Project 14: Evaluation and Optimization of Virtual Rigid Body
600.446 CIS II Project Proposal

Team Member and Mentors
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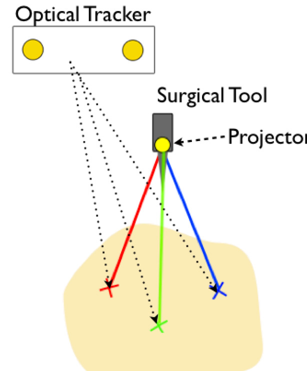
Stated Topic


Figures redrawn from (Cheng et. al., 2014)

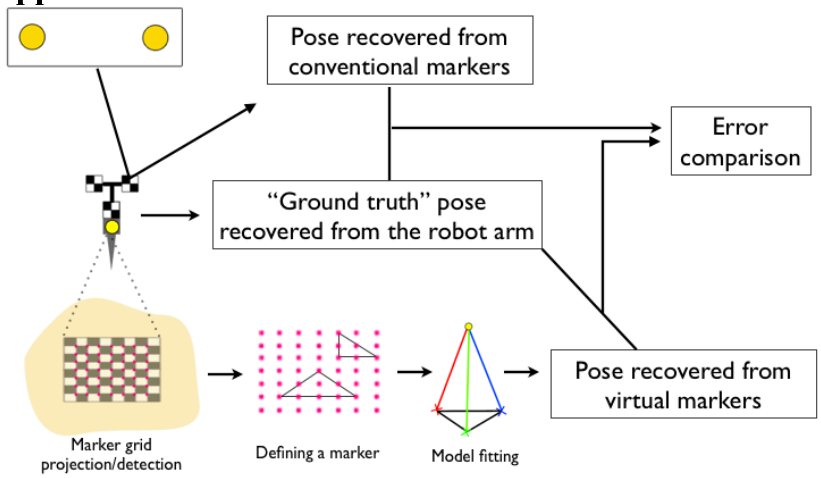
Virtual rigid body is a novel type of marker that is tracked by an optical tracker. A projector is attached to a surgical tool, which projects markers of light onto the surface of interest. The markers are detected, and their positions in optical tracker coordinates are defined. Three of these markers are triangulated and fitted into a pyramidal model that uniquely characterizes the pose of the projector and the surgical tool. Mathematical details are described in (Cheng et. al., 2014)[1]

Statement of Relevance
Virtual rigid body provides several advantages to the conventional markers.

- Freedom of marker size
  Larger markers allow more accurate tracking, but conventional markers are limited in size due to restricted space around the surgical tool, especially in the crowded laparoscopic environment. Virtual markers can be created on a surface of interest in various sizes and shapes without crowding the space.
- Field of view and freedom of tool movement
  Optical trackers serve not only as a tracking device but also as a camera to view the surface of interest. Conventional markers are attached to the surgical tool, which therefore must be placed within the optical tracker's field of view. The virtual markers are projected on the surface. The tool gains higher degree of freedom in movement as it does not have to be within the field of view, and the tracker can be centered on the surface of interest.
- Robustness to occlusion
  Conventional markers cannot be tracked if occluded, for example, by the surgeon's hand. On the other hand, the pose can be recovered from the projections of the virtual markers on the surgeon's hand. Furthermore, virtual rigid bodies provide higher degree of redundancies.

Goal of the Project
The current generation of virtual markers shows accuracy comparable to the conventional markers. The maker specifications, however, have not yet been optimized. This project aims to evaluate and analyze the tracking accuracy of the virtual markers using different set of marker designs. The factors of interest include, but not limited to, size, shape, and number of the markers. These factors will be evaluated for sets of fixed or moving trajectory of the projector poses. From the analyses, the optimal design will be determined.

Technical Approach



The technical approach is illustrated in the diagram above. Performance of the virtual markers is evaluated by comparing the accuracy to that of the conventional markers. The projector is attached to a robot arm. A set of conventional markers is attached to the projector, while the projector shoots a grid ("checkerboard") of virtual markers onto a surface of interest. A pose of the projector is recovered from the conventional markers. From the virtual marker grid, a set of three markers is selected to produce desired marker triangulation, and the pose is recovered. The recovered poses of the projector from conventional and virtual markers are compared with the ground truth pose extracted from the robot arm. This metric of accuracy is compared between the two types of markers.

Deliverables

<u>Minimum</u>

- Marker grid
- Experimental routines in form of python or C++ codes
- Experimental data

<u>Expected</u>

- Analysis and evaluation of the virtual markers
- Optimal design of virtual markers

<u>Maximum</u>

- Publication
- Experimental data on non-level surfaces.
- Introductory ideas on projector design.

Key Dates

<u>Feb. 28th: Preparation</u>

- Literature study, training for UR5 control
- Virtual marker grid development
- Resolution of all dependencies

<u>Mar. 15th: Experimental Setup</u>

- Development and documentation of a package of routines to acquire data from the MicronTracker and UR5 robot.

<u>Mar. 31st: Experiments and Data Acquisition</u>

- Experimental design (robot arm trajectories, marker specifications)
- Data acquisition for fixed pose and a trajectory of poses
- **Minimum deliverables**

Apr. 15th: Evaluation and Analysis

- Analysis and determination of optimal marker parameters.
- **Expected deliverables**

Apr. 30st: And Beyond

- Publication, further experiments, such as on non-level surfaces
- **Maximum deliverables**

May 9th: Cleanup, poster presentation, and final report

Dependencies

Hardware

- MicronTracker (Optical tracker)
- Universal Robots robot arm and controller
- Robot - projector adapter - To be printed with a 3D printer.
- Laptop

Commercial Software

- MicronTracker SDK
- Universal Robots control system

Internal algorithm and software

- Pose estimation of the projector given the coordinates of markers

Miscellaneous

- Access to Hackerman hall Robotorium - Paperwork in process

Management Plan

- Appointment with Alexis every Tuesday at 16:30 and with Dr. Boctor by appointment.
- Coordination with other groups using UR5 and MicronTracker systems will be necessary.
- Log.

Reading List

1. Cheng et. al., *Virtual Rigid Body: A New Optical Tracking Paradigm in Image Guided Interventions,* to appear in CARS 2014
2. Mcllroy et. al., *Kinectrack: Agile 6-DoF Tracking Using a Projected Dot Pattern,* ISMAR, 2012
3. West et. al., *Designing Optically Tracked Instruments for Image-Guided Surgery,* IEEE Transactions On Medical Imaging, 2004
4. Wieness et. al., *Sceptre - An Infrared Laser Tracking System for Virtual Environments,* VRST, 2006
5. Wiles et. al., *Accuracy assessment and interpretation for optical tracking systems,* Medical Imaging 2004: Visualization, Image-Guided Procedures, and Display, 2004