

Fingerprint Pose Estimation Based on Faster R-CNN

Shiyu Luo, Xinda Huang, Qianying Yu

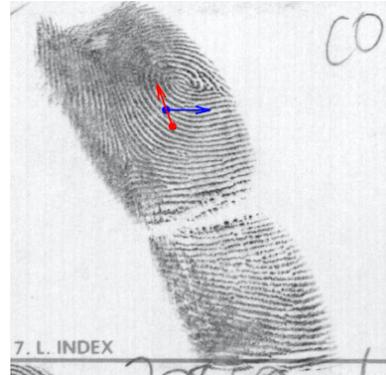
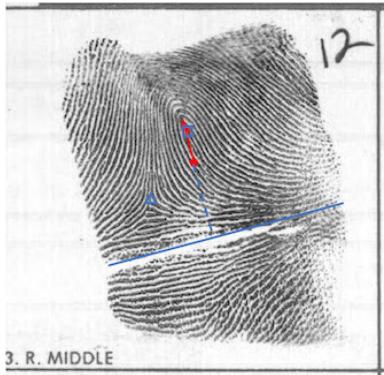
Northwestern

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1. Introduction

Why Fingerprint Pose Estimation?

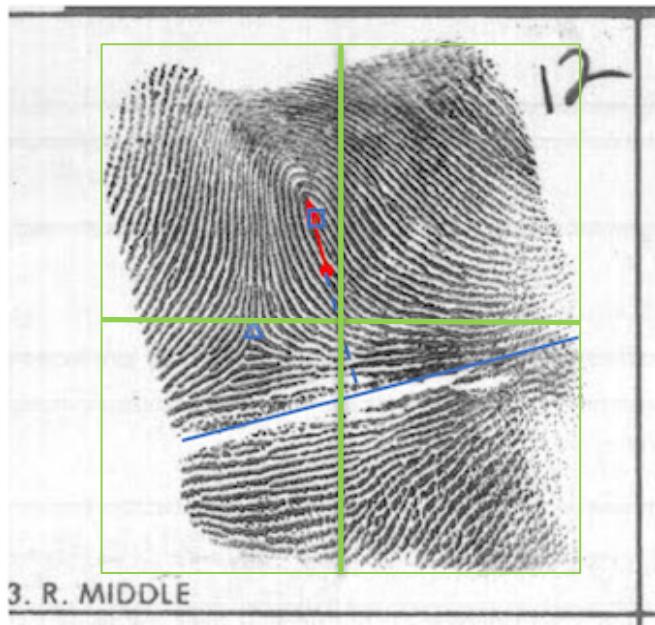
- People are creative while printing their fingerprints...



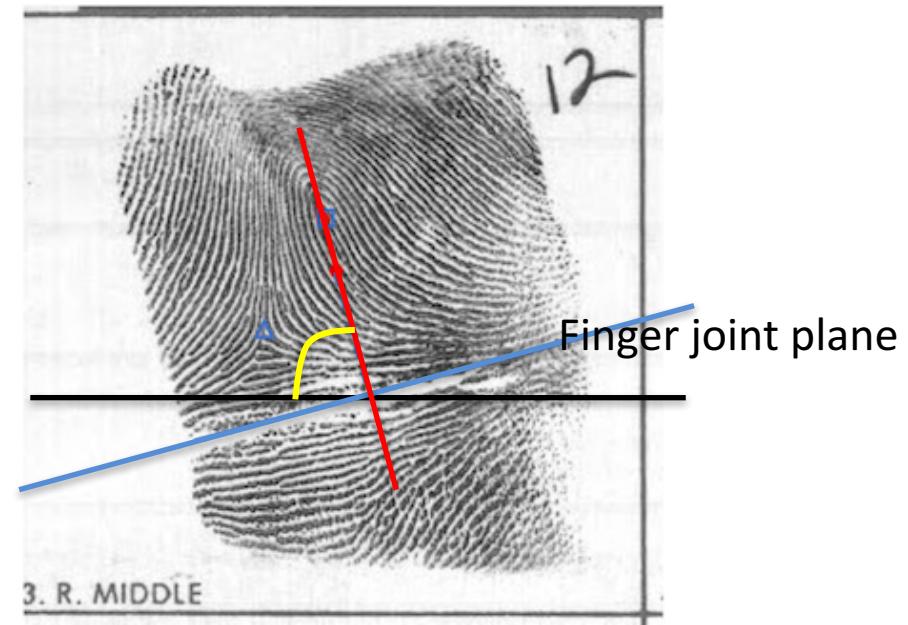
- But perfect alignment of fingerprint is critical for verification and recognition!

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Fingerprint Pose Estimation: Definition



Center Point

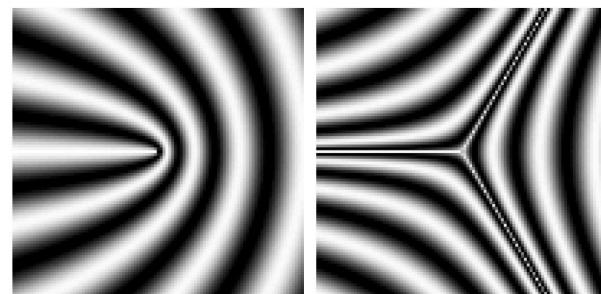


Orientation

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Fingerprint Pose Estimation: Previously...

Hand-crafted features + filters: sensitive to noise



Filters

Singular Points



Reference

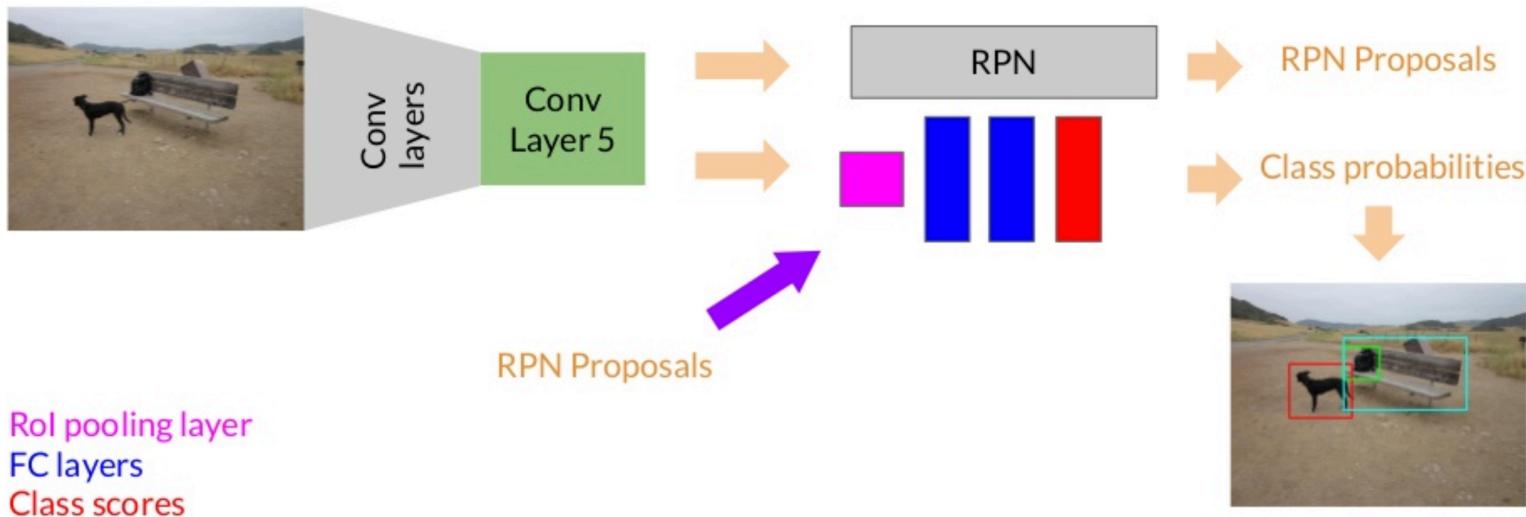


Test

Nilsson, Kenneth, and Josef Bigun. "Localization of corresponding points in fingerprints by complex filtering." *Pattern Recognition Letters* 24.13 (2003): 2135-2144.

Object Detection: New Approach, Faster R-CNN

Robust to noise while maintaining speed



<https://www.slideshare.net/xavigiro/faster-rcnn-towards-realtime-object-detection-with-region-proposal-networks>

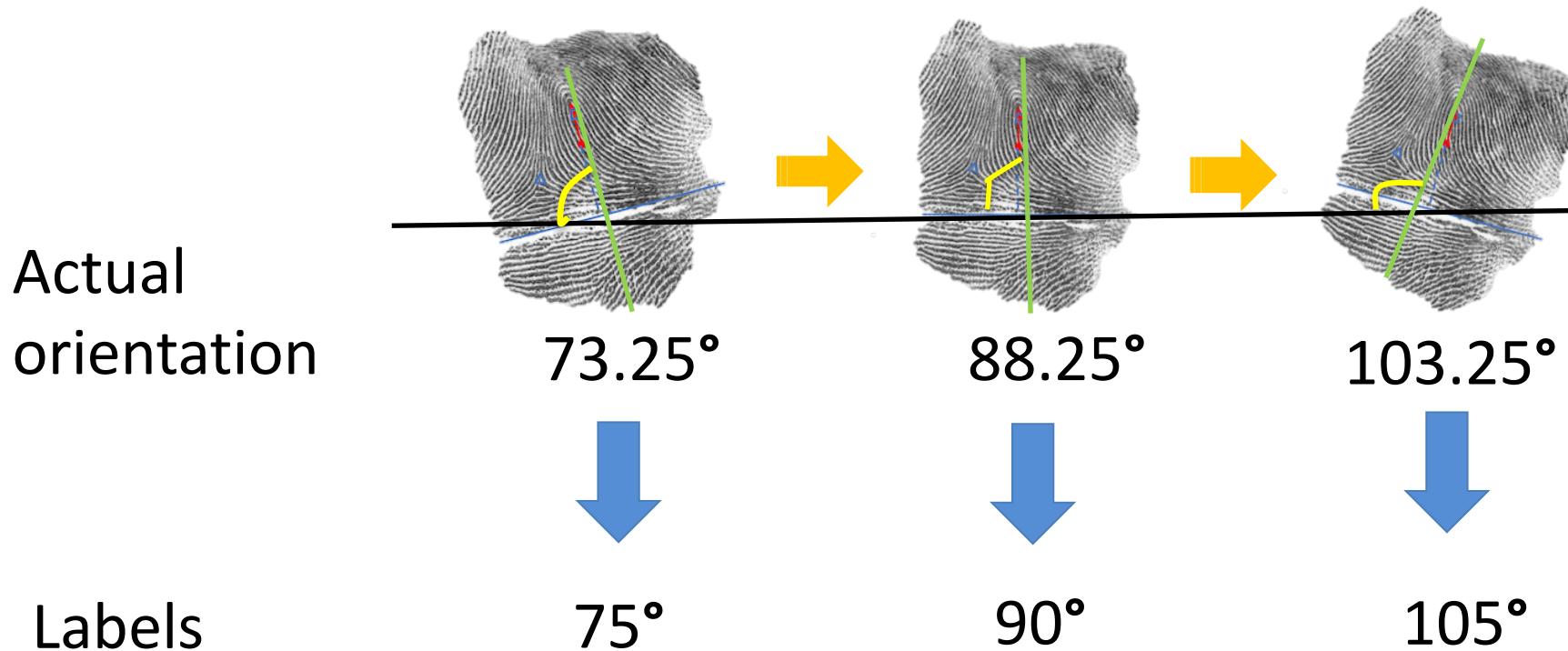
2. Methodology

DATA PREPARATION

- NIST 14 Database, 1500 pairs, with manually labeled orientations
- Discretized orientations, 24 classes (every 15 degrees)
- Training data is augmented by such 24 rotations and rounding-off to nearest classes

Data Preparation

Labels: $15^\circ, 30^\circ, \dots, 180^\circ, -15^\circ, -30^\circ, \dots, -180^\circ$



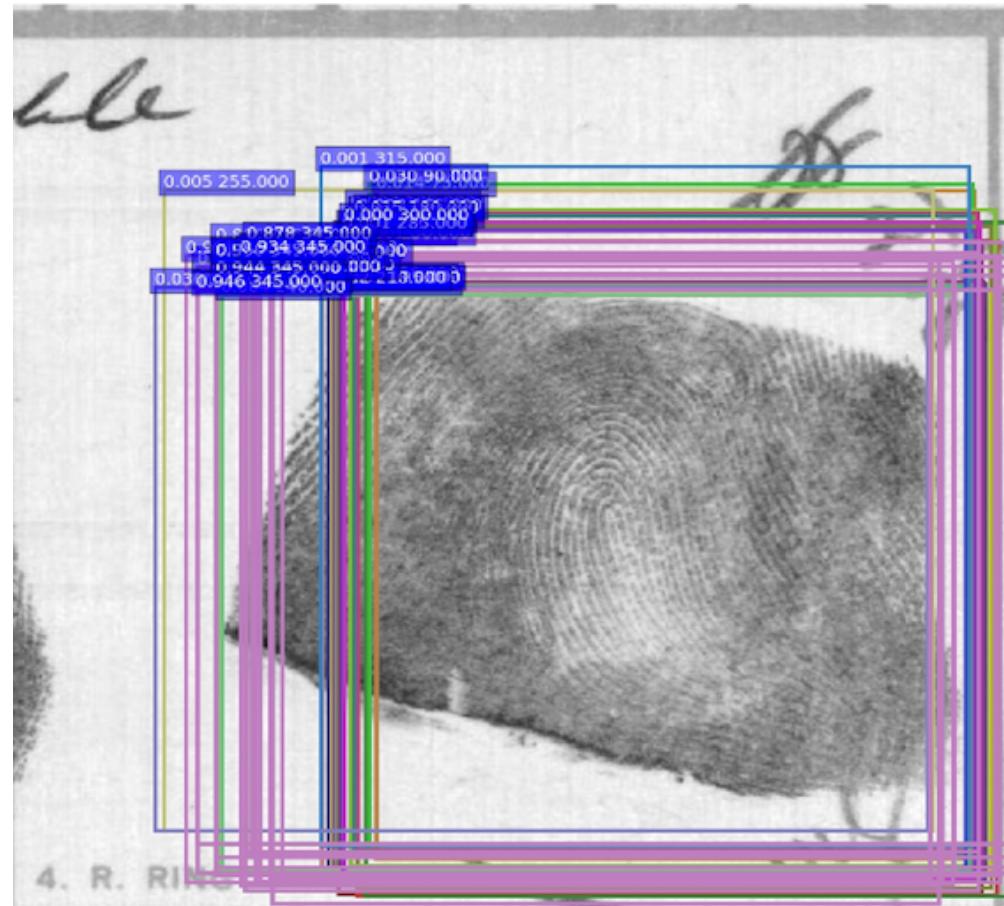
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3-step Pose Detection

- Step 1: Fingerprint detection with Faster R-CNN by fine-tuning VGG16 model
- Step 2: Select the strongest bounding box of each class
- Step 3: Calculate precise box and class by interpolation

3-step Pose Detection: Step 1

Input:
a fingerprint image
Output:
bounding boxes
with probabilities
& classes



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3-step Pose Detection: Step 2

Algorithm

Input: predicted bounding boxes of 24 classes

for bounding boxes of each class **do**

 remove bounding boxes except

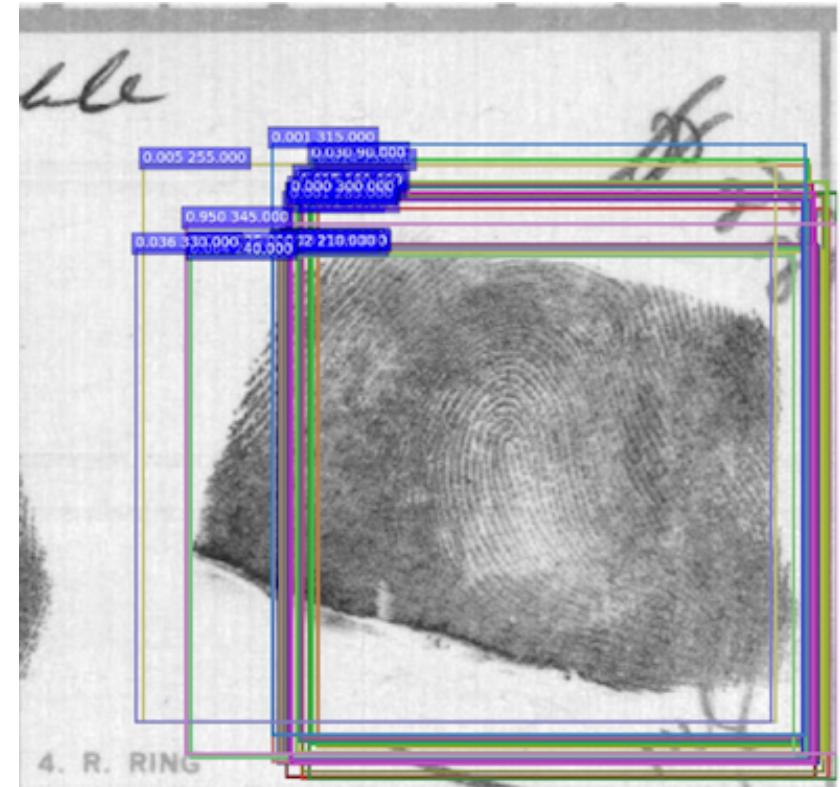
 boxes with confidence level above threshold

 boxes with maximal confidence

 select the strongest box with NMS

end for

Output: a single strongest bounding box for each class



Result

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3-step Pose Detection: Step 3

Algorithm 1 Inter-class Combination

Input: predicted bounding boxes of 24 direction types
for each fingerprint in the image **do**

$box_1 \leftarrow$ box with highest confidence

$box_2 \leftarrow$ box with second highest confidence

$pose \leftarrow box_1$

if $box_2.confidence < thresh_{conf}$ **then**

$diff \leftarrow abs(box_1.angle - box_2.angle)$

if $diff < thresh_{diff}$ **then**

$pose \leftarrow interpolation$

end if

end if

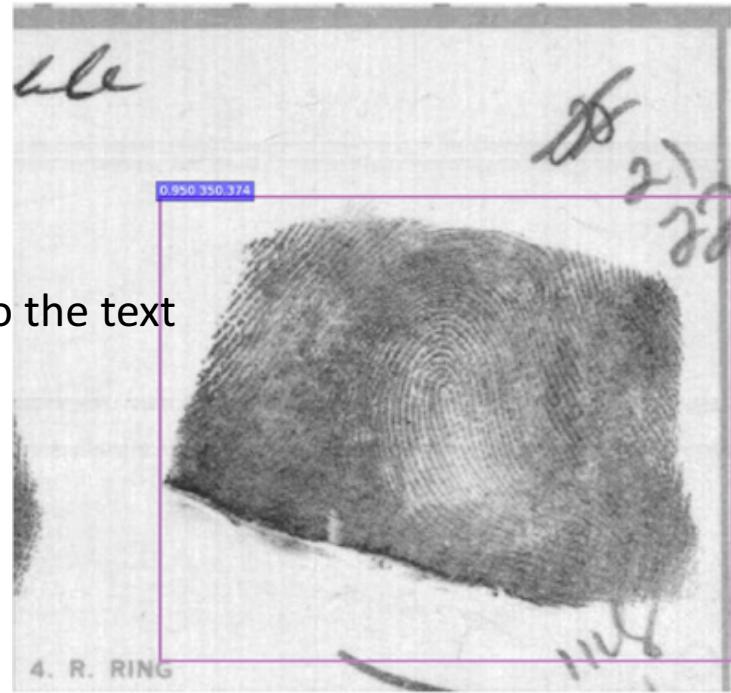
end for

Output: pose

↓ Linear interpolation

$$\hat{\theta} = \frac{p_1\theta_1 + p_2\theta_2}{p_1 + p_2}$$

$$\hat{box} = \frac{p_1box_1 + p_2box_2}{p_1 + p_2}$$

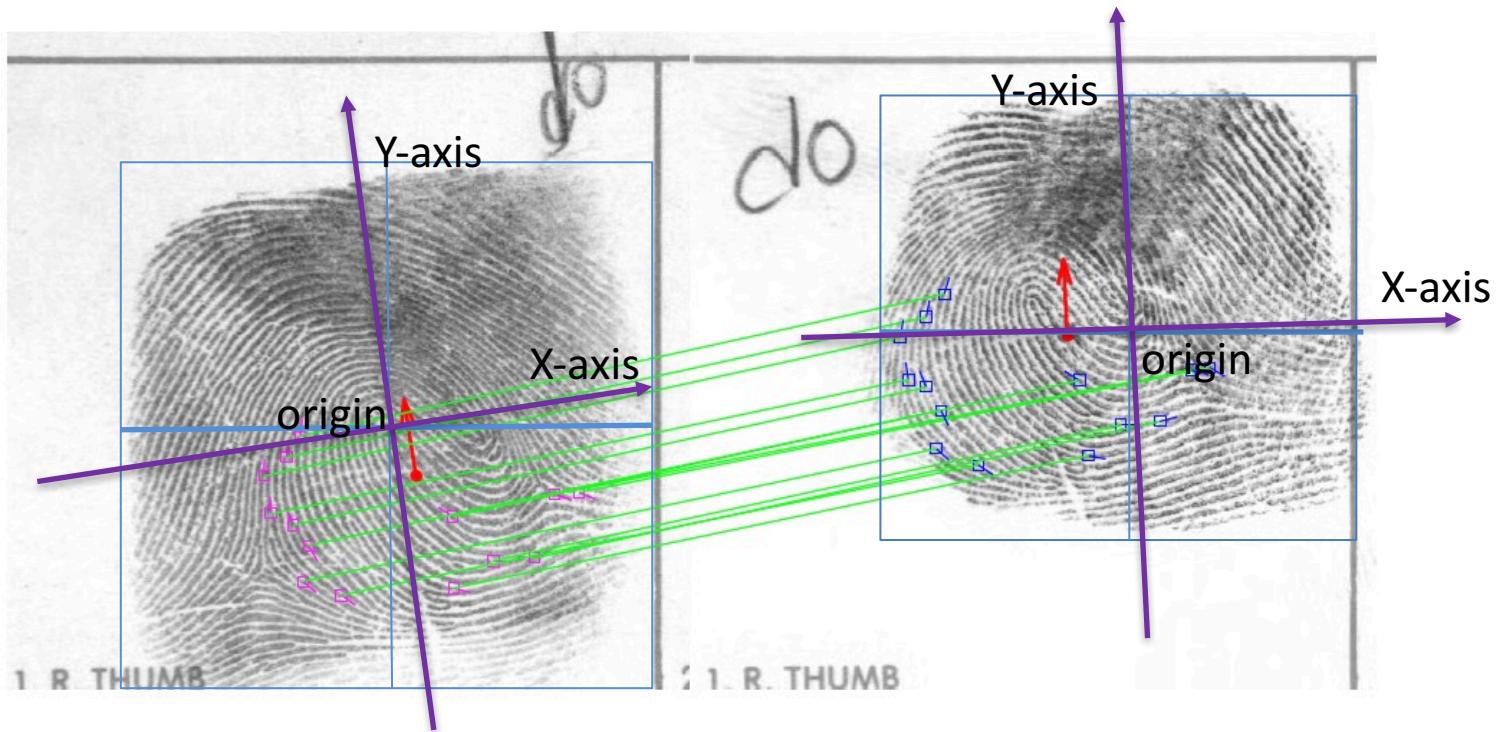


Result

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3. Experiment

Experiment : Evaluate by matching minutiae pairs

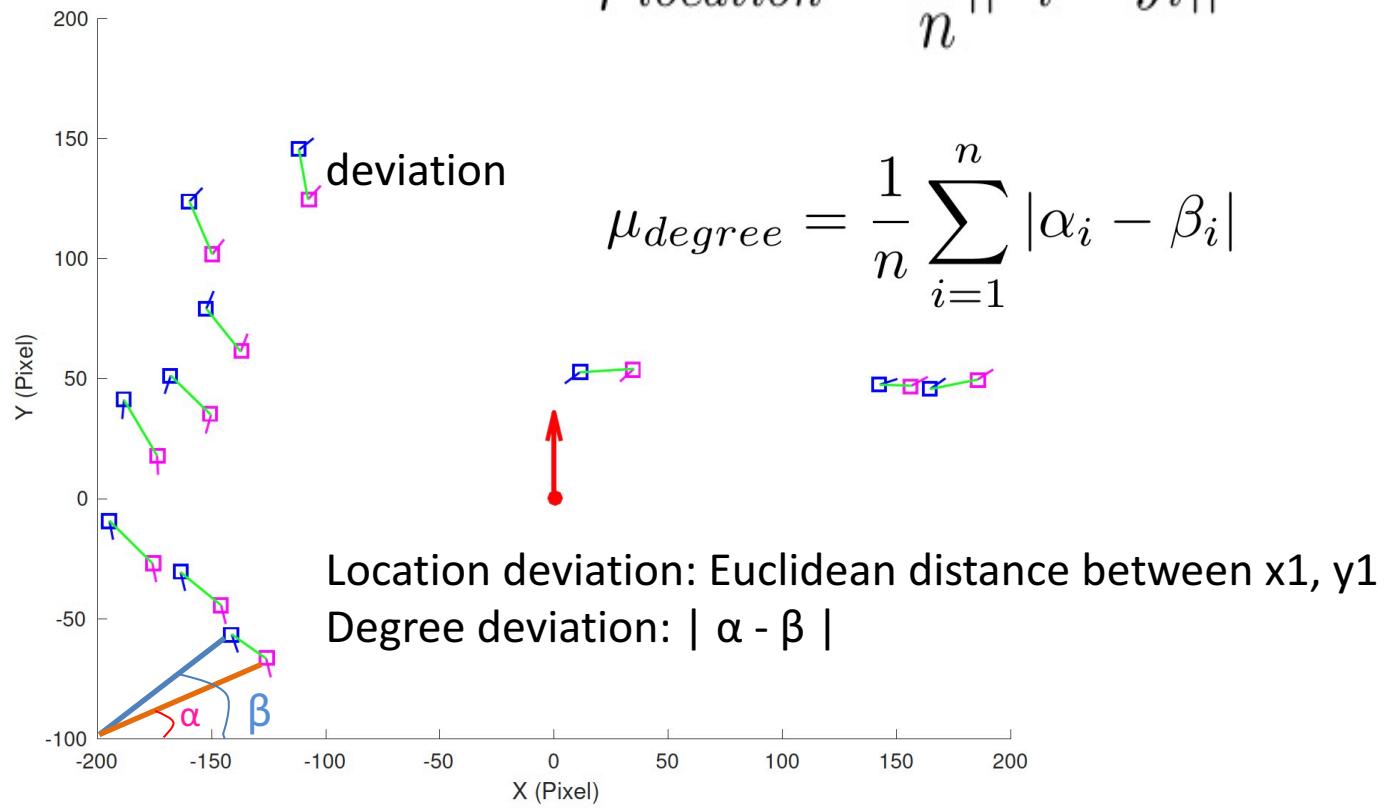


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Experiment : Evaluate by matching minutiae pairs

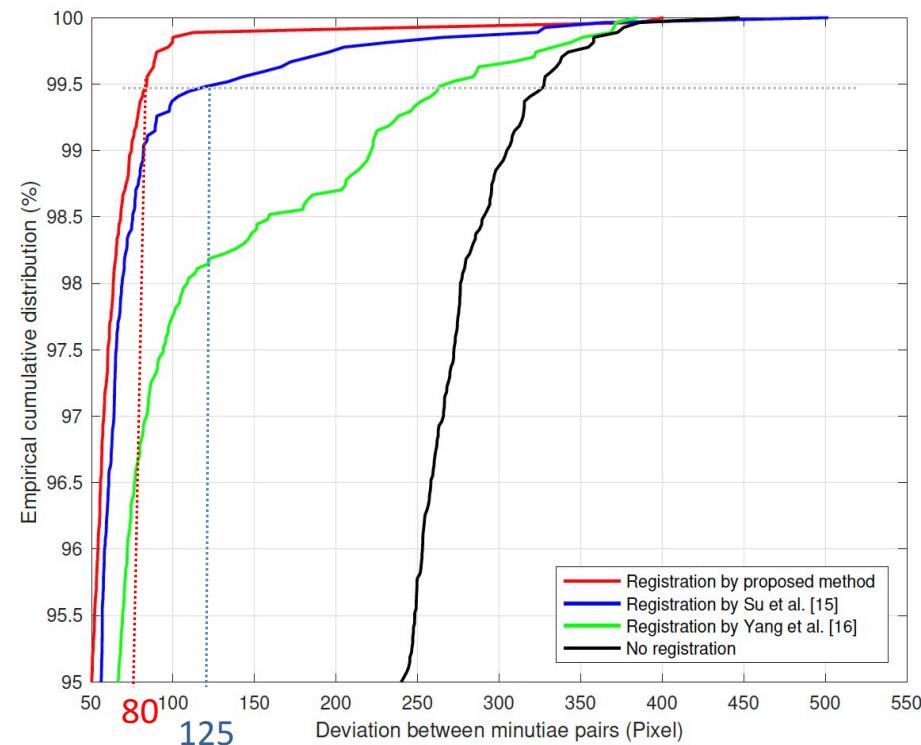
$$\mu_{location} = \frac{1}{n} \|x_i - y_i\|$$

$$\mu_{degree} = \frac{1}{n} \sum_{i=1}^n |\alpha_i - \beta_i|$$

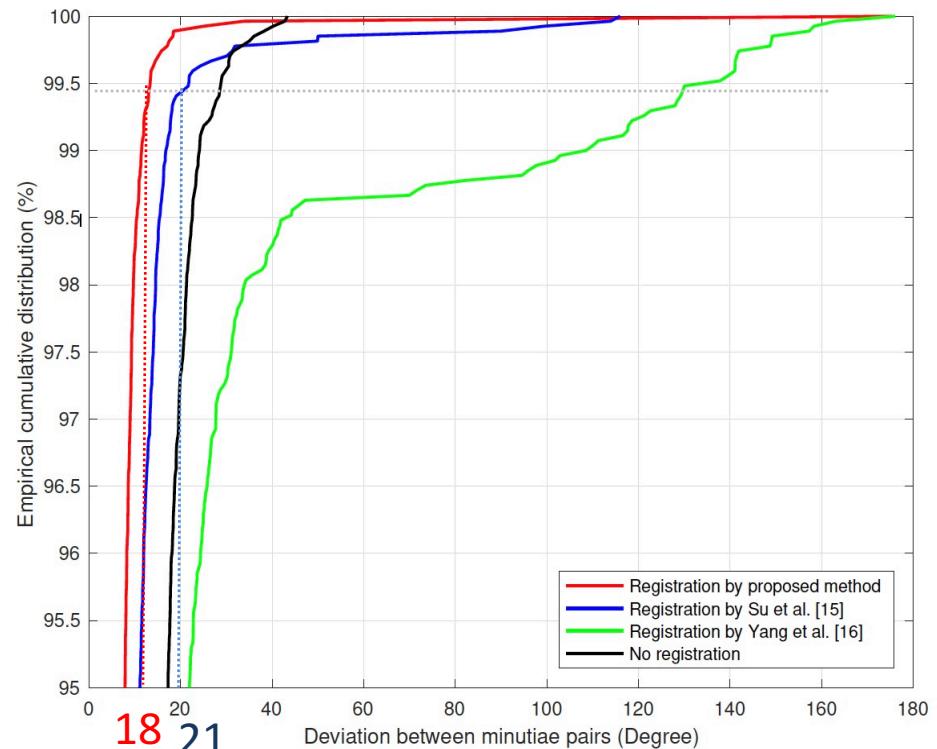


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Experiment : Evaluate by matching minutiae pairs



Significant improvement in fingerprint detection!



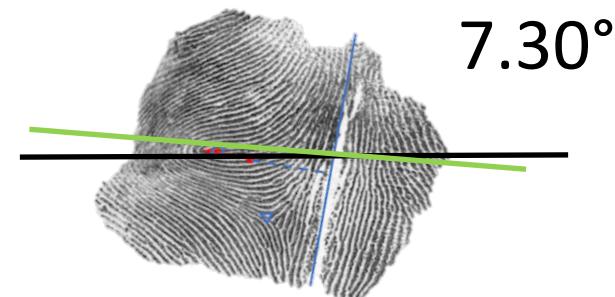
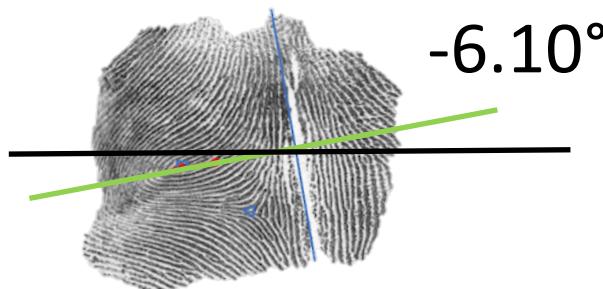
Insignificant improvement in degree prediction?

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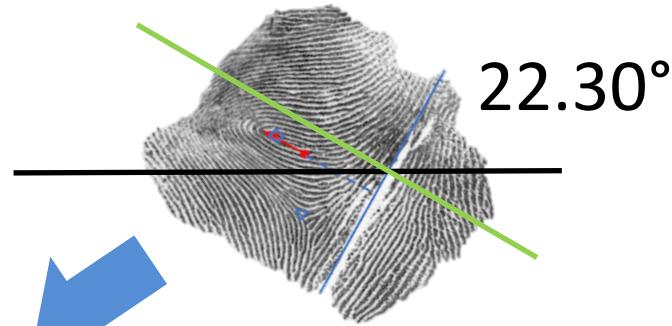
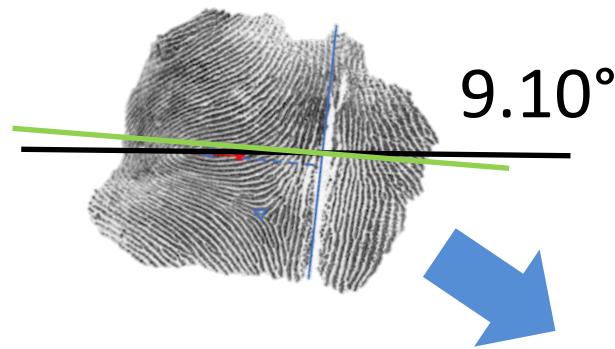
4. Possible Improvements

Original Data Preparation

Error ϵ = actual orientation – class of orientation



Data augmentation in 15° increment

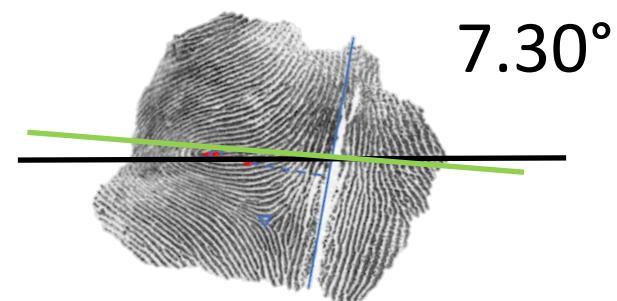
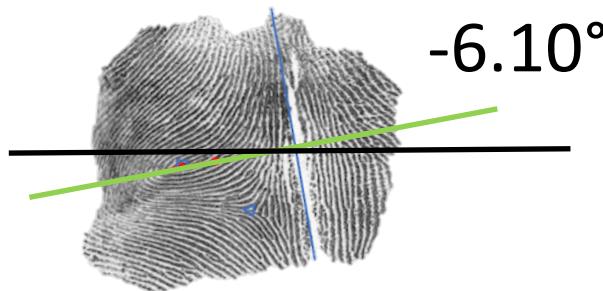


Label: 15°

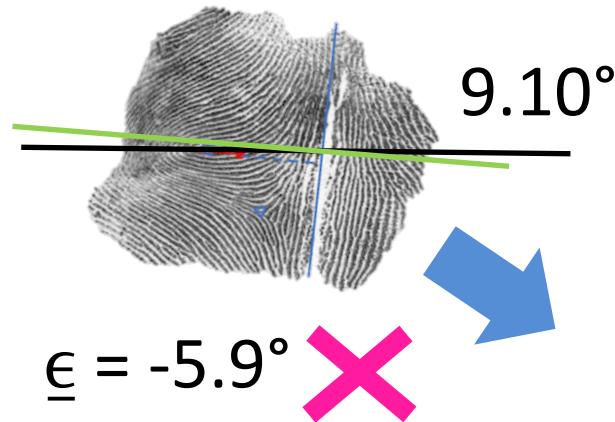
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Original Data Preparation

Error $\underline{\epsilon}$ = actual orientation – class of orientation

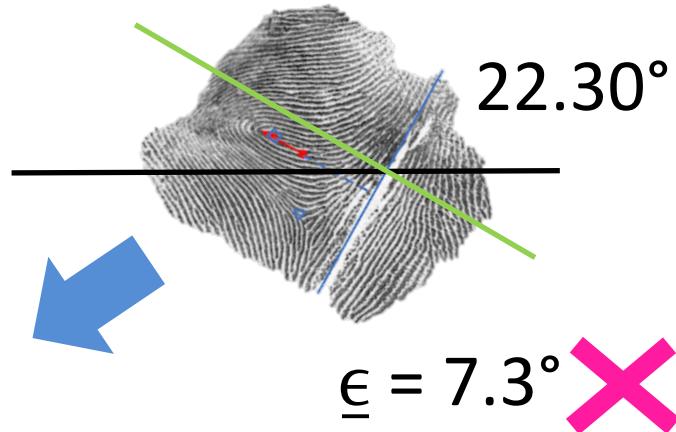


Data augmentation in 15° increment



$$\underline{\epsilon} = -5.9^\circ \times$$

Label: 15°

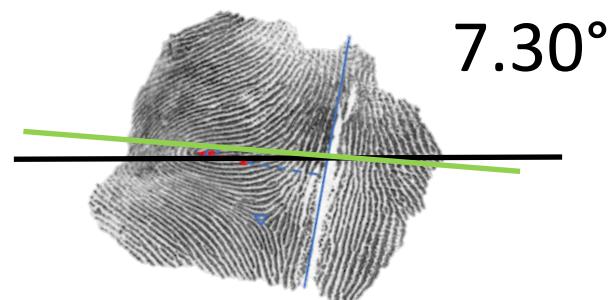
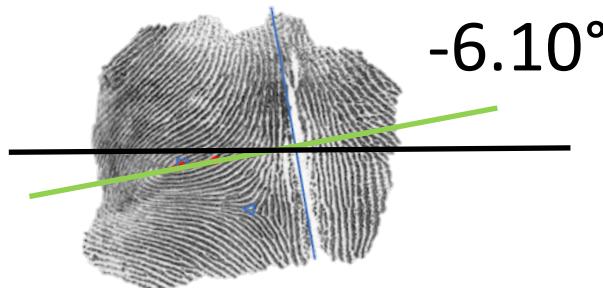


$$\underline{\epsilon} = 7.3^\circ \times$$

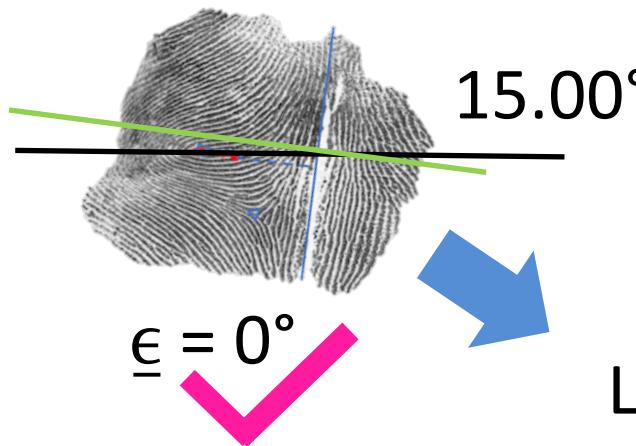
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Suggested Data Preparation

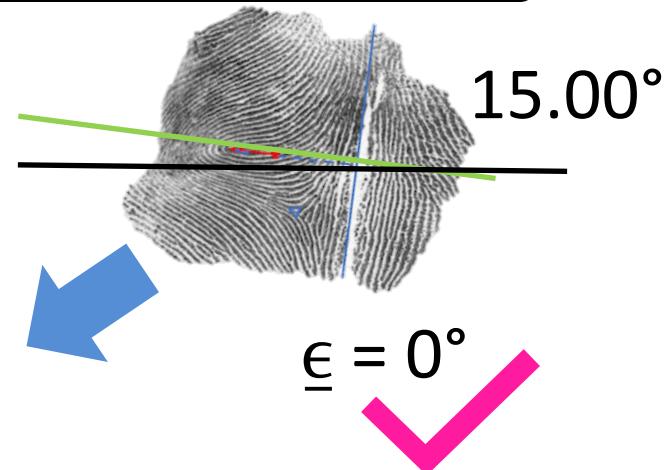
Error $\underline{\epsilon}$ = actual orientation – rounded orientation



Continuous rotation



Label: 15°



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Other Suggestions

- Ad-hoc and intuitive linear interpolation. Why not polynomial interpolation?
- Why not more classes and smaller inter-class distance, e.g. 360 classes in 1° increment?
- Lack of statistics: variances, statistical tests (p-value, etc)

Thank you!