Tool Tracking for Periacetabular Osteotomy using CamC

Project Proposal

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Goals: The goal of this project is to track an osteotom during a periacetabular osteotomy in order to allow the surgeon to better visualize the cuts that they are making which will limit the use of multiple X-rays.

Background and previous works:

Periacetabular osteotomy (PAO) is a surgery that realigns the misaligned hip. It is used to treat congenital or developmental dysplasia of the hip (DDH). People suffering from DDH typically have reduced femoral head coverage with the hip. PAO surgery can improve femoral coverage and relieve joint pain by realigning the acetabular fragment. Surgeons need to perform the realignment without introducing further complications. Overcorrection can lead to femoroacetabular impingement and reduced range of motion. So, intraoperative feedback is crucial during the surgery. This lead to multiple X-rays during the surgery which will increase the X-ray exposure and longer operation time [1].

Several studies have proposed that computer-aided surgery for PAO has a number of potential benefits, including a better visualization for fragment and tools[2,3]. With the help of RGBD camera and 3D fragment tracking methods, it will be more effective to identify the intraoperative position of the fragment also reduce X-ray shots[1].

Motivation:

As overcorrection and undercorrection may either introduce complications or inefficiency of the surgery which may lead to revision operation, proper alignment of acetabular fragment is quite crucial for PAO surgery. The project is to propose and implement a tool tracking method which can assist surgeons to align the bone fragment more accurately intraoperatively using intra-op. RGBD and X-ray data. Hopefully, this would potentially reduce the learning curve of this procedure.

Technical Approach:

Data acquisition:

The RGBD camera we use in this project is Intel RealSense SR300. It consists of a IR camera, IR laser projector and a color camera. The color camera can either works independently from IR cameras and projectors or synchronously with IR camera and IR projector to provide color + infrared + depth frames.

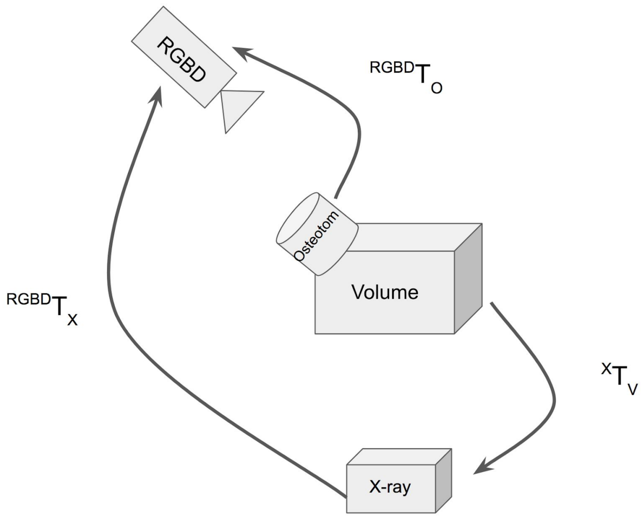
Segmentation:

In order to track the osteotom to display on the CAD model, we first need to extract the point cloud data from the RGBD camera.From this point cloud we must segment it so that the points we have correspond to just the osteotom and nothing else. One way to do this, which we will implement to start, is background subtraction. Background subtraction is a process where it takes a frame in a video and compares it to another frame in the same video. If the object is stationary within a certain degree of freedom it is considered background and is thus removed. However, this is not a very efficient algorithm, so afterwards we will implement the graph cut method. Graph cut is a graph theory algorithm where the set of vertices are partitioned into two sets where all the edges that connect vertices in those two sets are cut. In terms of segmentation, each pixel in the image would be a vertex with an edge connecting adjacent pixels and are partitioned based on similarity of values and distance away from each other.

Pose Estimation:

Once the point cloud containing only osteotom points is found The next step is to find out the orientation of the tool. This is done by iterative closest point or ICP between the point cloud and the CAD model. ICP is an algorithm in which iterates through a set of points comparing each point to a point in a separate set of points in a different frame of reference so that the points of the two sets can be paired together. With ICP, the point cloud points can be mapped to specific spots on the cad model which we will then be able to use ro view the pose of the osteotom.

Tool Tracking:



To find out the relationship between the osteotom and the volume, we need to complete the transformation chain above from volume to the osteotom.

$$^{V}T_{O} = {}^{X}T_{V}^{-1} * {}^{RGBD}T_{X}^{-1} * {}^{RGBD}T_{O}$$

The transformation from RGBD camera to the osteotom ($^{RGBD}T_O$) is found by ICP in pose estimation. As both X-ray and RGBD camera is fixed on the C-arm during the operation, $^{RGBD}T_X$ is a constant which can be find by calibration. The relationship between the X-ray and the volume ($^{X}T_V$) is obtained from existing 3D/2D registration of pre-op. CT intra-op. X-ray.

Deliverables:

<u>Minimum:</u>

Working Segmentation

- Basic background subtraction code

Pose estimation

- initialize and implement using ICP

<u>Expected:</u>

Improved segmentation

- Graph cut
- or Machine Learning

Better pose estimation

- Global optimal ICP

Visualize the cut plane

Maximum:

Start collect data base upon the prototype; start investigating the planning approach

Schedule:

	Start Date	End Date	Status
The Whole Project	2-19-2018	5-11-2018	
Literature review on clinical background and technical solutions	2-19-2018	2-26-2018	Active
Download PCL and intel RealSense SDK	2-20-2018	2-24-2018	Complete
Visualize the point cloud using SR300 in C++	2-23-2018	2-26-2018	Complete
Written project plan	2-24-2018	2-25-2018	Active
Try segmentation using background subtraction	2-19-2018	2-27-2018	Active
Create a bitbucket repository	2-28-2018	3-12-2018	Complete
Code documentations	3-1-2018	4-23-2018	Upcoming
Read literature and implement initialzation of ICP	3-1-2018	3-6-2018	Upcoming
Implementing pose estimation using ICP	3-4-2018	3-18-2018	Upcoming
Testing background subtraction and ICP	3-19-2018	3-24-2018	Upcoming
Tracking between point cloud and CAD model	3-22-2018	4-6-2018	Upcoming
Reading literature on more advanced segmentation approach	3-16-2018	3-26-2018	Upcoming
Implementing better segmentation approach (graph cut)	3-22-2018	4-9-2018	Upcoming
Reading literature on better pose estimation approach	3-21-2018	3-31-2018	Upcoming
Implementing better pose estimation approach	3-27-2018	4-14-2018	Upcoming
Testing the better segmentation and pose estimation approach	4-14-2018	4-19-2018	Upcoming
Visualize the cutting plane	4-9-2018	4-19-2018	Upcoming
Dry-run with mentor	4-20-2018	4-27-2018	Upcoming
Collect and label data base upon our prototype	4-16-2018	5-1-2018	Upcoming
Reading literature on planning approach	4-16-2018	4-23-2018	Upcoming
Implementing the planning approach	4-23-2018	4-30-2018	Upcoming
Prepare for final presentation	4-27-2018	5-1-2018	Upcoming
Prepare final report and poster	4-27-2018	5-11-2018	Upcoming

Dependencies:

Dependency	Solution	Date
Access to previous code (2D/3D registration, etc.)	Email Dr. Unberath	Feb 23 Done
Access to Intel RealSense SDK	Download it from website	Feb 20 Done
Access to PCL (Point Cloud Library)	Download it from website	Feb 20 Done
Access to the C-arm x-ray	Complete radiology certification	Mar 16 not started
Access to RGBD camera, scanner	Email Javad	Feb 23 Done
Access to the CAD model and the True model	Email Dr. Armand.	March 16 in Progress

Management Plan:

- The source code for our project will be stored in a private git repository on bitbucket.
- We have weekly meeting with our mentors to discuss our progress and obtain advice and direction on the project.
- We will also have additional meetings between ourselves so that we can collaborate on code and combine our parts.

Reading List:

1. Murphy, R. J., Armiger, R. S., Lepistö, J., & Armand, M. (2016). Clinical evaluation of a biomechanical guidance system for periacetabular osteotomy. *Journal of orthopaedic surgery and research*, *11*(1), 36.

2. Murphy, R. J., Armiger, R. S., Lepistö, J., Mears, S. C., Taylor, R. H., & Armand, M. (2015). Development of a biomechanical guidance system for periacetabular osteotomy. *International journal of computer assisted radiology and surgery*, *10*(4), 497-508.

3. Murphy, R. J., Otake, Y., Lepistö, J., & Armand, M. (2013). COMPUTER-ASSISTED X-RAY IMAGE-BASED NAVIGATION OF PERIACETABULAR OSTEOTOMY WITH FIDUCIAL BASED 3D ACETABULAR FRAGMENT TRACKING. *Bone Joint J*, *95*(SUPP 28), 84-84.

4. Otake, Y., Armand, M., Armiger, R. S., Kutzer, M. D., Basafa, E., Kazanzides, P., & Taylor, R. H. (2012). Intraoperative Image-based Multiview 2D/3D Registration for Image-Guided Orthopaedic Surgery: Incorporation of Fiducial-Based C-Arm Tracking and GPU-Acceleration. IEEE Transactions on Medical Imaging, 31(4), 948–962.

5. Lee, S. C., Fuerst, B., Tateno, K., Johnson, A., Fotouhi, J., Osgood, G., … Navab, N. (2017). Multi-modal imaging, model-based tracking, and mixed reality visualisation for orthopaedic surgery.

Healthcare Technology Letters, 4(5), 168–173.

6. Fotouhi, J, et al. "Pose-aware C-arm for automatic re-initialization of interventional 2D/3D image registration." International Journal of Computer Assisted Radiology & Surgery 12.7(2017):1221-1230.

References:

[1] Murphy, R. J., Armiger, R. S., Lepistö, J., & Armand, M. (2016). Clinical evaluation of a biomechanical guidance system for periacetabular osteotomy. *Journal of orthopaedic surgery and research*, *11*(1), 36.

[2] Akiyama, H, et al. "Computed tomography-based navigation for curved periacetabular osteotomy. " *Journal of Orthopaedic Science,* 15.6(2010):829-833.

[3] Hsieh, P. H., Y. H. Chang, and C. H. Shih. "Image-guided periacetabular osteotomy: computer-assisted navigation compared with the conventional technique: a randomized study of 36 patients followed for 2 years. " *Acta Orthopaedica,* 77.4(2006):591-597.