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

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.

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.

   - 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 surgery workflow

Encoder

Patient

Optical Tracker (OT)
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/phantom
   - 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 understanding and established tools
Technical Approach - GUI
Deliverables

MIN
- Registration 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 physical 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

<table>
<thead>
<tr>
<th>Dependencies</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Accessibility</td>
<td>Available in lab</td>
</tr>
<tr>
<td>C-arm/ SITA</td>
<td>Available in lab</td>
</tr>
<tr>
<td>Optical Trackers/Markers</td>
<td>Available in lab</td>
</tr>
<tr>
<td>Phantoms/ Phantom CT data</td>
<td>Available in lab</td>
</tr>
<tr>
<td>Software (VTK, Visual Studio, TREK, etc)</td>
<td>Downloaded</td>
</tr>
<tr>
<td>Access to existing tools</td>
<td>Access acquired</td>
</tr>
<tr>
<td>Keep track of partner’s work / Version control</td>
<td>Jupyter, Git</td>
</tr>
<tr>
<td>Radiation Safety Training</td>
<td>Not done</td>
</tr>
<tr>
<td>Find working schedules with mentors</td>
<td>Scheduled</td>
</tr>
<tr>
<td>Access to the Lab</td>
<td>Access acquired</td>
</tr>
</tbody>
</table>
# Project Timeline

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Date by</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting with Mentors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Get Resources, finish setup</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Minimum Deliverables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Get familiar w/ existing softwares</td>
<td>8</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implement angular/orbital source movement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Define detector based on source</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apply physical constraints of C-arm movement</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Registration - CT/C-arm, Pt-CT</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verify registration with TRE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finalize UI &amp; FluoroSim module</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verify compliance to the physical constraints</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Expected Deliverables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop Physical Interface</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acquisition of real-time source position</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verification: Compare X ray Image with DRR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop Computer Interface</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital manipulation of source position</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verification: Compare X ray Image with DRR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maximum Deliverable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drive C-arm using SITA (Computer Interface)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Registration:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encoder-based C-arm registration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3D-2D image patient registration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

[Image: I-STAR logo]

600.446 CIS II Spring 2016
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


