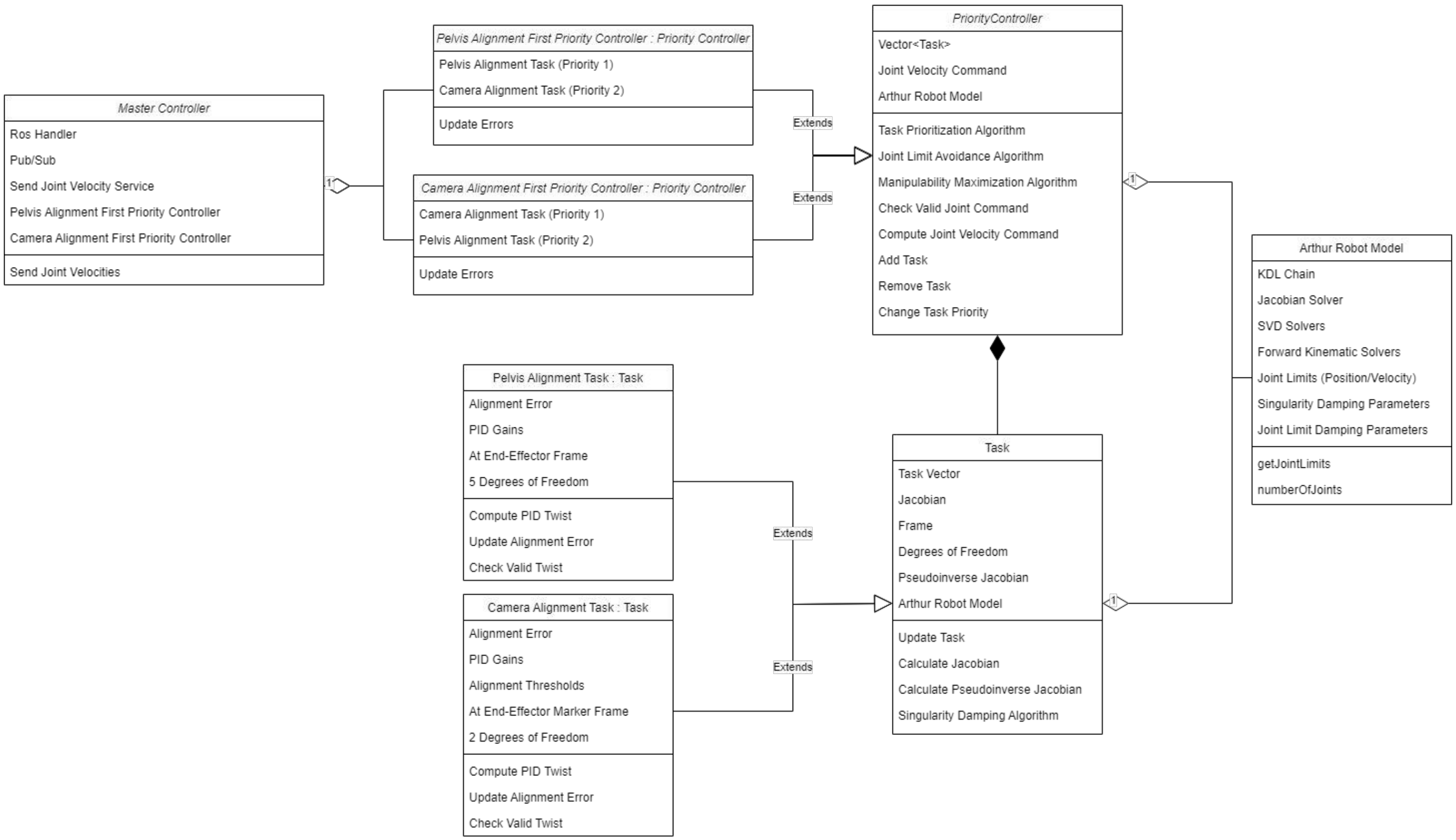


- Position Error < 2 mm
- Orientation Error < 1.5 degrees

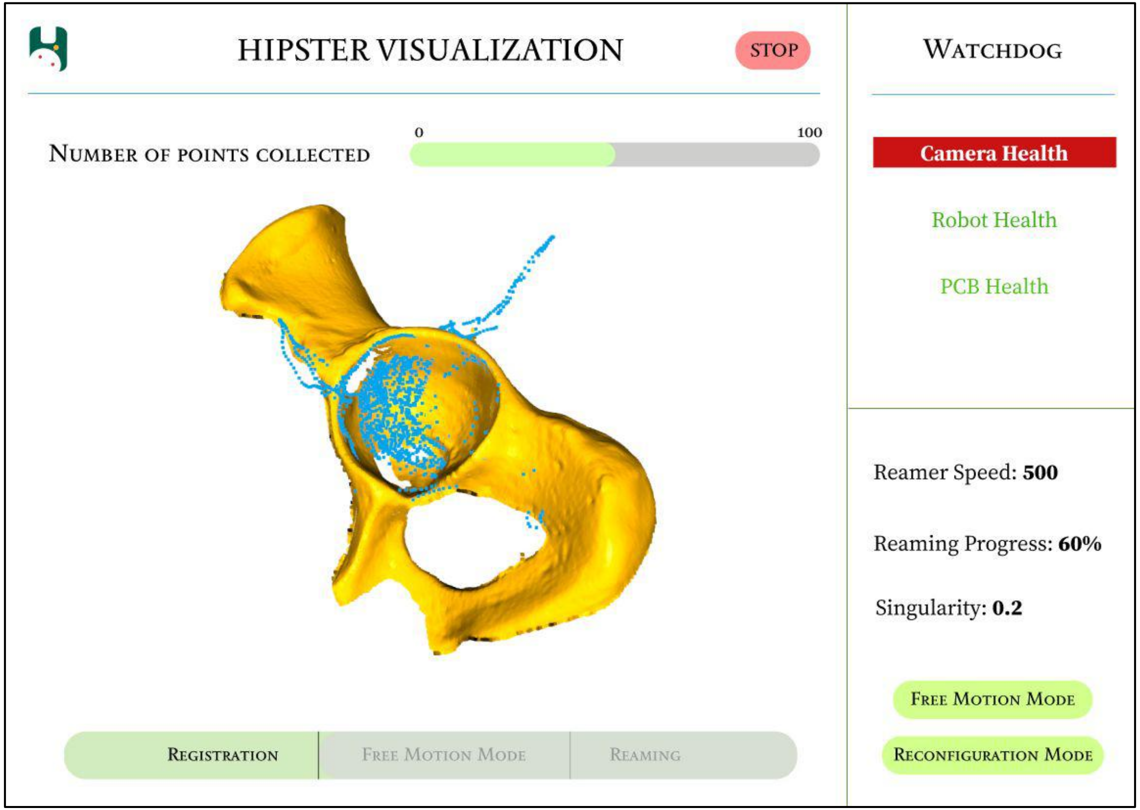
Test 2: Challenges

- 40 Hz bottleneck with Kinova ROS API
- Many tunable parameters in the framework
- Dealing with joint-limits for continuous joints in the code
- Robot arm potentially blocks camera during tracking in the real-world test

Task Prioritization Framework

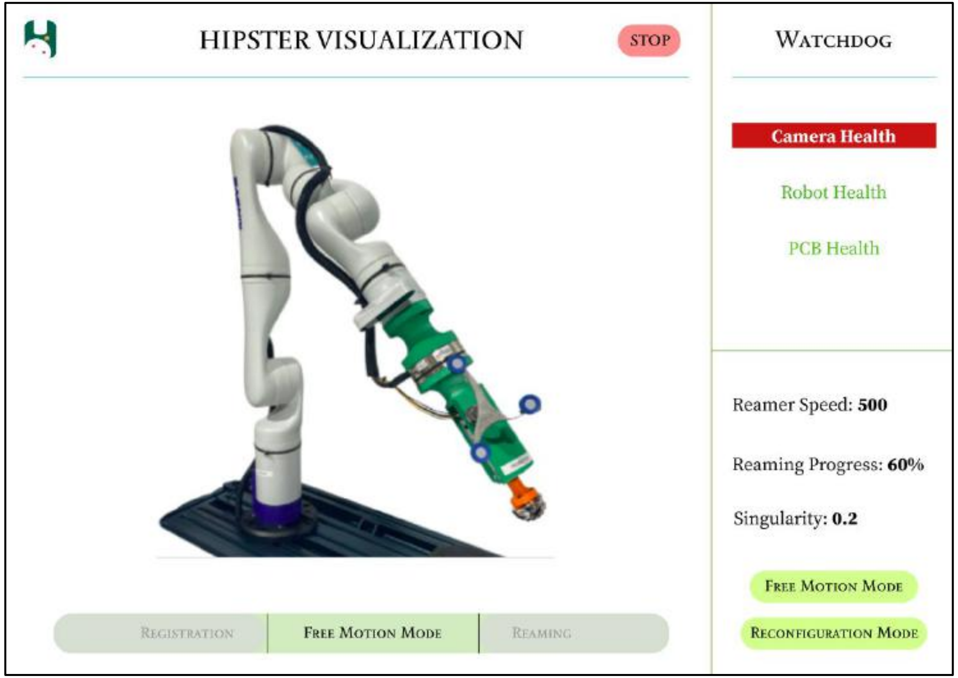


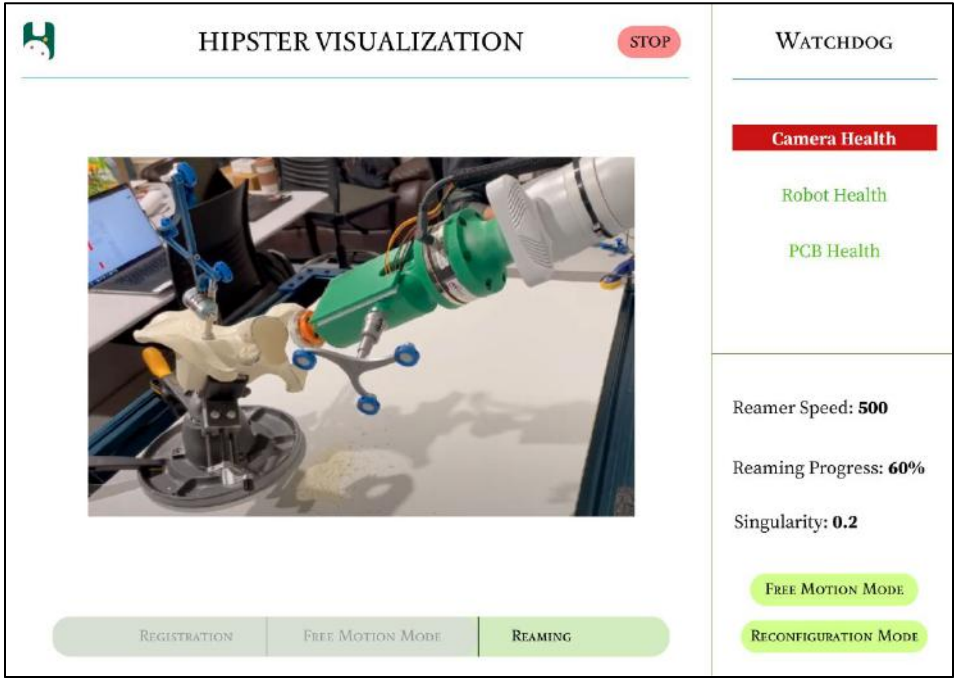
UI Wireframe



- Spoke with Costa to validate industry standards on medical UI screens
- UI wireframe has features for surgeon/user to interact and monitor the system
- Emphasis on simple, intuitive, and neat design
- Finalized Tools
    - RQt [Overall] + Open3D [Registration]

UI Wireframe





**The images will not be camera inputs as shown. They will be RViz/pointcloud viz.

Future Work

Future Work

- Develop WatchDog v1 (Terminal Logger) and UI v1
- Iterate on end-effector design and get integrated with electrical subsystem
- Evaluate use of ballistics gel as a proxy for soft tissue around the pelvis
- Implement task prioritization on simulation and real arm

Thank you!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