Computer-Guided X-Ray C-arm Positioning

Group 5: Ju Young Ahn, Seung Wook Lee
Mentor: Dr. Jeff Siewerdsen
Dr. Matthew Jacobson, Dr. Tharindu da Silva, Dr. Joseph Goerres

Project Overview - Challenge

C-arm: X-ray device with C-shaped arm with a source and detector in each side.

- Commonly used in orthopedic surgeries for localization and guidance
- Angular/orbital movements (multiple DOF)
  - ability to set preferred viewpoint

http://www.simeks.com.tr/en/portfolio-item/siemens-cios-alpha/

Challenge: “Fluoro-hunting”

- Surgeons normally take 5~10 shots on average to set an optimal fluoroscopic view.
- Problem: time-consuming, more radiation exposure to both patients and physicians, physically cumbersome, safety issues.

Project Overview - Solution

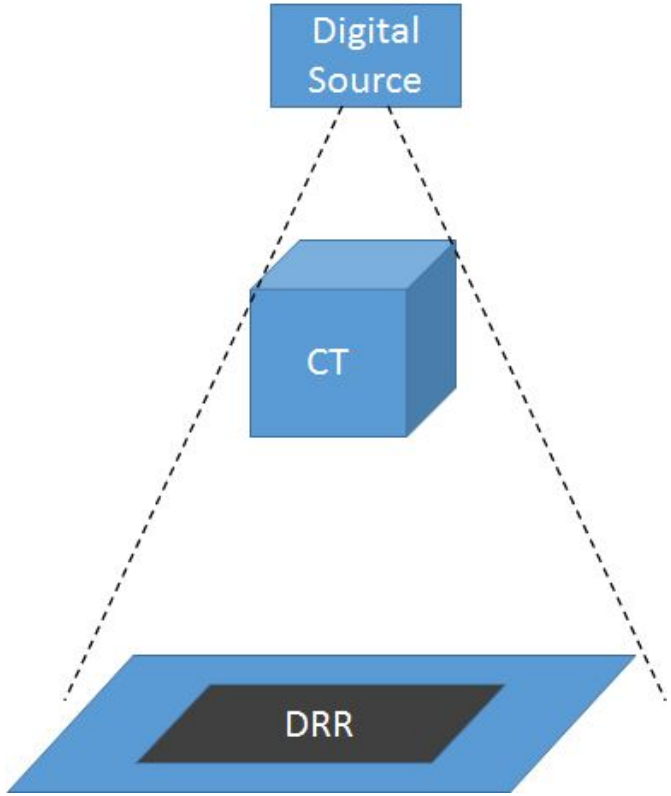
Solution: Find an optimal C-arm position with a digitally reconstructed radiograph (DRR) generated from preoperative CT, which simulates X-ray image without radiation.

DRR: simulated 2D X-ray scan of patient from 3D CT data.

Goals: Develop user-friendly interfaces to overcome problems associated with fluoro-hunting.

Approaches: 1. Computer Interface 2. Physical Interface

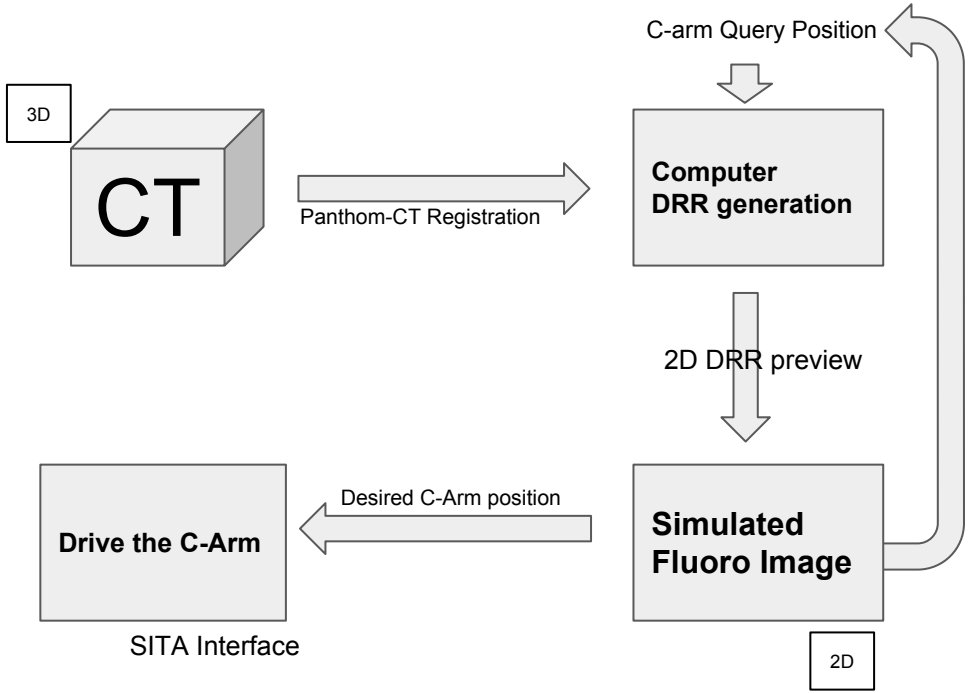
- Less time consuming, potential reduction of radiation dose



Computer Interface (CI)

Method
- Generate DRR from 3D CT data
- Allow manipulation of the source to simulate fluoro image (DRR)
- Drive the C-Arm to the desired position using SITA interface and then acquire X-ray image

Pros:
- Less physically cumbersome
- Motorized movement of C-Arm to the desired position



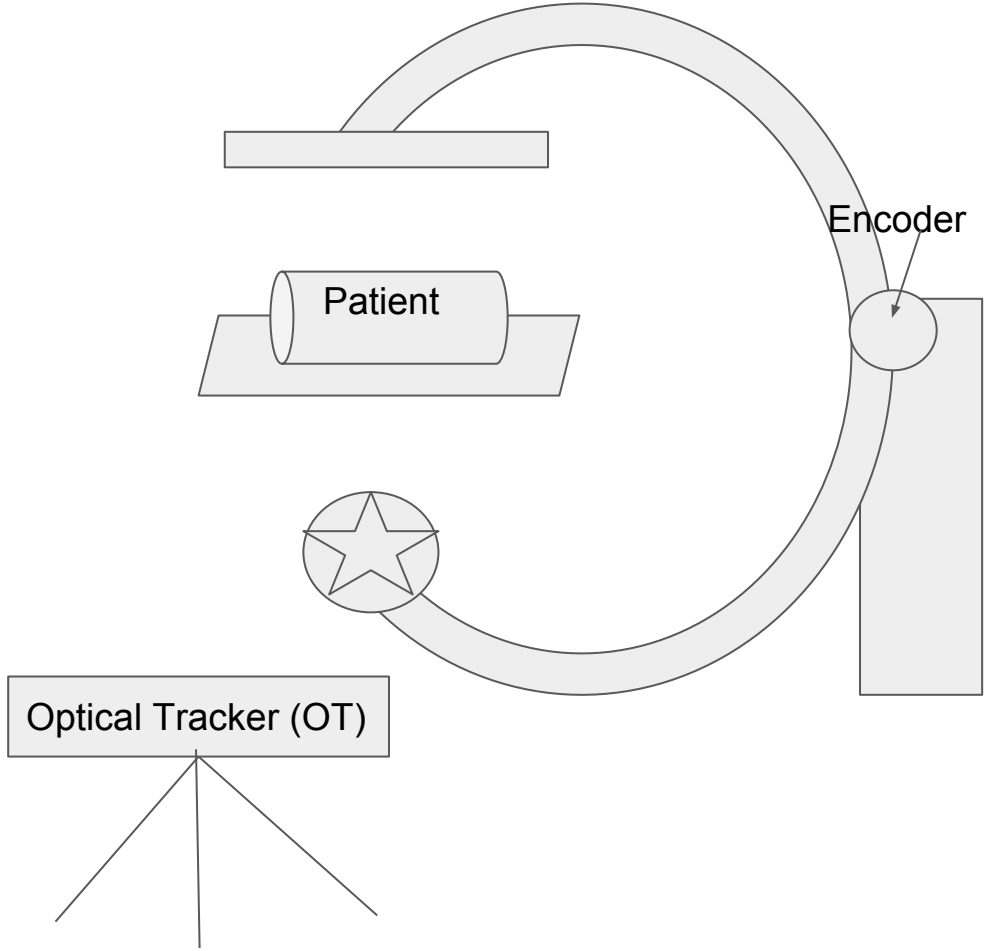
Physical Interface (PI)

Methods:

- Load CT data, register Patient-CT data
- C-arm position acquired physically
- Allow surgeons to physically move the C-Arm while generated DRR preview is displayed in real-time
- Once the C-Arm is in desired position, acquire X-ray image

Pros:

- Seamless integration to surgury workflow



Methods for measurement / registration

C-Arm Position Measurement

1) Tracker Based
   - Attach optical markers on C-Arm
   - Registered to optical tracker (OT)

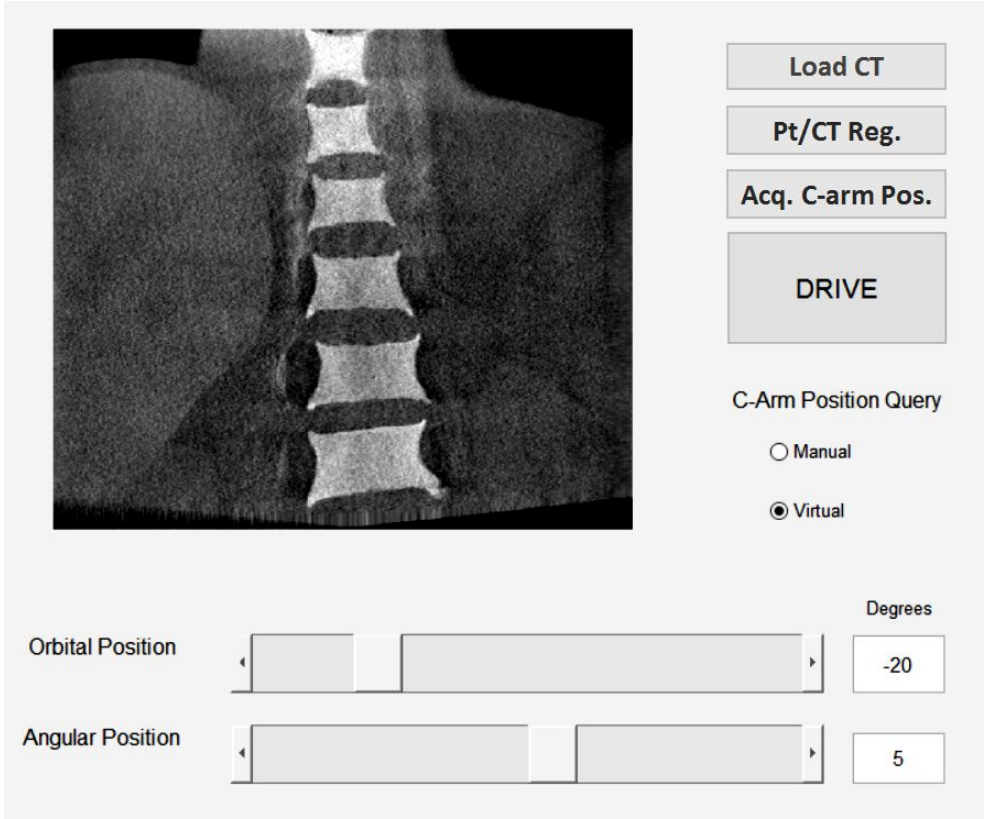
2) Encoder Based
   - Read C-Arm position from encoder embedded inside C-Arm

Phantom-CT Registration

1) Tracker Based
   - Attach optical markers on patient/panthom
   - Registered to optical tracker (OT)

2) 3D-2D image registration
   - Take 2 shots of X-ray images
   - Register 2D images to 3D CT data
   - Need undersatanding and established tools

Technical Approah - GUI



Deliverables

MIN

- Registeration of C-arm, patient, and patient CT data with an optical tracker/markers
  - Verification process through Target Registration Error (TRE)
- Modify existing DRR generation module to comply with physical constraints of the C-arm
  - Verification of compliance of the module to physical constraint of C-arm

EXP

- Physical Interface, capable of acquisition of pyhsical C-arm position and display of DRR
- Computer Interface, capable of specifying virtual C-arm position and displaying DRR
  - Validation that generated DRR matches the actual X-Ray image through a test object with physiological landmarks and measure geometric error/ alignment

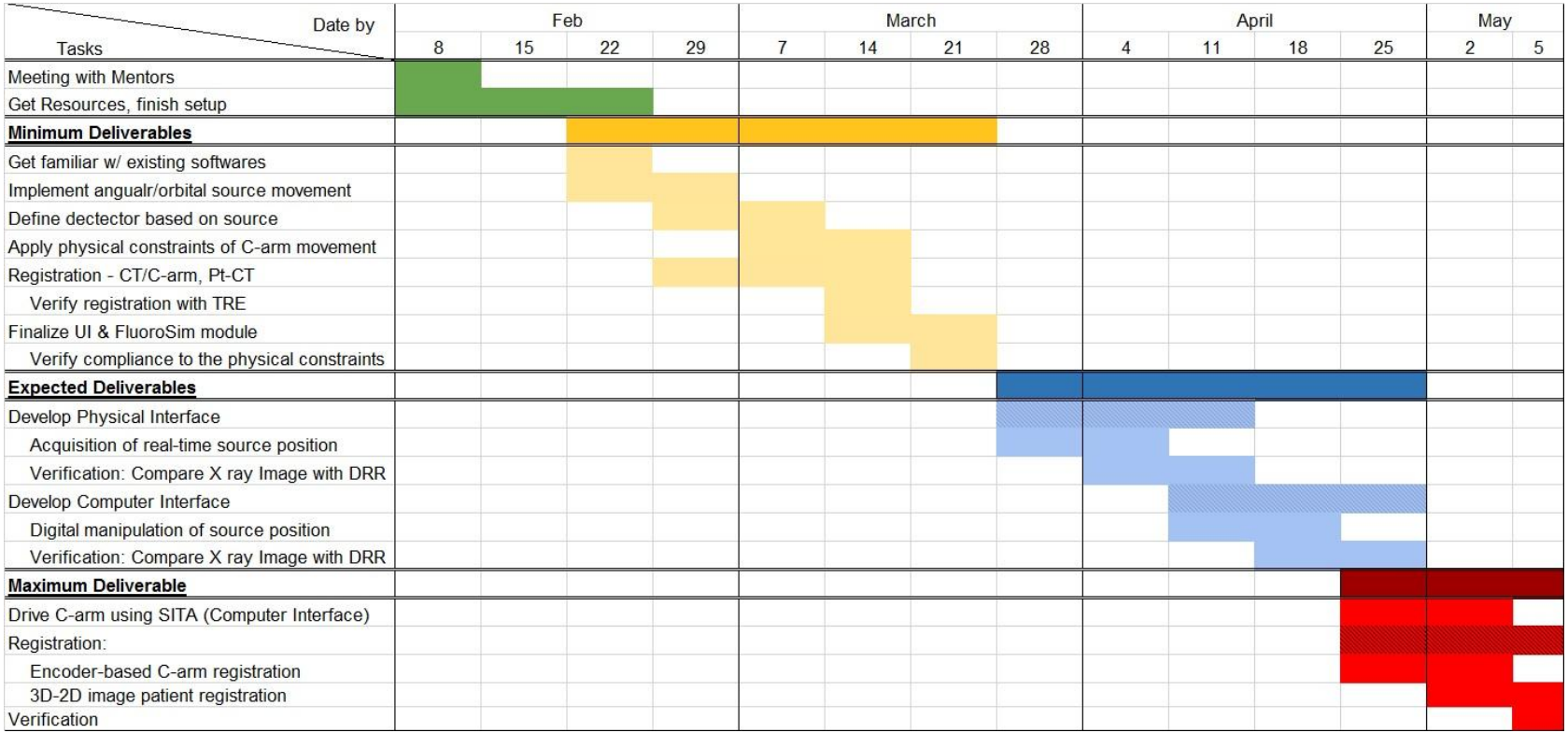
MAX

- Physical/Computer Interfaces:
  Encoder-based C-arm positioning, Pt-CT reg. w/ 3D-2D image registration
- Computer Interface: Drive the C-arm to preferred position with SITA interface
  - Verification: Measure accuracy of C-Arm positioning, TRE.

Dependencies & plan for resolving

Dependencies	Resolution
Equipment Accessibility	
C-arm/ SITA	Available in lab
Optical Trackers/Markers	Available in lab
Phantoms/ Phantom CT data	Available in lab
Software (VTK, Visual Stuido, TREK, etc)	Downloaded
Access to existing tools	Access acquired
Keep track of partner's work / Version control	Jupyter, Git
Radiation Safety Training	Not done
Find working schedules with mentors	Scheduled
Access to the Lab	Access acquired

Project Timeline



Key dates & assigned responsibilities

Seung Wook Lee:

- Background: Medical imaging, Instrumentation, Matlab, Python
- Responsibility: C-arm based DRR module/UI Development

Ju Young Ahn:

- Background: Matlab, C/C++, Java, Python
- Responsibility: CT/Pt/C-Arm Registration, UI Development

Weekly meeting schedule:

- Monday/Wednesday from 3:00PM to 6:00PM at Dr. Siewerdsen's Lab
- Saturday from 2:00PM to 6:00PM at Homewood
- Meeting with Dr. Siewerdsen on Wednesday for progress check/guidance

Reading List

[1] Navab, Nassir, Stefan Wiesner, Selim Benhimane, Ekkehard Euler, and Sandro Michael Heining. "Visual Servoing for Intraoperative Positioning and Repositioning of Mobile C-arms." Medical Image Computing and Computer-Assisted Intervention – MICCAI 2006 Lecture Notes in Computer Science (2006): 551-60. Web.

[2] Siddon, Robert L. "Fast Calculation of the Exact Radiological Path for a Three-dimensional CT Array." *Med. Phys. Medical Physics* 12.2 (1985): 252. Web.

[3] Hartley, Richard, and Andrew Zisserman. "More Single View Geometry." *Multiple View Geometry in Computer Vision*: 153-163. Web.

[4] Long, Yong, Jeffrey A. Fessler, and James M. Balter. "3D Forward and Back-Projection for X-Ray CT Using Separable *Footprints." IEEE Transactions on Medical Imaging IEEE Trans. Med. Imaging 29.11 (2010): 1839-850. Web.*

[5] *Otake, Y. et al. "Automatic Localization of Vertebral Levels in X-Ray Fluoroscopy Using 3D-2D Registration: A Tool to Reduce Wrong-Site Surgery."Physics in medicine and biology 57.17 (2012): 5485–5508. PMC. Web.*

[6*] Uneri, A. et al. "Known-Component 3D-2D Registration for Image Guidance and Quality Assurance in Spine Surgery Pedicle Screw Placement."Proceedings of SPIE--the International Society for Optical Engineering 9415 (2015): 94151F. PMC. Web.*