Tool Tracking for Periacetabular Osteotomy using CamC

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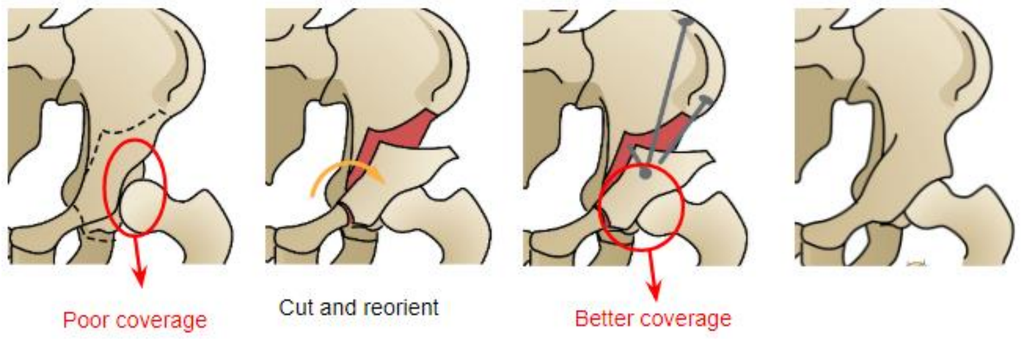
Introduction

- Periacetabular Osteotomy (PAO) is for patients suffering from developmental dysplasia of the hip (DHH). It is mostly caused by reduced coverage of the femoral head.



In PAO, the acetabulum is repositioned to increase the coverage of femoral head

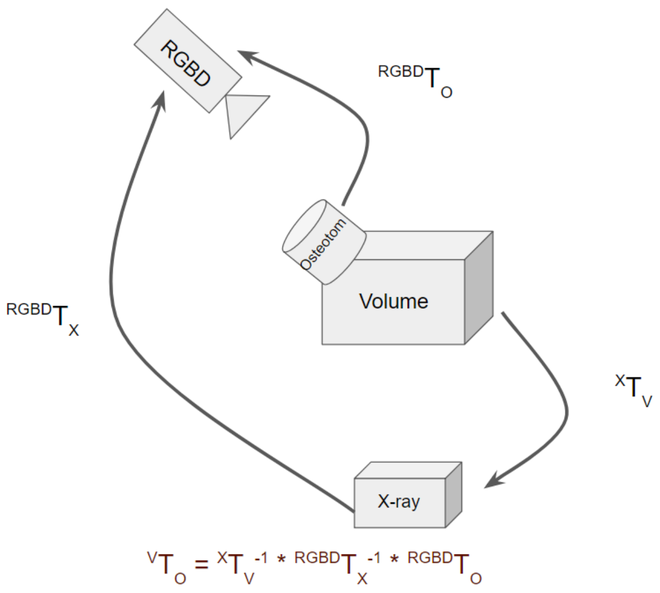
- Tool tracking is required in order to ensure the acetabular component is well positioned after surgery which requires registration of unknown components.
- Current tool tracking requires multiple x-ray images which is both harmful and time consuming
- This work presents a pipeline of tracking the tool with RGBD camera. As RGBD camera could provide real-time feedback during the surgery, it could reduce the number of X-ray images required [1].

Problem

- Orthopedic surgeries such as PAO are difficult to perform due to problems such as complex anatomy, limited starting point and trajectory, and small margin of error.
- Because of the limited visibility, it is sometimes hard to keep track of how the fragment is cut and the location of vessels and arteries that need to be avoided.
- Therefore, the ability to intraoperatively analyze the state of surgery and update the preoperative plan is especially important for PAO [2].
- There has been previous works done on tracking the bone fragment, but not as much done into tracking the tool itself and the path that it goes through to make the cut.

The Solution

- **CAMC**, short for **camera-augmented mobile C-arm** provides us with a better solution [3]. Tracking the osteotom using RGBD camera could reduce the amount of X-ray image required.
- This entailed us first segmenting the tool in the video by color, which collects the pixels in a certain color threshold, combined with OpenCV's mixture of gaussian background segmentation [4] to take away any static parts of the video.
- Next the point cloud is passed to an ICP algorithm for fine alignment. The initialization of ICP is done by sample consensus rejective algorithm in PCL library [5].



Schematics of the transformation chain to track the position of osteotom with respect to pelvis (volume).

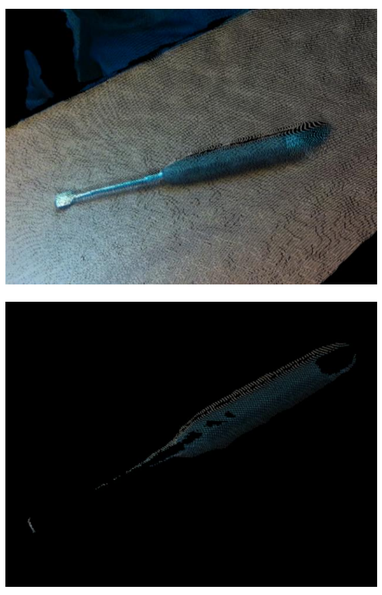
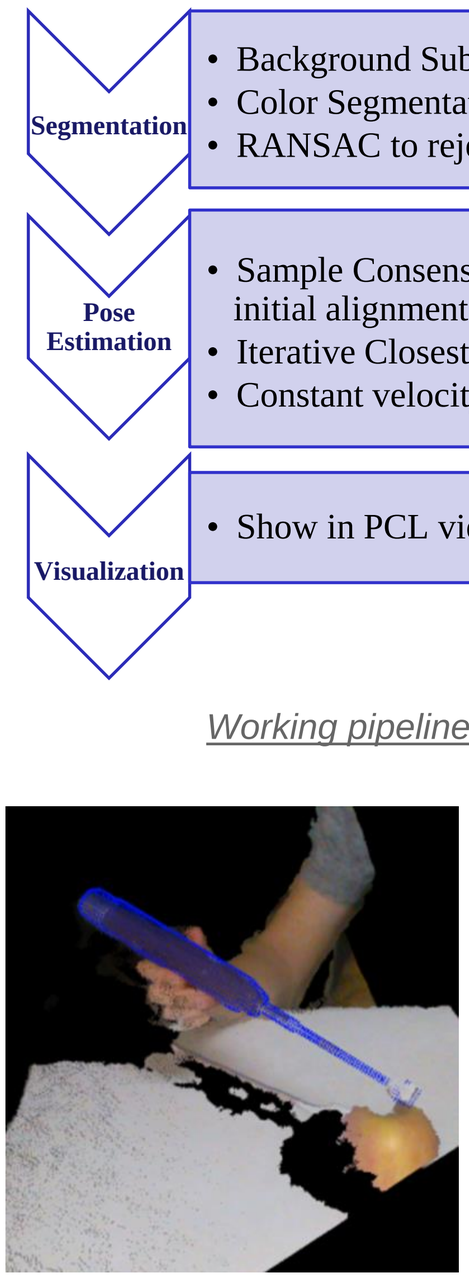
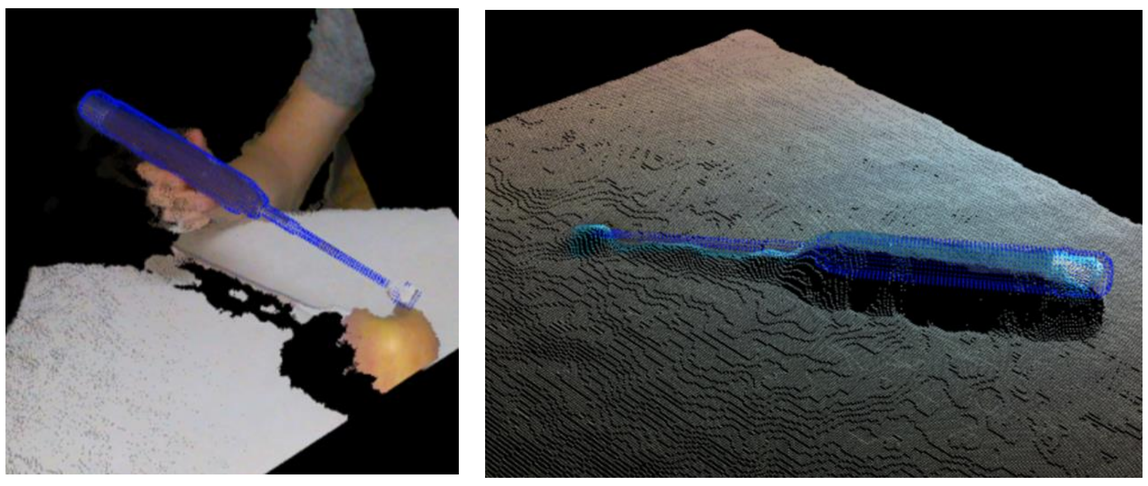


Image of the tool on the table before and after segmentation



Working pipeline of the tool tracking algorithm



Tool under tracking (blue shade indicates the tracking result)

Outcomes and Results

- Tool tip error along length axis is within 11mm and error along the width axis is within 2mm.
- Not robust to fast movement and rotation along length axis.

Future Work

- Machine learning should be used to improve upon the current segmentation method.
- The tool tracking should be combined with the pre-operative plan so that the tool can be adjusted to match the planned cut intra-operatively.
- Tool tracking should be used to improve fragment tracking algorithms by allowing a better estimate of the shape of the cut bone.

Credits

- Wenhao Gu - Pose Estimation and documentation.
- Billy Carrington - Segmentation and documentation.

Publications

[1] Lee S C, Fuerst B, Tateno K, et al. Multi-modal imaging, model-based tracking, and mixed reality visualisation for orthopaedic surgery[J]. Healthcare technology letters, 2017, 4(5): 168-173.

[2] 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.

[3] Navab N, Heining S M, Traub J. Camera augmented mobile C-arm (CAMC): calibration, accuracy study, and clinical applications[J]. IEEE transactions on medical imaging, 2010, 29(7): 1412-1423.

[4] Benezeth Y, Jodoin P M, Emile B, et al. Comparative study of background subtraction algorithms[J]. Journal of Electronic Imaging, 2010, 19(3): 033003.

[5] Buch, A. G., Kraft, D., Kamarainen, J. K., Petersen, H. G., & Krüger, N. (2013, May). Pose estimation using local structure-specific shape and appearance context. In Robotics and Automation (ICRA), 2013 IEEE International Conference on (pp. 2080-2087). IEEE.