Paths Replanning in Robotic Stereotactic Radiosurgery

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INTRODUCTION

- Previously, patient head positioning precision has been shown to be accurate to within 0.5 mm and 0.5° stereotactic precision based on a feedback control of a Stewart-Gough robot on which the patient lies [1].
- However, the head-neck joint introduces motion couplings along axes that complicate independent control along specific of head motion freedoms.
- In addition, the robot's reachability in SE(3) is limited by its actuators' freedoms and constraints given the variance in neck freedoms for various head anatomy.
- Here, we first find collision-free paths in a trajectory optimization motion planner; and then improve the plan into a better plan if the original plan stalls, exceeds positioning accuracy thresholds or does not satisfy C-space constraints.

AIM

- To demonstrate that our previous trajectory optimization algorithm is able to generate collision-free paths for heads motion in SE(3) [2].
- To demonstrate the efficacy of our newly proposed trajectory replanning algorithm.

METHODS

- A 6-6 Stewart-Gough robot platform was positioned beneath a volunteer patient's cranium on a mock treatment couch (Fig. 1).
- Head motion control trajectories were generated in LabVIEW (National Instruments, Austin TX) to manipulate the patient's cranium along predefined anterior-posterior (AP), superior-inferior (SI) and left-right (LR) translational motions in a mock motion correction setup.
- With infrared markers on the patient's forehead, an optical camera measured the patient's pose in real-time. This pose is then transformed to the robot's frame based on Kabsch's algorithm [3].
- We then run open-loop trajectory on the patient's cranium in real-time.

METHOD

- We first generate sinusoidal-like trajectories offline for the head to follow over a fixed time horizon.

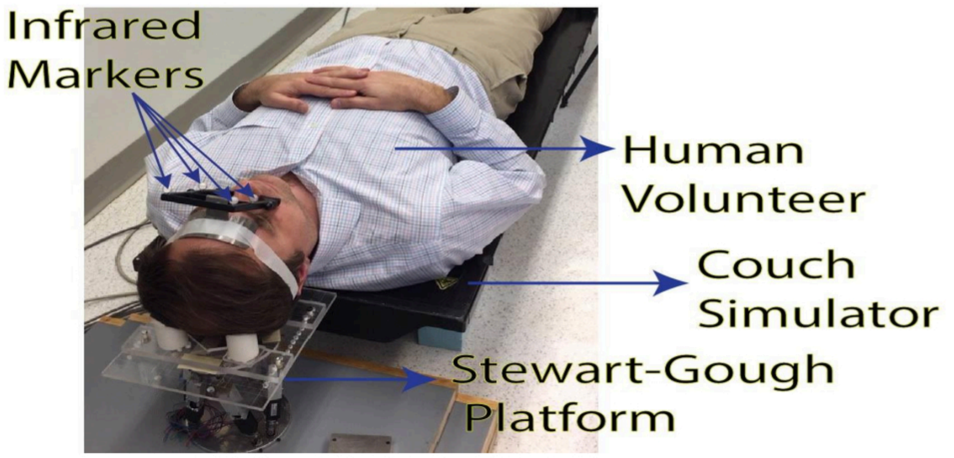

Fig. 1: Patient lying supine on a treatment couch with head on a 6-6 motion correction platform

METHODS & DISCUSSION

METHODS (CONT'D)

- We then run the generated trajectory on a volunteer patient's head in real-time to validate that the robot can stabilize the head and neck motions along x, y, and z translational directions
- When the robot stalls, due to the infeasibility of the found path along current trajectory, or due to neck freedom constraints, the planner is restarted along an alternate path

DISCUSSIONS

- We see that for each independent axial motion correction along the translational directions, the robot is able to fulfill the desired pseudo-sinusoidal motions
- Along the y-axis, owing to this patient's head and neck geometry, motion correction is incongruent.
- An hierarchical motion planner may be needed whereby a lower level task planner chooses among a set of alternate plans so as to assure that overall system requirements are optimally met

RESULTS

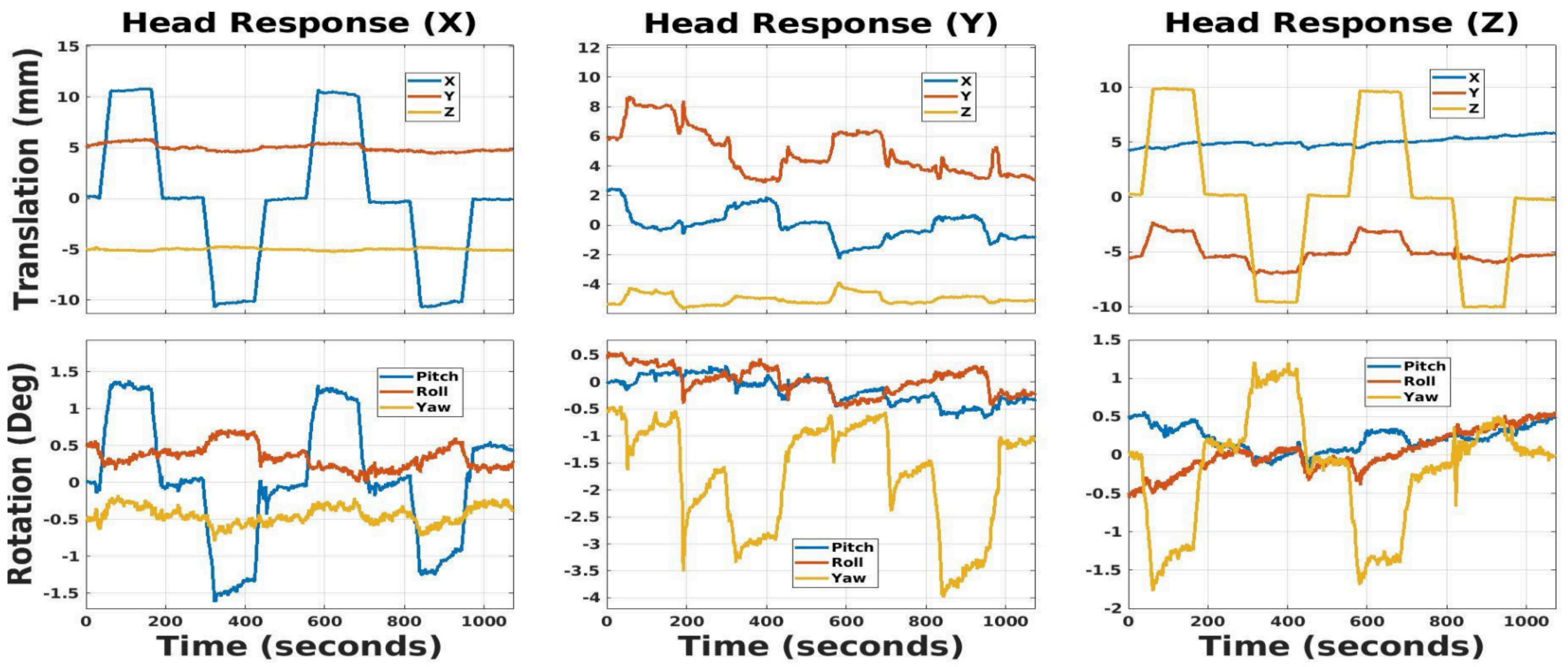

Fig. 2: Replanning results in translational SO(3) showing head position correction at steady state.

FUTURE WORK

- Device a planning algorithm that works for head motion correction in SE(3) while accounting for re-planning.
- Develop a hierarchical motion planner that switches head stabilization planning context from a higher-level planner to a lower level planner that switches between alternate head motion plans.

CONCLUSIONS

- We have shown that planned trajectories may need re-planning in head motion correction
- Established motion planning protocols do not yet account for the need for this re-planning
- Ongoing work in our lab is inculcating a re-planner in our trajectory optimization algorithm

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REFERENCES

1. AH Belcher, X Liu, Z Grelewicz, E Pearson, RD Wiersma. *Development of a 6DOF robotic motion phantom for radiation therapy.* Medical physics 41 (12), 121704
2. X Liu, RD Wiersma. *Optimization based trajectory planning for real-time 6DoF robotic patient motion compensation systems.* PloS one 14 (1), e0210385
3. Kabsch, Wolfgang (1976). *A solution for the best rotation to relate two sets of vectors*. Acta Crystallographica. A32 (5): 922.

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