Development Of A Bespoke Tracking System For Dual Mobility Hip Implant Liner Orientation

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INTRODUCTION

- Dual mobility (DM) implants (Figure 1) are increasingly being used in total hip arthroplasty as they offer greater range of motion and stability.
- Unlike conventional implants, the liner of a DM implant is rotationally unconstrained with two separate articulating surfaces.
- During in-vitro testing, line of sight to the implant is obscured (Figure 2) preventing measurement of liner movements.
- The aim of this work was to develop a DM liner tracking system for use under realistic test conditions, without line-of-sight, to better understand the mechanics of DM implants.

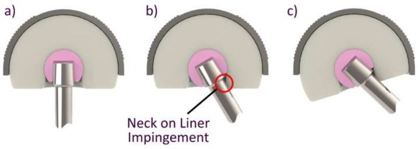

Figure 1. During use, when a DM implant moves away from a) the neutral position, initially the b) inner articulation engages until the femoral neck impinges on the liner causing the c) outer articulation to move, extending the available range of motion.

TRACKER DESIGN

- Custom, waterproof tracker circuit board (Figure 3) designed to mount on the annular face of a DM liner (BI-MENTUM™ Dual Mobility Hip System 69mm cup/28mm head, DePuy Synthes).
- Low-cost, 9-DOF inertial measurement unit (IMU) and open-source sensor fusion algorithm were used to evaluate 3D orientation.
- Power and data transfer carried to controller and data-logging PC over a 2.5mm diameter, flexible tether.
- 3D Orientation data output at up to 200Hz.

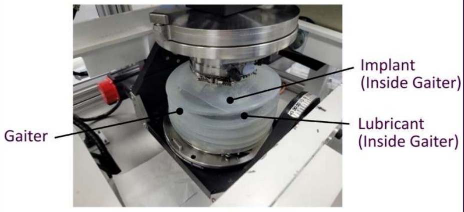

Figure 2. Typical hip simulator setup for in-vitro DM implant testing. Note how the implant is obscured by the test lubricant and gaiter.

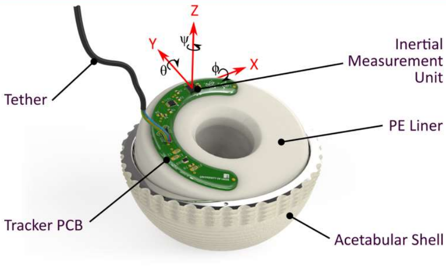

Figure 3. Illustration of how the trackers mounted to dual mobility implants and how the coordinate system of the inertial measurement unit relates to the PE liner.

PERFORMANCE VALIDATION

- Prior to testing, all sensors were calibrated to account for bias, scale and cross-axis sensitivity.
- Tracker performance was determined by applying controlled rotations using a robot arm (UR3, Universal Robots) while recording orientation data.
- Peaks in the orientation data were matched and compared with readouts from the robot arm to calculate angular error.
- Each test consisted of 60 cycles of sinusoidal motion about all 3 axes simultaneously.
- Range of motion and cycle time were varied to observe their effects on measurement error.
- In total 5 different trackers were tested.

RESULTS

- The combined results of all tests from all 5 trackers are shown in Figure 4.
- Measurement error at the peak of each cycle was consistently less than 0.15 ± 0.68° (mean ± SD) for ϕ and θ rotations and less than 1.05 ± 1.85 for ψ rotations.
- No trend between measurement error and cycle time period or range of motion was found.

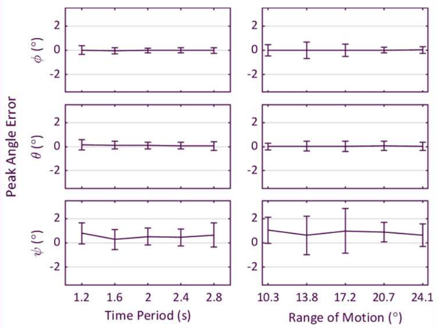

Figure 4. Angular error between robot arm and tracker peak angle measurements. Each data point is the mean peak error for 60 cycles across 5 different trackers. Error bars represent standard deviation.

CONCLUSION

- An inexpensive, IMU-based tracking solution was able to produce real-time orientation measurements with ≈ 1° accuracy, repeatably across 5 unique trackers.
- The tracker met the design goals of being able to operate submerged in lubricant, without line of sight while being able to fit within the space available on a 69/28 DM liner.
- Ongoing work includes performance assessment in a hip simulator environment and using the trackers to perform DM liner motion analysis.

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