Deep Learning in Fluoroscopic Feature Detection

Liujiang Yan

Mentors: Robert Grupp, Dr. Russell Taylor

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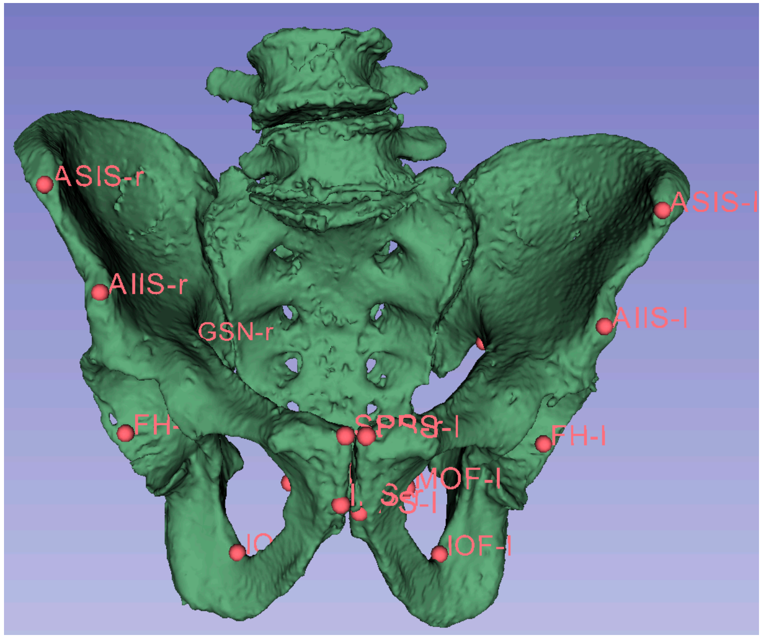
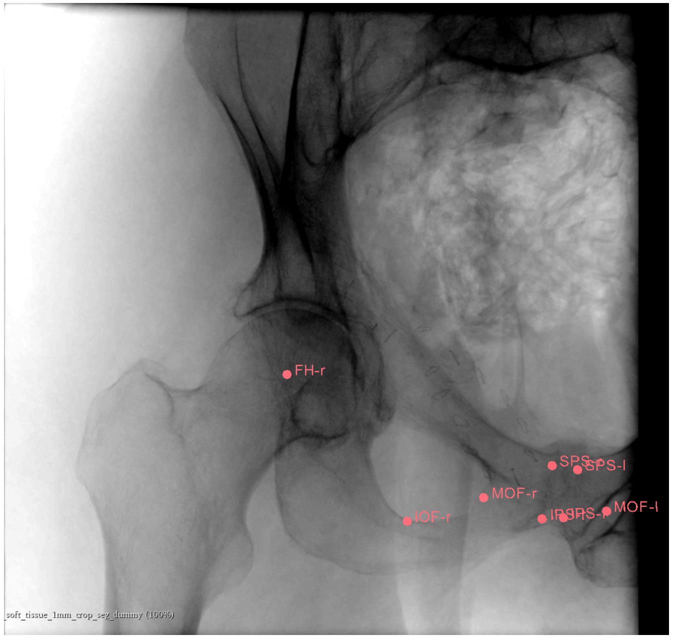
Project Goal

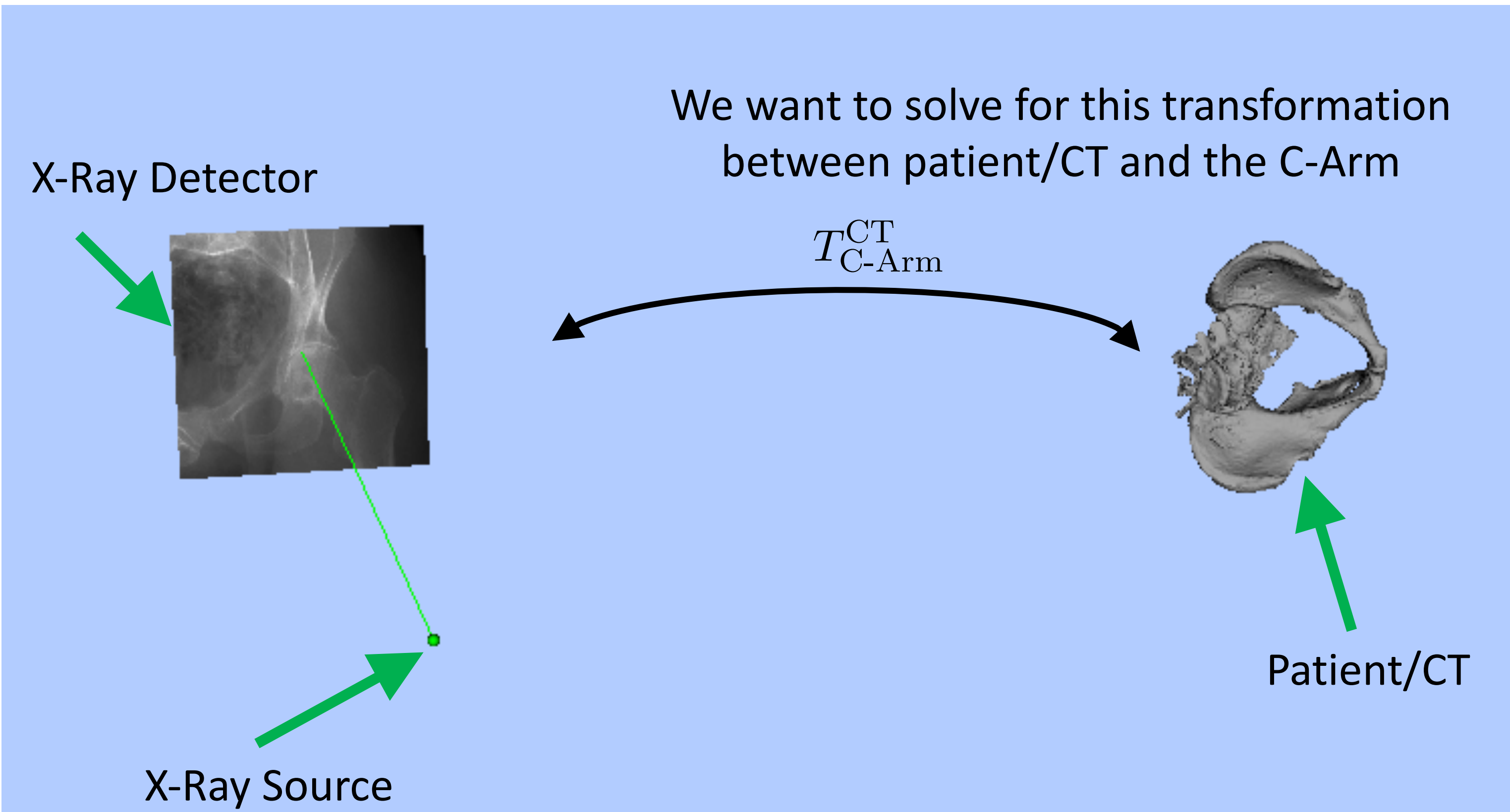
- Training neural network to identify anatomical landmarks in 2D fluoroscopic images.





* From Robert Grupp's Project Introduction Slides

Project Motivation



* From Robert Grupp's 2D-3D Registration Slides

Landmark Driven Registration

- **Step 1: identify corresponding landmarks in pre-operative 3D model and intra-operative 2D image.**
- Step 2: Estimate the transformation by minimizing following cost function.

$$\underset{\theta \in SE(3)}{\arg\min} \sum_{i} \frac{1}{2} \left\| \mathbf{p}_{\text{2D}}^{(i)} - \mathcal{P}(\mathbf{p}_{\text{3D}}^{(i)}; \theta) \right\|_2^2$$

- Currently, landmark annotation is manually done - time consuming
- This project aims to identify corresponding landmarks in intra-operative 2D fluoroscopic images, by deep neural network approach.

* From Robert Grupp's 2D-3D Registration Slides

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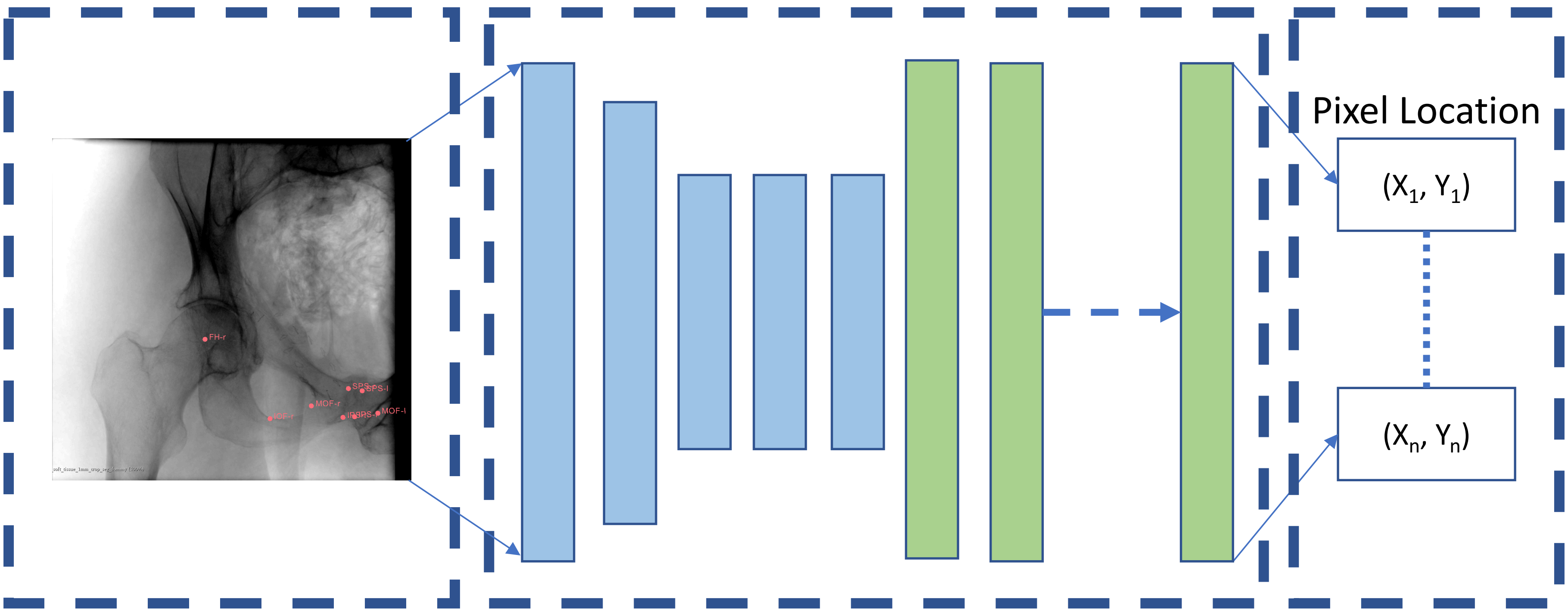
Proposed Pipeline Overview



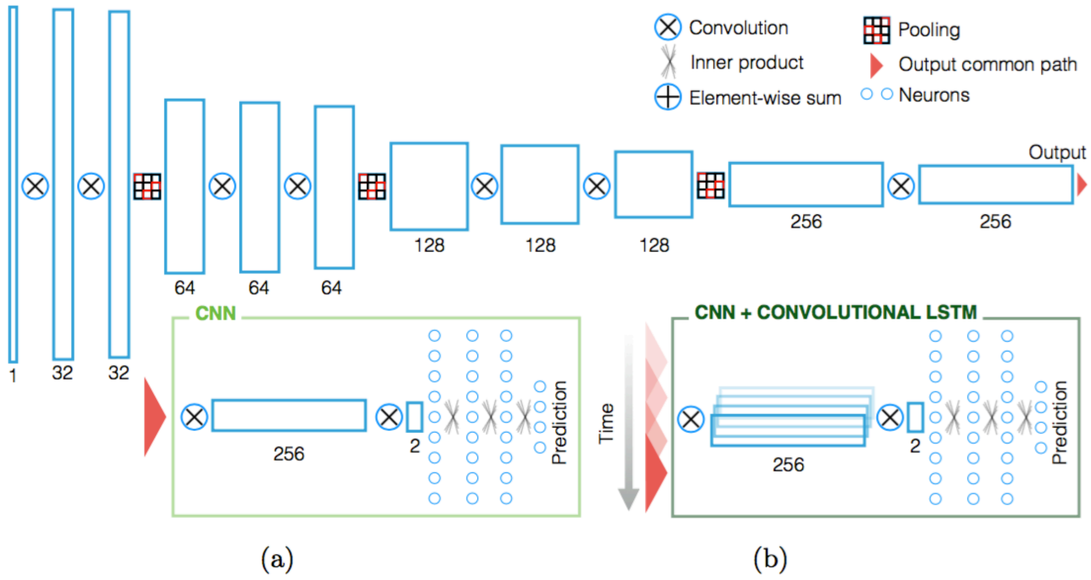
Input

Architecture
CNN + ANN

Position Regression

Technical Approach Overview

- Regression Problem on Position
- Insight from other detection problems
  - e.g. Convolutional Neural Network for position regression



* Sofka, Michal, et al. "Fully convolutional regression network for accurate detection of measurement points."

Technical Approach Overview

- Regression Problem on “HeatMap”
- Insight from other detection problems
  - e.g. CNN architectures for heatmap regression.

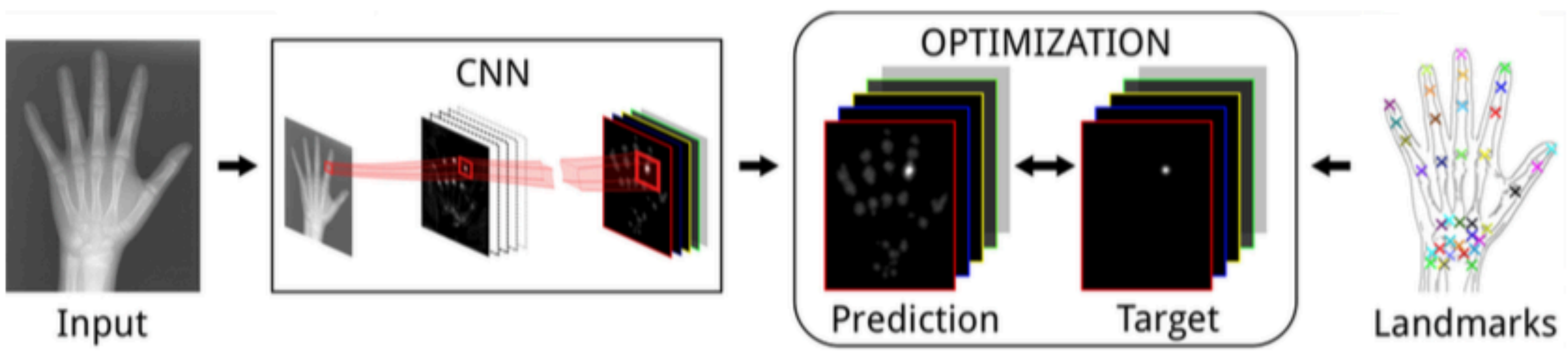
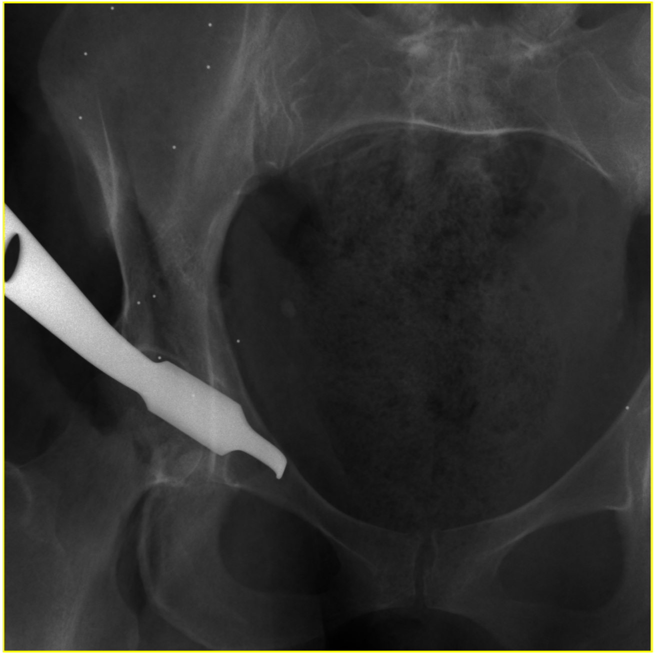


Fig. 1. Multiple landmark localization by regressing heatmaps in a CNN framework.

* Payer, Christian, et al. "Regressing heatmaps for multiple landmark localization using CNNs

Additional Work

- **Tool Extraction in Field of View - Segmentation**
- Contour Detection - Edge Detection
- End to End Pose Estimation - No Idea



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- **Contour Detection - Edge Detection**
- More Realistic Simulation Data

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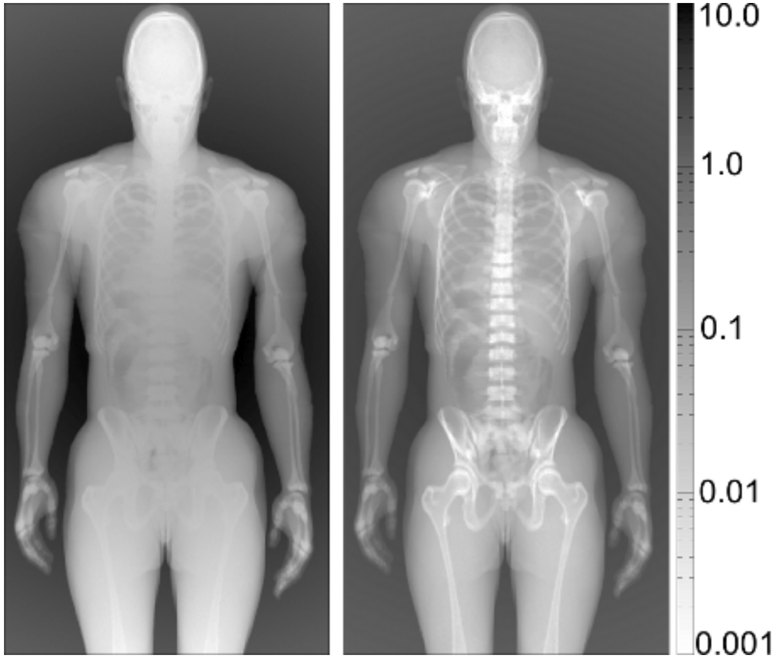

* From MCGPU example image.

Limitations

- Training data all from simulated osteotomies
- No soft tissue
- No change in intrinsics
- No tools in field of view (comparing to operation)
- Not enough real X-ray data for training

Deliverables

- <u>Minimum Deliverables:</u>
  - Environment setup and data preparation.
  - Initial network architecture validated on toy data set.
  - Network training on larger / refined data.
  - Accuracy Report by evaluated on simulated / real data.
  - Final Report / Poster.
- <u>Expected Deliverables:</u>
  - Tools segmentation from field of view.
  - Better simulation software involved.
- <u>Maximum Deliverables:</u>
  - Edge / contour detection.
  - Pose estimation.

Dependencies

- Access to Data
  - Simulated data with landmarks annotated for training.
    - Already have initial training data set from Rob.
  - Sophisticated simulated data for training.
    - e.g., Soft tissue, tools.
  - Real data set for test.
- Access to High Performance Computer
  - Have permission to work on thin6.
- Access to Mentors
  - Weekly meeting with Robert Grupp.
  - Schedule meeting with Dr. Taylor as needed.

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Management Plan

- Source Code and Version Control via Github.
- Document control via Course Wiki.
- Weekly meeting with Robert Grupp.

Key Milestones

- February 25: All simulated data obtained and validated.
- March 15: Environment and initial training network Set up.
- March 29: Deploy neural network for complete training data set.
- April 12: Evaluate accuracy in (simulated / real) test data set.
  - **Minimum Deliverables Achieved.**
- April 19: Utilize advanced software for simulated data.
- April 19: Training network for segment tools in field of view.
  - **Expected Deliverables Achieved.**
- May 03: Training network for contour detection.
  - **Maximum Deliverables Achieved.**
- May 11: Final Report / Poster Session.

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Detailed Task Schedule

Task	02/22	03/01	03/15	03/29	04/05	04/12	04/19	04/26	05/03	05/10
Minimum Deliverables										
Project Proposal	■									
Environment Set Up	■	■								
Initialize Neural Network	■	■	■							
Seminar Report		■	■	■						
Training on Larger data			■	■	■					
Training on Better Simulation			■	■	■					
Evaluating Accuracy				■	■	■				
Final Report / Poster								■	■	■
Expected Deliverables										
Tools in field of view					■	■	■			
Simulation Software					■	■	■			
Maximum Deliverables										
Contour Detection							■	■	■	
Pose Estimation								■	■	

Reading List

- Feature Detection:
  - Evaluation and Comparison of Anatomical Landmark Detection Methods for Cephalometric X-Ray Images: A Grand Challenge
  - Regressing Heatmaps for Multiple Landmark Localization using CNNs
  - Integrating geometric configuration and appearance information into a unified framework for anatomical landmark localization
  - Fully convolutional regression network for accurate detection of measurement points
  - U-Net: Convolutional Networks for Biomedical Image Segmentation
  - Human pose estimation via Convolutional Part Heatmap Regression
  - Simultaneous Multi-Person Detection and Single-Person Pose Estimation With a Single Heatmap Regression Network
  - Efficient Object Localization Using Convolutional Networks

Reading List

- X-ray Simulation:
  - Accelerating Monte Carlo simulations of photon transport in a voxelized geometry using a massively parallel graphics processing unit
  - Monte Carlo Simulation of X-Ray Imaging Using a Graphics Processing Unit
  - Geant4-based Monte Carlo simulations on GPU for medical applications
  - A GPU tool for efficient, accurate, and realistic simulation of cone beam CT projections

References:

- Payer, Christian, et al. "Regressing heatmaps for multiple landmark localization using CNNs." International Conference on Medical Image Computing and Computer-Assisted Intervention. Springer, Cham, 2016.
- Sofka, Michal, et al. "Fully convolutional regression network for accurate detection of measurement points." Deep Learning in Medical Image Analysis and Multimodal Learning for Clinical Decision Support. Springer, Cham, 2017. 258-266.
- Ghammraoui, B., et al. "Including the effect of molecular interference in the coherent x-ray scattering modeling in MC-GPU and PENELOPE for the study of novel breast imaging modalities." Medical Imaging 2014: Physics of Medical Imaging. Vol. 9033. International Society for Optics and Photonics, 2014.

Thank you for listening.

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