

Autonomous Reaming for Total Hip Replacement (ARTHUR)

Progress Review - 10

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Goals & Tests

Goals:

- End effector and electrical subsystem completed
- Task prioritization controller tested on real arm
- Watchdog & UI initially integrated

Tests:

- Test 2: Velocity Controller Tracking Moving Frame
- Test 6: Communicate Cup Implant Pose via UI
- Test 7: Singularity Damping
- Test 8: Joint Limit Avoidance
- Test 9: Task Prioritization
- Test 10: WatchDog+UI
- Test 11: End-Effector Controls ROS Integration

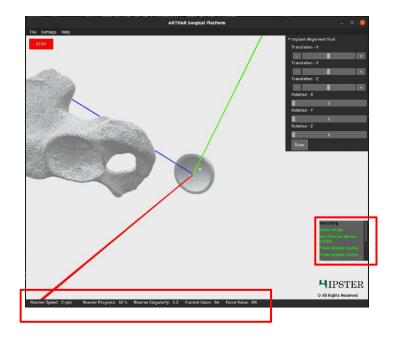


Progress and Challenges

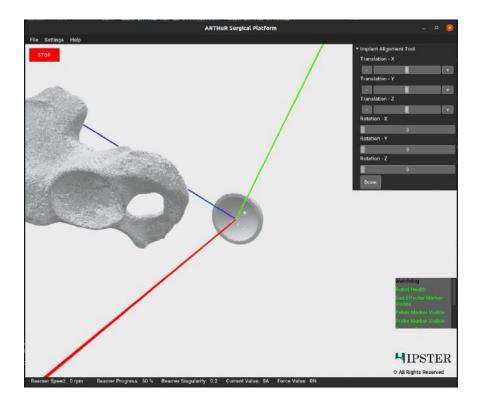
UI Subsystem (Development and Integration)

| Overall Status | Subsystem | Tasks | Development | Integration | Debugging | Tests |
|--------------------------------|-----------|--|-------------|-------------|-----------|-------------------|
| Ongoing Perception and Sensing | | Perform and visualize pointcloud collection | Complete | Complete | Ongoing | |
| | | Select landmark correspondences between pelvis scan and collected pointcloud | Complete | Complete | Ongoing | |
| | | Perform registration and obtain transformation matrix as a result | Ongoing | TODO | Ongoing | |
| TODO | Controls | Align pelvis with implant and obtain transformation matrix | Ongoing | TODO | TODO | Test 6 (PR10) |
| | | Publish reaming endpoint | TODO | TODO | TODO | |
| Ongoing | Watchdog | Display metrics | Complete | Complete | Ongoing | Test 10 (PR10) |
| | | Display camera/robot health | Complete | TODO | Ongoing | |

Progress







UI Subsystem (Challenges)

- Building UI is hard!
- Currently unable to properly handle all event callback threads; leads to latency issues; UI pauses
- Large codebase and debugging sometimes takes hours
- No elegant way of integrating with ROS
 - Subscriber callbacks interfere with UI callbacks
- Should have started with implant alignment and perfected it
 - Not too late though!
- Fallback plan: only have well-test implant alignment tool + watchdog display



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| Issue | ~ | |
| Mouse middle button causes UI to crash | | |
| Inexistant points selected during landmark selection | | |
| Unable to get index of selected landmark from pointcloud | | |
| Move mouse to update metrics/collected pointcloud – updates only wh mouse events are triggered | en | |
| segfaults during pointcloud collection, handle number of points collect | ed | |
| collected pointclouds don't appear in the correct position | | |

Test 11: End-Effector Controls

| Objective | | | | |
|---|--|--|--|--|
| specified end-point, | nanufactured end-effector is capable of receiving a command to start reaming to a reams to that end-point while maintaining a consistent RPM and not exceeding force rts important values to a ROS topic throughout the procedure | | | |
| Equipment | Desktop workstation, robot arm, end-effector, electrical subsystem | | | |
| Elements | Entire hardware subsystem | | | |
| Personnel | 2 people necessary, one person at the workstation to observe the data being received by certain ROS topics, and one person to observe the arm | | | |
| Location | NSH B512 | | | |
| Procedure | | | | |
| dynamically and rea 3. Click to begin real 4. Once the reaming 5. After contact is m 6. Verify that the rea 7. Using the stop bu actuating as soon as 8. Restarting the pro moves along the axi | cal procedure for the fall validation demonstration, set up the arm to track the pelvis m to a specified end-point ming on the user interface and verify that the ballscrew motor begins actuating head makes contact, verify that an axial force is reported in the user interface ade, verify that the reaming motor turns on and maintains a consistent rpm ming operation is not impeded when the arm dynamically compensates for motion it into the user interface, verify that the reaming motor and ballscrew motor both stop is the stop is pressed cedure from the beginning, verify the stability of the end-effector as the reamer head is of the pelvis and that the force threshold is not exceeded I-effector reams to the endpoint and the resulting pelvis matches the surgical plan | | | |
| , and a distribution | | | | |
| Ballscrew motor is Reamer velocity of The axial force ap force threshold Motors stop in the | capable of being turned on and off by ROS autonomously s capable of being turned on and off by ROS autonomously an be monitored via the user interface and remains controlled to a set velocity plied to the pelvis can be monitored via the user interface and does not exceed the set end-effector in less than 500 ms from when a stop command is sent sation does not effect the end-effectors ability to ream the pelvis | | | |

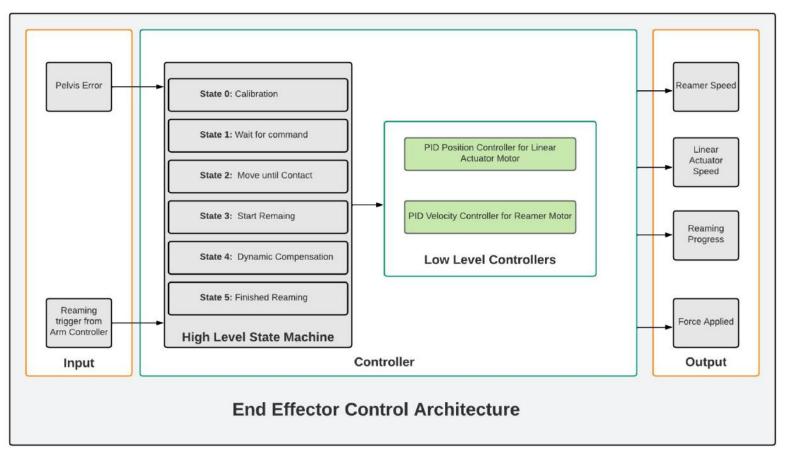
Completed:

- Motors can both be turned on and off
- Velocity can be monitored in UI
- Current sensor calibrated
- Current can be monitored in UI
- Limit switches can limit motion of system
- State machine developed

To Do:

- Correlate current to force
- Finalize state machine controls and integrate with full system

End Effector Controls Architecture

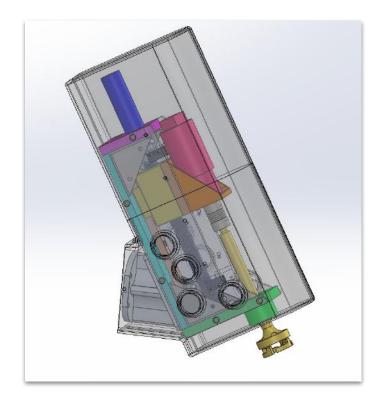


End-Effector Controls Challenges

- Messy code
 - Our current code is based on the previous PID Velocity control we developed last semester, which worked well for what we needed then but has made our current code bulky and inefficient
 - Need to refactor
- Reaming motor recently had the wires pulled off of it
 - Required some janky soldering to the bottom of a hard to reach PCB
 - \circ \quad Ordered new replacement motors and have to implement into system



End-Effector Updates



Completed:

- Finalized manufactured end-effector design and began printing it
- Ordered parts off Xometry

To Do:

- Change reamer handle geometry
- Redesign cover + marker geometries



Controls: Singularity Damping on Real Arm

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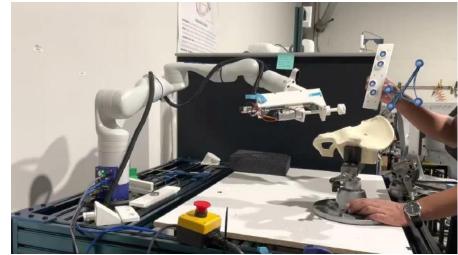
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Controls: Collision Detection



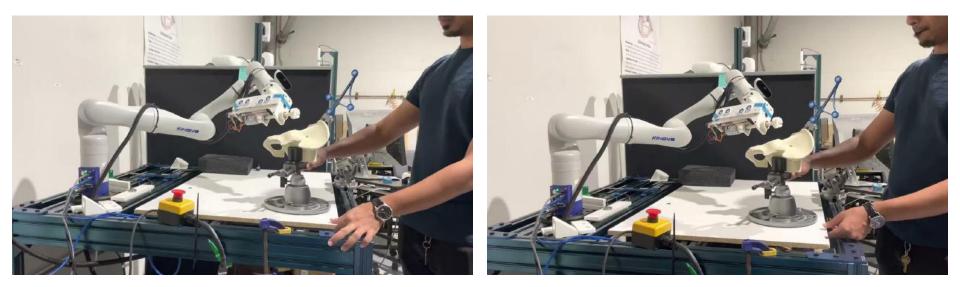


Controls: Task Prioritization on Real Arm

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| network_topic operating_mode_topic | | | | | |
| pickup/cancel | | | | | |
| pickup/feedback | 0 | | | | |
| pickup/goal | | | | | |
| pickup/result | | | | | |
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| place/cancel place/feedback | | | | | |
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| | -5 | | | | |
| lace/status | 1151 | | | | |
| lanning_scene lanning_scene_world | | | | | |
| protection zone topic | - 2594 | 2596 | 2598 | 2600 | 2602 |
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Watchdog + Controls





Future Work



Future Work

- UI Development: Implant alignment/Controls -> Watchdog -> Perception
- End-Effector: Finalize controls and integration with ROS, assemble final manufactured end-effector
- Controls: Integrate End-Effector Controls with Arm Controls and Online Calibration
- RECOVER (it's been a long two weeks)

