HIPSTER

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

Progress Review - 9

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Goals & Tests

Goals:

- Develop first version of User Interface
- Develop functioning watchdog data logger to display system-critical information
- Integrate end-effector with the electrical sub-system
- Evaluate reaming end-effector performance based on actual reaming
- Evaluate the efficacy of using ballistics gel as a proxy for soft-tissue around the pelvis
- Begin sending out quotes for end-effector manufacturing

Tests:

- Test 3: Watchdog logger test
- Test 4: Electrical sub-system integration test
- Test 5: Ballistics gel validation test

Progress and Challenges

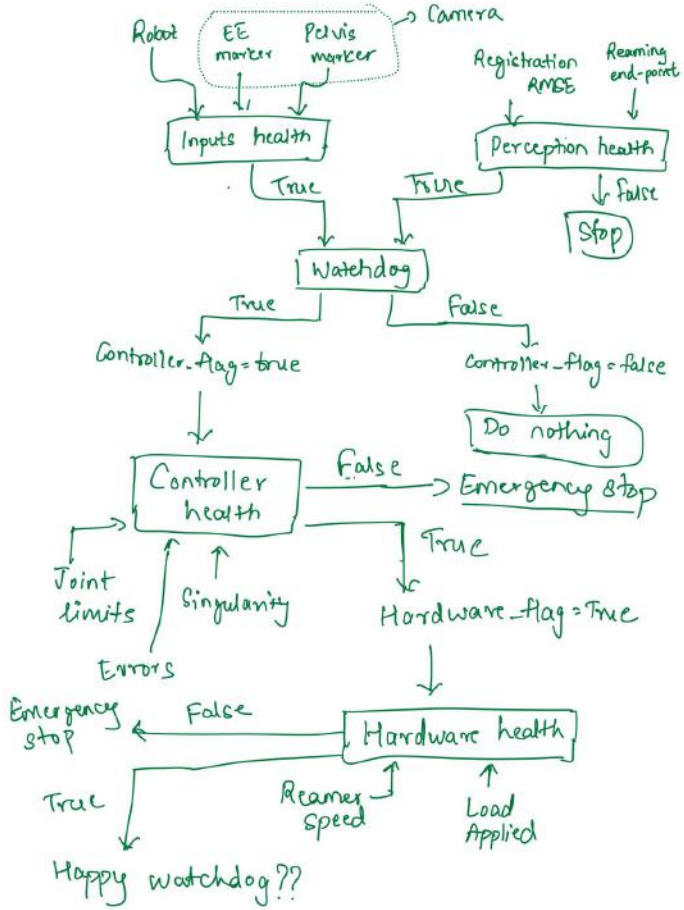
Test 3: Watchdog Logger Test

Objective	
Test functioning of the first version of the watchdog, the terminal logger.	
Equipment	Desktop workstation, robot arm
Elements	Software
Personnel	2 people necessary; 1 person checking all the logs on the workstation and another person to manipulate the arm, hit e-stop etc.
Location	NSH B512
Procedure	
1. Turn on the Gen3 arm, the Atracsys camera, and the electrical subsystem for the end-effector. 2. Launch the watchdog node on the workstation to start logging the critical features of the system on the terminal. 3. Launch the perception node and check if the watchdog is recieving data from the camera about the pose of the end-effector marker, pelvis marker, and registration probe. 4. If perception subsystem health is ok, watchdog will send a signal to controller node to initiate reaming alignment. 5. Send command to end-effector from watchdog to start reaming process after reaming alignment is completed. 6. Check if reamer speed and load cell force is logged on the terminal during reaming.	
Validation	
1. Watchdog is able to communicate with all the subsystems. 2. Watchdog acts as a filter between subsystems to monitor communication and identify any malfunctions. 3. Watchdog is able to log all the critical information on the terminal for user/surgeon to evaluate.	

Test 3: Watchdog Logger Test

Deliverables:

1. Create to watchdog node with ROSCPP
2. Check camera health by validating data stream through topic
3. Check registration RMSE error
4. Check joint limits, singularity, and alignment error from controls subsystem
5. Log all health parameters as text/boolean on the terminal
6. Check reamer speed and load applied from hardware subsystem



Test 3:

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rmse_error: True
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mrsd-team-c@hipster-mrsd:~/arthur_ws$ rostopic list
/controller_flag
/end_effector_pose
/initial_reaming_point
/input_health
/pelvis_error
/pelvis_pose
/percep_rmse
/perception_health
/probe_pose
/reaming_end_point
/rosout
/rosout_agg
/tf
/tf_static
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End-effector not visible
End-effector not visible
End-effector not visible
End-effector not visible
End-effector not visible
[ INFO] [1665600172.527141385]: Pelvis marker is visible

End-effector not visible
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[ INFO] [1665600172.545164140]: Pelvis marker is visible
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Test 3 Challenges:

- CMake compilation issues with multiple subsystems
- Integration still in progress as subsystems are still under development
- Code structure and modularity
- Rigorous testing and validation of watchdog performance
  - Identifying edge case where any system could fail
- Coming up with the decision tree for how information should flow between subsystems

Test 4: Electrical Sub-System Integration

Deliverables:

1. Reamer motor can be turned on and off
2. Ball-screw motor can be turned on and off
3. PID Velocity control
4. Commands can be sent and received via ROS
5. Limit switches functional
6. Limit switch turns off both motor when upper/lower limit is reached

Objective	
Verify that the end-effector is properly integrated with the electrical system and capable of reporting the axial force applied to the pelvis and the rotational velocity of the reamer to a ROS topic	
Equipment	Desktop workstation, robot arm, end-effector, electrical subsystem
Elements	Hardware subsystem: need all elements that allow end-effector to properly function
Personnel	2 people necessary, one person at the workstation to observe the data being received by certain ROS topics, and one person to manipulate the arm and end-effector
Location	NSH B512
Procedure	
1. Attach the end-effector to the end of the Kinova Gen-3 arm 2. Connect all wires from the end-effector to the electrical subsystem 3. Using admittance mode, move the arm so that the reamer head is within 50 millimeters of a foam pelvis when the end-effector is fully retracted 4. Echo the ROS topics which report axial pelvis force and reamer velocity 5. Send a command via a ROS topic to the arduino to start the reamer motor spinning at 300 rpm and verify that it starts and that the reported reamer velocity measured via encoders remains consistent 6. Send a command via a ROS topic to the arduino to begin rotating the ballscrew motor and verify that it starts to move the reamer head 7. Once the reamer head makes contact with the pelvis, verify that a force is recorded in ROS and that the reamer velocity remainds consistent at 300 rpm	
Validation	
1. Reaming motor is capable of being turned on and off 2. Ballscrew motor is capable of being turned on and off 3. Reamer velocity can be monitored via a ROS topic and remains controlled to a set velocity via PID control 4. The axial force applied to the pelvis can be monitored via a ROS topic either by indirect current sensing or load cells 5. Electrical subsystem and end-effector report no errors during test	

Test 4: Electrical Sub-System Integration

Completed Tasks to Accomplish Integration:

- Elongated reamer motor wires
- Elongated linear actuator wires
- Soldered to and attached wires to limit switches
- Placed all wires in cable sleeve and routed along the arm
- Developed Arduino code using previous motor control code which is capable of controlling both motors and uses interrupts to detect the encoders and limit switches
- Validated that all performance criteria for the electrical system was met

Test 4 Challenges:

- Issues with Cytron MD10C
  - Two we initially received had no terminal blocks, so we had to solder on two two-block terminal blocks instead of one four-block terminal block
  - Cytron we received to replace this soldered one did not work
- Delays in receiving current sensors
  - While Chris was gone our current sensors were not ordered, so we are still waiting to integrate that -> not a part of this test however
- The wiring is a rats nest
  - Will need to develop a 3D printed part to hold all components and organize the wires better

Test 5: Ballistics gel evaluation

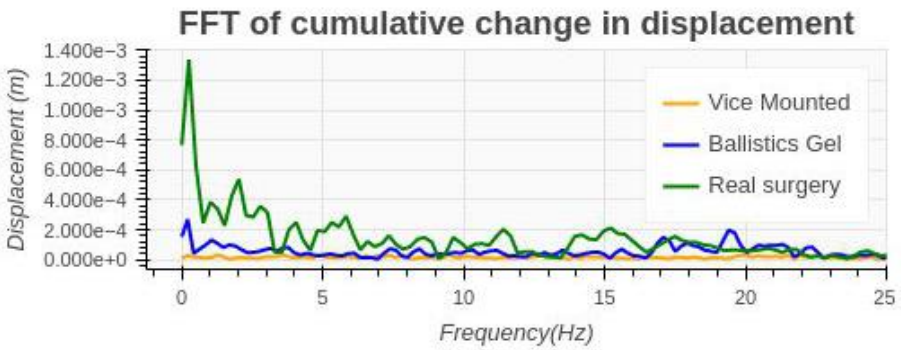
Objective	
Validate the efficacy of the ballistics gell in simulating the real dynamics of pelvis motion during reaming.	
Equipment	Desktop workstation, Robot arm with reaming end-effector, pelvis foam bone encased in ballistic gel
Elements	Surgical setup test
Personnel	Two people are needed - one to operate the system, and another for manual intervention in-case test setup becomes unstable and requires manual intervention.
Location	NSH B512
Procedure	
1. Encase the pelvis foam bone in a container filled with Ballistics gel, while ensuring that the acetabulum is visible and accessible to the robot arm. 2. Use mounting screws to screw in the pelvis tracking marker on the Illiac Crest of the pelvis. 3. A few seconds before collecting the reaming data, start a rosbag file to record the pelvis marker pose topic 3. Perform the reaming operation on the pelvis. Continuously monitor the setup to carry out any manual intervention and stop the system if the setup becomes unstable. 4. Post-process the data and obtain the frequency spectrum of the collected data.	
Validation	
1. The marker's frequency spectrum of velocity and acceleration during reaming should be comparable to the data obtained during the Cadaver Lab. 2. The maximum range of motion of the pelvis should be comparable to the data obtained during the Cadaver lab.	

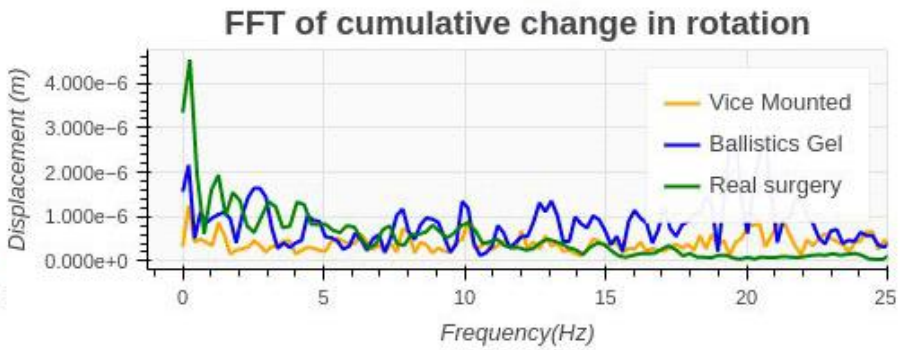
Test 5: Ballistics gel evaluation

Before

After

Test 5: Ballistics gel evaluation





Test 5: Challenges

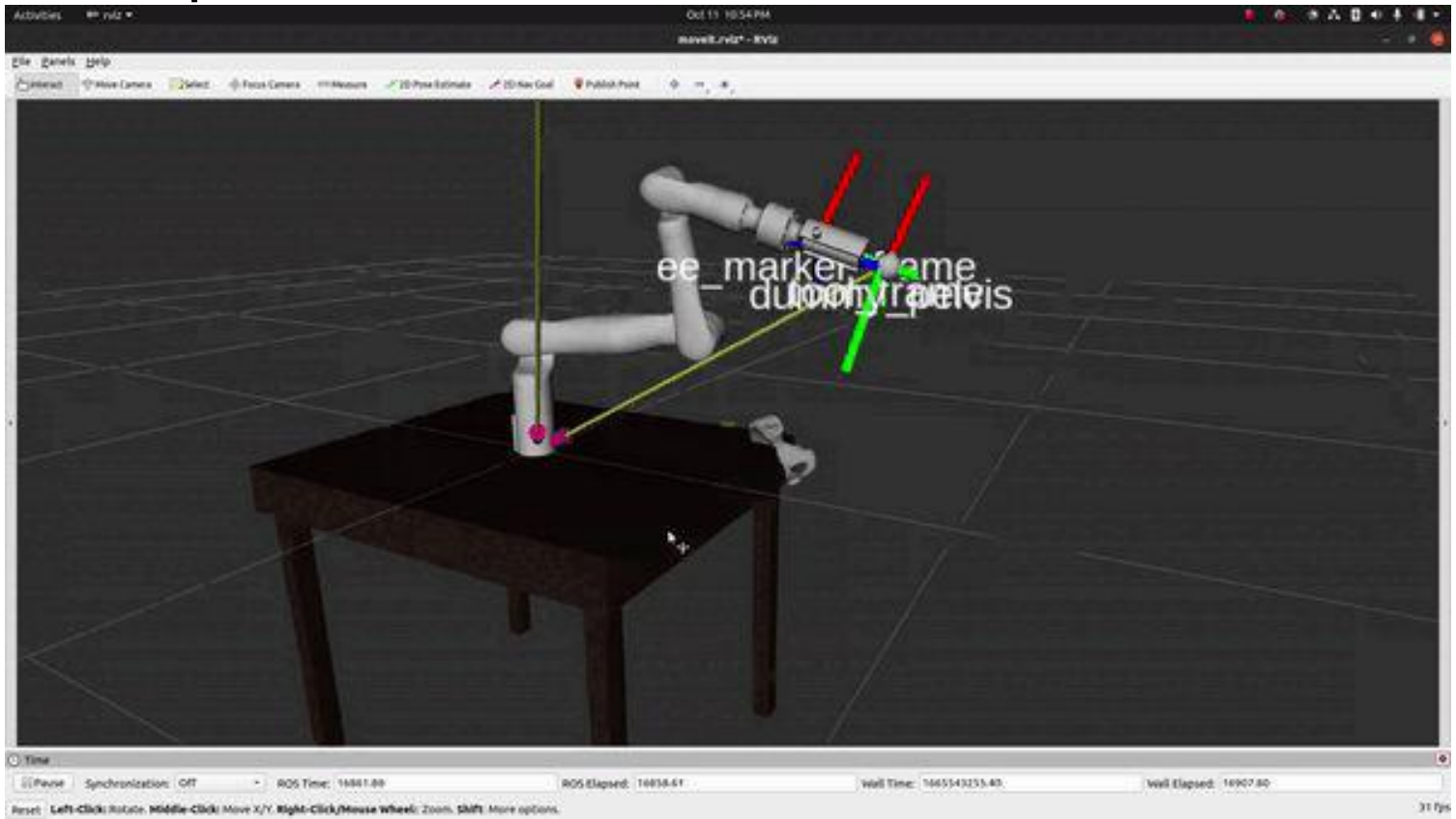
- Variation in amount of input force exerted
  - Assumed 50 N axial reaming force
- Bone vs foam-bone variations
- Utilizing raw camera data for FFT analysis
- Variation in camera update frequencies (60 Hz vs 330 Hz)
- Swapping between different pelvis models after testing
- Maintenance and storage of Ballistics gel
  - Peppermint oil

User Interface : Version 1

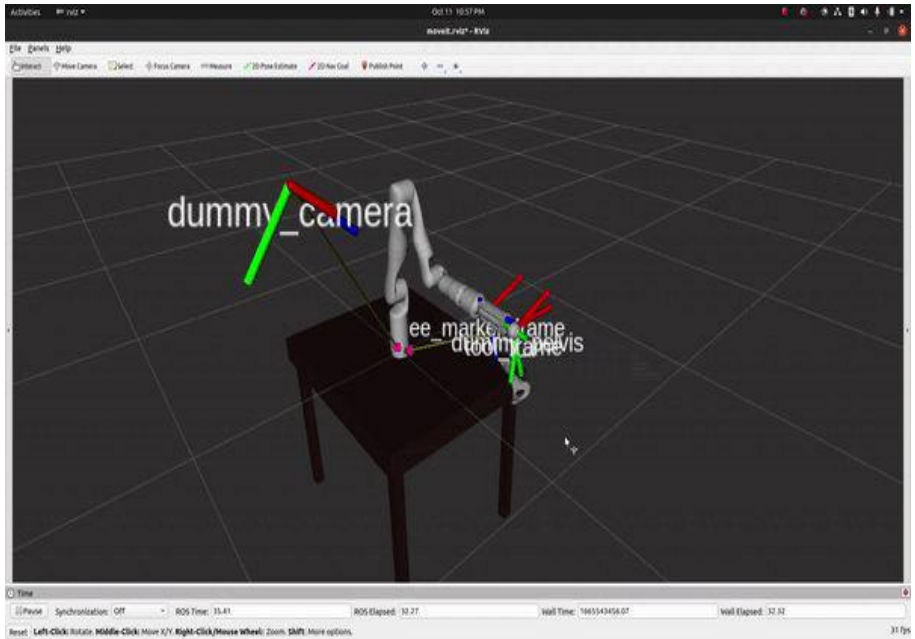
User Interface : Version 1 Improvements + Future Work

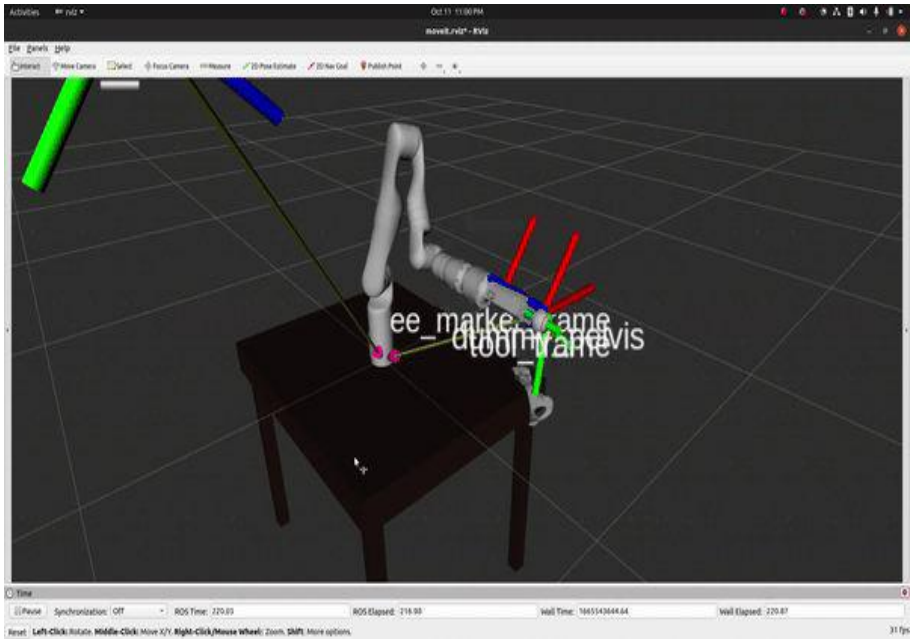
- Add alignment assistance with transform handles (axis visualization)
- Colored pointclouds for better usability
- Compute relative transformation between pelvis and implant to obtain final reaming end-point
- Watchdog + UI Integration in progress

Controls Update: Joint Limit Avoidance Fixed

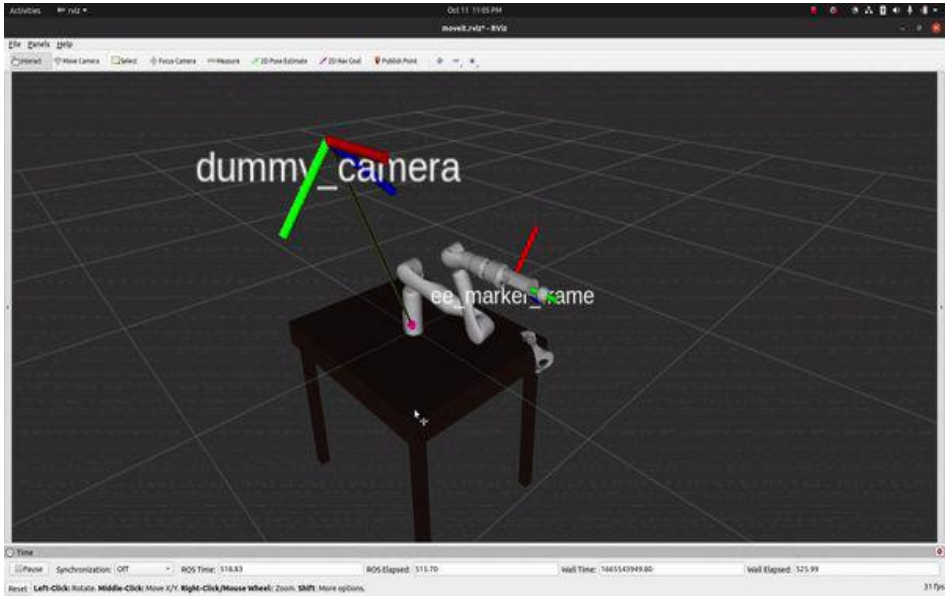
- 

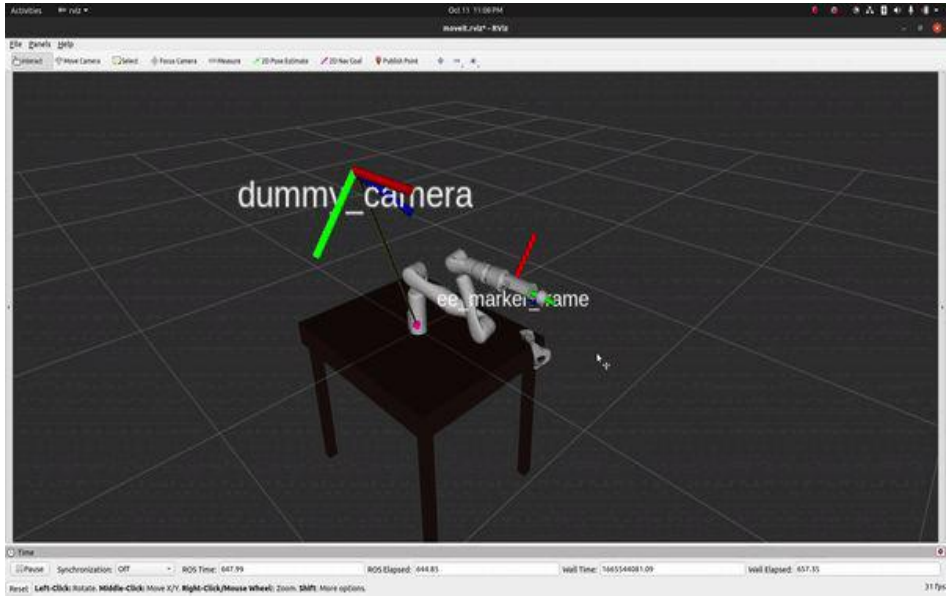
Controls Update: Singularity Avoidance





Controls Update: Task Prioritization/Camera Alignment





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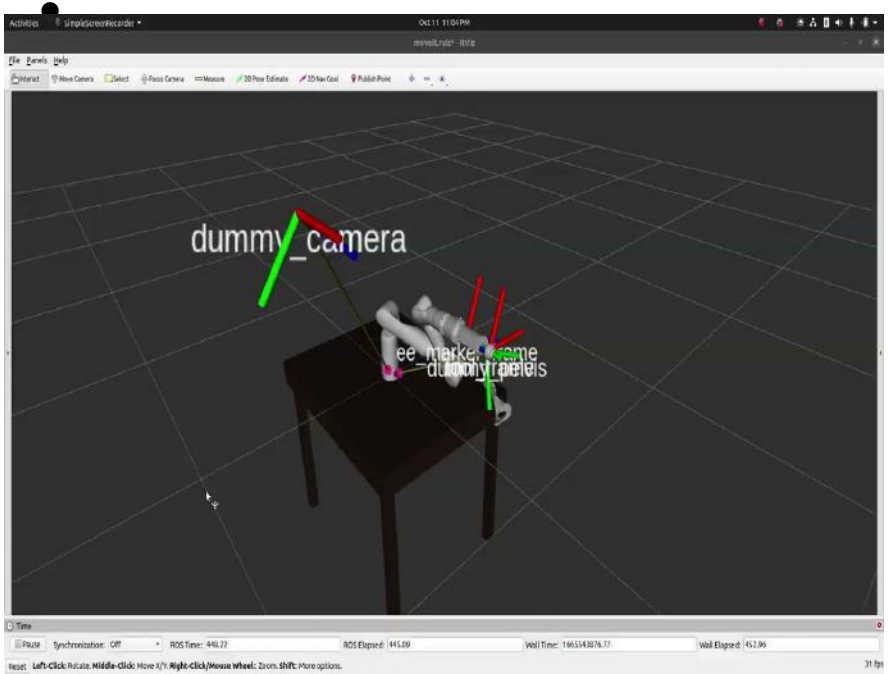

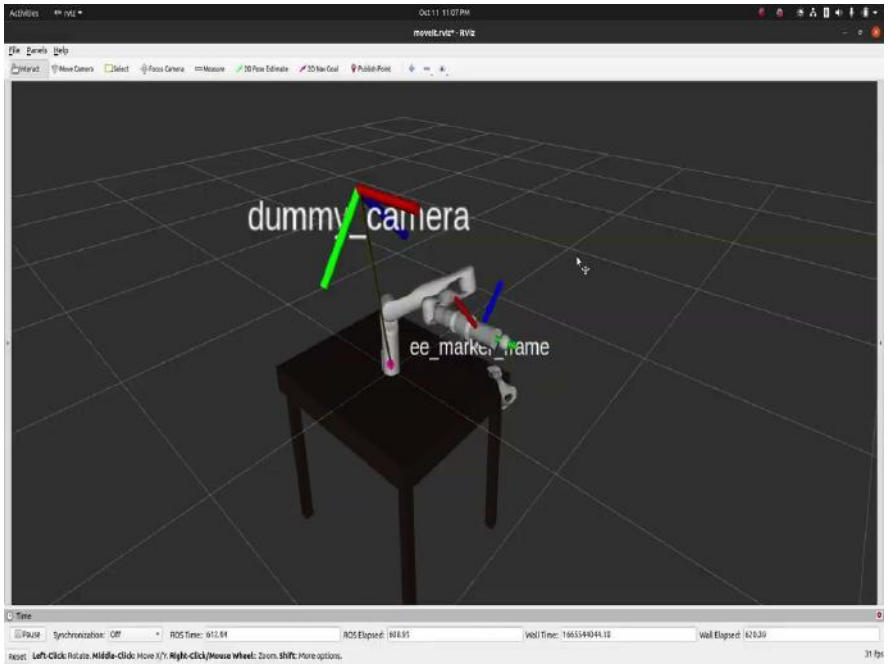

Future Work

Future Work

- Task prioritization working on the real arm
- End-effector controls integrated with ROS
- Finalized user interface
- Watchdog integration with all sub-systems
- Allow the communication of a surgical plan using the user-interface

Thank you!