X-Ray Image-Based Navigation for Hip Osteotomy

Checkpoint Presentation

Jesse Hamilton and Michael Van Maele

Group #3

March 29, 2012

Mentors: Dr. Mehran Armand, Dr. Yoshito Otake, Ryan Murphy

Course: Computer Integrated Surgery II (EN.600.646)

Summary

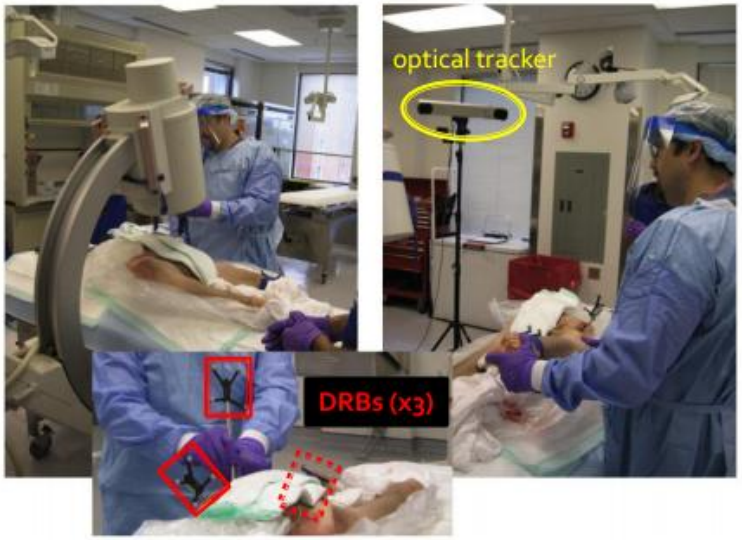
Project Overview

Summary

Current system:

Periacetabular osteotomy (PAO) to correct developmental dysplasia of the hip (DDH) navigated by an optical tracker.

- Polaris camera.
- Dynamic rigid bodies (x3)
- Point-based registration.



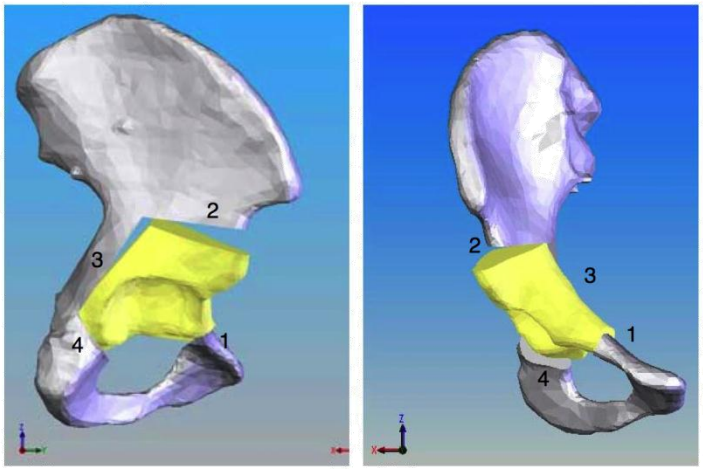
Optical tracker PAO setup.

Courtesy of Ryan Murphy

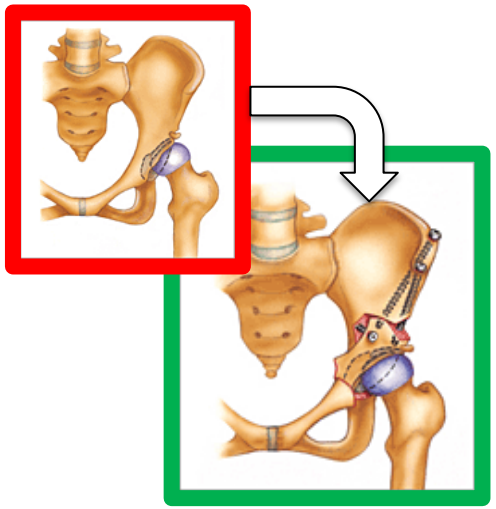
Summary

Current system:

The Biomechanical Guidance System (BGS) utilizes angle and contact pressure to estimate the optimal fragment realignment .



3D model of hip and fragment.
Courtesy of Ryan Murphy



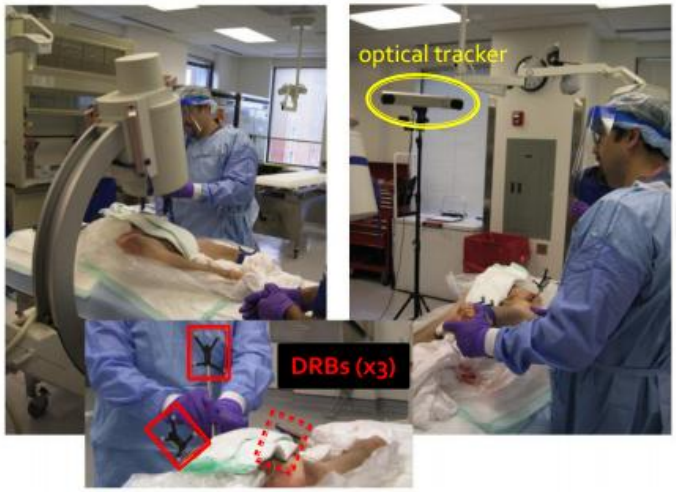
PAO procedure.*

*http://www.hipandpelvis.com/patient_education/periace/page2.html

Summary

<u>Our goal</u>:

We want to replace optical tracker navigation with X-ray navigation.



Optical tracker PAO setup.

Courtesy of Ryan Murphy

C-arm fluoroscopy.*

*http://www.anteriorhipreview.com/wp-content/uploads/2011/07/c-arm-during-anterior-total-hip-arthroplasty.jpg

Summary

Our motivation:

- X-ray navigation is more in line with what surgeons are already doing.
- C-arm more accessible than optical tracker.
- Surgeons have occasionally disputed the results of the optical tracker method.

Summary

Our aims:

1. to design and implement a surgical **pipeline** for X-ray image-based navigation for hip osteotomy, and

2. to **compare** the proposed method with the current method (optical tracker-based navigation) experimentally.

Dependencies

Descriptions & Status

Dependencies

No critical dependencies remain.

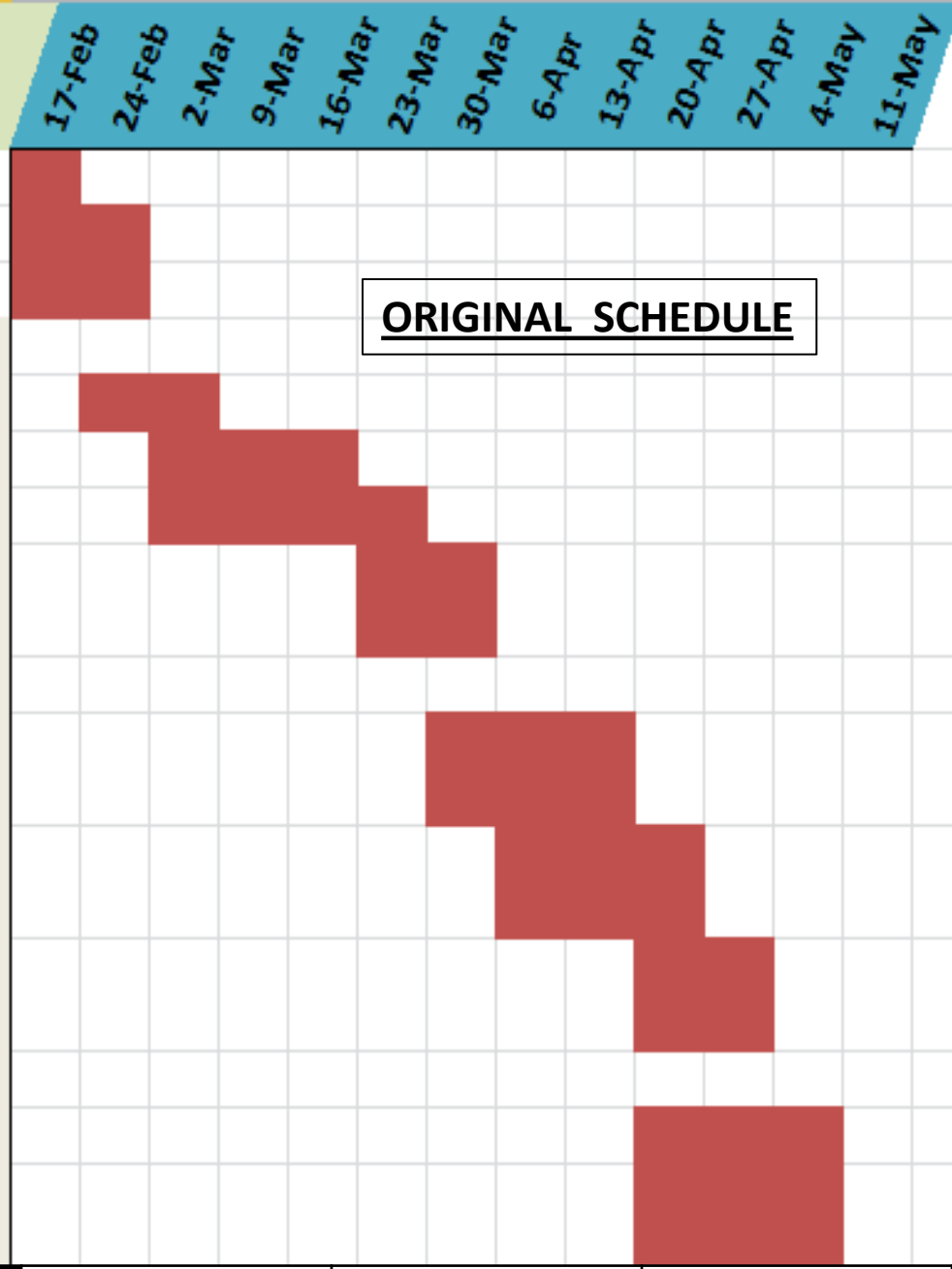
Dependency	Target Date	Comment
Get mock OR access.	**DONE**	J-Cards enabled.
Schedule mentor meetings.	**DONE**	Thursdays at 10:30 AM, weekly.
Get radiation badges.	**DONE**	Stored in mock OR.
Get radiation training.	**n/a**	No response from training liaison.*
Get BGS-compatible PCs.	**DONE**	Hackerman B08
Install BGS software.	**DONE**	Hackerman B08

*Able to work with C-arm under mentor supervision.

Milestones

Progress Report

Project Timeline



- Proposal presentation
- Radiation training
- Obtain computers, install BGS software

MINIMUM DELIVERABLES

- Exploratory run-through of mock osteotomy
- Resolve method for BB attachment
- Develop & report detailed pipeline
- Mock surgery on pelvic phantom with conventional & proposed procedures

EXPECTED DELIVERABLES

- Integrate software for proposed procedure with BGS
- Develop method for non-rigid attachment of FTRAC
- Cadaver study with conventional & proposed procedures

MAXIMUM DELIVERABLES

- Test alternatives to FTRAC
- Investigate alternatives for pose estimation besides Kang's EM algorithm

Improved Schedule

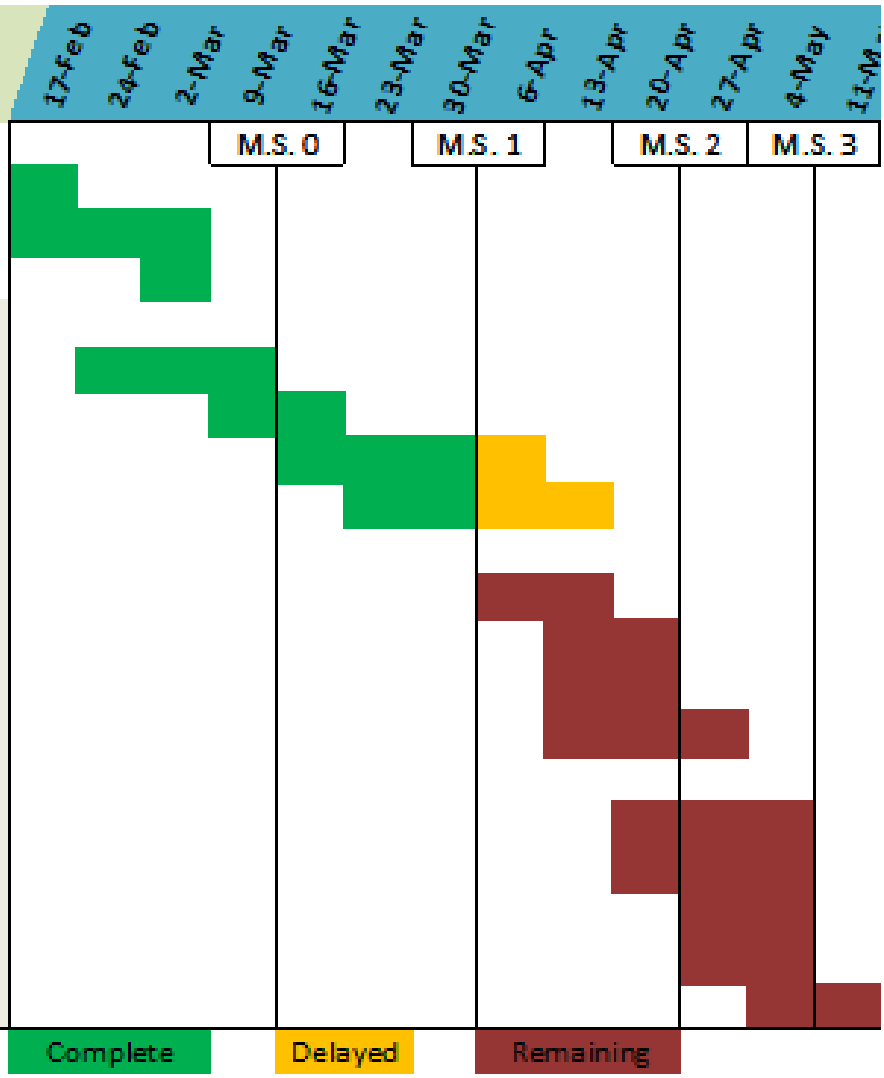
Project Timeline

MILESTONES:
- Proposal presentation
- Obtain computers, install BGS software
- Radiation badges

MINIMUM DELIVERABLES
- Convert high-level pipeline to low-level MATLAB script
- Resolve method for BB attachment to phantom
- Perform and report on mock surgery on pelvic phantom
- Resolve any technical implentation issues in pipeline.

EXPECTED DELIVERABLES
- Resolve method for BB attachment to bone
- Integrate software for proposed procedure with BGS
- Resolve method for non-rigid attachment of FTRAC
- Perform and report on cadaver surgery.

MAXIMUM DELIVERABLES
- Perform error analysis with FTRAC.
- Attempt to automate ECM algorithm initialization.
- Investigate alternatives to FTRAC design.
- Finalize any pipeline adjustments.
- Poster session & project report



Milestone 0

Convert high-level pipeline to low-level MATLAB script and debug with test data. **(3/12)**

Status: **COMPLETED**

Tasks:

- ✓ Perform a walk-through of the optical tracker-navigated procedure.
- ✓ Agree on pipeline flowchart for X-ray-navigated procedure.
- ✓ Convert chart components to script functions.
- ✓ Debug script functions with test data.

Milestone 1

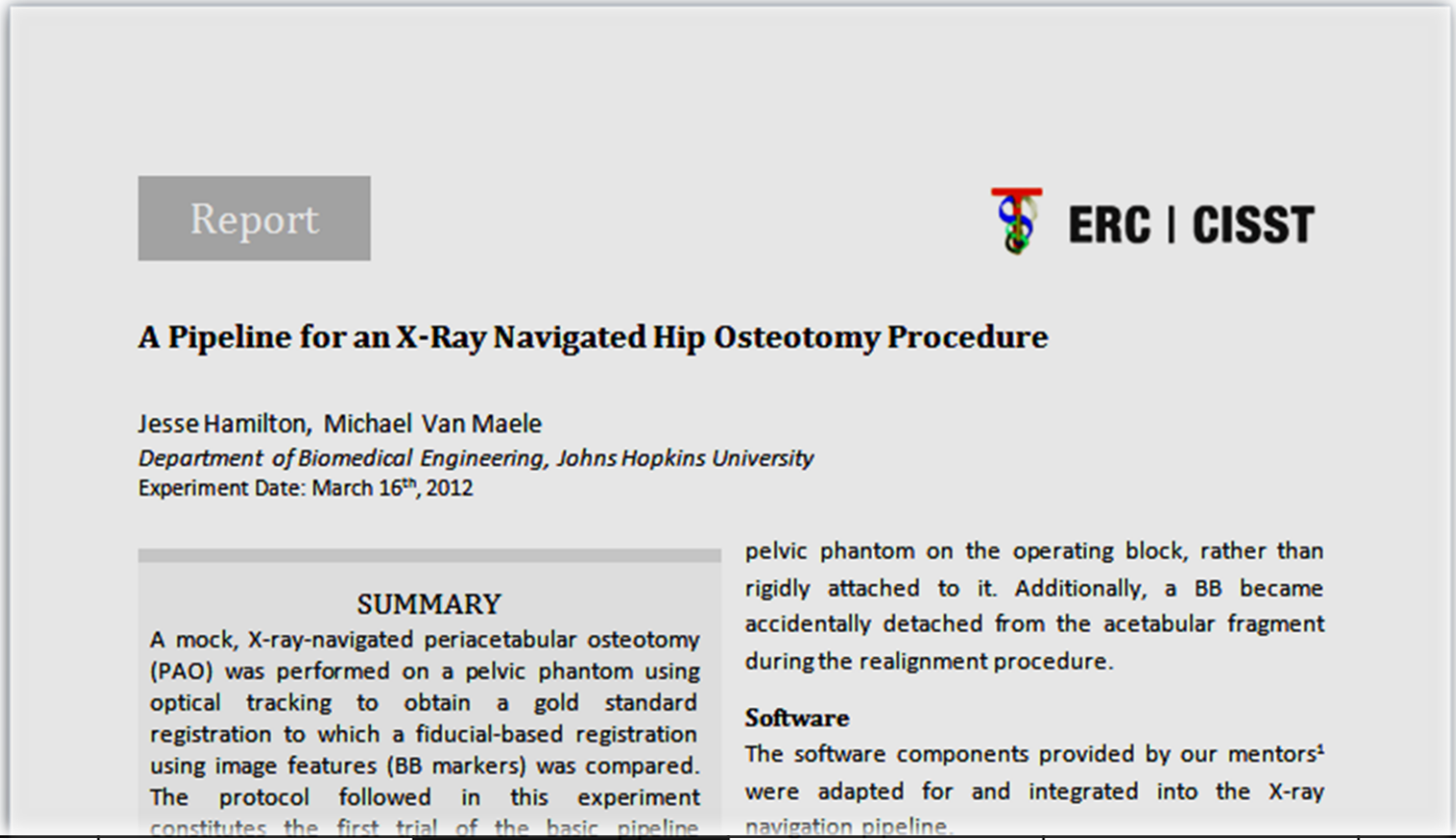
Perform and report on mock surgery using X-ray navigation pipeline. **(3/30)**

Status: **NEARLY COMPLETED**

Task	Completion	Comment	Target Date
Perform mock surgery.	100%	In mock OR with pelvic phantom.	**DONE**
BB classification.	100%	Classification is currently manual.	**DONE**
Code and debug pipeline in MATLAB.	80%	Mild debugging issues.	**4/3**
Write report on mock surgery.	70%	Need fully formed pipeline to process data.	**4/3**

Milestone 1

Report must be finished.



Report

ERC | CISST

A Pipeline for an X-Ray Navigated Hip Osteotomy Procedure

Jesse Hamilton, Michael Van Maele
Department of Biomedical Engineering, Johns Hopkins University
Experiment Date: March 16th, 2012

SUMMARY

A mock, X-ray-navigated periacetabular osteotomy (PAO) was performed on a pelvic phantom using optical tracking to obtain a gold standard registration to which a fiducial-based registration using image features (BB markers) was compared. The protocol followed in this experiment constitutes the first trial of the basic pipeline

pelvic phantom on the operating block, rather than rigidly attached to it. Additionally, a BB became accidentally detached from the acetabular fragment during the realignment procedure.

Software

The software components provided by our mentors[1] were adapted for and integrated into the X-ray navigation pipeline.

Milestones 2 & 3

Prepare the navigation pipeline for online use. **(4/13)**

Status: **BEGIN NEXT WEEK**

Perform and report on cadaver surgery using X-ray navigation pipeline and conclude any pipeline adjustments. **(5/4)**

Status: **BEGIN NEXT WEEK**

Deliverables

Full List and Progress Report

Deliverables

On schedule to achieve all deliverables (as of 3/29).

Minimum

- Manual BB classification solution. (3/16) **(100%)**
- X-ray navigation pipeline/protocol. (3/30) **(80%)**
- Report on results of mock surgery with pelvic phantom. (3/30) **(70%)**

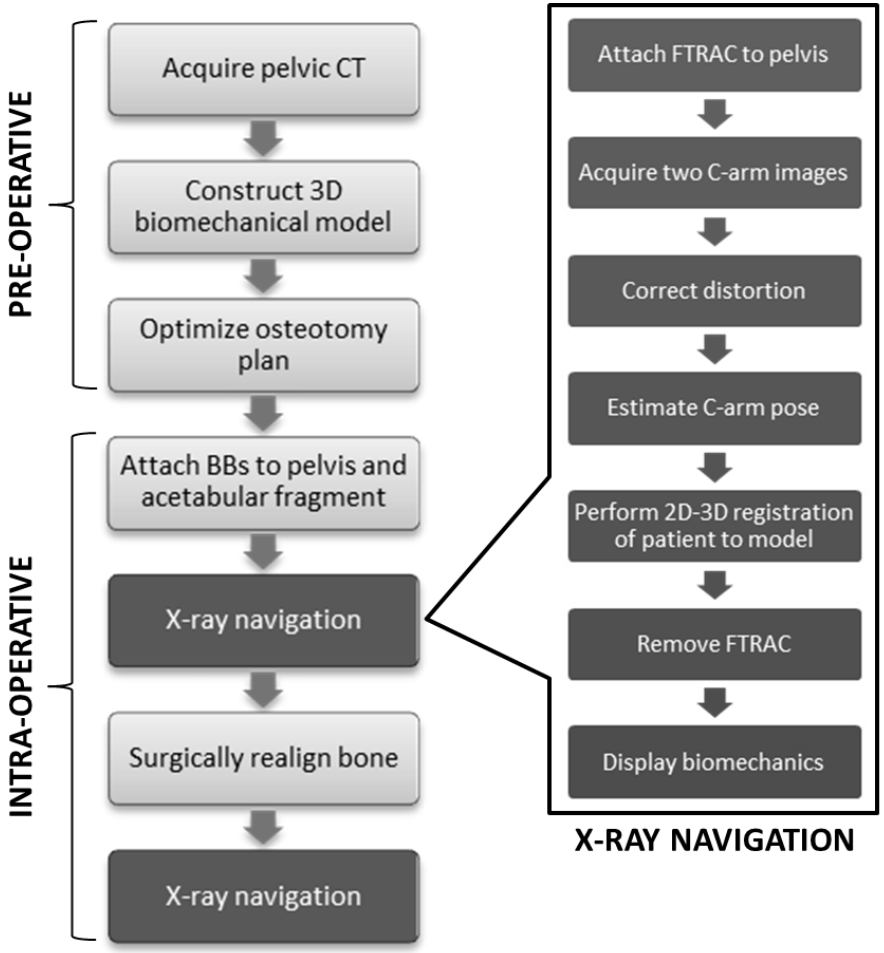
Expected

- BGS software with X-ray navigation pipeline integrated. (4/20)
- Analysis of non-rigid FTRAC attachment methods. (4/20)
- Report on results of cadaver surgery. (4/27)

Maximum

- Simulated error analysis of FTRAC. (5/4)
- Automatically initialized EM pose estimation algorithm. (5/4)

Nearly Completed Deliverable: Pipeline



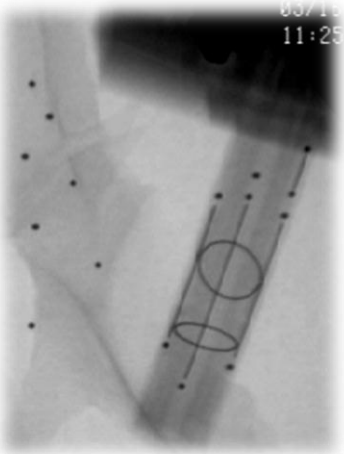
Achieved Deliverable: BBs

BB Attachment:

- Trivial to do for pelvic phantom.
- May be trickier for the cadaveric specimen.

Tear from BB reel.

Place on bone.



View with C-arm.

Experiment

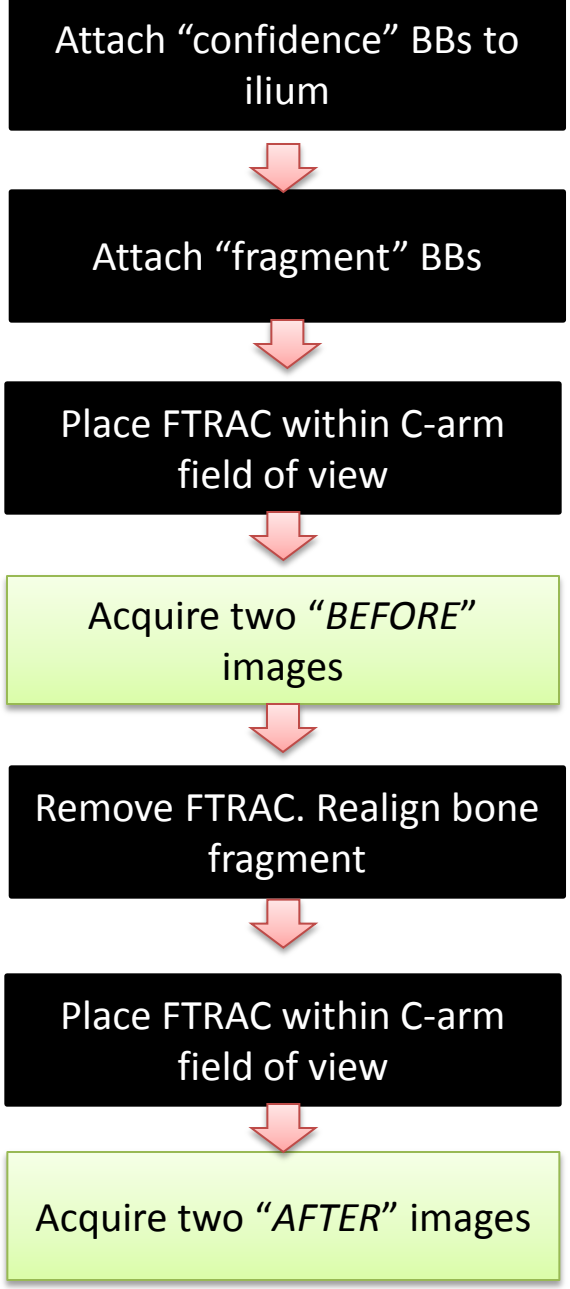
Test of Pipeline with Pelvic Phantom

Experiment

Purpose:

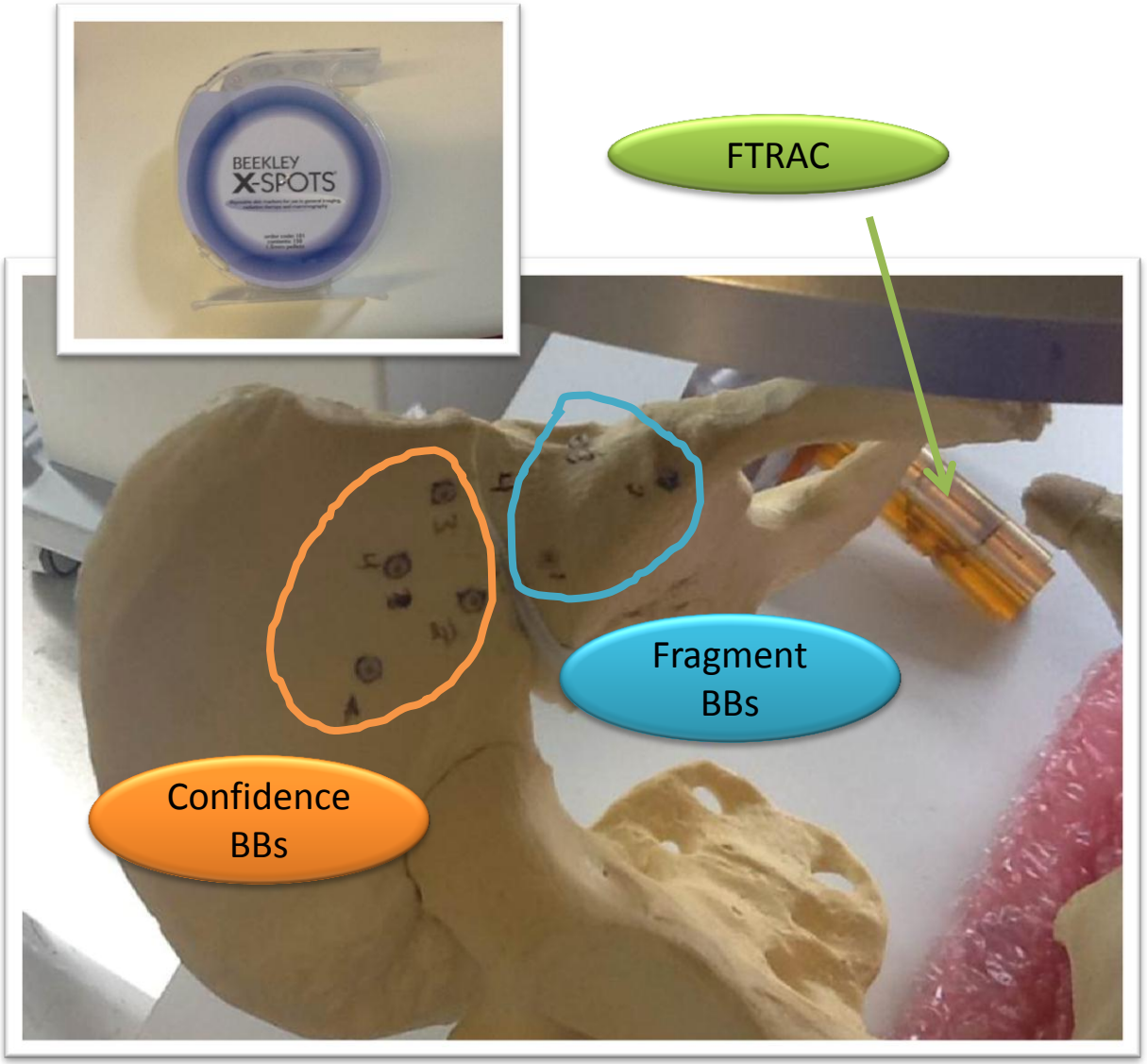
- Demonstrate proof of concept for proposed x-ray navigation pipeline using:
  - non-rigid FTRAC attachment
  - pelvic phantom
- Acquire raw C-arm images to use when creating MATLAB code for pipeline.
- Gauge accuracy of X-ray navigation method versus optical tracker method.

Intraoperative Pipeline



Intraoperative Pipeline

- Attach “confidence” BBs to ilium
- Attach “fragment” BBs
- Place FTRAC within C-arm field of view
- Acquire two “*BEFORE*” images
- Remove FTRAC. Realign bone fragment
- Place FTRAC within C-arm field of view
- Acquire two “*AFTER*” images



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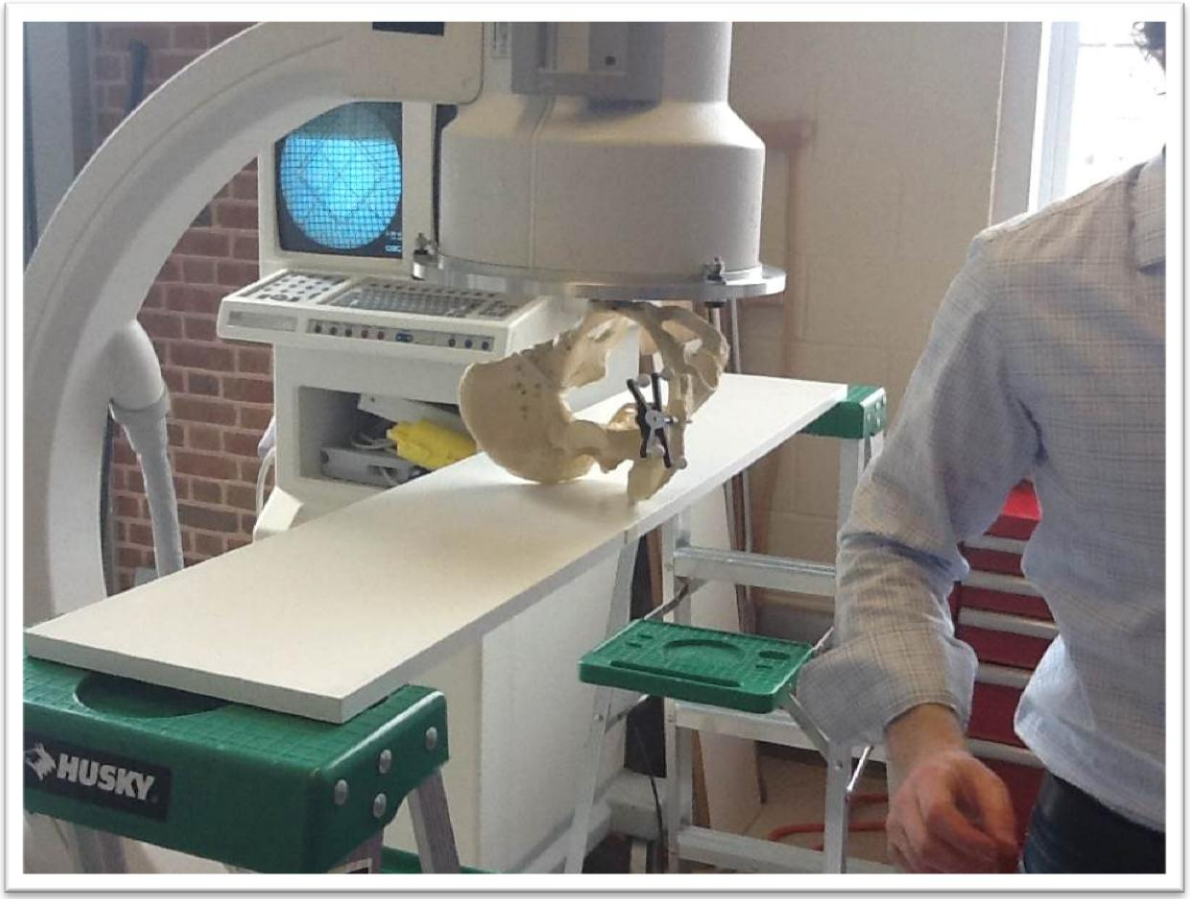
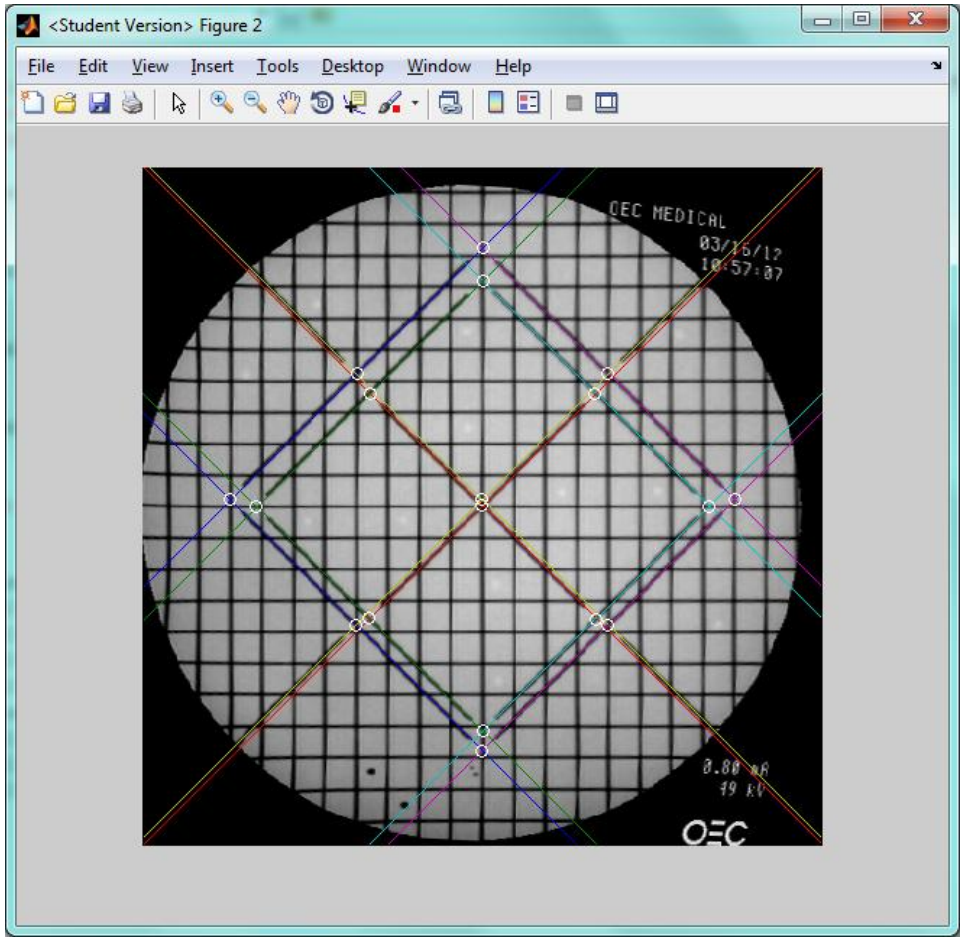


Imaging Subroutine



Calibration phantom

Dewarp C-arm distortion

↓

Segment BBs globally

↓

Classify BBs as
1. FTRAC
2. Confidence
3. Fragment

↓

Estimate **C-arm pose** using FTRAC

↓

Register C-arm images with CT volume

↓

Display biomechanics & radiographic angles

Imaging Subroutine

Before rectification

After rectification

Dewarp C-arm distortion

↓

Segment BBs globally

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1. FTRAC
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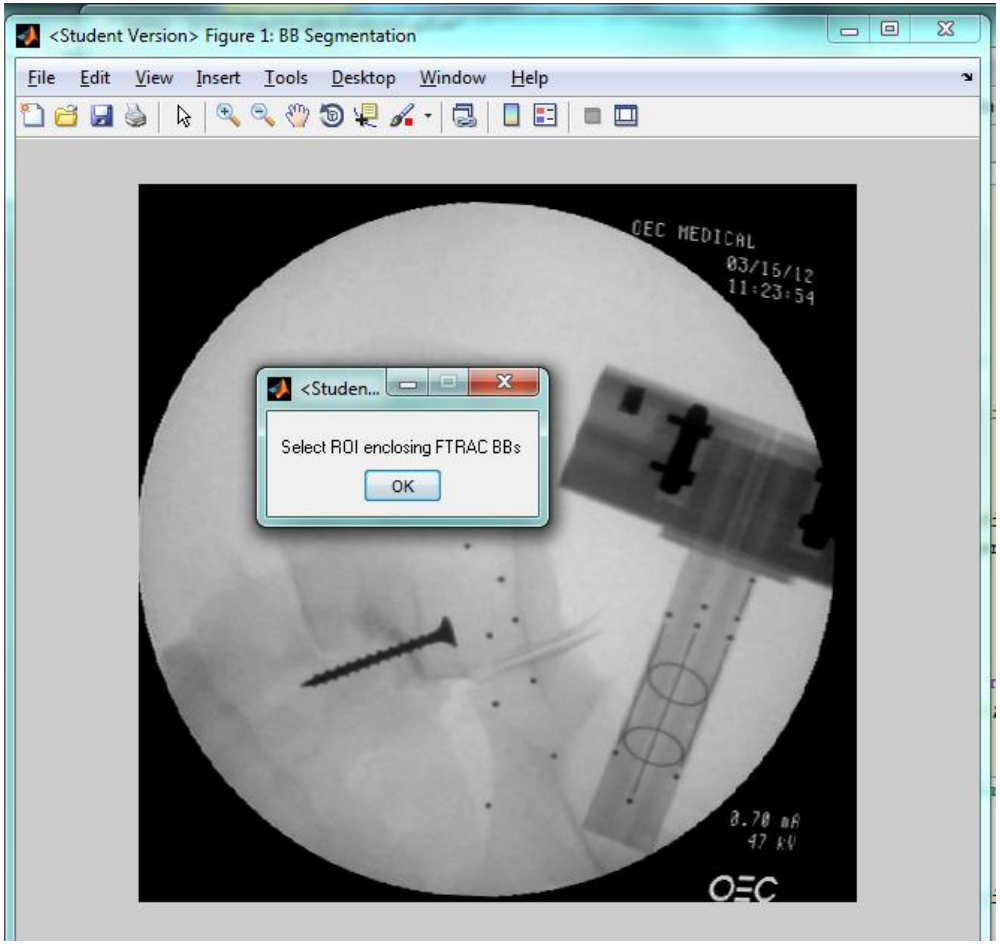
Imaging Subroutine



At the moment, we use `roipoly()` to distinguish BB types

Dewarp C-arm distortion

↓

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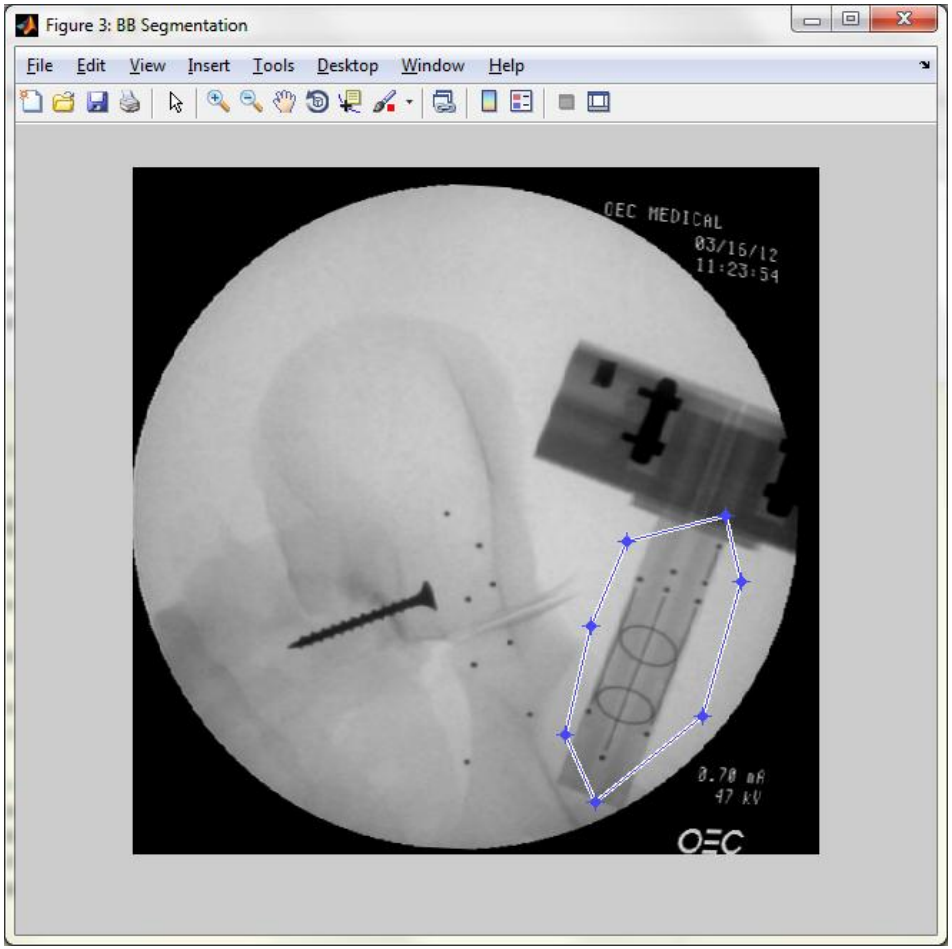

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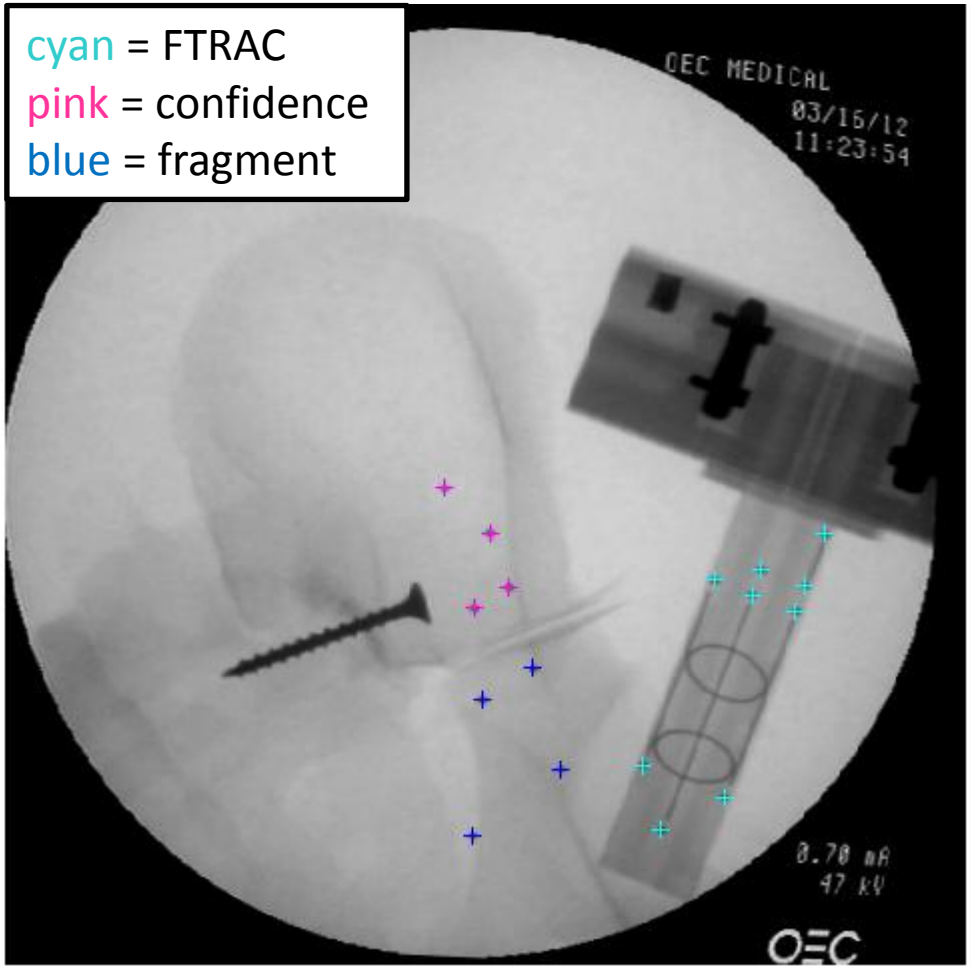


Results of BB classification

Dewarp C-arm distortion

↓

Segment BBs globally

↓

Classify BBs as
1. FTRAC
2. Confidence
3. Fragment

↓

Estimate **C-arm pose** using FTRAC

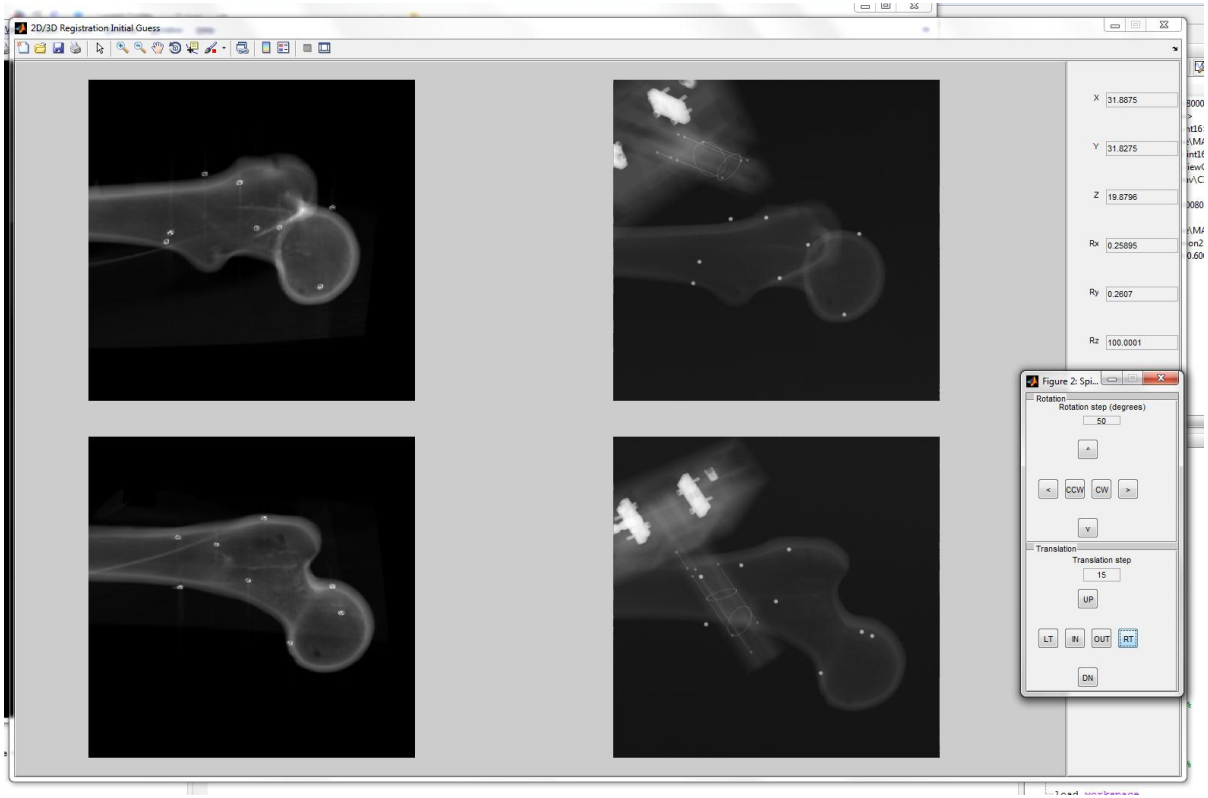
↓

Register C-arm images with CT volume

↓

Display biomechanics & radiographic angles

Imaging Subroutine



Existing software will perform 2D-3D registration using a correspondenceless expectation-maximization algorithm.

Dewarp C-arm distortion

↓

Segment BBs globally

↓

Classify BBs as
1. FTRAC
2. Confidence
3. Fragment

↓

Estimate **C-arm pose** using FTRAC

↓

Register C-arm images with CT volume

↓

Display biomechanics & radiographic angles

Imaging Subroutine

We regard the registration from the optical tracker method as **ground truth**.

Dewarp C-arm distortion

↓

Segment BBs globally

↓

Classify BBs as
1. FTRAC
2. Confidence
3. Fragment

↓

Estimate **C-arm pose** using FTRAC

↓

Register C-arm images with CT volume

↓

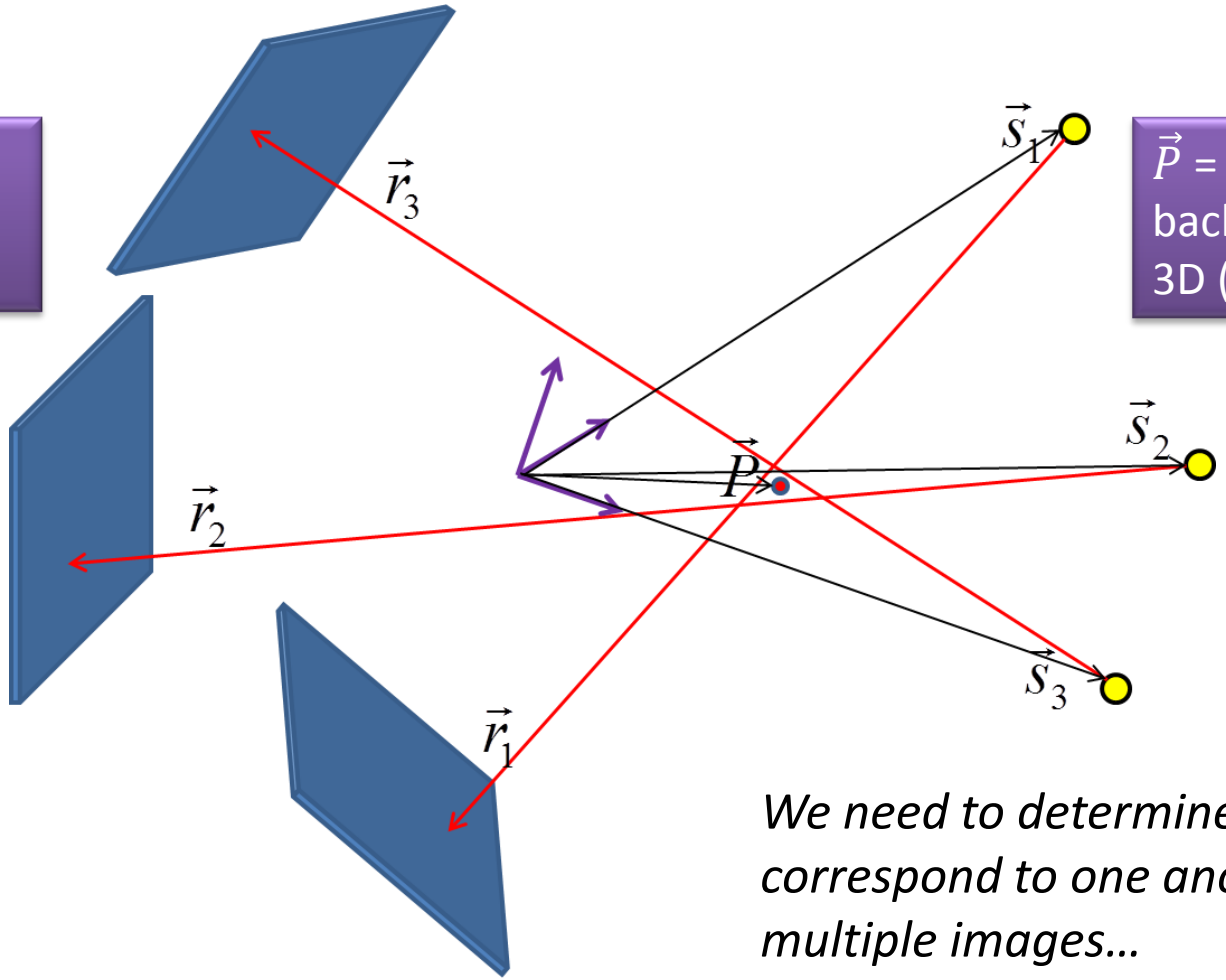
Display biomechanics & radiographic angles

To Be Completed

(1) BB Backprojection

- Incorporate code to backproject BBs segmented in 2D x-ray images onto 3D CT volume

$\vec{r_i}$ = projection of point in x-ray image i

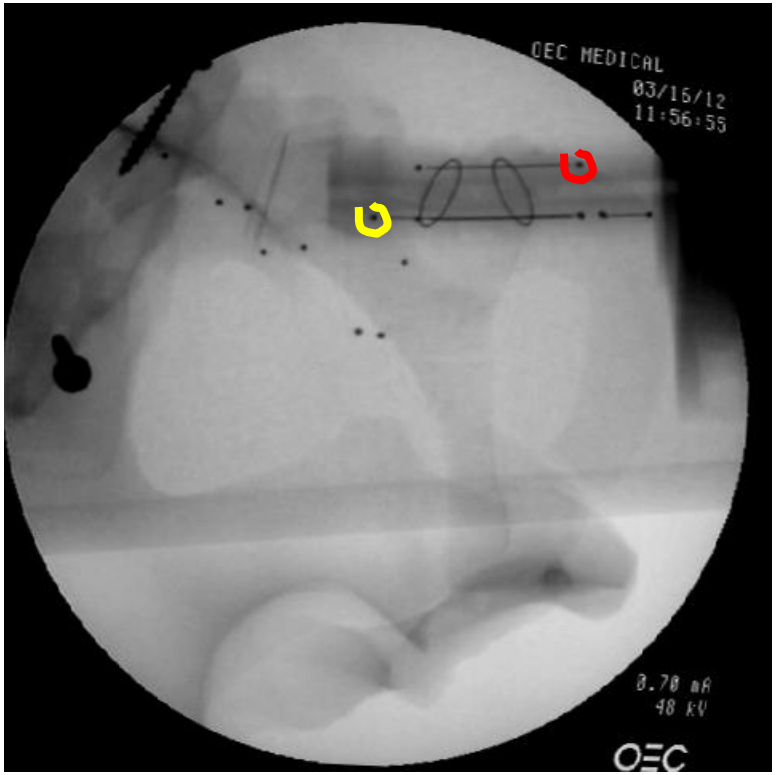


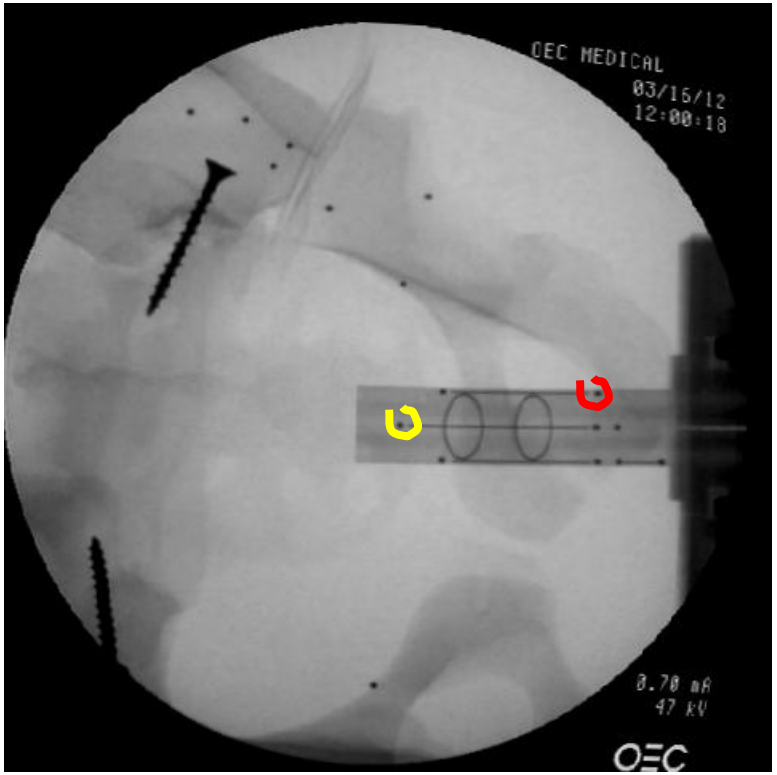
We need to determine which BBs correspond to one another across multiple images…

To Be Completed

(2) Locate Corresponding BBs

- Determine which BBs correspond to one another across multiple pre-op (or post-op) image sets





To Be Completed

(2) Locate Corresponding BBs

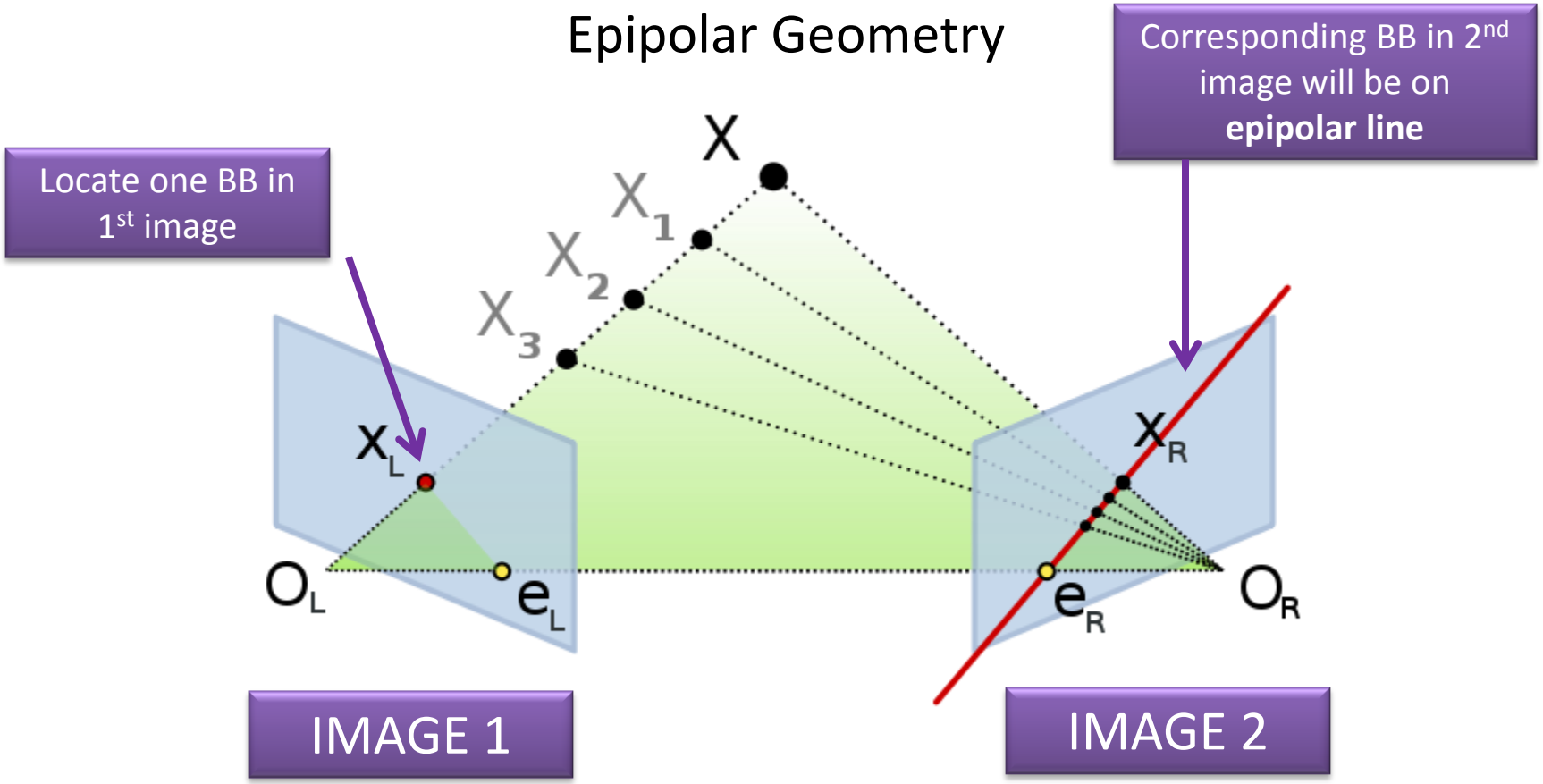


Image from: http://en.wikipedia.org/wiki/Epipolar_geometry

To Be Completed

(3) Compute Fragment Movement

- Determine fragment transformation between pre-op & post-op images
- Transformation may be computed in **model** (3D) space or **image** (2D) space

(4) Better BB Classification

- Create robust solution for differentiating FTRAC, confidence, & fragment BBs
- Desired, but not necessary

References

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2. Armiger RS, Armand M, Lepisto J, Minhas D, Tallroth K, Mears SC, Waites MD. Evaluation of a computerized measurement technique for joint alignment before and during periacetabular osteotomy. Computer Aided Surgery 2007;12(4):215-24.

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7. Jain AK, Mustafa T, Zhou Y, Burdette C, Chirikjian GS, Fichtinger G. FTRAC---A robust fluoroscope tracking fiducial. Med Phys 2005 October 2005;32(10):3185-98.

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