Fall Validation Demonstration **Team C: Hipster**

Objective: System must autonomously localize, plan, and execute an acetabular reaming operation.
Location and Personnel: NSH B512 | Kaushik Balasundar, Parker Hill, Anthony Kyu, Sundaram Seivur, Gunjan Sethi
Equipment List: Kinova Gen3, Atracsys Sprytrack 300 Camera, Fiducial Marker Arrays, Custom End-effector
Procedure:

1. Begin by setting up the work environment by clamping the Sawbone pelvis which is encased in ballistics gels in a new position in a vise, fixing a fiducial marker screw mount on the pelvis, and placing the fiducial marker onto the end-effector of the robot arm.
2. The system will then be turned on and a user interface will appear on the screen to take surgeons through the procedure step by step. The surgeon will start by determining the surgical plan by choosing the acetabular implant's pose on a pelvis mesh obtained preoperatively.
3. Utilizing a registration probe, the surgeon collects a set of points on the acetabulum to register the pelvis to a known pelvis mesh obtained preoperatively. Using the computed transformation, the endpoint of the reaming operation will be determined using the surgical plan with respect to the robot's base.
4. Utilizing free motion mode, the robot arm will be placed near the center of the acetabulum. The surgeon will then examine the user interface to ensure there are no joint singularities.
5. Control will then be given over to the arm and it will then navigate to a position where the reamer head is less than 50 mm away from the acetabulum axially and begin to actuate the reamer head towards the pelvis.
6. The robot arm will then be reset with free motion mode and the reaming operation would then be allowed to progress freely.
7. As the robot arm begins to ream the acetabulum, the pelvis would experience motion because of the ballistics gel, causing the pelvis to move as would occur in a normal procedure, forcing the arm to dynamically compensate for the motion during the reaming operation. For further demonstration of dynamic compensation, a team member will manually move the pelvis to mimic a jerking motion that could be seen during a procedure.
8. When the robot arm has completed the reaming operation, it will remove itself from the pelvis, and the resulting acetabulum can be analyzed.
9. During this procedure, all processes can be seen on the user interface and all issues would be reported to the watchdog.

Performance Metrics

1. The comparison of two 3D meshes, one of a theoretically reamed pelvis and the other mesh obtained after reaming with our system has a difference less than 2mm. In other words, we are comparing the desired bone removed to the actual bone removed using our system.
2. The camera is able to localize the registration probe, end-effector marker, and pelvis marker within a latency of 25 ms.
3. The system is able to detect pelvis position error greater than 1.5 mm, and an orientation error greater than 1.5 degrees within a latency of 25 ms.
4. Personnel should be able to move robot arm freely with the free motion mode.
5. Once the e-stop is pressed the motor turns off and the arm stops moving within 500 ms.
6. The axial force applied to the pelvis must not exceed 100 Newtons.
7. When the pelvis error is more than 2 mm or 1.5 degrees, the end-effector will retract and the arm will realign with the pelvis pose before reaming again.
8. While reaming, the pelvis alignment error is less than 2 mm and less than 1.5 degrees.
9. User interface allows for control and visualization of the procedure with latency no greater than 150 ms.