HIPSTER

Autonomous **R**eaming for **T**otal **H**ip **R**eplacement **(ARTHuR)**

Progress Review - 11

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Goals & Tests

Goals:

- Manufactured End-Effector Integrated with ROS
- System Integrated and Tested

Tests:

- Test 11: Fully Manufactured End-Effector Integrated

Progress and Challenges

Test 11: End-Effector Controls

Objective	
Verify that the fully-manufactured end-effector is capable of receiving a command to start reaming to a specified end-point, reams to that end-point while maintaining a consistent RPM and not exceeding force thresholds, and reports 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	
1. Verify that the end-effector is connected firmly to the Kinova Gen-3 arm, and that all wires connecting the electrical subsystem to the end-effector are properly connected 2. Following the typical procedure for the fall validation demonstration, set up the arm to track the pelvis dynamically and ream to a specified end-point 3. Click to begin reaming on the user interface and verify that the ballscrew motor begins actuating 4. Once the reaming head makes contact, verify that an axial force is reported in the user interface 5. After contact is made, verify that the reaming motor turns on and maintains a consistent rpm 6. Verify that the reaming operation is not impeded when the arm dynamically compensates for motion 7. Using the stop built into the user interface, verify that the reaming motor and ballscrew motor both stop actuating as soon as the stop is pressed 8. Restarting the procedure from the beginning, verify the stability of the end-effector as the reamer head moves along the axis of the pelvis and that the force threshold is not exceeded 9. Verify that the end-effector reams to the endpoint and the resulting pelvis matches the surgical plan	
Validation	
1. Reaming motor is capable of being turned on and off by ROS autonomously 2. Ballscrew motor is capable of being turned on and off by ROS autonomously 3. Reamer velocity can be monitored via the user interface and remains controlled to a set velocity 4. The axial force applied to the pelvis can be monitored via the user interface and does not exceed the set force threshold 5. Motors stop in the end-effector in less than 500 ms from when a stop command is sent 6. Dynamic compensation does not effect the end-effectors ability to ream the pelvis	

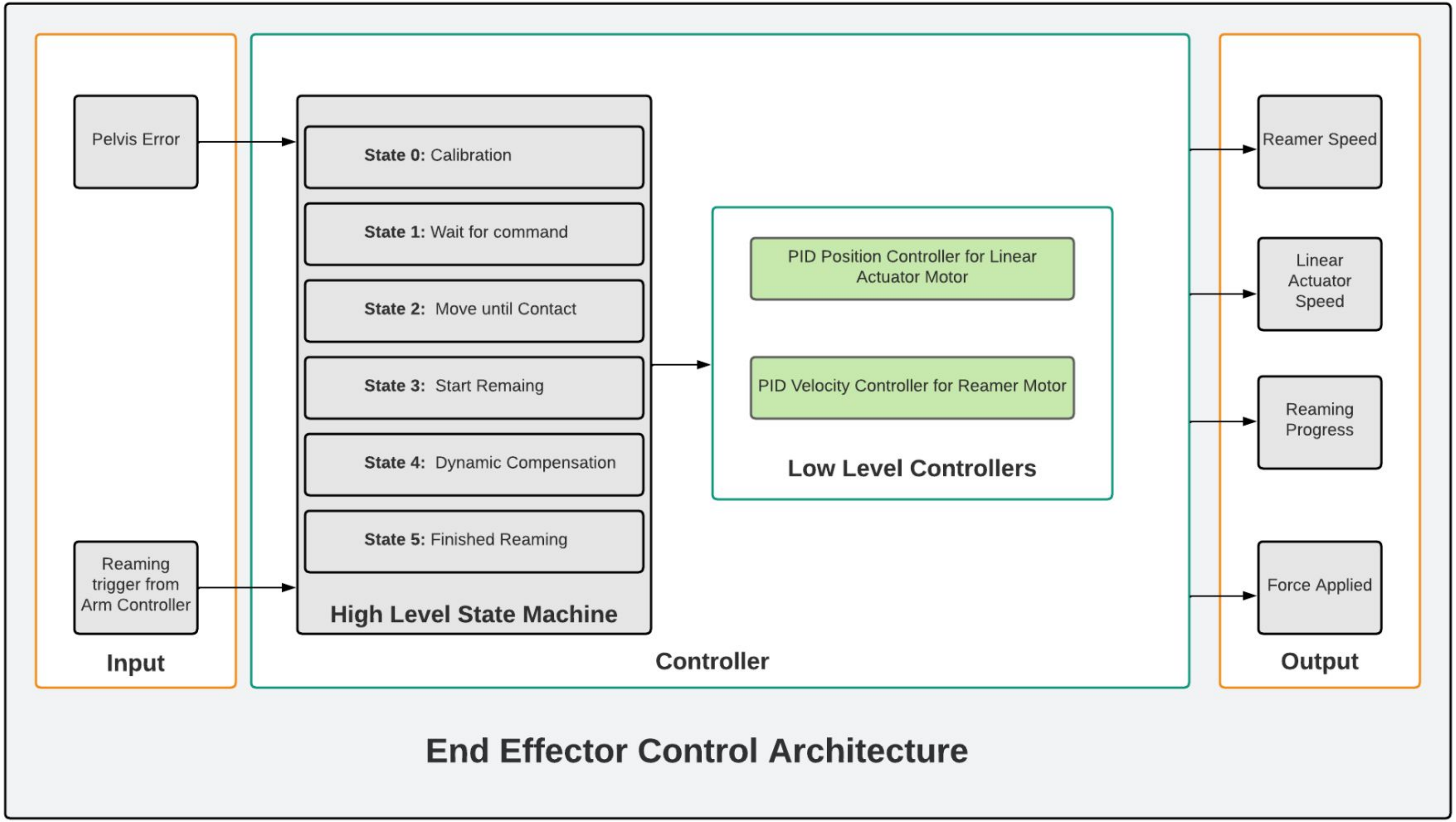
Completed:

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

Overview:

- ROS sends command to reaming end-effector to start reaming
- End-effector moves separately from ROS, only adjusting when the arm dynamically compensates
- Linear actuator motor velocity controlled by axial force

End Effector Controls Architecture



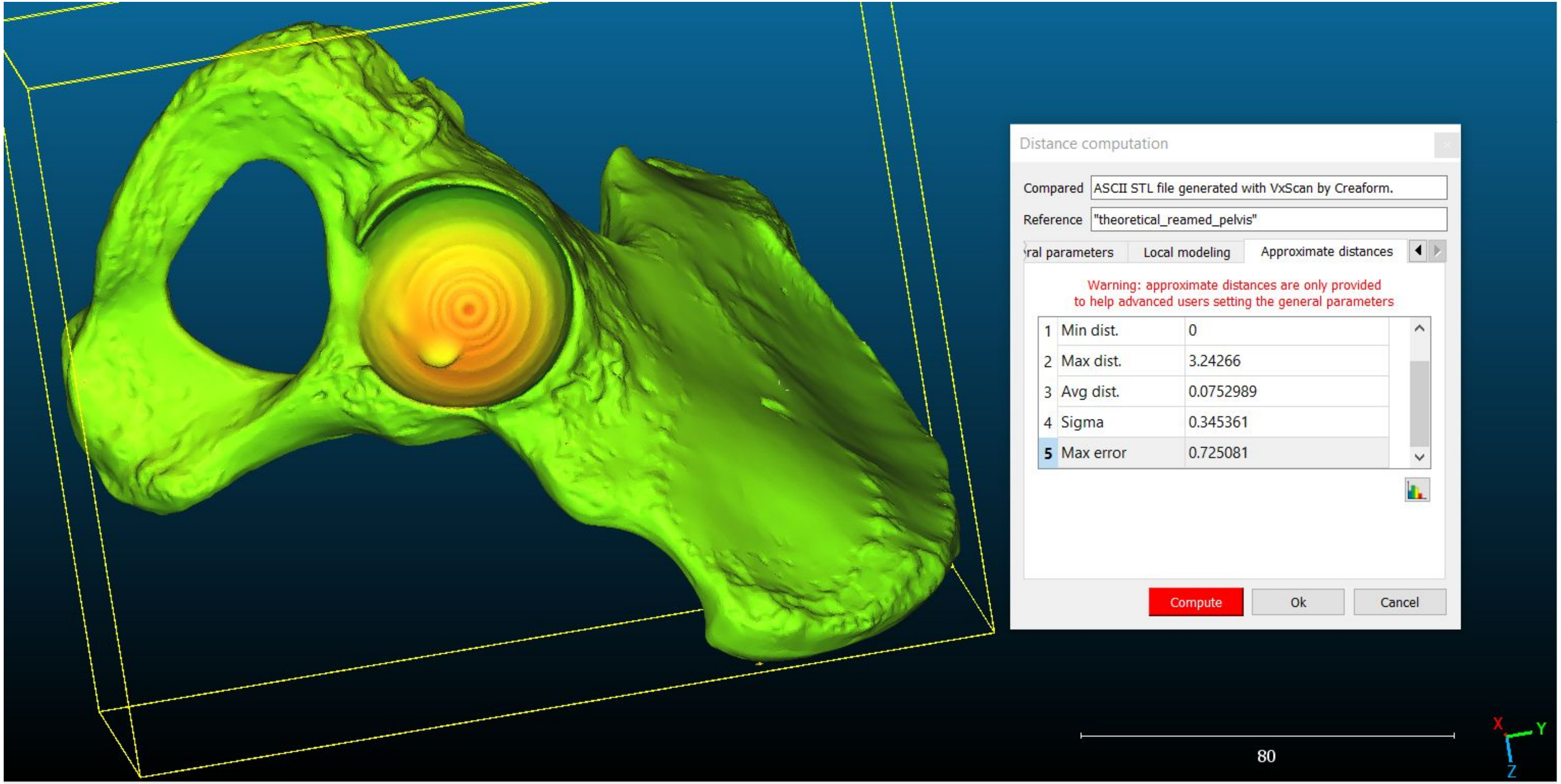
End-Effector Controls Challenges

- Cytron MD10C over-current protection
  - When reaming motor was stalled, the MD10C would cut off all current to the motor, such that even when the stalling object was removed the motor would not rotate
  - Initially believed to be an issue with the power supply until we validated that it was not by connecting the power supply directly to the motor
  - Fixed by changing to an MD30C which has a higher current capacity (hopefully the spike in current will not cause the same issue)
- Reaming motor torque too low
  - We initially chose a 600 rpm reaming motor as we believed our reaming speed needed to be near ~500 rpm, however this assumption was proven incorrect as ~300 rpm is valid for reaming, and the motors torque ended up being too little
  - Decided to order a 300 rpm version of the same motor (2 times higher torque) and found a replacement in inventory as well
- PID Gains and Current Sensing
  - Took a while to tweak our PID controls based on the current being sensed, current spikes near beginning of reaming necessitated changes in our logic in the state machine

Integration Challenges

- URDF + Perception + Reaming Head Misalignment
  - Stack up of tolerances and misalignments was hard to parse
- Watchdog publishing too fast
  - Led to the end-effector controls getting blocked
- ARM GO SMASH (on table)
  - Had the pelvis frame reversed (led to the arm trying to reach a highly incorrect orientation)
- Linear actuator motor too strong
  - Force control would not work with this as current is too narrow of a range to work with
- Cover printing taking a while
  - Blue filament is not very happy with us
- Transformation Matrices
  - Transformations for reaming end-point were not behaving as expected

FVD Metric


Distance computation
Compared
ASCII STL file generated with VxScan by Creaform.
Reference
"theoretical_reamed_pelvis"
ral parameters
Local modeling
Approximate distances
Warning: approximate distances are only provided
to help advanced users setting the general parameters
1 Min dist. 0
2 Max dist. 3.24266
3 Avg dist. 0.0752989
4 Sigma 0.345361
5 Max error 0.725081
Compute
Ok
Cancel
80
X
Y
Z

Now for a dress rehearsal of the entire system!

Thank you!