

Detection and Guidance of K-Wire Placement in Pelvic Trauma Surgery

Team: Kinjal Shah and Irina Bataeva

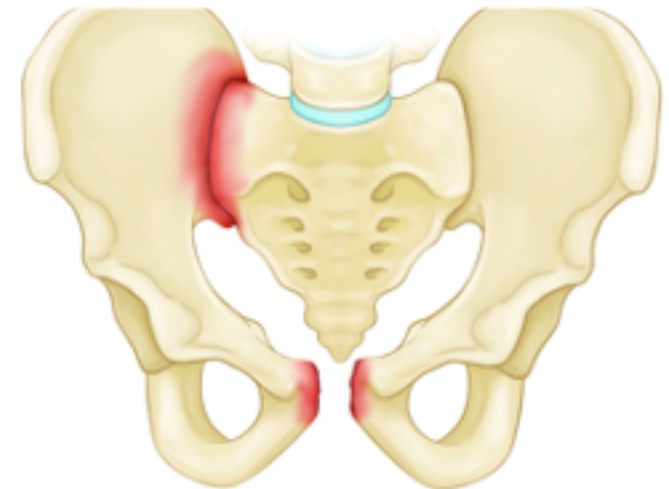
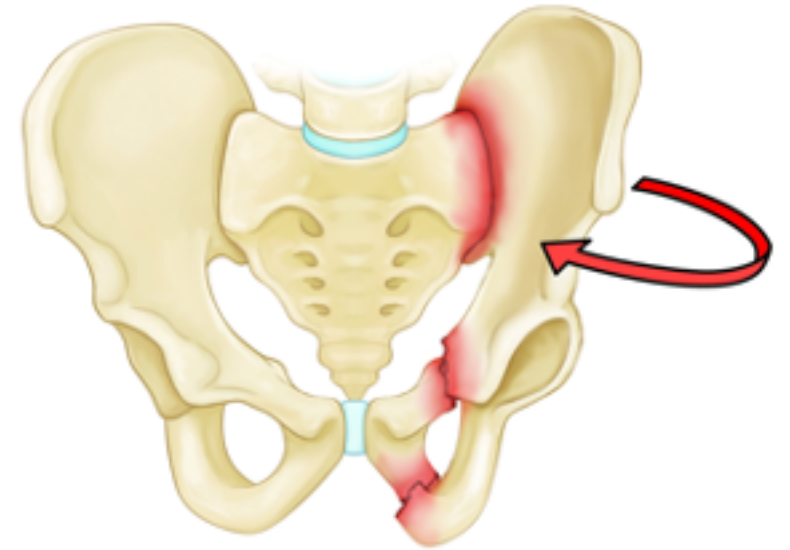
Mentor: Dr. Ali Uneri

CIS2 Project

February 20, 2020

Background: Pelvic Fractures

- **2–8%** of all injuries¹
- Young population
 - Traffic Accidents
- Older population
 - Ordinary Falls
- Growing concern: ~\$1.8B market by 2025²
- Complex fractures require **surgical stabilization**

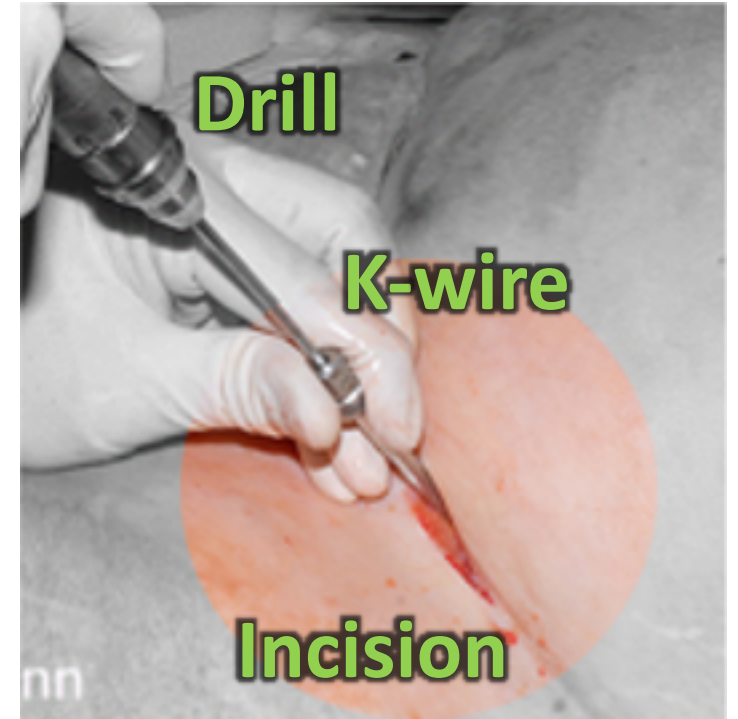


[1] Buller et al. 2016. *Geriatr Orthop Surg Rehabil.* 7(1) 9–17.

[2] Vu et al. 2017. *Injury.* 48(11) 2443-50

Background: Pelvic Fracture Fixation

- Minimally invasive surgery performed percutaneously
- Kirschner wires (K-wire) guide cannulated screws
- Long trajectories: up to 15 cm
- **K-wires deform**
 - High accuracy required: 1 mm and 5°
- Fluoroscopy is used for guidance
 - Fluoro-hunting: finding appropriate views
 - Trial-and-error: getting the trajectory right
 - **Up to 2 mins of radiation exposure per screw**



U. Culleman aofoundation.org

Background: Fluoroscopic K-wire guidance



Goerres et al. 2017

[1] Dzupa et al. 2009. Acta Chir Orthop Traumatol Cech. 76(5) 404–9.

[2] Poole et al. 1992. Am Surg. 58(4) 224-31.

Screw malposition
20–30% suboptimal,¹ **6%** breach²



Neurological injuries



Vascular injuries



Longer surgery times

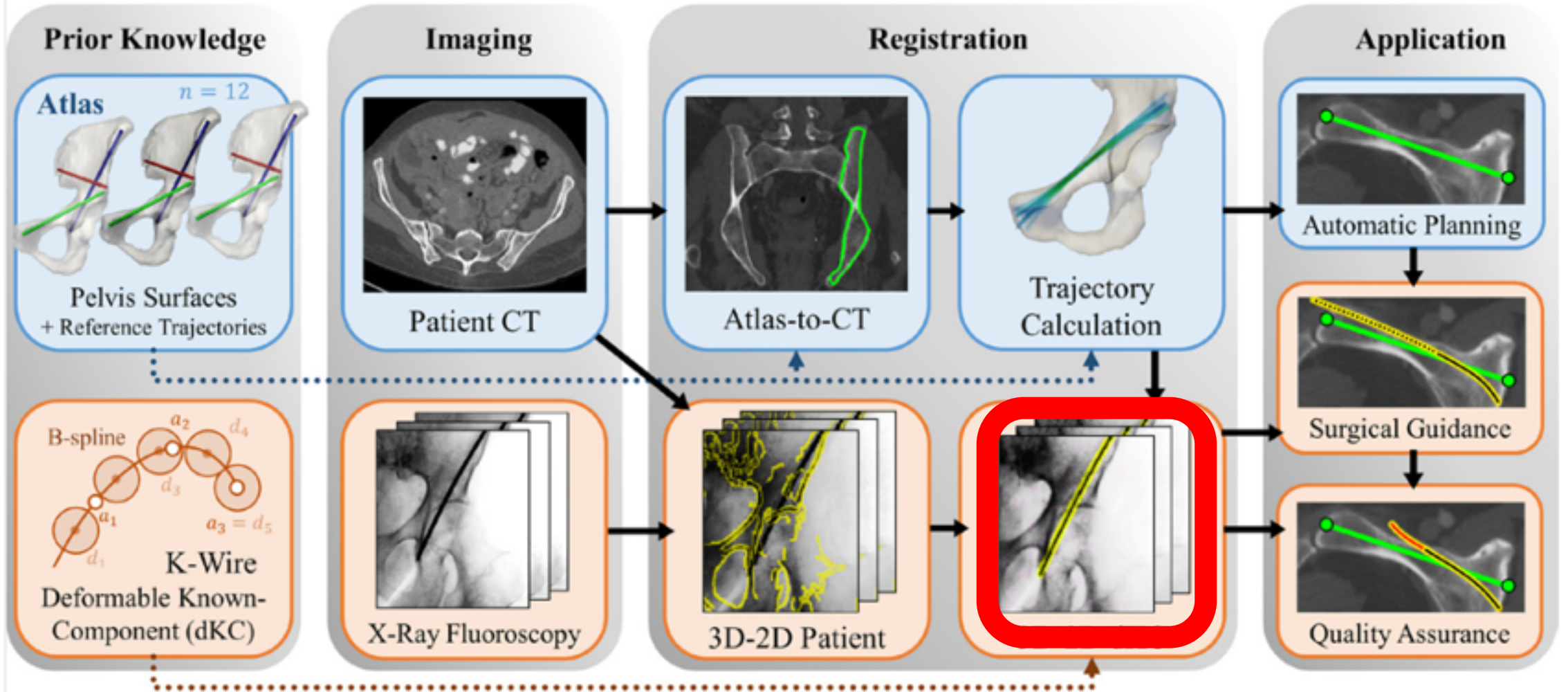


Pelvic Instability

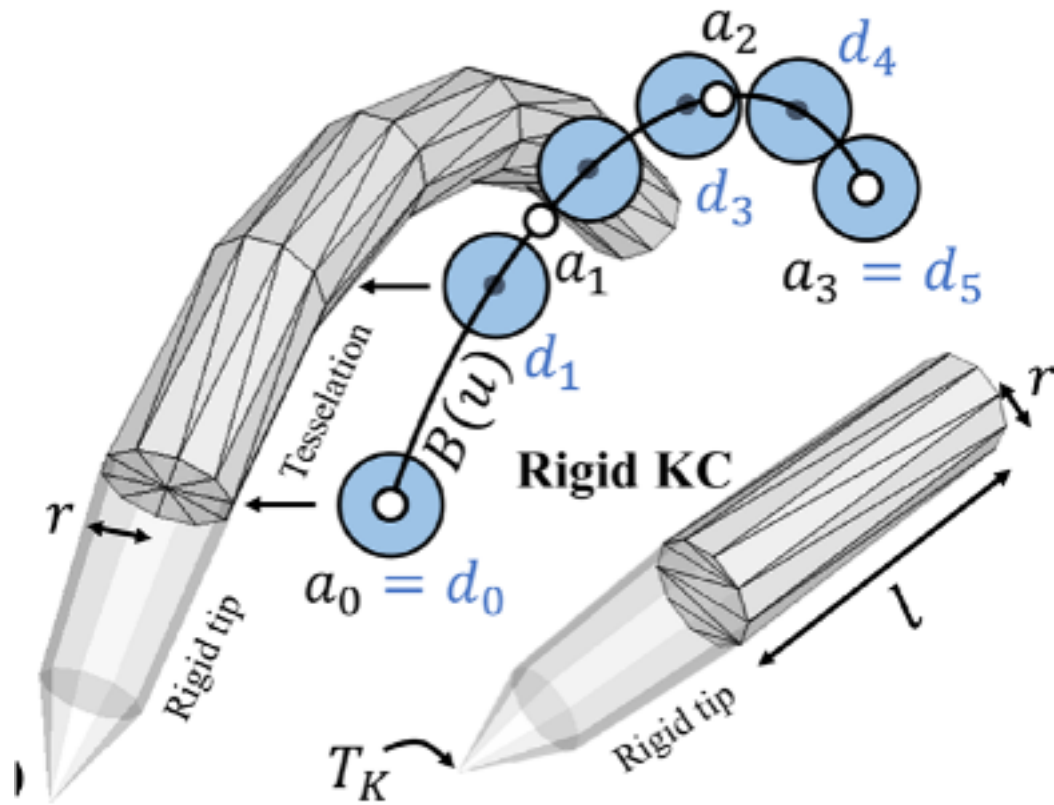


DePuy Synthes K-wire and a cannulated screw

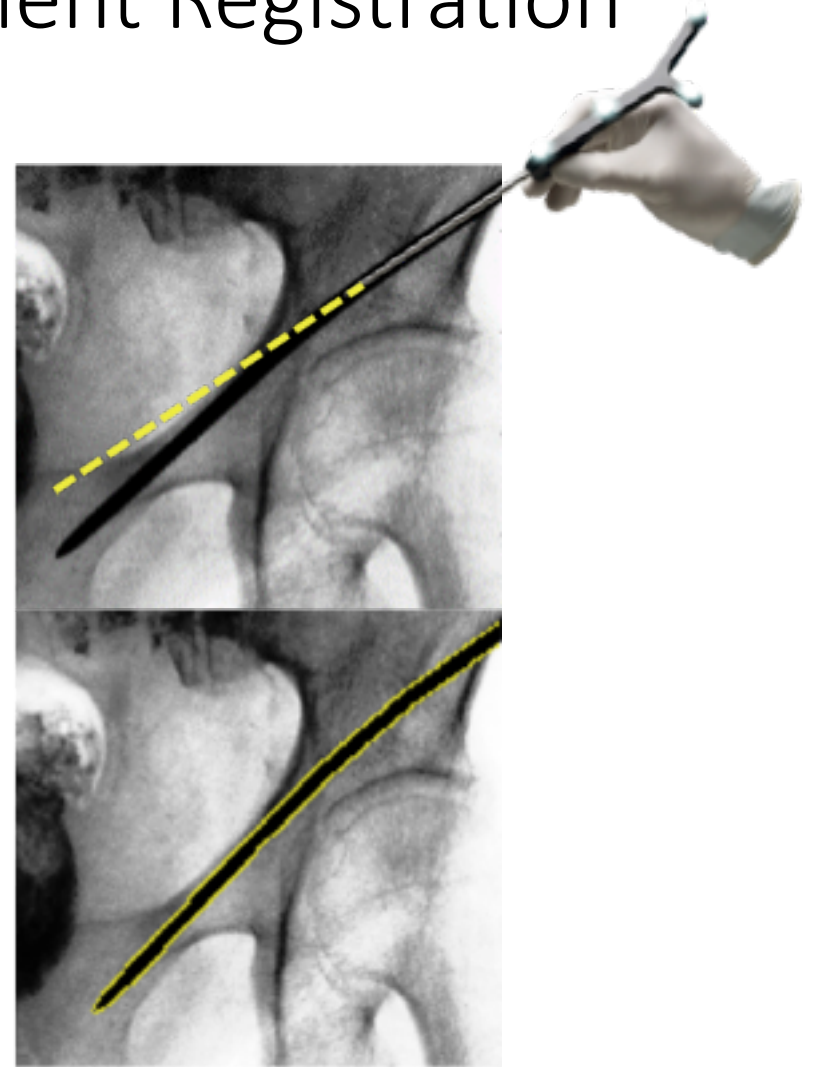
Background: Navigation Workflow



Prior Work: Deformable Known-Component Registration

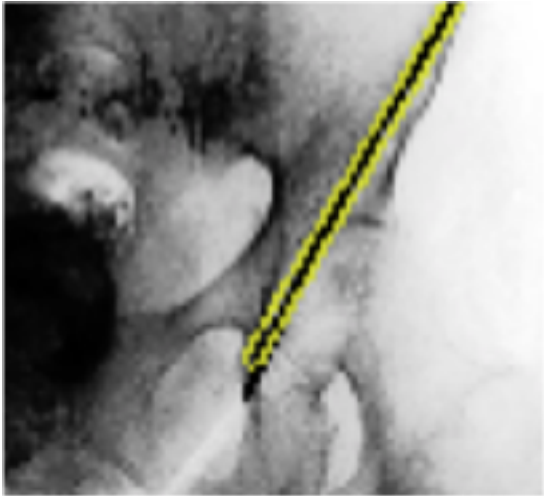


B-spline based deformable mesh model

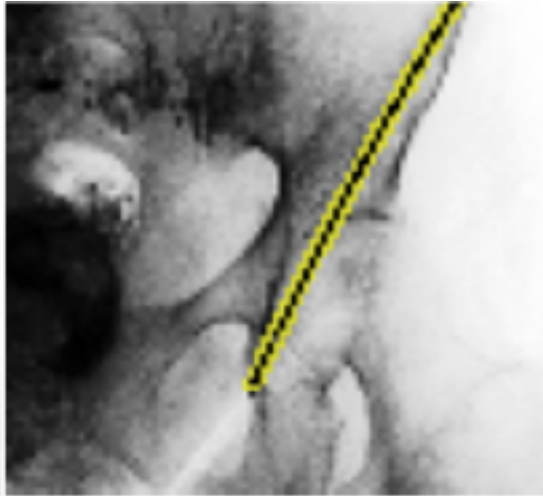


Conventional navigation with rigidity assumption

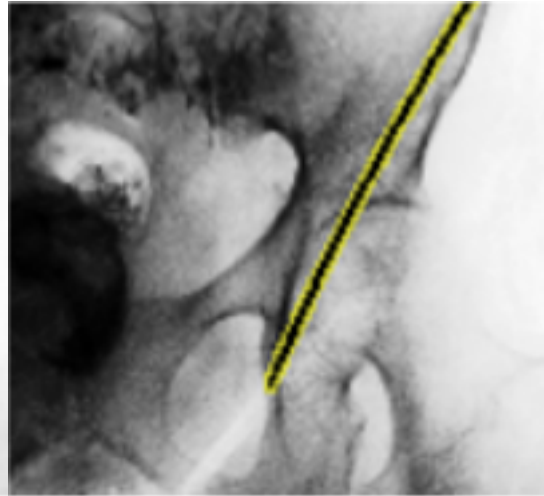
Prior Work: Accuracy and Runtime



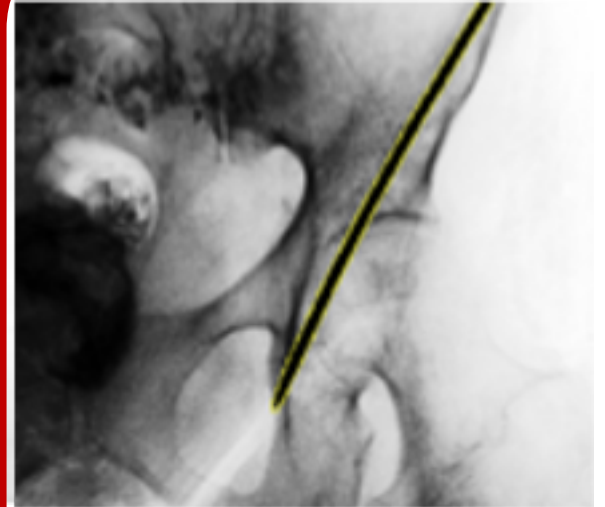
3x3 mm² pix
Multi-start rigid
2.5±1.1 mm
10x2 s



2x2 mm² pix
3 knots
1.9±1.3 mm
+40 sec



1.5x1.5 mm² pix
4 knots
1.4±1.7 mm
+1:30 mins



1x1 mm² pix
5 knots
1.1±1.6 mm
+2 mins

Project Motivation and Goals

Motivation: Improve accuracy to reduce injury while limiting radiation exposure

Objective: Use emerging deep learning methods to:

(1) Detect K-wires in 2D radiographs of the pelvis

(2) Localize their 3D pose to provide surgical navigation during fracture fixation

Figures of Merit

- Faster localization through better initialization: **Target < 2 min**
- Improved accuracy of K-Wire Detection: **Target < 1.1±1.6 mm**
- Improved robustness resulting in fewer outliers
- Fewer fluoroscopic images necessary for detection and guidance

Proposed Technical Approach: Dataset Generation

Virtual Deformable K-Wire Model

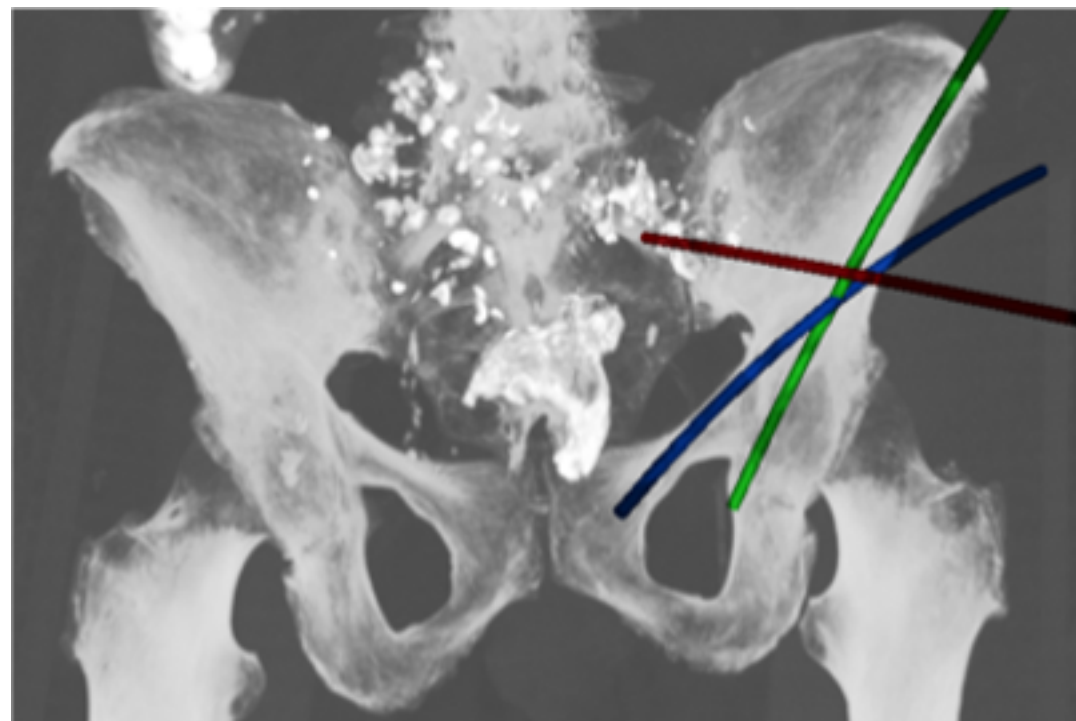


3 Fluoro shots (-38°, -10°, 16°)

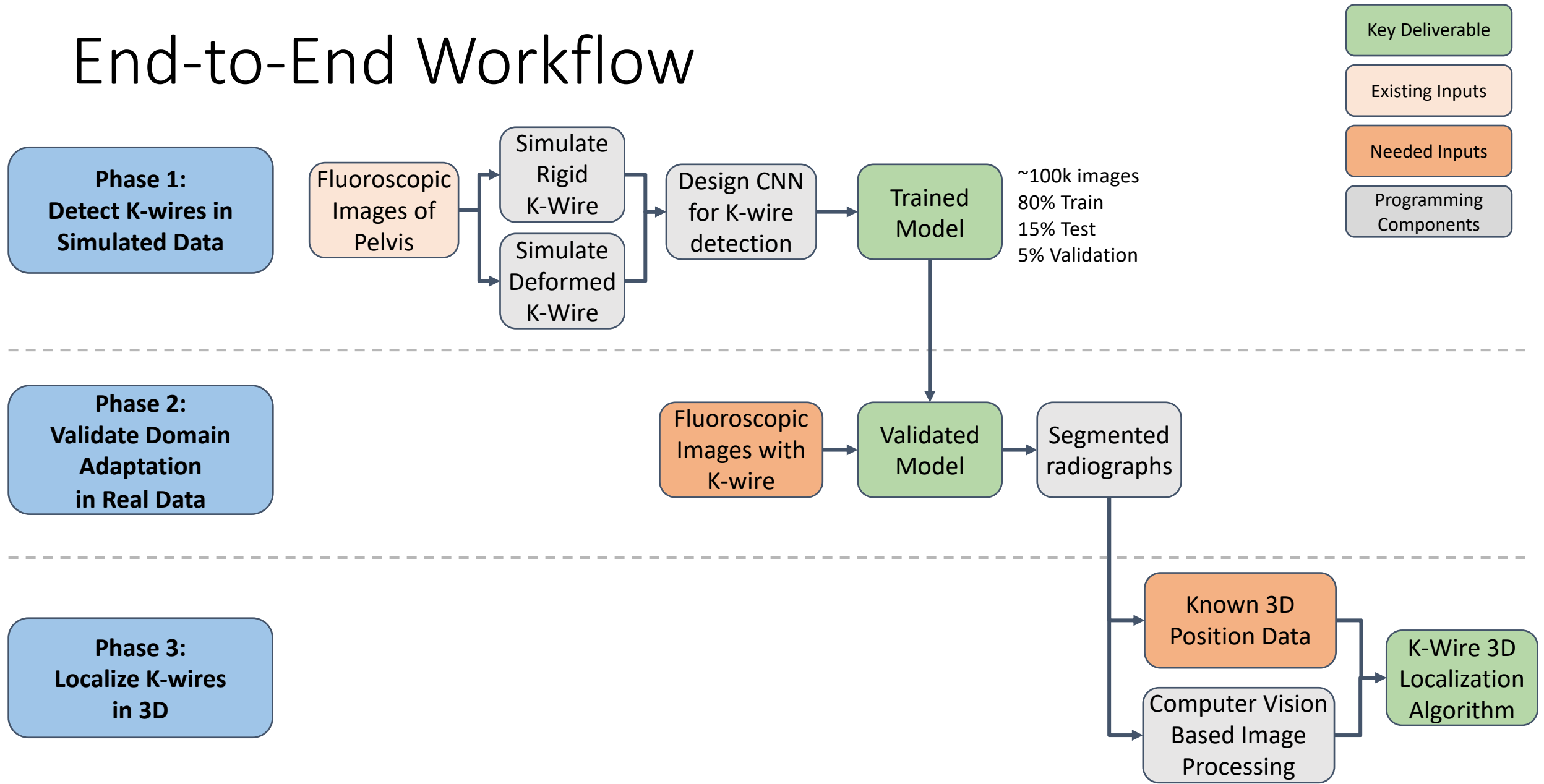
3 K-wire Trajectories (to start)

- Superior ramus
- AIIS to PSIS
- Iliac crest to posterior column

~100K images



End-to-End Workflow



Deliverables

Minimum:

Train Model on Simulations

- Simulated K-wire images
- Trained and validated CNN to detect K-wire in 2D radiographs
- Figures of merit for simulated data results

Expected:

Evaluate Model on Real Data

- Establish “real image” data set
- Transfer Learning from simulated data to real data
- Figures of merit

Maximum:

3D Localization and Guidance

- Evaluations of existing stereo x-ray images to 3D localization implementations
- Design of 3D localization algorithm
- Evaluation of dose/x-ray protocols
- Conference submission

Milestones

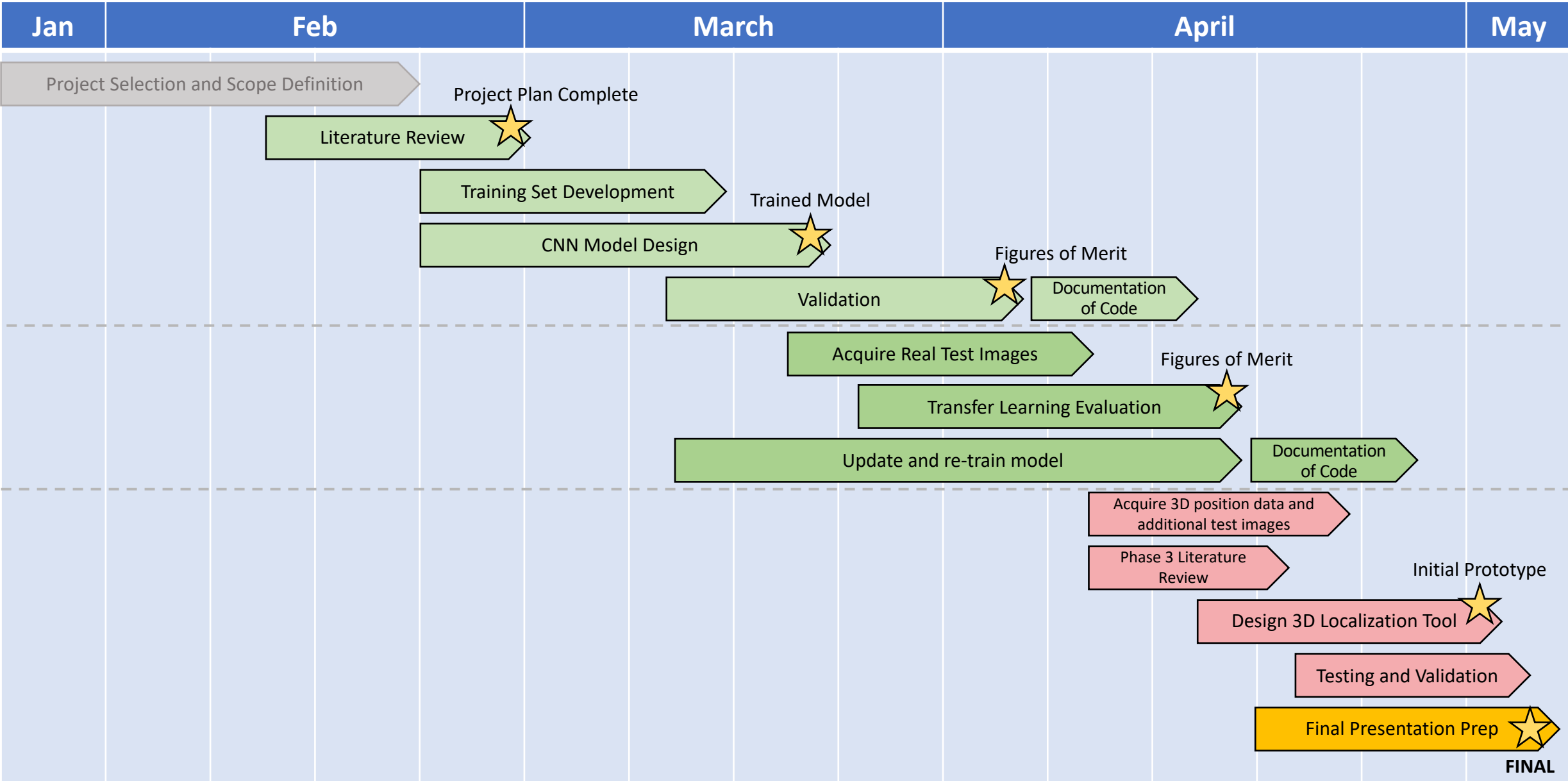
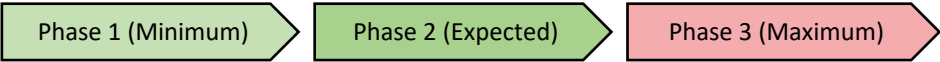
Milestone	Planned Date	Expected Date	Status
Complete Development of Training Set	Monday, March 16	Monday, March 16	On Track
Collation of existing data	Monday, March 2	Monday, March 2	On Track
Collation of publicly available medical images	Monday, March 2	Monday, March 2	On Track
Data augmentation of pelvic images with simulated K-wires	Monday, March 16	Monday, March 16	On Track
Obtain Trained Model	Friday, March 20	Friday, March 20	On Track
Identify candidate CNN architectures based on literature review	Friday, February 28	Friday, February 28	On Track
Establish necessary architecture for chosen solution	Wednesday, March 4	Wednesday, March 4	On Track
Design CNN	Monday, March 16	Monday, March 16	On Track
Code Documentation	Friday, March 27	Friday, March 27	On Track
Obtain Figures of Merit - Simulated Data	Monday, April 6	Monday, April 6	On Track
Define Validation Process	Tuesday, March 10	Tuesday, March 10	On Track
Conduct robust testing on Training dataset	Friday, March 20	Friday, March 20	On Track
Obtain Figures of Merit - Real Data	Monday, April 20	Monday, April 20	On Track
Definition of experimental plan and validation process	Tuesday, March 20	Tuesday, March 20	On Track
Data acquisition	Friday, April 10	Friday, April 10	On Track
Code Documentation	Monday, April 27	Monday, April 27	On Track
3D Localization Algorithm Developed	Friday, May 1	Friday, May 1	On Track
Literature Review Report	Monday, April 20	Monday, April 20	On Track
Initial program draft complete, validation initiated	Friday, May 1	Friday, May 1	On Track
Final Poster Presentation/Report	Tuesday, May 5	Tuesday, May 5	On Track
Conference Submission	Summer 2020	Summer 2020	On Track

Dependencies

Dependency	Contact	Date Required	Status	Solution	Contingency
Availability of real radiographs of the pelvis	Dr. Ali Uneri	2/28	In Progress	Leverage software tools and radiographs provided by the I-STAR lab	Generate image set using radiographs simulated from CT
Access to C-arm, phantoms, and surgical instruments	Dr. Jeffrey Siewerdsen, Dr. Ali Uneri	2/26	Resolved	Access to all equipment to be provided by I-STAR, Rohan Vijayan will assist with C-arm operation	Undergo training if significant amount of data needs to be collected
Computational Resources	Dr. Ali Uneri	2/27	In progress	Access to a shared GPU cluster at I-STAR, dedicated lab workstation, and personal laptops	Request access to resources at LCSR
I-STAR lab Git repository access	Dr. Ali Uneri	2/21	Resolved	Dr. Uneri will initiate and share a dedicated repository at https://git.lcsr.jhu.edu/	
Cadaver Access	Dr. Jeffrey Siewerdsen	3/15	Available if needed	Cadaver studies (for related projects) are planned for upcoming weeks.	Phantoms
Access to real images with K-wires	Dr. Ali Uneri	3/20	Under Evaluation	If images not are available, we will be able to obtain additional images with phantoms	
Access to scripts / solutions for data generation and training	Dr. Ali Uneri	NA	Resolved	Jupyter notebooks, TensorFlow, PyTorch, OpenCV	

Schedule

Key



Team Management

Responsibility Ownership

Irina Bataeva	Kinjal Shah
<ul style="list-style-type: none">• K-wire images dataset generation• Cadaver/phantom experiments	<ul style="list-style-type: none">• Training model design and development• Model evaluation

Meeting Cadence

- Weekly meetings as a group every Sunday, Wednesday
- Weekly meetings with Dr. Ali Uneri on Fridays *subject to change

Collaboration

- Code storage and version control on GitLab at <https://git.lcsr.jhu.edu/>

Reading List

1. Ketcha MD, De Silva TS, Han R, Uneri A, Vogt S, Kleinszig G, and Siewerdsen JH. "**Learning-based deformable image registration: effect of statistical mismatch between train and test images,**" Journal of Medical Imaging 6(4), 044008 (17 December 2019). doi:<https://doi.org/10.1117/1.JMI.6.4.044008>
2. Uneri A, Goerres J, De Silva TS, Jacobson MW, Ketcha MD, Reaungamornrat S, Kleinszig G, Vogt S, Khanna AJ, Wolinsky JP, Siewerdsen JH. "**Deformable 3D-2D registration of known components for image guidance in spine surgery.**" Med Image Comput Comput Assist Interv, 9902, pp. 124–32, 2016 doi:10.1007/978-3-319-46726-9_15.
3. J. Goerres, M. Jacobson, A. Uneri, T. de Silva, M. Ketcha, S. Reaungamornrat, S. Vogt, G. Kleinszig, J.-P. Wolinsky, G. Osgood, and J. H. Siewerdsen "**Deformable 3D-2D registration for guiding K-wire placement in pelvic trauma surgery**", Proc. SPIE 10135, Medical Imaging 2017: Image-Guided Procedures, Robotic Interventions, and Modeling, 101350A (3 March 2017); doi:10.1117/12.2255952
4. Pauly, Olivier, et al. "**A Machine Learning Approach for Deformable Guide-Wire Tracking in Fluoroscopic Sequences.**" Medical Image Computing and Computer-Assisted Intervention – MICCAI 2010 Lecture Notes in Computer Science, 2010, pp. 343–350.,
5. Ma, Yingliang, et al. "**A Novel Real-Time Computational Framework for Detecting Catheters and Rigid Guidewires in Cardiac Catheterization Procedures.**" Medical Physics, vol. 45, no. 11, 2018, pp. 5066–5079., doi:10.1002/mp.13190.
6. Wagner, Martin G., et al. "**Deep Learning Based Guidewire Segmentation in x-Ray Images.**" Medical Imaging 2019: Physics of Medical Imaging, 2019, doi:10.1117/12.2512820.
7. Wu, Yu-Dong, et al. "**Automatic Guidewire Tip Segmentation in 2D X-Ray Fluoroscopy Using Convolution Neural Networks.**" 2018 International Joint Conference on Neural Networks (IJCNN), 2018, doi:10.1109/ijcnn.2018.8489337.