Project Checkpoint Presentation

Team 07: Real-time Integration of Fully Automatic 2D/3D Pelvic Registration with Robotic X-ray Acquisition

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Mentors:

- Benjamin Killeen
- Prof. Mathias Unberath

Project Recap - 2D/3D Registration

- **Intraoperative fluoroscopy** is a type of fluoroscopy that is used during surgical procedures to obtain real-time X-ray images of the surgical site [1].

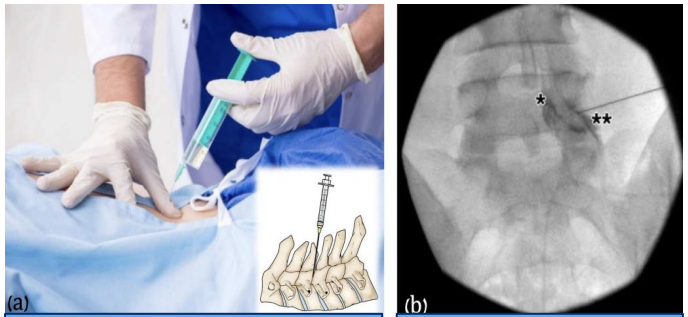
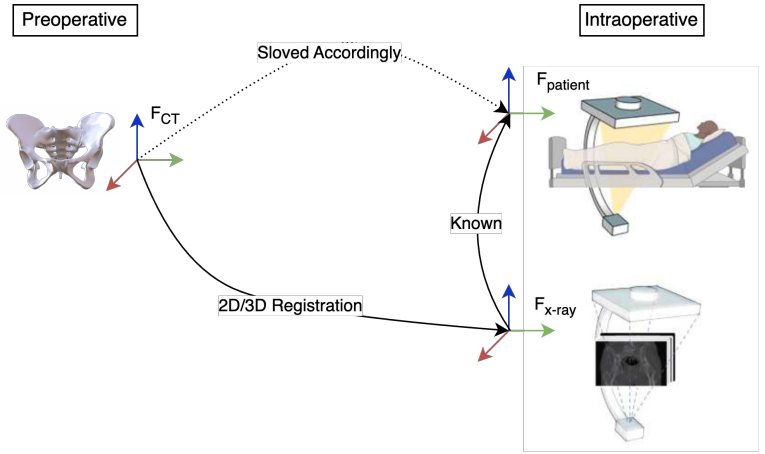


Illustration of spine injection | Intraoperative X-ray

Mandell, J. C., Czuczman, G. J., Gaviola, G. C., Ghazikhanian, V., & Cho, C. H. (2017). The Lumbar Neural Foramen and Transforaminal Epidural Steroid Injections: An Anatomic Review With Key Safety Considerations in Planning the Percutaneous Approach. *AJR. American journal of roentgenology*, *209*(1), W26–W35.

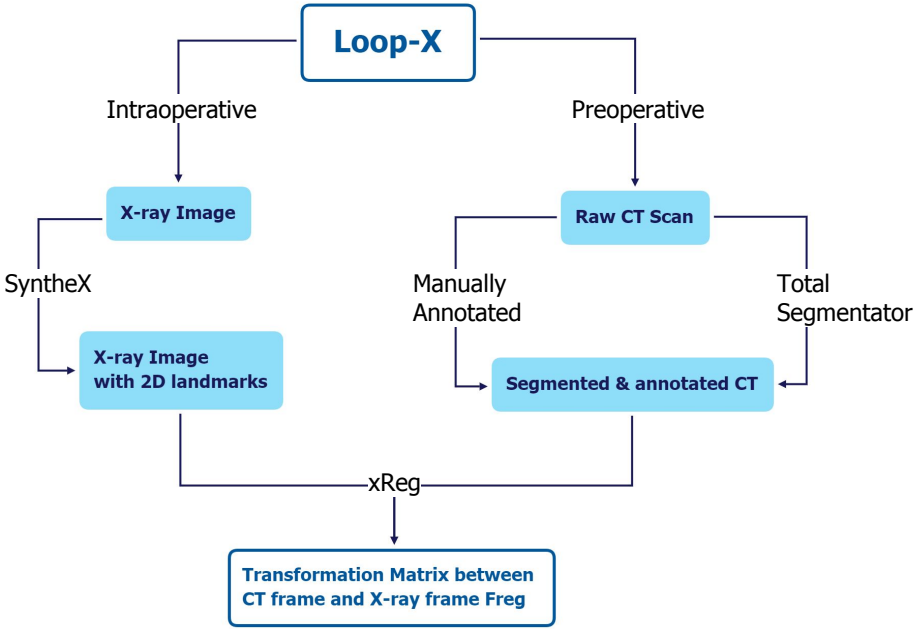
- 2D/3D Registration is a method that can find the **Projection Matrix** between the intraoperative fluoroscopic X-ray image frame and the preoperative CT frame [2].



Project Recap - Project Goal

- Our project aims to develop a pipeline that **automatically perform the 2D/3D registration** process between X-ray images and CT Scan intra-operatively. To be specific, we need to integrate the:
  - Image Acquisition Process
  - Data Synthesizing Process
  - 2D Landmark Detection
  - Online 2D/3D Registration
- These four components will be integrated into one sole package with a user-friendly GUI.

Pipeline Architecture



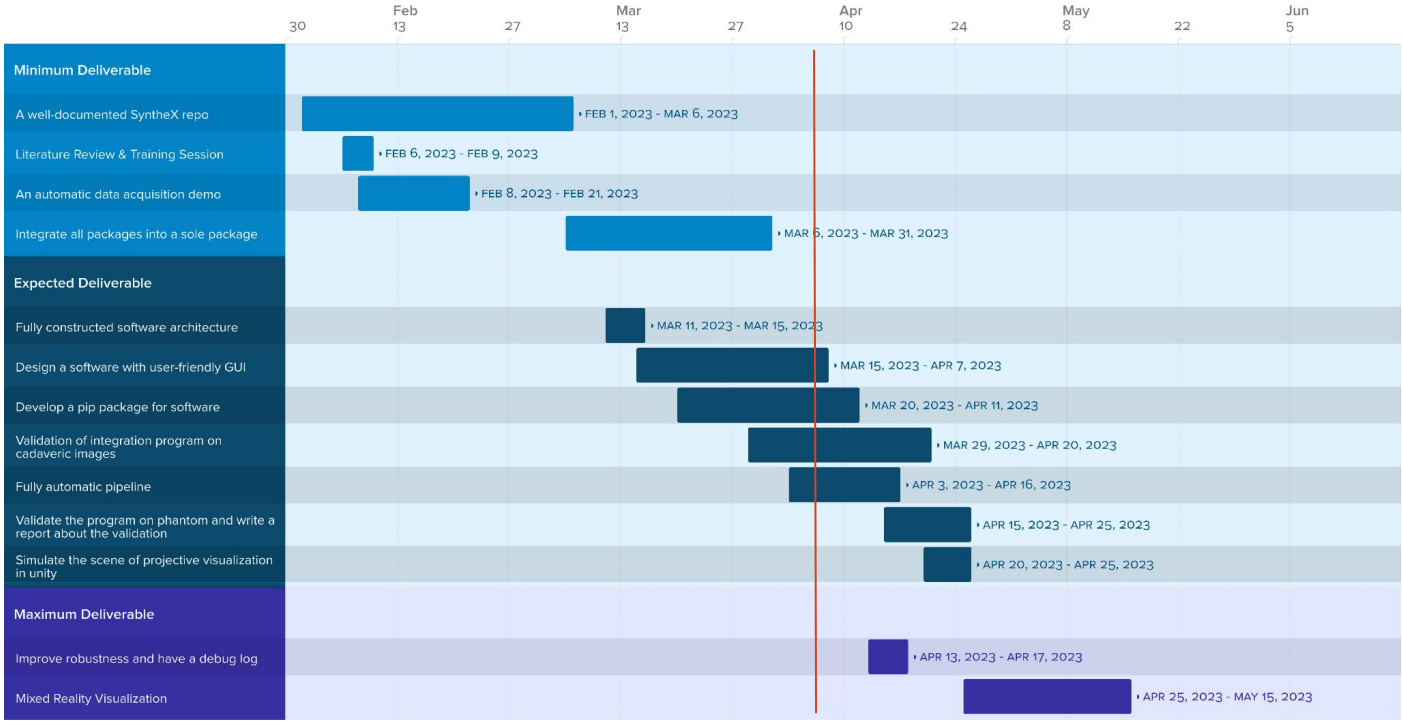
Dependency

	Need	Followup	Contingency Plan	Planned	Hard DL	Status
MOCK OR Lab Access	manipulate Loop-X	N/A	Ask Benjamin for access	Feb 06	Feb 10	✓
Loop-X	Generate X-ray and CT Scan	N/A	Ask Benjamin for access	Feb 06	Feb 10	✓
SyntheX	Generate Domain Generalized X-ray Open source github repository	N/A	Request the source code from Dr. Cong Gao	Feb 01	Feb 06	✓
Model Checkpoint	Hyper parameters of SyntheX On private onedrive folder	Keep secured		Feb 08	Feb 12	✓
xReg	Compute registration parameter between CT scan and X-ray Image, open source github repository	N/A	Request the source code from Dr. Grupp	Feb 08	Feb 12	✓
CT DataSet	As a input used in Xreg	Keep secured	N/A	Feb 06	Feb 20	✓
Total Segmentator	Do CT Scan segmentation	Downloaded	N/A	Feb 18	Feb 20	✓
Computers	Our own computer with an environment for software development	Ready to use	"PACKMAN" ARCADE Server	Jan 23	N/A	✓

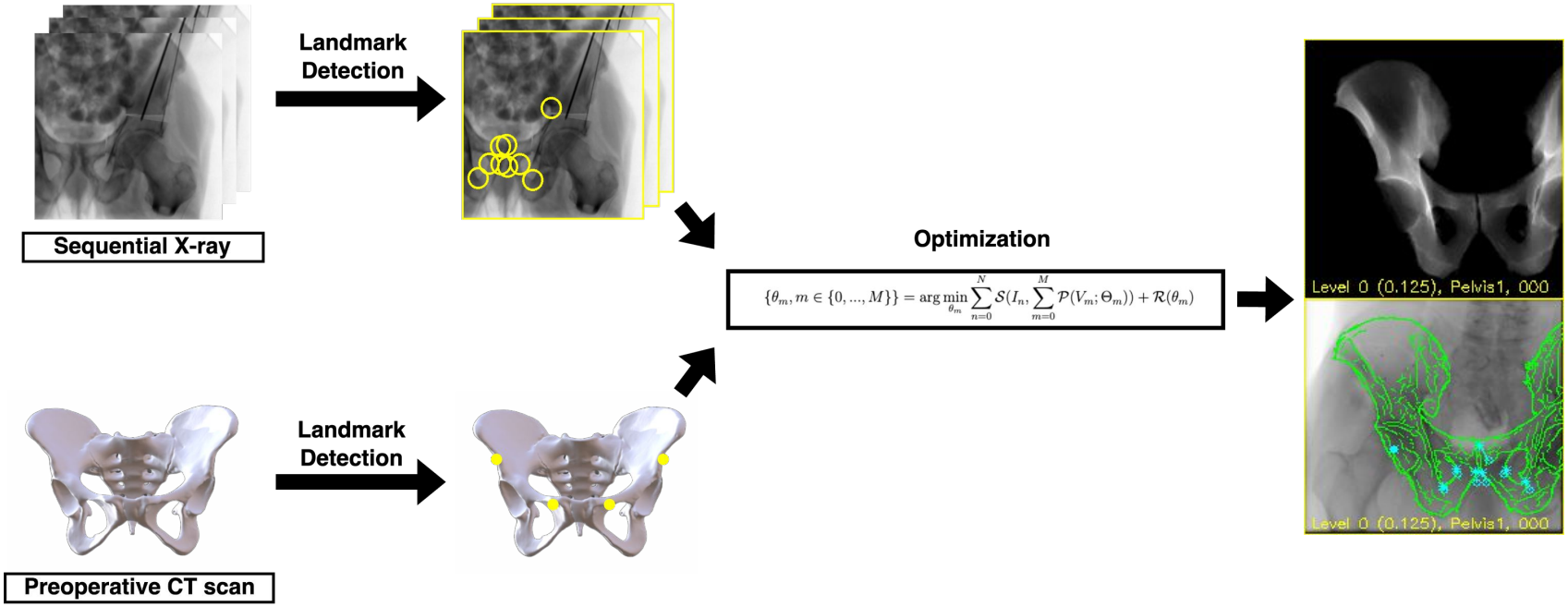
Deliverables

	Deliverable	Key Milestones	Status
Minimum	Documentation for SyntheX, provide applicable interfaces	Documentation and well-organized repository for SyntheX	☑
	Data exchange channel	Scripts for reading and writing h5 and dicom files	☑
	A well-documented program integrating previous works	Python Scripts incorporates previous works	☑
Expected	validation of integration program on cadaveric images	Test of the program on dicom file from loop-X	☑
	Fully constructed software architecture	Reconstruction of python scripts for future users' modification	☑
	A python pip package for integration software	A Python installation package	90%
	A user-friendly GUI	A GUI designed to import input and run the program	☑
	A fully automatic pipeline	A well-designed, documented, and automatic pipeline	70%
	A view-rendering application for projective visualization	Simulated scene of projective visualization in unity	☒
	A report for Validating our application on cadaveric images	A well-analyzed report about validating the program	☒
Maximum	Integration with mixed reality visualization of relevant anatomy	Simulation app executable in HMD	☒

Project Timeline

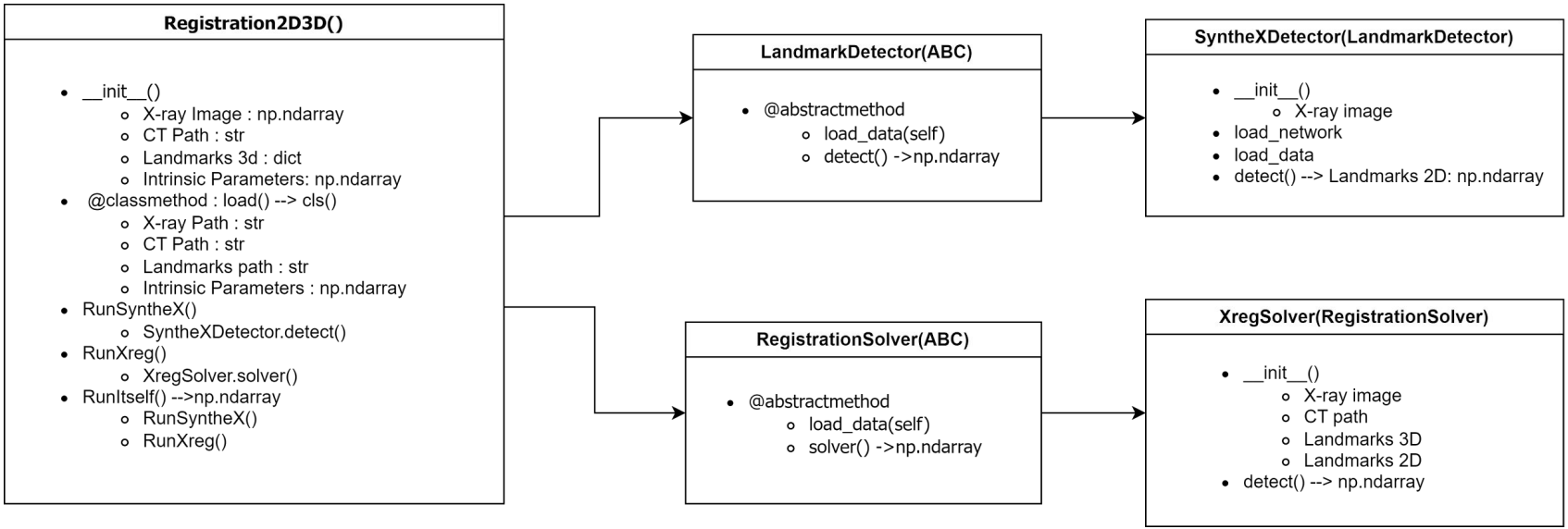


Completed Work - Integrated 2D/3D Registration Workflow



Expect Date: Mar/31
Actual Date: Mar/27

Completed Work - Package Architecture



- The documentation for specifying the inputs and outputs of the package is available on our WIKI page and Github Repo. It also contains the duty distribution of the team members.

Expect Date: Mar/15
Actual Date: Mar/21

Completed Work - Integrated Program

2D Landmark Detection

SyntheX provides a well-trained Trans-Unet model to automatically detect the landmarks on the X-ray images.

Annotation for Given CTs

Segmentation is done using TotalSegmentator.

3D landmarks are manually annotated by the professional personnel. The annotation results (3D landmarks) are already provided by our mentor.

Solving Registration Problem

Loading x-ray image, CT scan and their corresponding landmarks

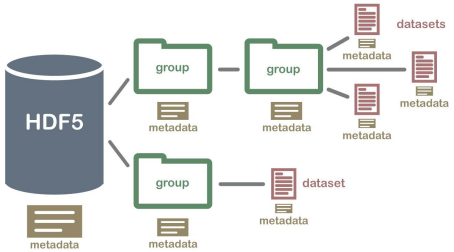
Call xReg to solve the registration problem

Expect Date: Mar/10
Actual Date: Mar/15

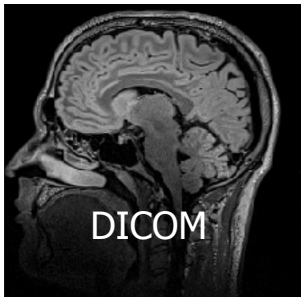
Completed Work - Data Exchange

- Transfer data format into required format

Read and write HDF5



Read X-ray DICOM Image



Read 2D landmarks in Pandas Dataframe

pandas

land	row	col	time
0	-1	-1	0.001871
1	289	77	0.001012
2	208	321	0.000839
3	209	101	0.000783
4	-1	-1	0.000843
5	-1	-1	0.000801
6	343	260	0.000743
7	341	171	0.000718
8	327	232	0.000701
9	325	204	0.000703
10	359	229	0.000697
11	-1	-1	0.000704
12	180	334	0.000702
13	185	33	0.0007

Expect Date: Mar/01
Actual Date: Mar/06

Completed Work - Documentation

- **SyntheX Tutorial:**
  - Naming rules of files
  - Basic algorithm
  - Steps to run SyntheX
- **Data Specification:**
  - Examples on loading different data
  - Every HDF5 data structure
  - Every FCSV data structure

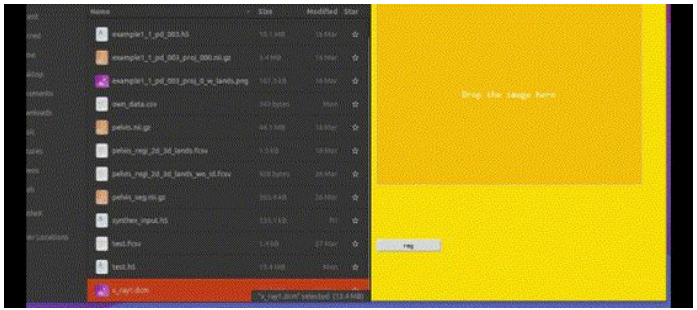
All documentation files are available on the WIKI page and GitHub repo

Expect Date: Apr/01
Actual Date: Mar/27

In-progress Work

GUI

- ✓ 1 : Interface Design
- ✓ 2 : Drag files to import them
- ❑ 3 : Features implementation – 60%



PyPi package

- ❑ 1 : Source Code – 90%
- ❑ 2 : Distribution and License
- ❑ 3 : README

Test plan

Performance Test

- Specify test environment
- Measure performance metrics such as latency and frame rate

Accuracy Test

- Specify test environment
- Measure performance metrics such as dice-score

Summarize the results in an assessment report.

Management

Meetings with Benjamin Killeen:

- 3:00 pm every Monday, in-person

ARCADE Lab meetings:

- 4:15 pm every Thursday, in-person

Discussions between group members:

- Twice a week, 9:30 am every Monday and Wednesday, in-person

Communication:

- Email/Discord

Reference

[1]. Gao, C., "SyntheX: Scaling Up Learning-based X-ray Image Analysis Through In Silico Experiments", *arXiv e-prints*, 2022. doi:10.48550/arXiv.2206.06127.

[2]. Arcadelab, "Arcadelab/synthex," *GitHub*. [Online]. Available: https://github.com/arcadelab/SyntheX. [Accessed: 21-Feb-2023].

[3]. C. Gao, "Fluoroscopic navigation for robot-assisted orthopedic surgery," dissertation, 2022.

[4]. P. Markelj, D. Tomaževič, B. Likar, and F. Pernuš, "A review of 3D/2D registration methods for image-guided interventions," *Medical Image Analysis*, vol. 16, no. 3, pp. 642–661, 2012.

[5]. R. B. Grupp, M. Unberath, C. Gao, R. A. Hegeman, R. J. Murphy, C. P. Alexander, Y. Otake, B. A. McArthur, M. Armand, and R. H. Taylor, "Automatic annotation of hip anatomy in fluoroscopy for robust and efficient 2D/3D registration," *International Journal of Computer Assisted Radiology and Surgery*, vol. 15, no. 5, pp. 759–769, 2020.

[6]. Y. Otake, M. Armand, R. S. Armiger, M. D. Kutzer, E. Basafa, P. Kazanzides, and R. H. Taylor, "Intraoperative image-based multiview 2D/3D registration for image-guided orthopaedic surgery: Incorporation of fiducial-based C-arm tracking and GPU-acceleration," *IEEE Transactions on Medical Imaging*, vol. 31, no. 4, pp. 948–962, 2012.