Making 2D/3D Registration Accessible

Computer Integrated Surgery II
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Introduction

- Proposed a unified and modularized architecture in Python for solving 2D/3D registration problem.
- Incorporated an AI-based 2D landmark detention model, SyntheX, with a registration solver, xreg, into an integrated pipeline.
- Encapsulated the functionalities into XREGI–a Python package with highly reconfigurable architecture. With XREGI, users can streamline registration process and achieve results efficiently.
- Our proposed approach simplified the tedious and time-consuming 2D/3D registration process so that it can be utilized in the intraoperative real-time applications without the need of expertize.

$ pip install xregi

Problem Formulation

- 2D/3D registration problem is to find the projection matrix between the CT coordinate system and the X-ray frame.
- The intraoperative applications of the existing 2D/3D registration solutions are limited by their incompatibility and lack of generalization.
- Intraoperative registration requires the solver to automatically solve the problem in the real-time.

These issues lead to frustration and inefficiency in the registration workflow, highlighting the need for a more user-friendly and streamlined solution.

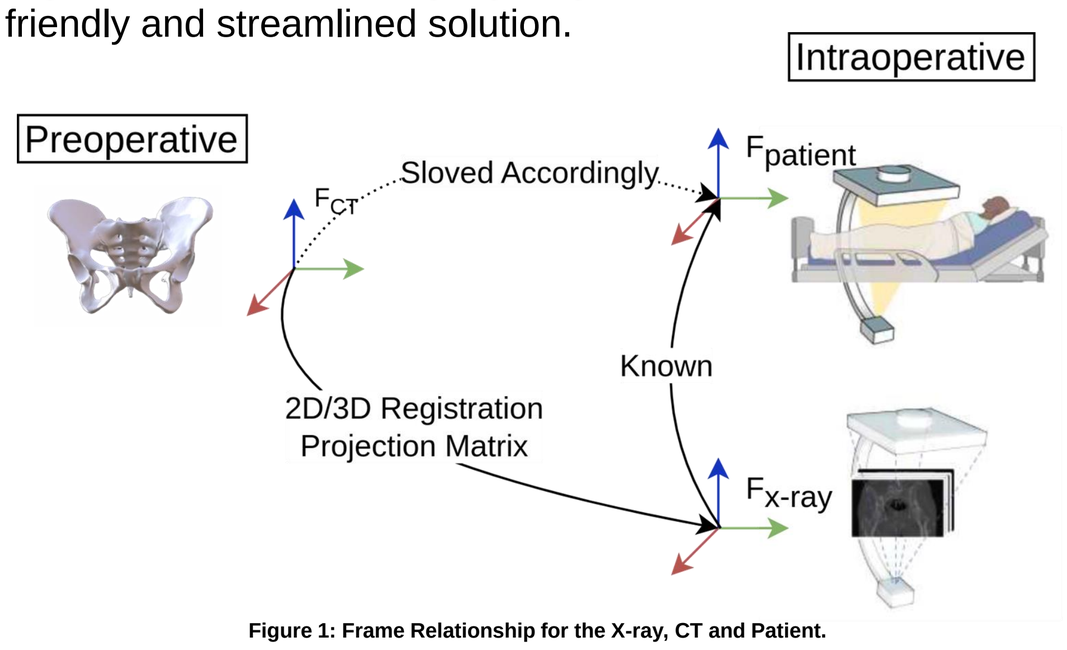

Figure 1: Frame Relationship for the X-ray, CT and Patient.

The Solution

- The registration workflow is proposed and implemented.

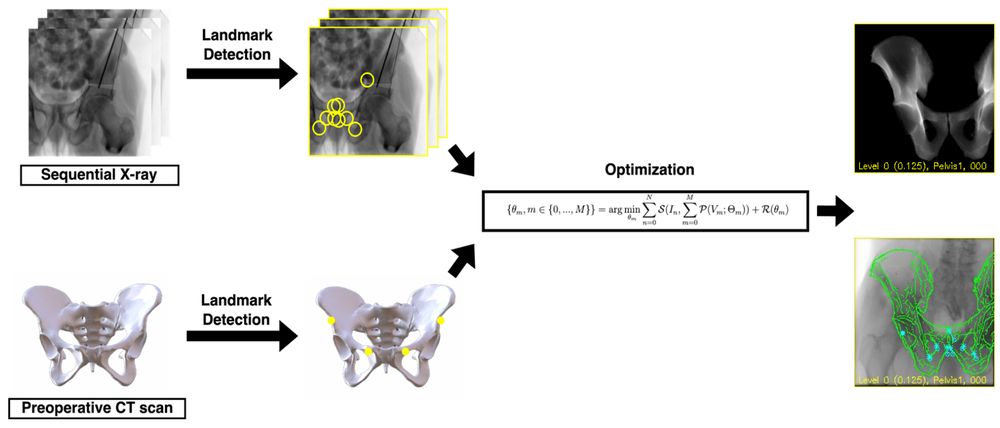

Figure 2: Basic Workflow for the Proposed 2D/3D Registration Pipeline.

- Our proposed package, XREGI, is modularized into three classes, namely **LandmarkDetector**, **RegistrationSolver** and **Registration2D3D**.
- The LandmarkDetector class and RegistrationSolver class integrate the features of SyntheX and xreg separately. The Registration2D3D computes the projection matrix by utilizing the functionalities of the other two classes.
- and provides interfaces for future modularization substitution and development.

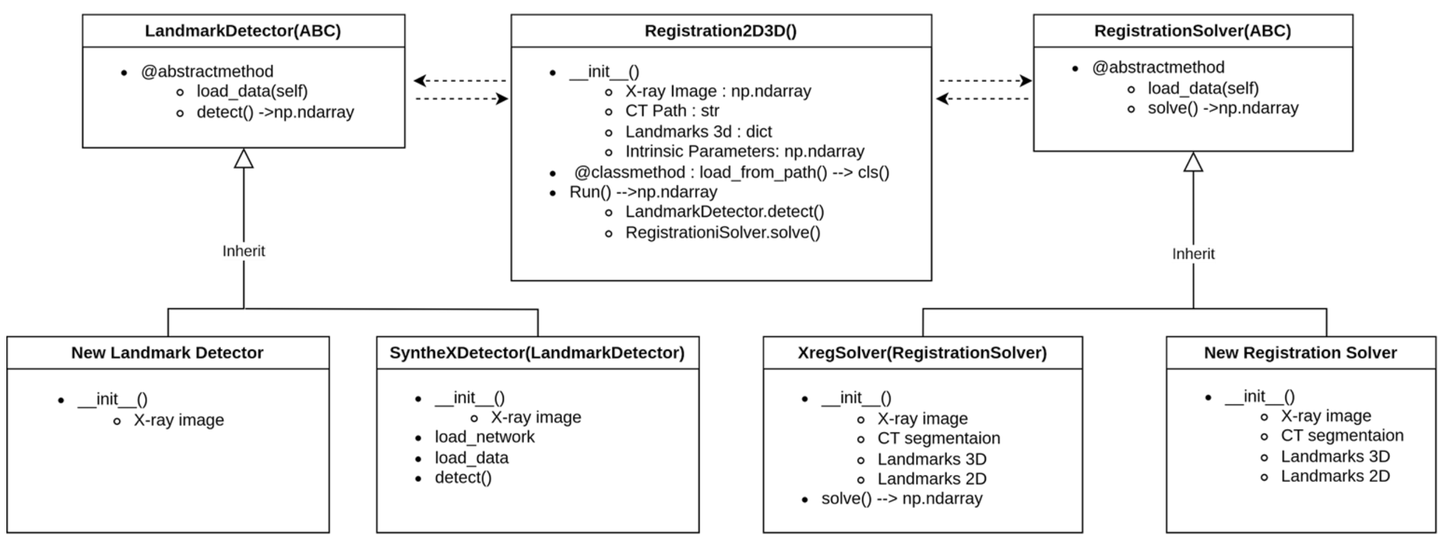

Figure 3: Class diagram for XREGI. Its modularized design has made it possible for incorporating more advanced detector and solver in the future

Outcomes and Results

- We successfully integrated SyntheX and xreg as a sole package called XREGI. The package can be installed and utilized with simple terminal commands:

```
$ pip install xregi
$ python -m xregi --xray XRAY_PATH --ct CT_PATH --landmarks 3D_LANDMARKS_PATH --seg SEGMENTATION_PATH
```

- XREGI provides a toolkit for processing data between every module, allowing for seamless integration and efficient data transfer.
- We created documentation for both SyntheX and XREGI, providing users with the necessary resources to effectively leverage the package to accelerate their research.

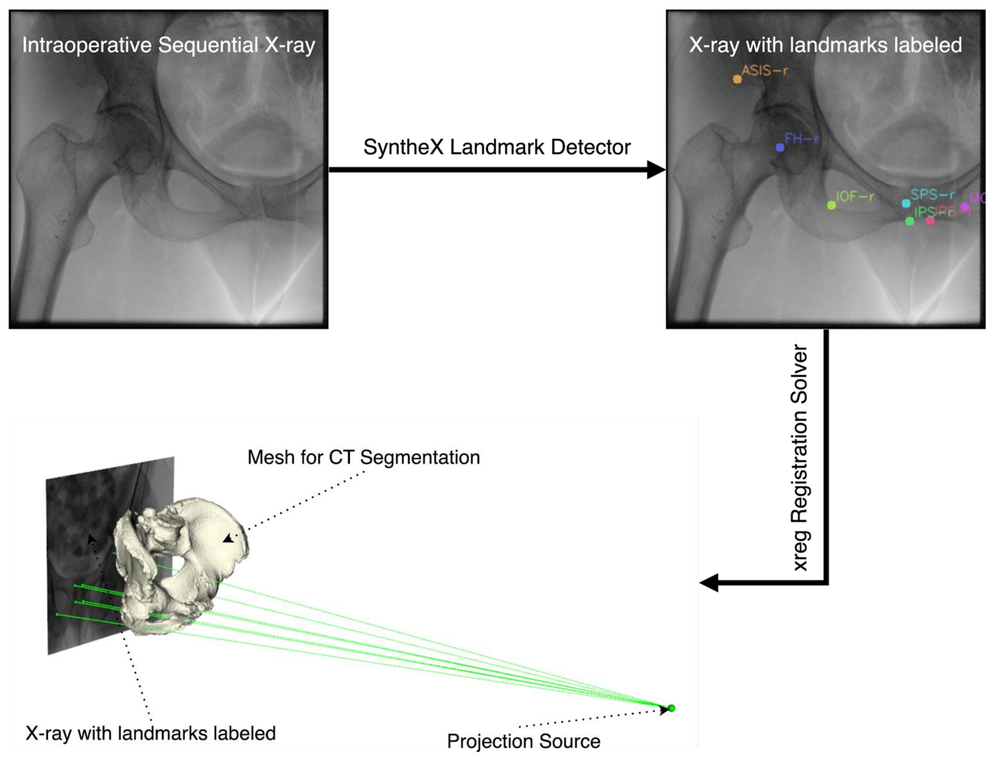

Figure 4: The landmarks are detected by SyntheX and the projection matrix is solved by xreg

Future Work

- Integration with novel projective paradigm to visualize the result on HoloLens
- Submission to a peer-reviewed conference or journal

Lessons Learned

- Having comprehensive documentation is crucial for facilitating understanding and collaboration on related projects

Credits

- Jiaming: xreg integration programming
- Zhangcong: SyntheX integration programming
- Both team members equally contributes to maintaining the repository and writing up the documentations.

Acknowledgements

- We thank Dr. Cong Gao and Dr. Robert Grupp for making the source code of SyntheX and xReg public
- We thank Prof. Russel Taylor, Prof. Mathias Unberath and Benjamin Killeen for their invaluable help and guidance

Reference

[1] C. Gao, “Synthetic data accelerates the development of generalizable learning-based algorithms for X-ray image analysis”, *Nature Machine Intelligence*, vol. 5, no. 3, pp. 294–308, 2023.
[2] Grupp, R.B., Unberath, M., Gao, C., Hegeman, R.A., Murphy, R.J., Alexander, C.P., Otake, Y., McArthur, B.A., Armand, M. and Taylor, R.H., 2020. Automatic annotation of hip anatomy in fluoroscopy for robust and efficient 2D/3D registration. International Journal of Computer Assisted Radiology and Surgery, pp.1-11.