Computer Integrated Surgery II

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Seminar Paper Summary

Plan in 2-D, execute in 3-D: an augmented reality solution for cup placement in total hip arthroplasty

Project Overview

Our project is to track the osteotom tool with respect to pelvis using RGBD and X-ray data in Periacetabular Osteotomy surgery. As the tool is fixed on the osteotom, we are tracking the osteotom that is mostly inside human body by tracking the tool. The application of RGBD camera can significantly reduce the number X-ray images required during the operation. Segmentation and pose estimation such as ICP will be used in this project.

Paper selection

The paper "Plan in 2-D, execute in 3-D: an augmented reality solution for cup placement in total hip arthroplasty" is chosen because it is written by our mentor and highly related to our project. It also uses RGBD and X-ray data intraoperatively to help surgeon place the anatomic feature more accurately. Reading this paper can help us understand the overall settings and how the camera -augmented C-Arm (CAMC) can help reduce the number of X-ray shot intraoperatively.

Significance

Although the surgery this paper talks about is not the same as PAO in our project, there are quite a few similarities. Proper positioning of the implant in the total hip arthroplasty is critical to surgical outcome. In our project, proper placement of the osteotom that is cut and re-oriented is also very important. The RGBD and X-ray data are used in this paper which is also like our project. While this paper provides a method to plan and visualize cup placement using RGBD and X-ray data, the tasks of our project also involve tracking the tool. The tracking problem is discussed in another paper that has been presented by my teammate Bill Carrington in previous seminar. Yet this paper still provides us reference how the RGBD data is used to decrease the number of X-ray shots required intraoperatively.

Background

Total hip arthroplasty (THA) is to replace the damaged bone and cartilage with prosthetic components. This surgery is widely performed in US and is expected an increase by 2030. While proper placement of the implant is crucial to the surgical outcome, this task is currently challenging to surgeons because the ideal position of the implant with respect to the anatomy is not straightforward, and it is not guaranteed that surgeons are able to place the implant within the suggested margin. The integration of intraoperative fluoroscopy can guide the placement of the cup effectively.

Methods

Workflow

After dislocation of the femoral head and reaming of the acetabulum, the size of the acetabular cup is identified based on the size of reamer. Two X-ray images are then acquired from two different perspectives, where the relative pose is estimated by the RGBD camera on the C-arm and a visual marker on the surgical bed. The cup position is planned by surgeon intraoperatively on both X-ray images. After that, the pose of the planned cup with respect to the RGBD camera can be estimated and visualized in the AR environment. The schematics of the clinical workflow is shown below.

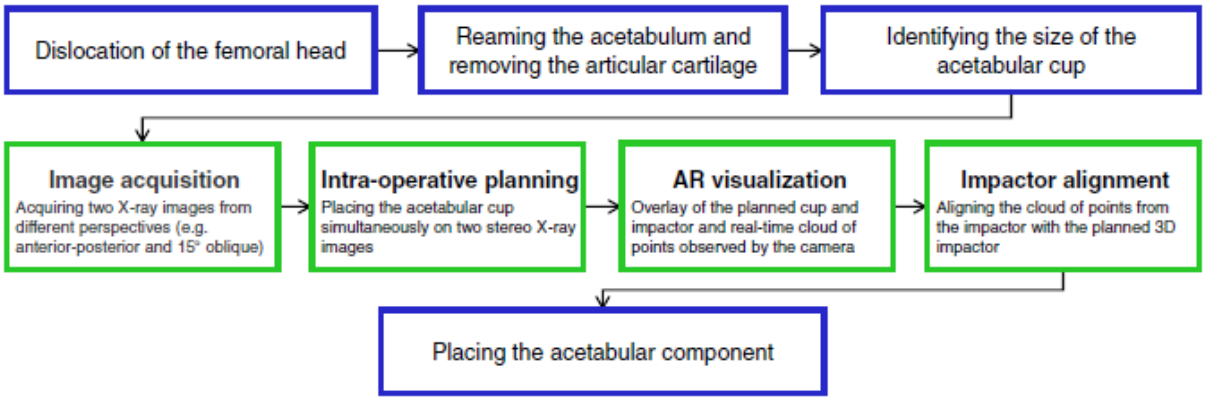
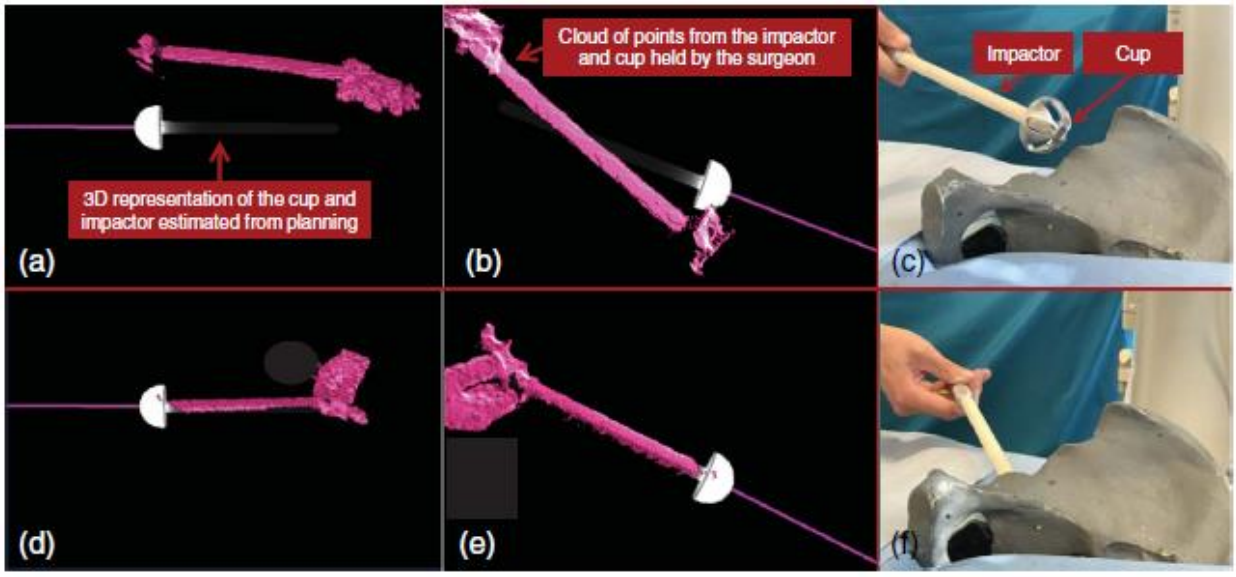
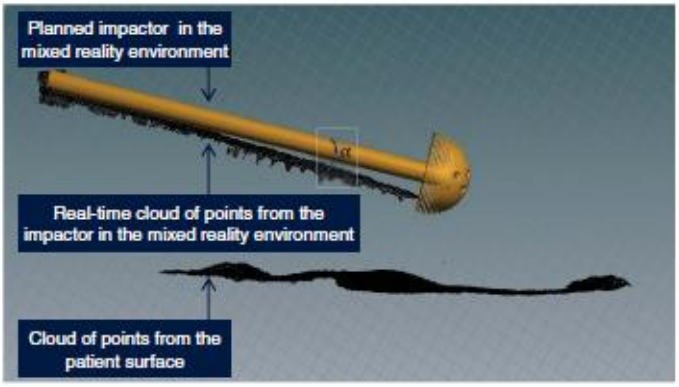


Figure (a)-(b) below shows multiple perspectives of surgical site before the cup is aligned and figure (d)-(f) below shows multiple perspectives of surgical site after the cup is aligned with virtual planned impactor.



Results

The experiment is repeated for 10 different poses and each time 4 virtual perspectives of the surgical site are used. The translational error and orientation errors of the proposed solution are 1.98 mm and 1.22 deg respectively.



Overall Assessment

Pros:

This paper introduces how the camera-augmented C-arm (CAMC) is used in a procedure to help surgeon place the implant more accurately. The results shows that this method is very promising as its translational and orientation error is smaller than classic approach and previous works (navigation-based system by Sato et al.).

Cons:

This paper only involves visualization in AR environment and does not include tracking of the impactor. While accuracy is increased compared with the classic approach, the error can further be reduced if the impactor can be tracked and moved to the planned position automatically.

In addition, a visual marker need to be placed in the surgical site to find out the relative pose between the X-ray images. Placing a marker in the surgical site might be inconvenient in real case during a surgery.

Besides, the patient is assumed to be static while placing the cup, which is also not practical. Additional fiducial might be needed to handle this problem.

Reference

Fotouhi, J., Alexander, C. P., Unberath, M., Taylor, G., Lee, S. C., Fuerst, B., ... & Armand, M. (2018). Plan in 2-D, execute in 3-D: an augmented reality solution for cup placement in total hip arthroplasty. *Journal of Medical Imaging*, *5*(2), 021205.