Deep Learning for Fluoroscopic Feature Detection

Mid Point Presentation

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Motivation

- Feature Detection for 2D-3D Registration
- Anatomical Landmark Detection
- Contour Detection

## Deliverable Status

- **Minimum Deliverable Achieved**
- **Medium / Maximum Deliverable Ongoing**

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<th>Task</th>
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Pipeline Summary

Data Preparation
- Data Collection
- Data Labeling

Training & Validation
- Training Data Loader
- Data Augmentation
- Training Process
- Evaluation

Registration
- Prediction
- 2D-3D Registration

Configuration

Fig. Pipeline Layout
Approach - Position Regression

• Problem identification: fixed number key point detection
Approach - Heatmap Regression

• Problem identification: fixed number key point detection

• Heatmap: Intensity given by Gaussian distribution with position as mean
Approach

Why regress heatmap instead of position? What is the tradeoff?
Network Architecture

• Convolutional Pose Machine
• Multi Stage Model
• Intermediate Supervision

Network Architecture

- Convolutional Pose Machine
- Multi Stage Model
- Intermediate Supervision
Hyperparameters - Stage Number

• More stages:
  • Larger parameter space; larger receptive field;
  • Overfitting; Harder to train; Takes more time and memory;

Fig. Convolutional Pose Machine[1]

Hyperparameters - Heatmap

- Output Size:
  - Larger size means more accurate localization; More resources to train;
- Gaussian Variance:
  - Larger variance means more information; less accurate localization;

![Heatmap with different variance and corresponding intensity histogram](image)
Evaluation and Visualization

- Multistage Visualization - Intuition
- 2D Error Plot - Quantitative Analysis
- Good Prediction / Bad Prediction - Case Study
Evaluation and Visualization

• Multistage Visualization - Intuition

• 2D Pixel Error Plot - Quantitative Analysis
  • Discretization: 10x downsample
    • Measure in original image size (768 by 768);
    • Heatmap size (63 by 63);

• Good Prediction / Bad Prediction - Case Study
Evaluation and Visualization

Fig. 2D Pixel Error
Evaluation and Visualization

Fig. 2D Pixel Error
Evaluation and Visualization

• Multistage Visualization - Intuition
• Spatial Error Plot - Quantitative Analysis
• Good Prediction / Bad Prediction - Case Study
Limitations & Data Augmentation

• Intra-operation scenario: Tool in the view
• Hard to synthesize samples with tool in the view

Fig. Tool in the view
Limitations & Data Augmentation

• Intra-operation scenario: Tool in the view

• Random Mask (shape; size; location; rotation; brightness)
  • Input: mask some connected region with random constant value;
  • Target: keep all landmarks visible;

Fig. Samples with Random Mask (not necessarily circular)
Spatial Error Plot

Landmark Spatial Error (With Mask)
Evaluation and Visualization

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Why regress heatmap instead of position

• Heatmap gives **uncertainty** measure about the prediction
• Heatmap generation is essentially the **prior about the annotation**
Why regress heatmap instead of position

• Heatmap gives **uncertainty** measure about the prediction
• Heatmap generation is essentially the **prior about the annotation**
• Could be used for detecting outliers
• 2D-3D registration by utilizing the distribution of 2D prediction
  • Let the prediction of landmark is given by $\mathcal{N}(\mu; \Sigma)$
  • The objective function could be derived by Mahalanobis distance

$$\arg\min_{\theta \in SE(3)} \sum_i \frac{1}{2} [P_{2D}^i - \mathcal{P}(P_{3D}^i; \theta)]^T \Sigma^{-1} [P_{2D}^i - \mathcal{P}(P_{3D}^i; \theta)]$$
Dependencies

- Simulated dataset with soft tissue / Real dataset
- Simulated dataset with contour annotated
- 2D-3D registration methods
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Dependencies

• Simulated dataset with soft tissue / Real dataset
• Simulated dataset with contour annotated
• 2D-3D registration methods
  • Evaluate performance by comparing the led registration result.

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

• Minimum deliverable achieved; Ongoing works on medium / maximum;
• Developed landmark detection pipeline using PyTorch;
• Tuned convolutional pose machine architecture;
• Perform data augmentation to address tool in the view problem;
• Evaluated and visualized results for further analysis;
• Need more training data (landmark, contour) for further experiment;
• Need registration method for evaluation.
Thank you for listening.