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# Fingerprints: Some Baby Steps

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# *F*ingerprints & Deep Learning

- Not enough ground truth, not enough data
- Data imbalance, augmentation difficult
- GANs for Latent Enhancement [WACV'19, CRC Press Book Chap'19]
- Explainable Fingerprint ROI Seg [WACV-W'21]
- Noise-Aware Fingerprint Pre-processing [IJCNN'21]
- Sensor-Inv Features for ROI Seg [IJCNN'21]
- Restoration of Degraded Fingerprints [MTA'21]



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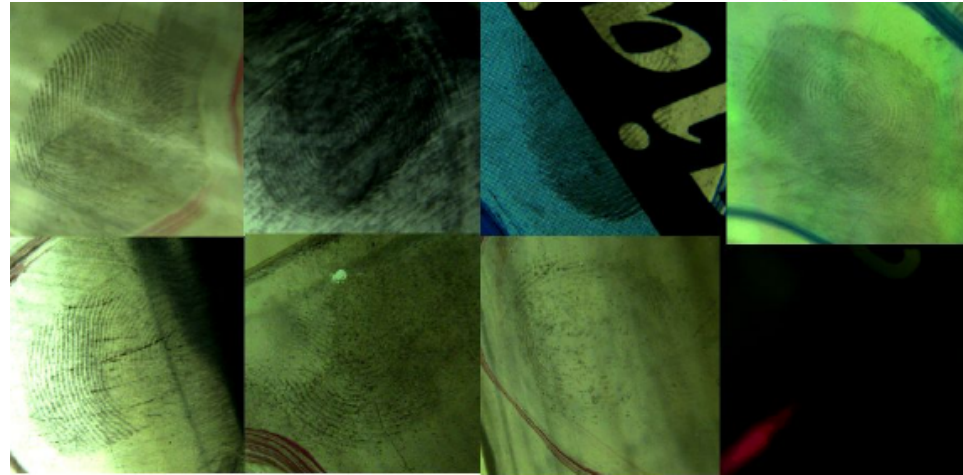
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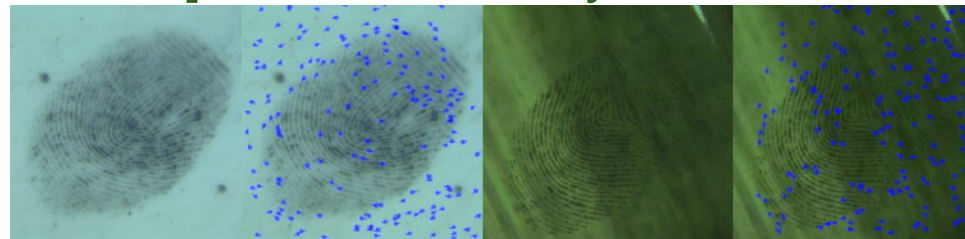
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# GANs for Latent Enhancement

[WACV'19, CRC Press Chap'19]



- [IIITD-MSLFD] unintentionally left on surfaces



- Motivation: feature detectors fail on latents!
- Literature: learning orientations, in spite of noise



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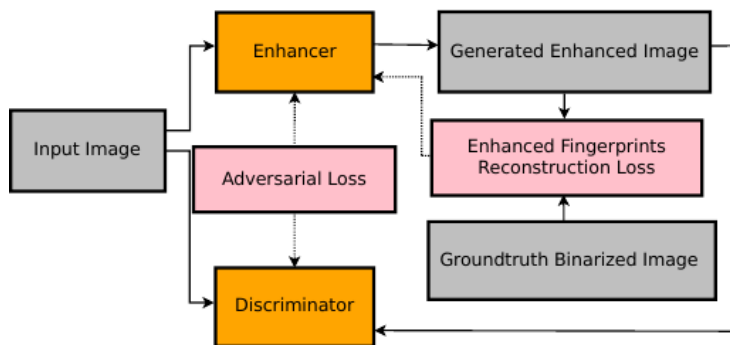
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- Cat-mouse Gen-Disc
- Generator generates new examples, Discriminator: real/fake
- Zero-Sum Adv game, till Disc fooled 50%
- GAN: Adv loss: Enhancer min, Disc: max
- Enh FP loss: penalises the Enhancer, forcing it to generate enhanced fp similar to the ground truth
- GAN: Gaussian rv seed, Disc: discarded post-trg
- Conditional GAN: rv conditioned with add'l info
- Why? generate a realistic binarised FP plus generate FP with ridge structure  $\sim$  input latent print



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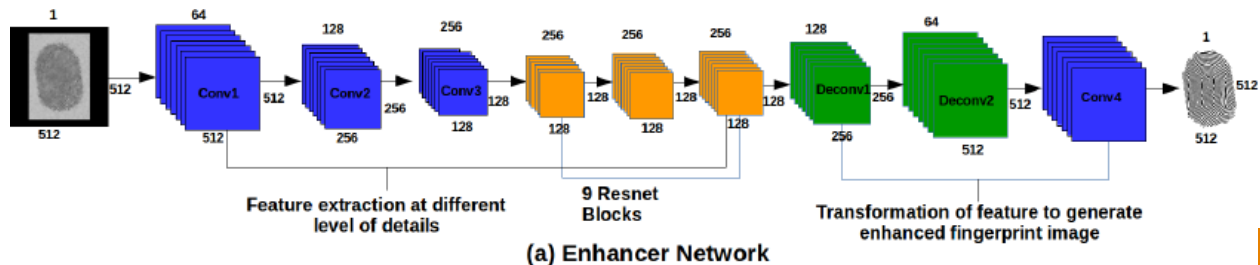
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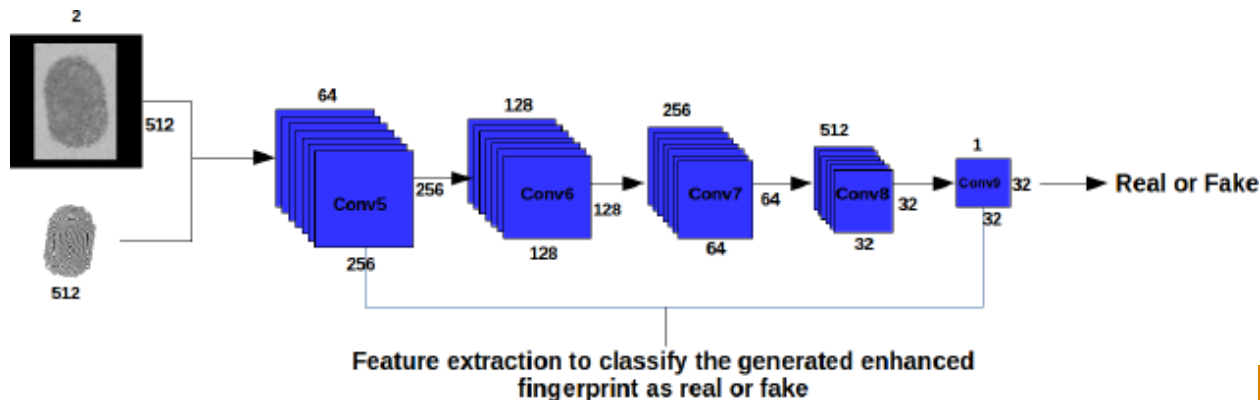
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- **Enhancer:** Enc-Dec, cascade ConvL+BN+ReLU...
- Residual layer: skip in place of cascades
- Vanishing grad, degradation problem, good learn



# Challenge: Training & Testing



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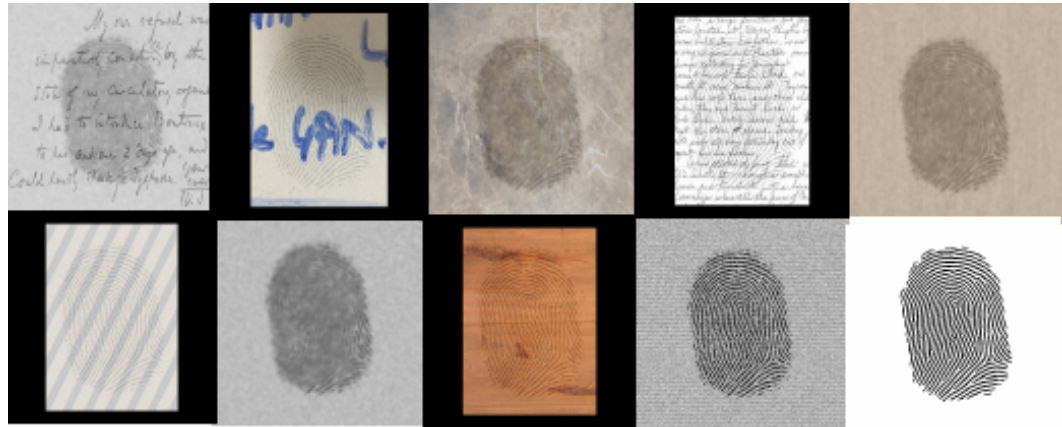
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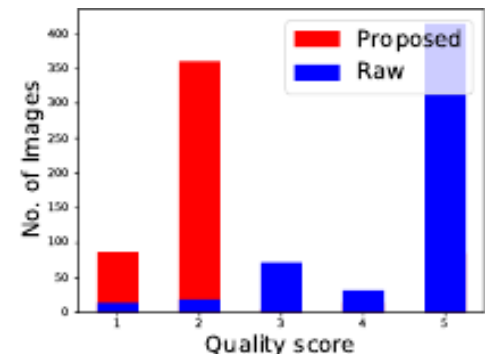
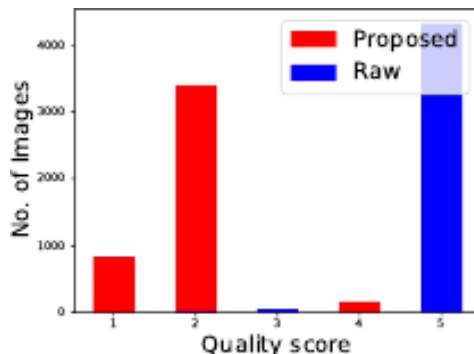
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- Synthetic latents, augment: size, blue, rotate
- Test? Quality, Features, Ridge, FP Matching
- Quality: NFIQ for IIITD-MOLF, IIITD-MSLF





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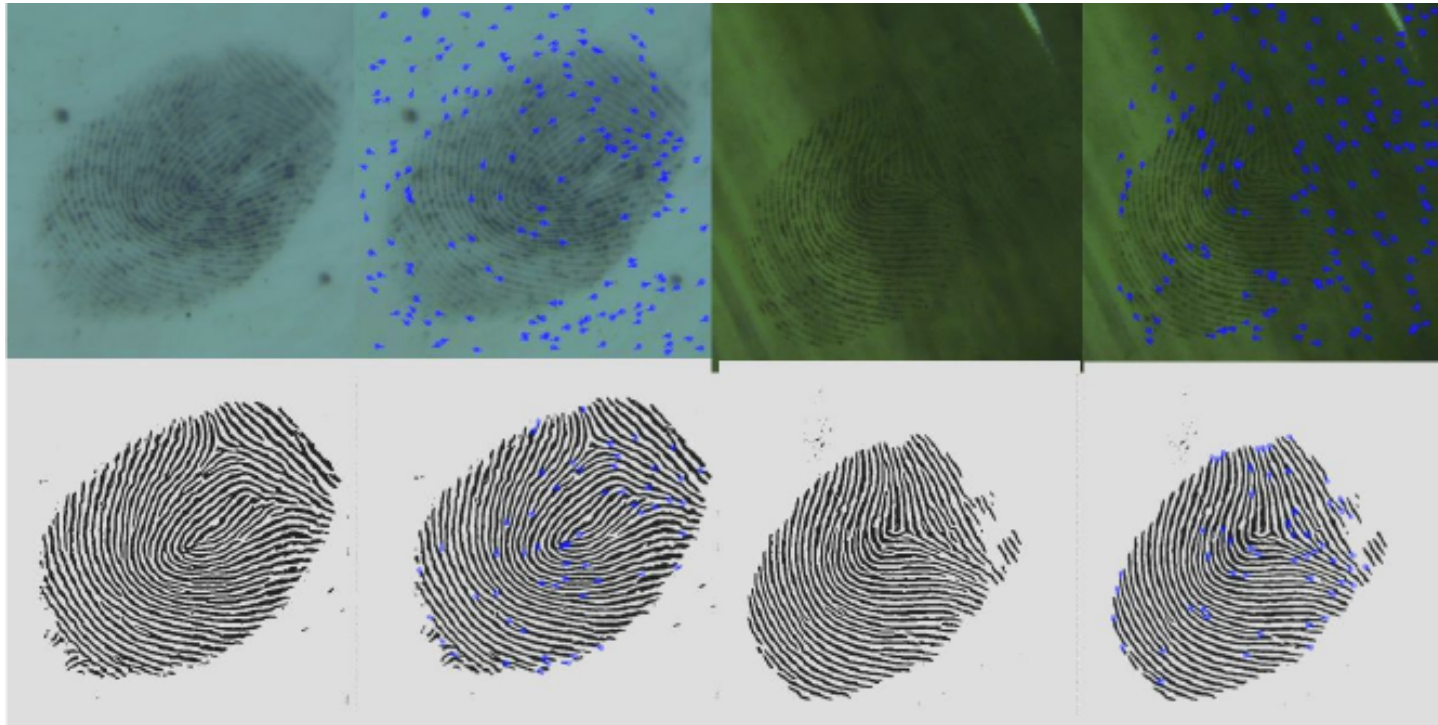
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# Improved feature extraction







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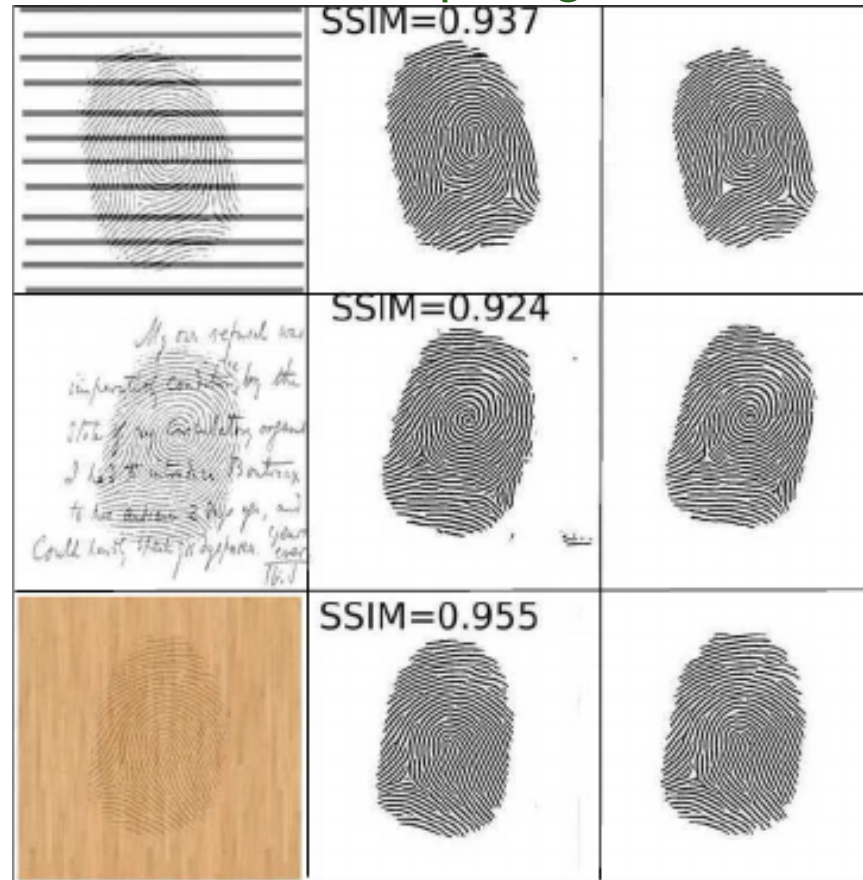
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# Ridge Structure, Matching%

Latent, GAN output, ground truth



Lumidigm: Raw: 5.45, [Svoboda]: 22.36, **GAN: 35.66**  
Secugen: Raw: 5.18, [Svoboda]: 19.50, **GAN: 30.16**





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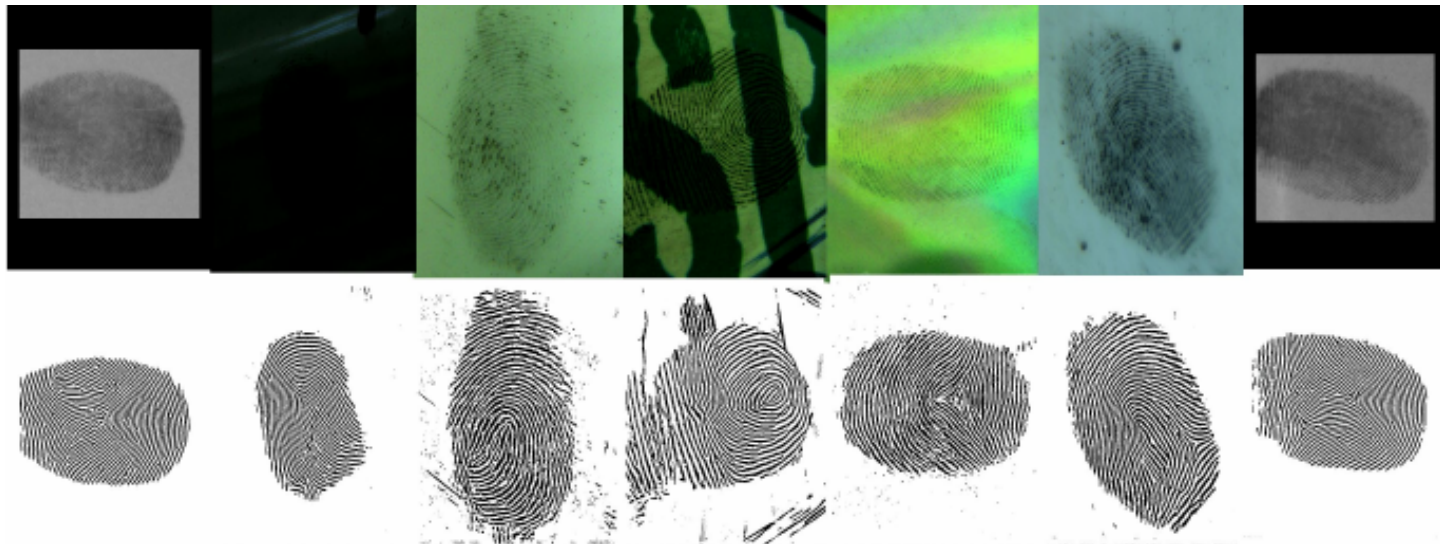
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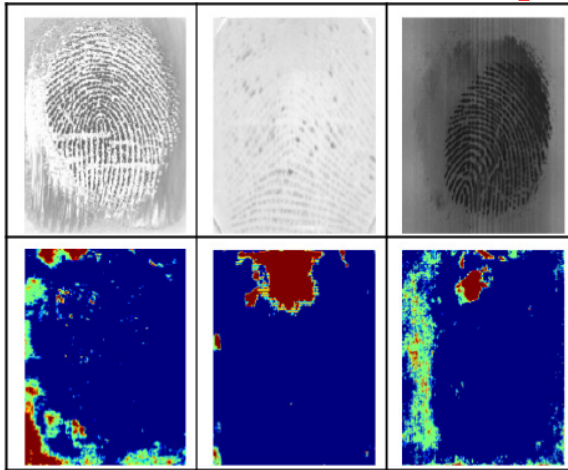
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# Successful Reconstruction



# Explainable ROI Segmentation

[WACV-W'21]



- fdet on ROI, less match time
- Explainable AI: Visualisation of Model Uncertainty
- Heat map of bg-vs-ROI
- 4 SotA semantic seg models
- Model Unc'y: attention mech
- Diff Sensors: Opt, capacitive, thermal, op diff!
- Lit: Fourier filtering: Gabor masks, freq range
- Morphological, Ridge-orientation flow
- ML-based: ROI/bg with intensity/texture/CNN
- Monte Carlo Dropout (approx of Bayesian NN)
- Only end-to-end methods suitable. Earlier: need post-processing (per-pixel labels may change)



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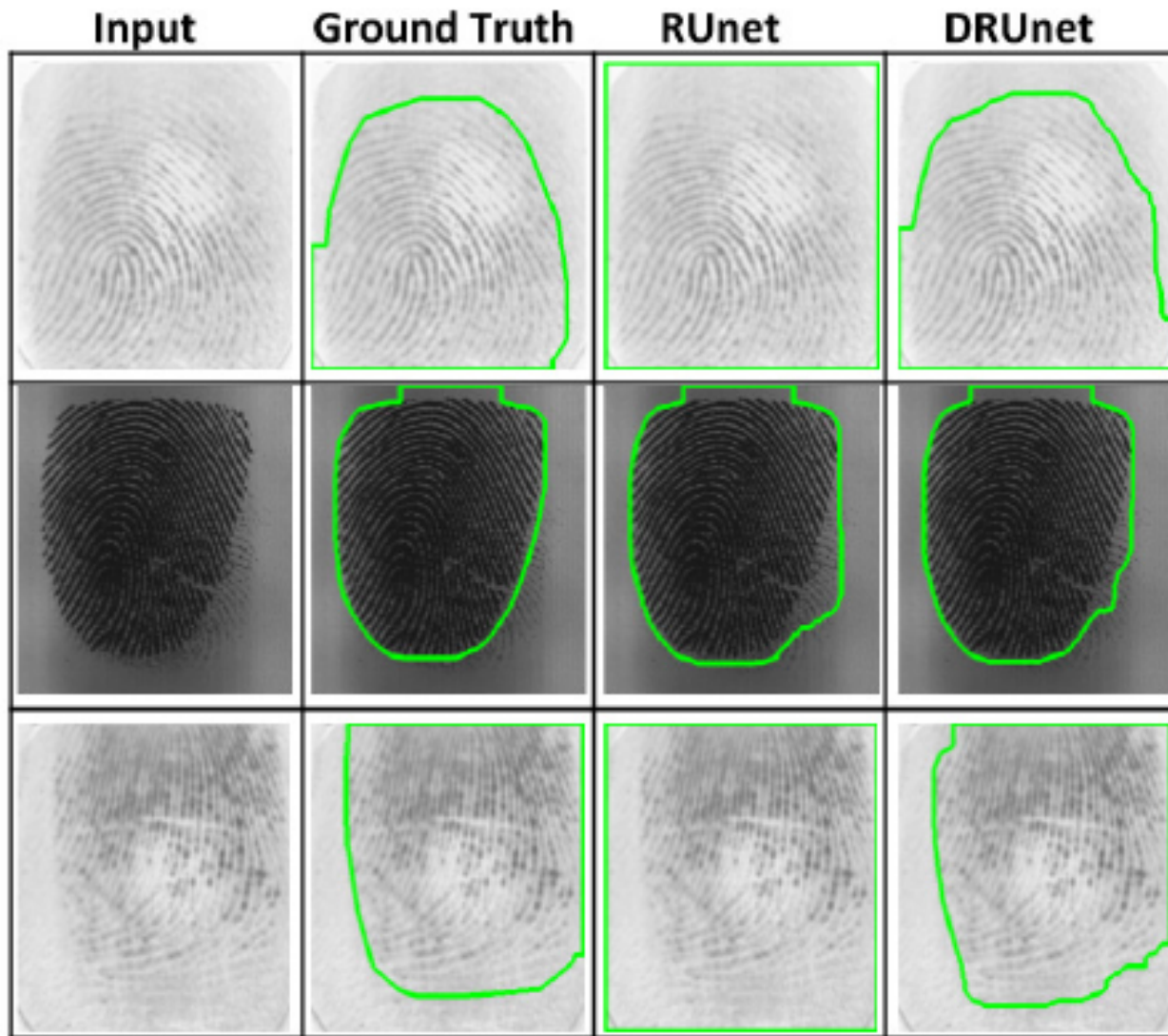
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- 4 State-of-the-art Segmentation Models
  - 1. Conditional GANs
  - 2. U-Net: Skip connections Enc-Dec. Contextual info: edge-level details. Small training
  - 3. CCNet: Criss-Cross Net. Cross-cross attention module, contextual info  $x, y$  dirns + global info
  - 4. RU-Net: Recurrent U-Net. Small training.
- Model Uncertainty: ~~last layer?~~ det  $\rightarrow$  prob nets
- $y = f(w, x)$ : trg input  $x_i$ , seg output  $y_i$ , params  $w$
- Bayesian NN: learn  $P(w|\{x_i\}, \{y_i\})$ : intractable
- $P(y|x, \{x_i\}, \{y_i\}) = \int P(y|x, w)P(w|\{x_i\}, \{y_i\})dw$
- [Gal, Gahramani ICML'16]: Monte Carlo Dropout: Approximation
- Metrics: Dice coeff, Jaccard coeff (IoU)  $\in [0, 1]$
- Results: RU-Net  $\uparrow$ , Dropout RU-Net best

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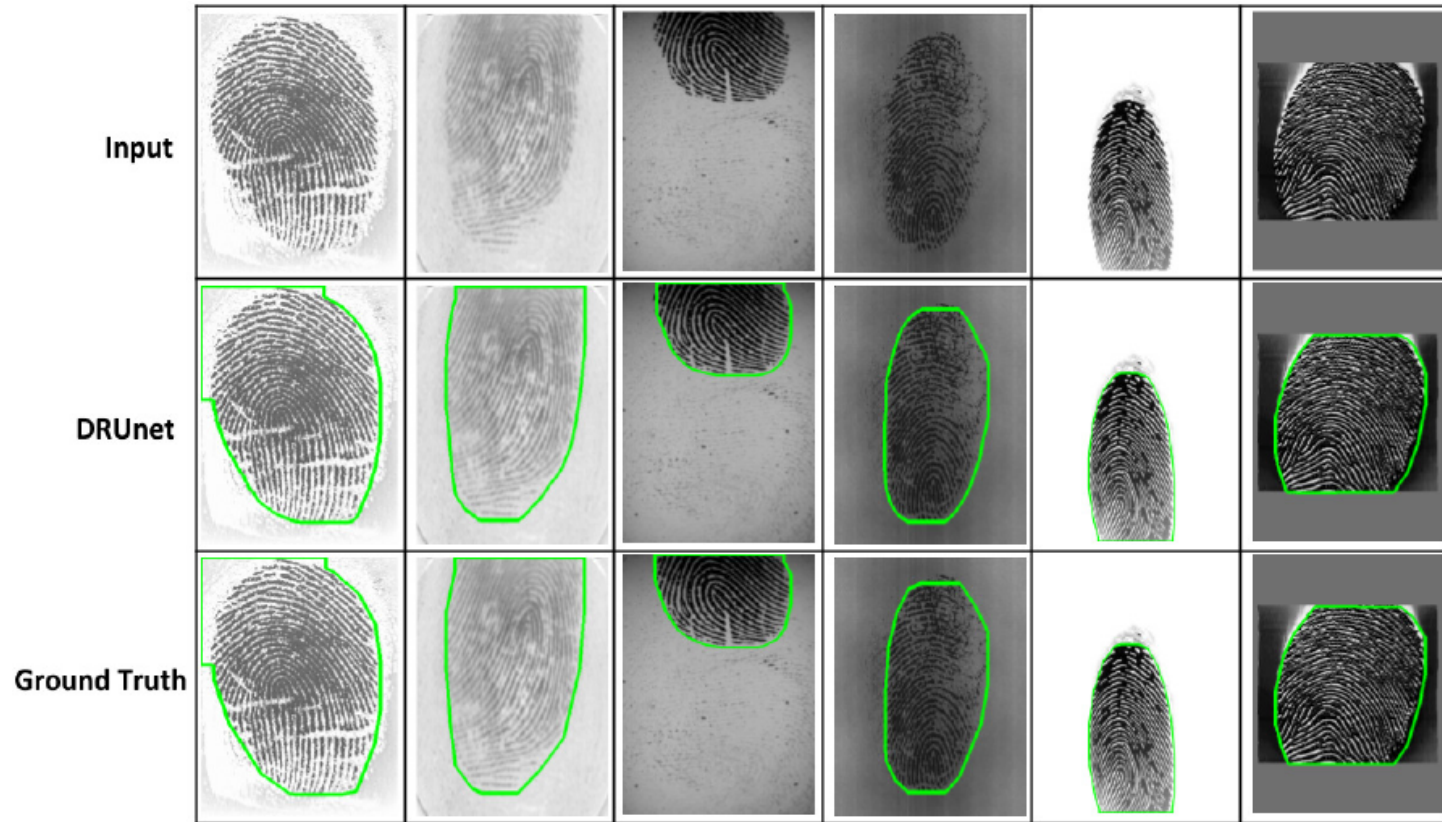
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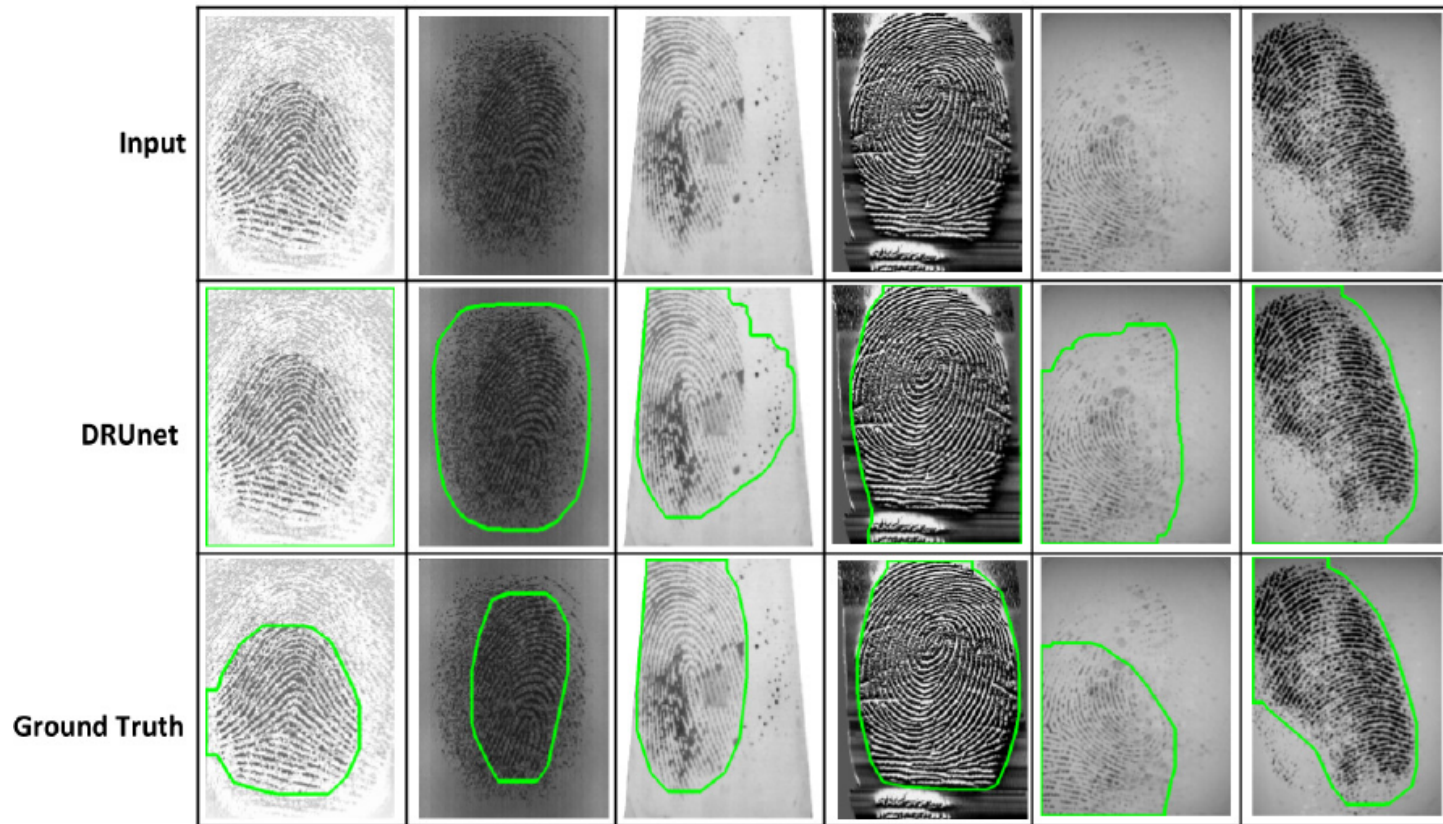
# DRU-Net: Good results





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# DRU-Net: Bad results

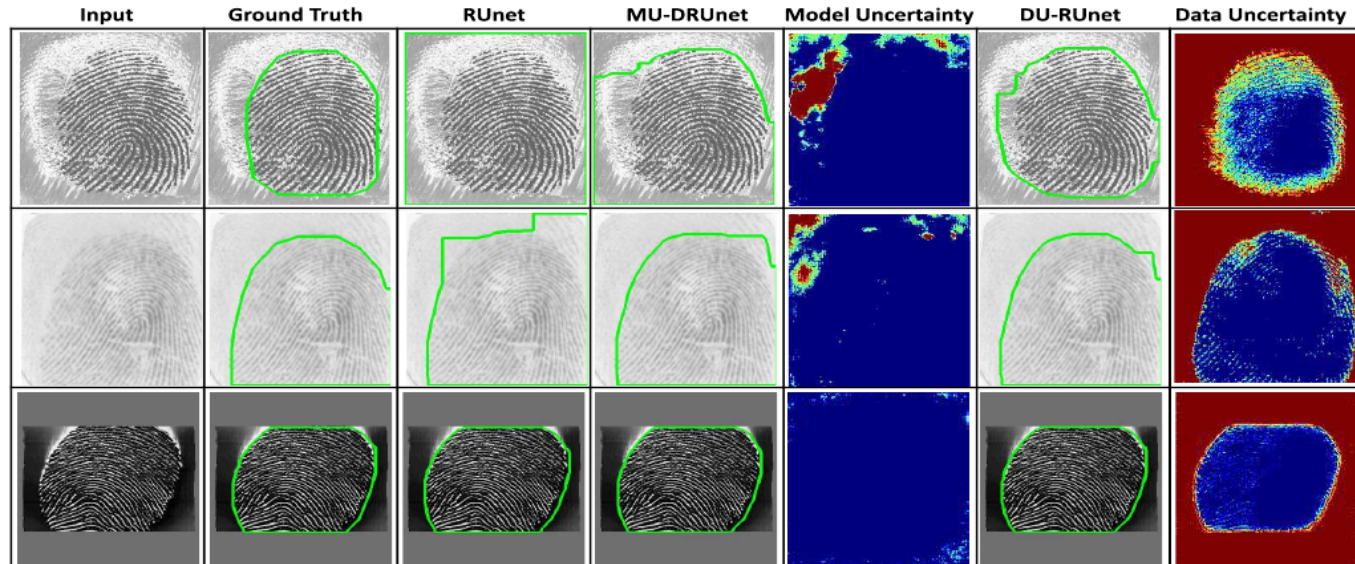




# Noise-Aware FP Pre-processing

## [IJCNN'21]

- Model Uncertainty + Data Uncertainty: Bayesian



- Model Uncertainty: model's confidence in prediction. higher uncertainty: incorrect predictions
- Data Uncertainty: input noise. Higher uncertainty: background, boundaries





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# Sensor-Inv Features: ROI Seg

[IJCNN'21]

- Retrain seg for new sensor? Opt/Cap/Thermal
- Recurrent Adversarial Feature Alignment: Ind
- Recurrent Sensor Discriminator: target/source



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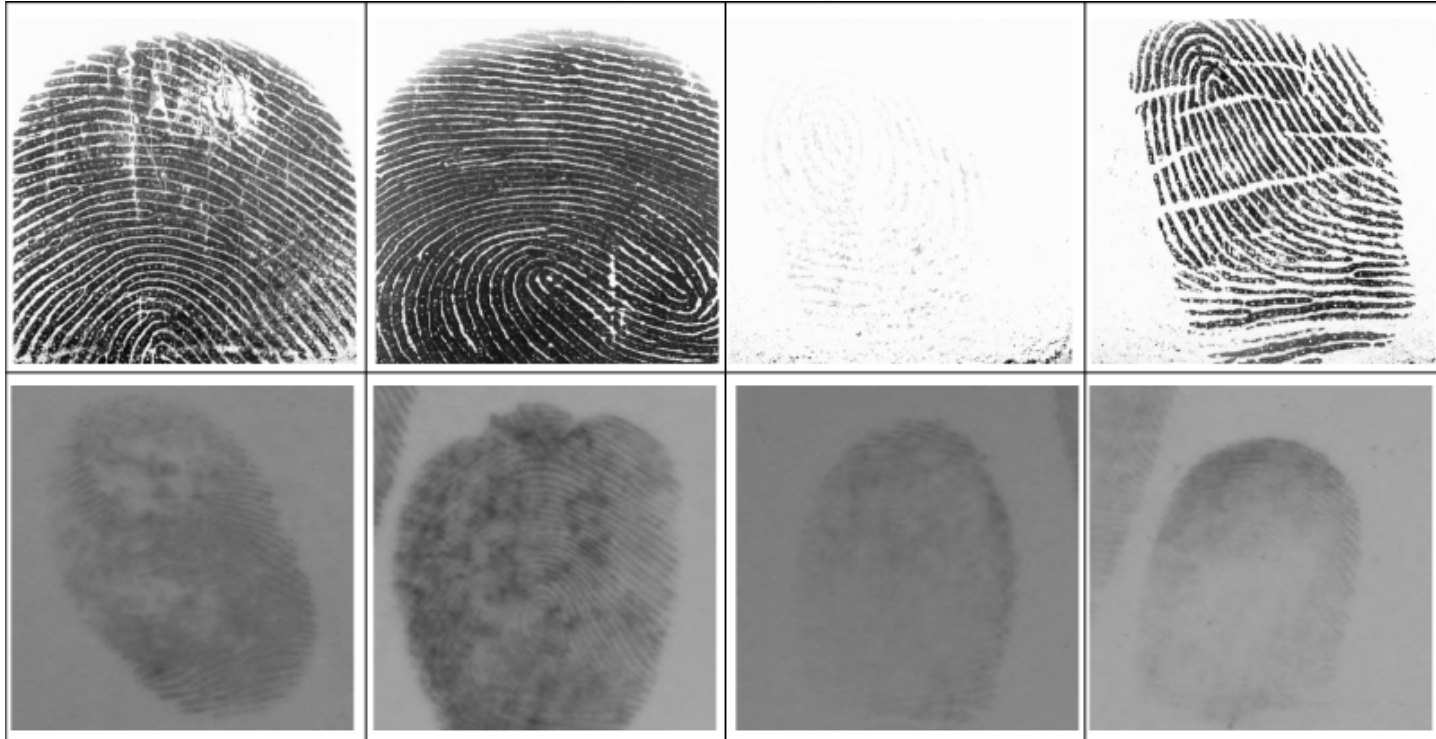
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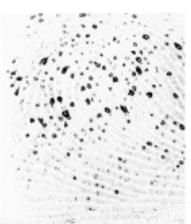

# Restoration of Degraded FPs





[MTA'21]



- Rural fingerprints, crime scene
- dry, wet, rural, warts, scars, creases, noise, o'lap

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Probe	Gallery	Match Score
		13
		0

Probe	Gallery	Match Score
		57
		18

- fdet fails, improve ridge st, NFIS match scores
- Deep: learn redundant features: SE, BlockAtt'18
- Channel Refinement: reduce feature redundancy
- SE: more params, redundancy, weak general'n



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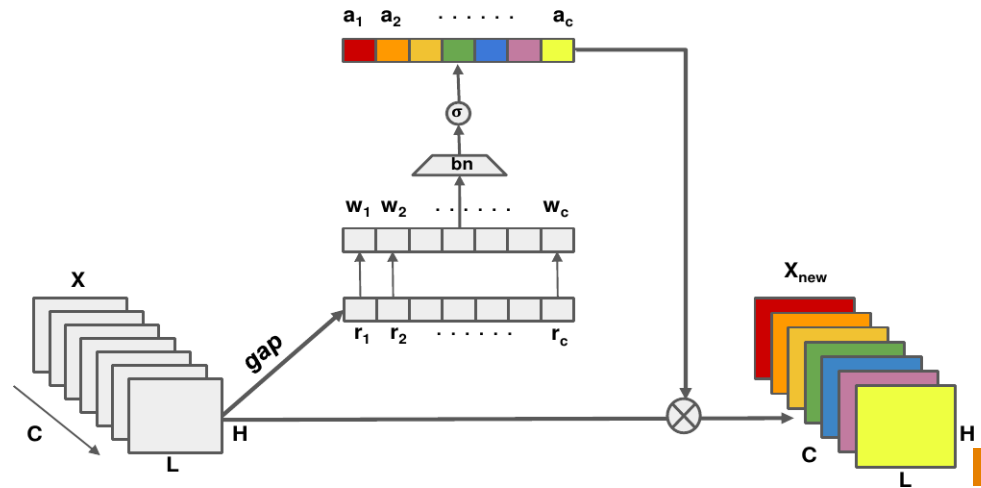
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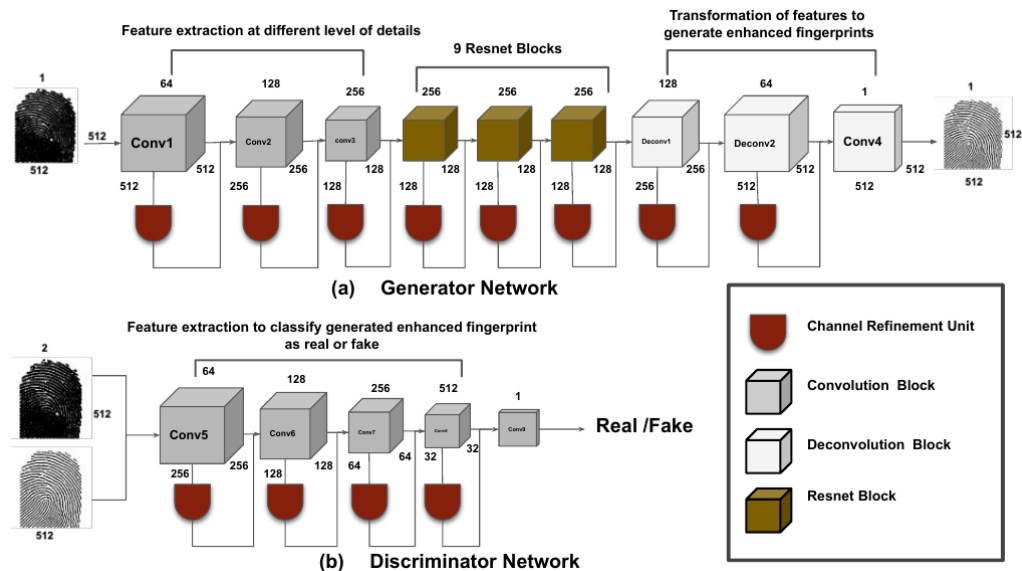
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- CRU: global avg pooling. CR-GAN: Gen-Disc





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