Deep Learning in Fluoroscopic Feature Detection

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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

We want to solve for this transformation between patient/CT and the C-Arm

\[ T_{C-Arm} \]

* 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.

\[
\arg \min_{\theta \in SE(3)} \sum_i \frac{1}{2} \left\| \mathbf{p}_{2D}^{(i)} - \mathcal{P}(\mathbf{p}_{3D}^{(i)}; \theta) \right\|_2^2
\]

• 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
Proposed Pipeline Overview

Input

Architecture
CNN + ANN

Position Regression

Pixel Location

\((X_1, Y_1)\)

\((X_n, Y_n)\)
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.
Additional Work

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

- Tool Extraction in Field of View - Segmentation
- **Contour Detection** - Edge Detection
- More Realistic Simulation Data
Additional Work

• Tool Extraction in Field of View - Segmentation
• Contour Detection - Edge Detection
• More Realistic Simulation Data

* 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

• **Minimum Deliverables:**
  • 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.

• **Expected Deliverables:**
  • Tools segmentation from field of view.
  • Better simulation software involved.

• **Maximum Deliverables:**
  • 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.
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.
## Detailed Task Schedule

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Reading List

• Feature Detection:
  • 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:


Thank you for listening.