Project 6: Augmented Reality for Orthopedic and Trauma Surgery
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Mentors: Dr. Nassir Navab, Bernhard Fuerst, Sing Chun Lee, Javad Fotouhi

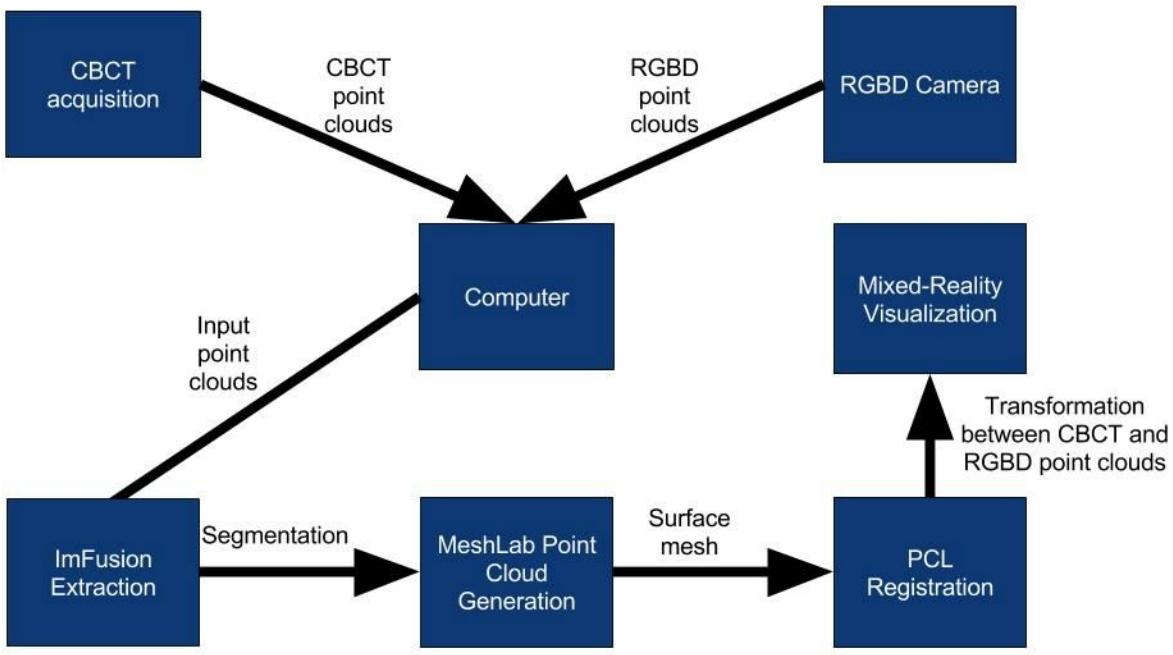
Goal

The goal of this project is to improve the calibration of overlaying Cone Based Computer Tomography (CBCT) and Red-Green-Blue-Depth (RGBD) camera meshes by creating an automated registration algorithm. Currently this registration is achieved by a long manual calibration, but this project will streamline this process to be intuitive for less-experienced users.

Relevance

Orthopedic surgeries often demand correct placement of a medical instrument and/or implant. Therefore, imaging techniques are utilized to confirm that tools are being inserted into correct bodily areas. Current solutions utilize continuous acquisition of X-ray images which result in high radiation exposure, numerous X-Rays captured, long surgical durations, and significant taskload (Fischer et. al). This new solution will allow a faster approach to generate a real-time 3D mixed-reality visualization and help guide the procedure with less time and usage of X-Rays (i.e. less radiation exposure).

Calibration Algorithm Block Diagram



Technical Plan

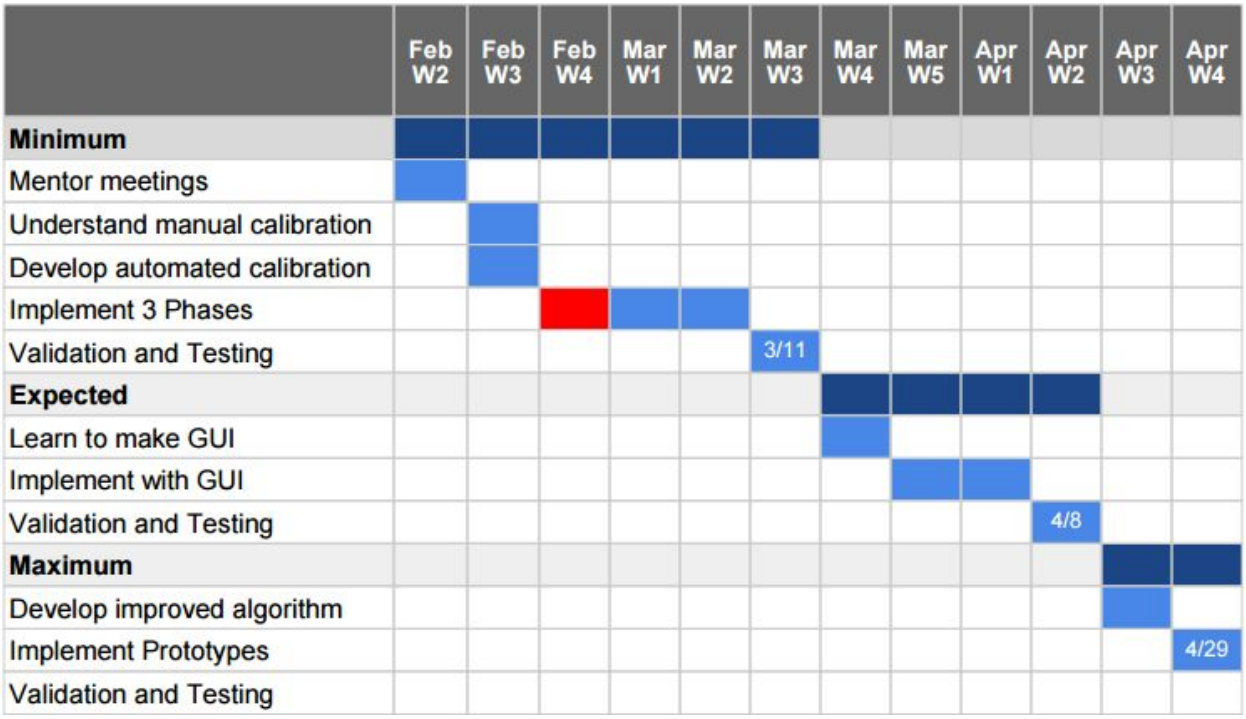
This calibration process has 3 main phases. Many of these tedious steps are conducted manually, such as the segmentation (Lee et. al). The first phase is done in ImFusion, using KinFu to generate the point cloud from the Kinect camera and segment the meshes from the CBCT. The second phase is done in MeshLab, extracting the useful point clouds from each data set. The third phase is done in the Point Cloud Library (PCL), finding a transformation between the point clouds using Fast Point Feature Histograms (FPFH) and Iterative Closest Point (ICP).

To validate the solution, comparisons between the resulting registrations of Lee's manual calibration and the automated calibration will be done at the end of each phase of development. The solution is expected to be significantly faster than manual calibration, and will be much less involved.

Deliverables

Minimum: To create an automated calibration algorithm between a CBCT scanner and RGBD camera, such that the program will take CBCT and RGBD raw data from a calibration phantom and return the registration between the CBCT and RGBD camera.
Expected: Create a simple Graphical User Interface (GUI) with ImFusion so that 3D visualization appears with minimal instruction (a "one-click" solution).
Maximum: Propose and implement prototypes for alternative methods of calibration from extensive literature research.

Timeline



Dependencies

Room:

- Mock OR environment with computer that can access CBCT and RGBD Data (**Met**)
- 24-hour access to computers with data (**Met**)

Hardware and Tools:

- Phantoms that have been used in manual calibration (**Met**)
  - If a phantom breaks, it is cheap and there has been confirmation it is easy to replace
- RGBD and CBCT scanners (**Unmet, will decide by 4/8/2016**)
  - NOTE: This is only needed if the maximum deliverable is reached, because more scan data might need to be taken to work with a different registration algorithm. There is a 30 minute radiation safety training that would need to be taken, and then this equipment could be accessed.

Software:

- Open source libraries: KinFu, MeshLab, and PCL libraries (**Met**)
- ImFusion (**Unmet, will decide by 3/14/2016**)
  - The software developers have a close relationship with Dr. Navab's lab and thus personal licenses can be acquired.
  - This will only be used in the last phase of the implementation, and the plan is open to using a different SDK.
- Compatible Environments (**Met on 2/24/2016**)
  - Local Linux environment with MeshLab and PCL for each team member.

Code Storage:

- LCSR Git access (**Met**)
- Git branch off of the existing LCSR to access and backup data (**Met on 2/20/2016**)
  - The team has also been granted permission to create own private-repository of needed data and code, and Bitbucket repositories are currently being used.

Management Plan

Dan is a BME/AMS double major with a CS minor. He has a mathematical modeling and data analysis background, C++ experience, and basic GUI design experience. Dan will ensure the algorithm is outlined to easily create the automation and design experiments and data analysis for validating the RGBD/CBCT registration. Dan will be responsible for communication between team members and mentors, and that the CIS II Wiki page is always updated with current documentation of progress.

Tiffany is a CS major and CIS minor. She has extensive C++ experience, computer vision and augmented reality work. She will implement the design algorithm, and develop component communication between each of the phases. Tiffany will be responsible for ensuring phase deadlines are met and that all code systems are backed up and documented.

As team members have strengths in different areas and to ensure proper communication, almost all development will be done together, at least twice a week. Additional research may be conducted individually then discussed at the collaborative work periods.

The team will be attending Dr. Navab's lab meetings Wednesday mornings at 9am, where they will have the opportunity to discuss concerns and updates with mentors**.**

References

Fischer M, Fuerst B, Lee SC, Fotouhi J, Habert S, Weidert S, Euler E, Osgood G, Navab N. Pre-Clinical Usability Study of Multiple Augmented Reality Concepts for K-Wire Placement. *International Journal of Computer Assisted Radiology and Surgery / International Conference on Information Processing in Computer-Assisted Interventions (IPCAI)*, Heidelberg, June 2016.

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Lee SC, Fuerst B, Fotouhi J, Fischer M, Osgood G, Navab N. Calibration of RGBD Camera and Cone-Beam CT for 3D Intra-operative Mixed Reality Visualization. *International Journal of Computer Assisted Radiology and Surgery / International Conference on Information Processing in Computer-Assisted Interventions (IPCAI)*, Heidelberg, June 2016

Rusu RB, Blodow N, Beetz M. 2009. Fast point feature histograms (FPFH) for 3D registration. In *Proceedings of the 2009 IEEE international conference on Robotics and Automation* (ICRA'09). IEEE Press, Piscataway, NJ, USA, 1848-1853.

Torr, P., Zisserman, A.: Mlesac: A new robust estimator with application to estimating image geometry. Computer Vision and Image Understanding 78(1), 138 – 156 (2000). DOI http://dx.doi.org/10.1006/cviu.1999.0832. URL http://www.sciencedirect.com/science/article/pii/S1077314299908329