A Lightweight Multi-label Segmentation Network for Mobile Iris Biometrics

Caiyong Wang[1,2], *Yunlong Wang*[2], *Boqiang Xu*[1,2], *Yong He*[2], *Zhiwei Dong*[3], *Zhenan Sun*[1,2,] ✉

[1]School of Artificial Intelligence, University of Chinese Academy of Sciences, China
[2]CRIPAC, NLPR, CASIA, China
[3]University of Science and Technology Beijing, China
caiyong.wang@cripac.ia.ac.cn, znsun@nlpr.ia.ac.cn

Outline

- Background
- Proposed Method
- Experimental Results
- Conclusion

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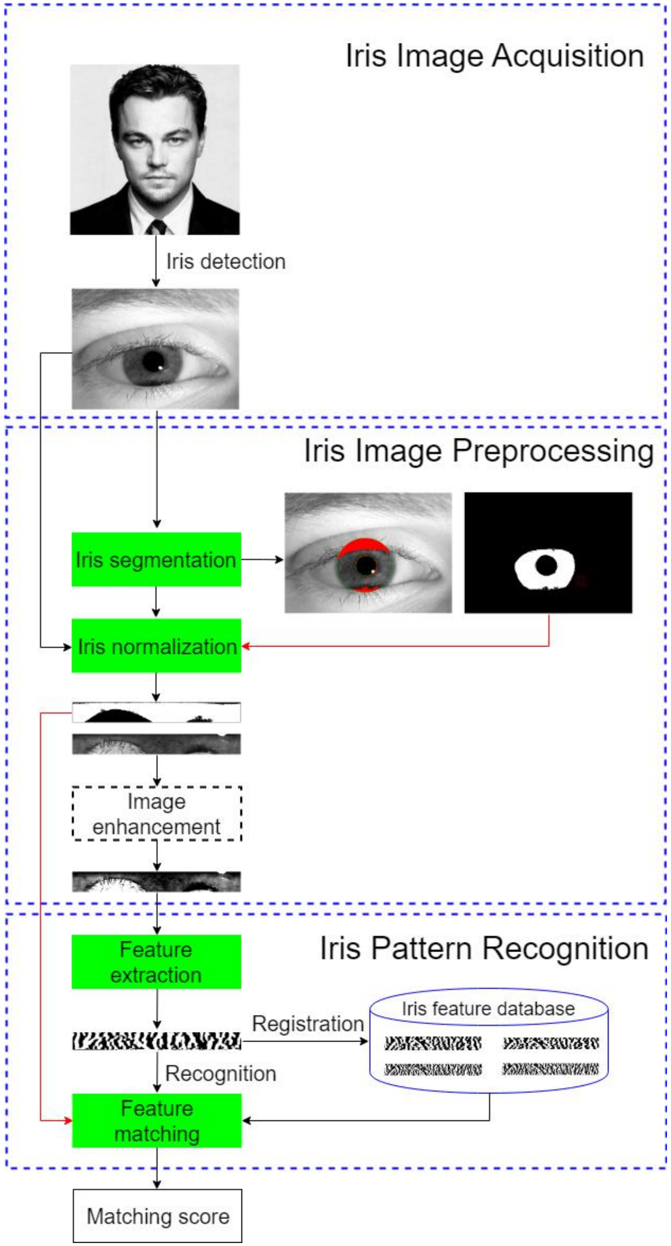
➢ Iris recognition



➢ Iris recognition

■ Hamming distance

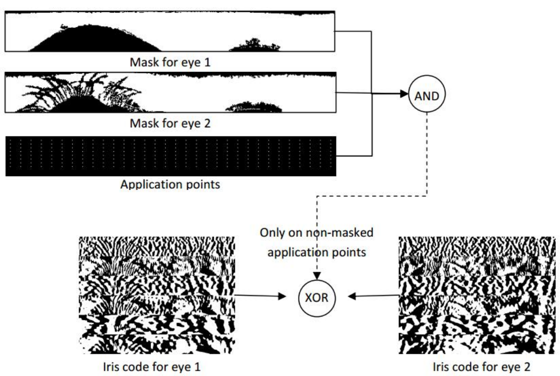
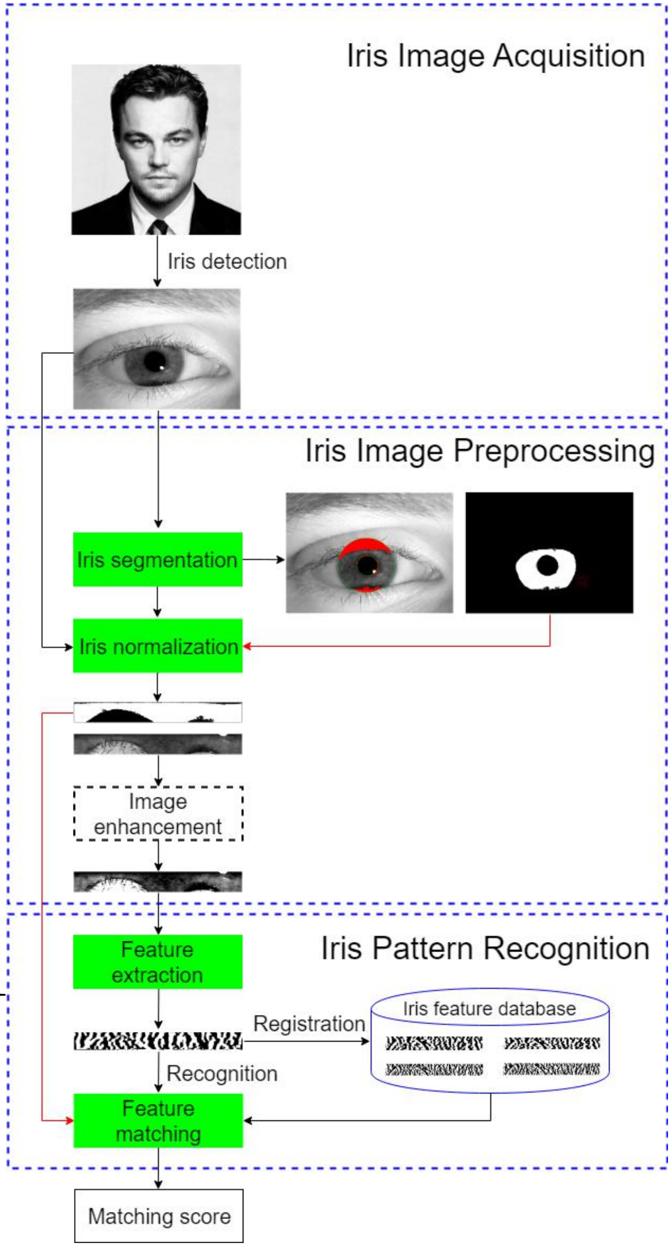


Figure 16: The XOR operator is used to compare two iris codes. Only the non-masekd application points are considered during the XOR operation

Only the **non-masekd application points** are considered during the XOR operation.



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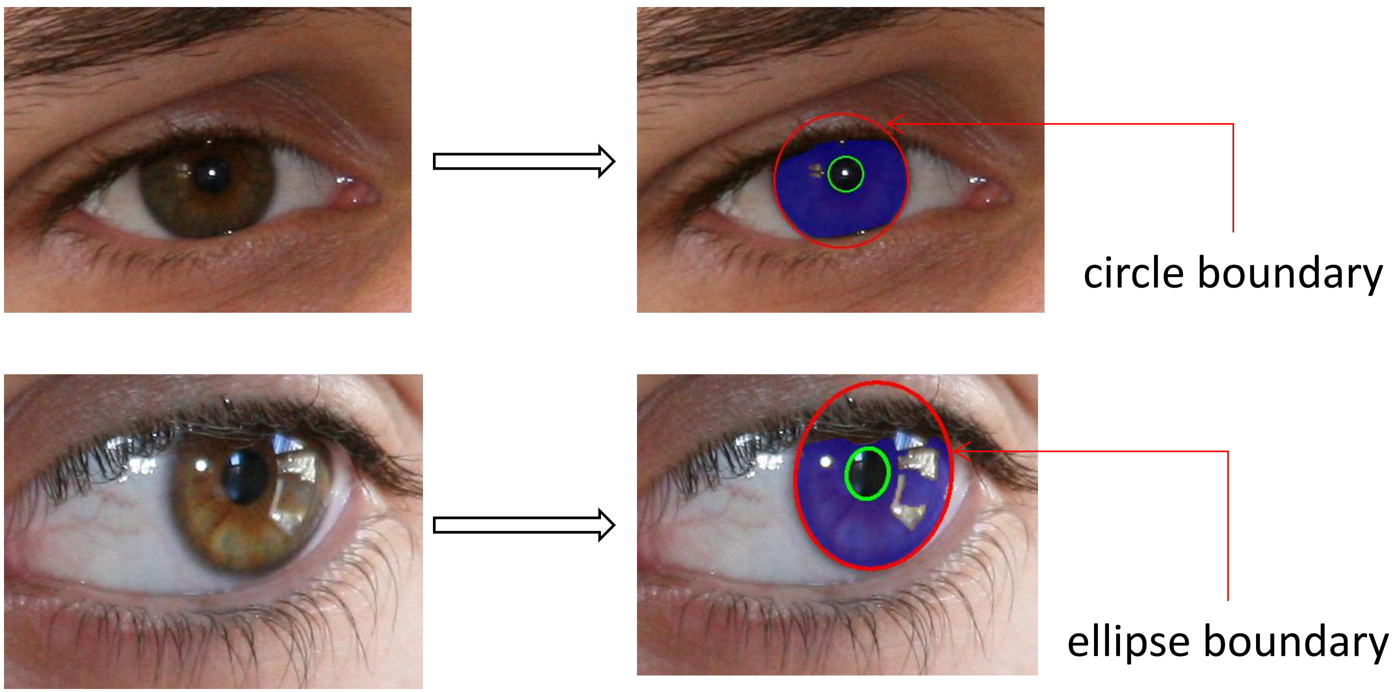
Iris segmentation (Complete)

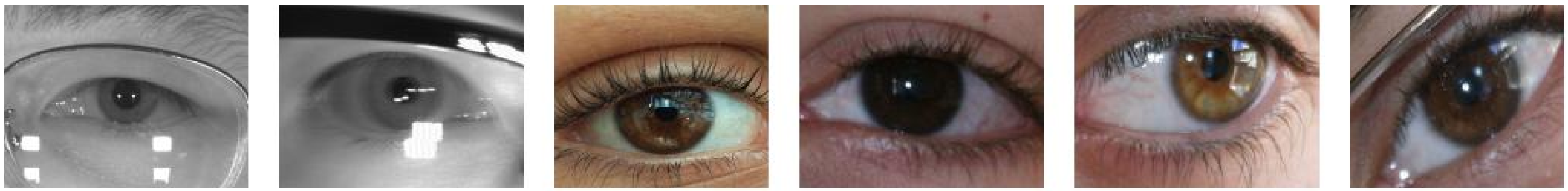
- Segmentation of iris noisy mask **(Optional)**
- Localization of parameterized iris inner and outer boundaries



➢ Iris segmentation on mobile devices

■ An ideal iris segmentation method on mobile devices should be:

❖ Accurate, Robust to noise



(a) (b) (c) (d) (e) (f)

(a) glass and reflection; (b) motion blur; (c) specular reflection; (d) dark iris;
(e) off angle; (f) rotated iris.

❖ Lightweight, fast

✓ It should consider the limited resource of computing and storage of mobile devices.

✓ It should be fast (real-time) for accelerating recognition process.

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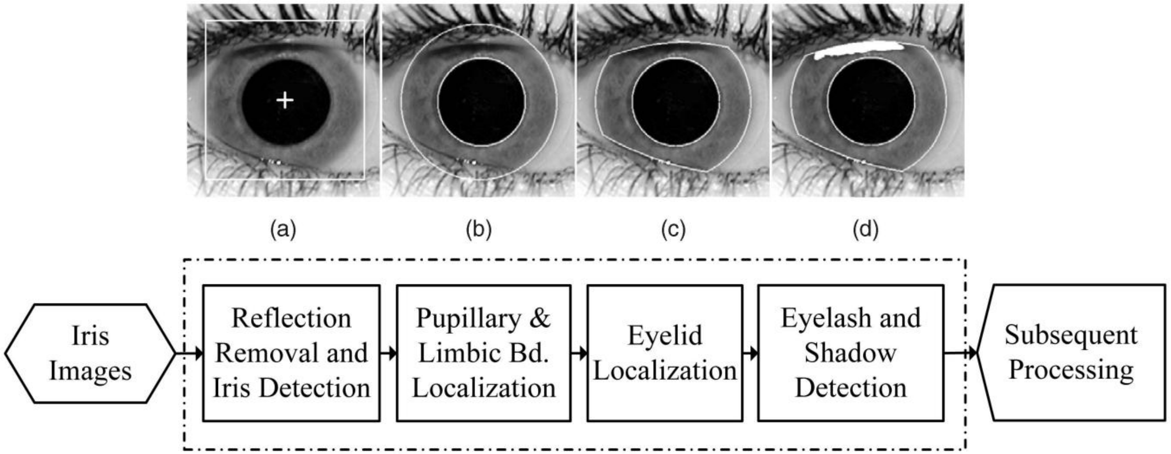
➢ Two typical iris segmentation methods



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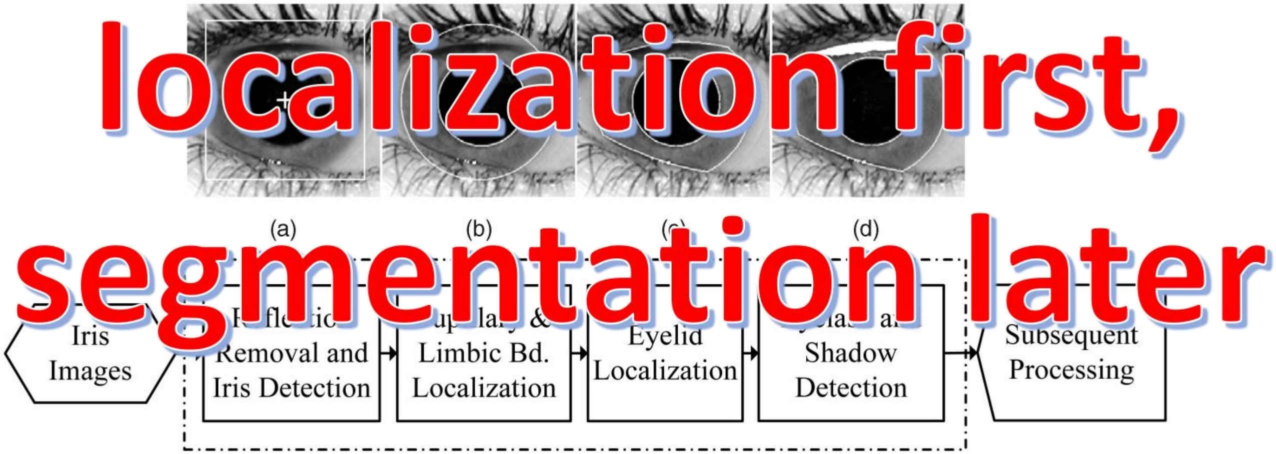

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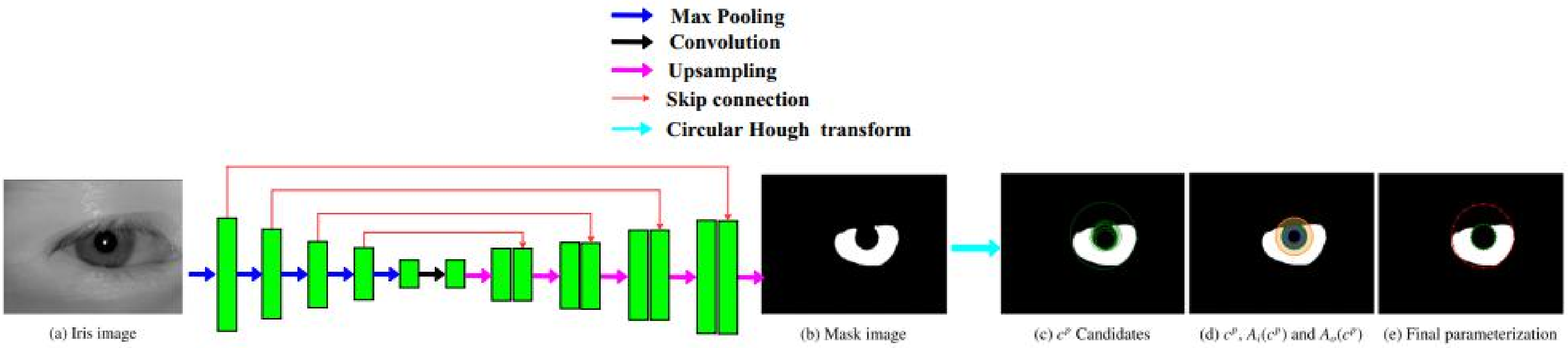

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➢ Two typical iris segmentation methods

segmentation first, localization later

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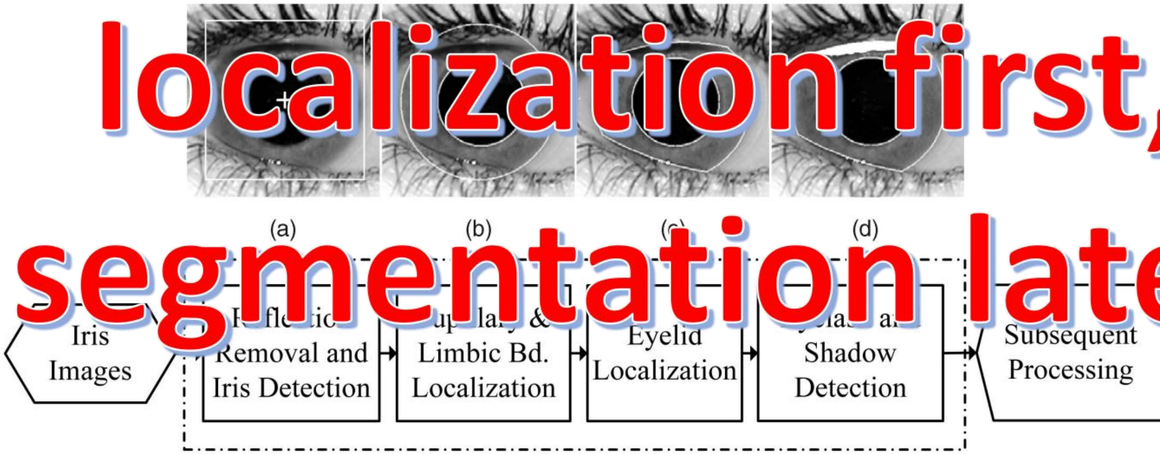

localization first, segmentation later

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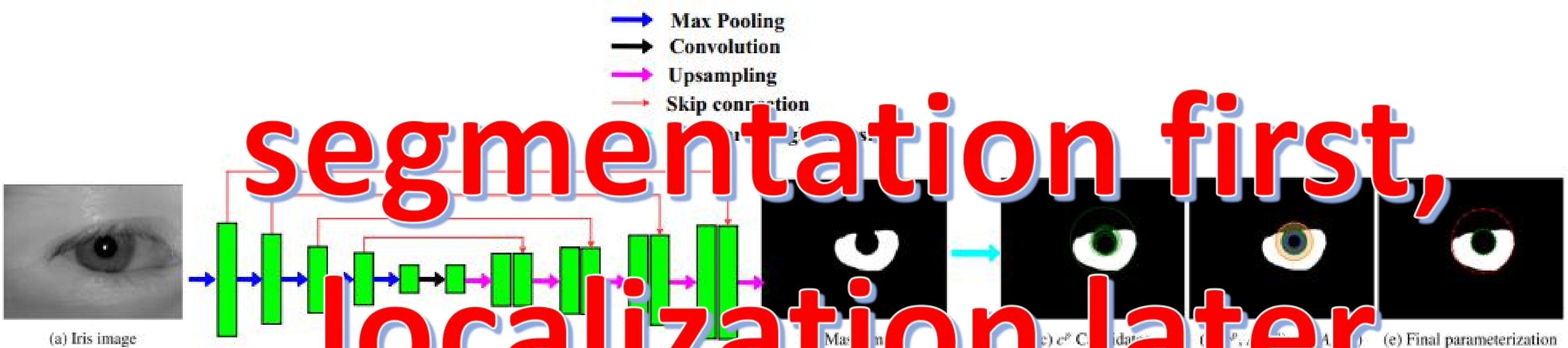

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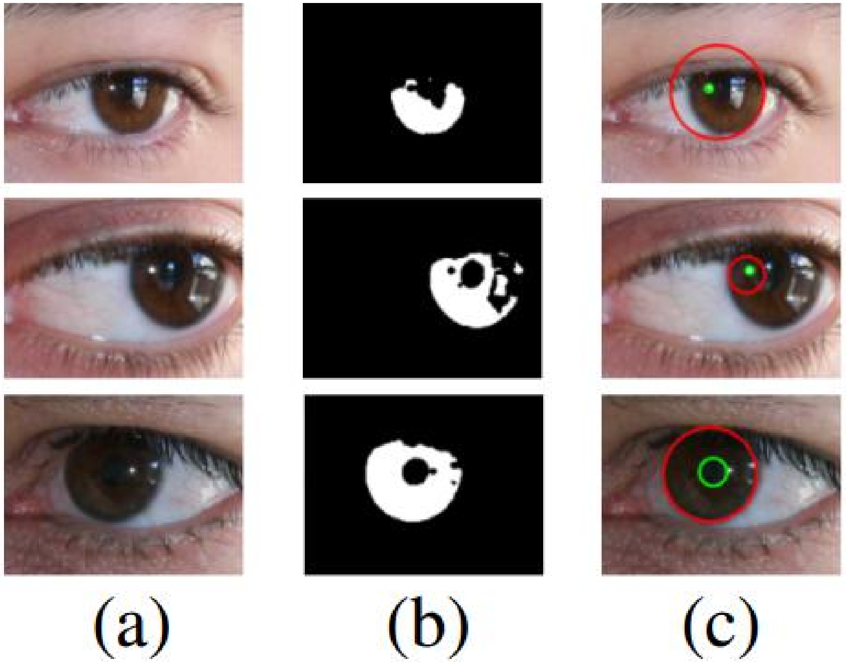
➢ Failure samples of CNNHT



- CNNHT is easy to fail when confronted with highly irregular or extremely noisy segmentation masks.
- CNNHT also takes a large amount of time on searching for optimal iris boundary paramters.

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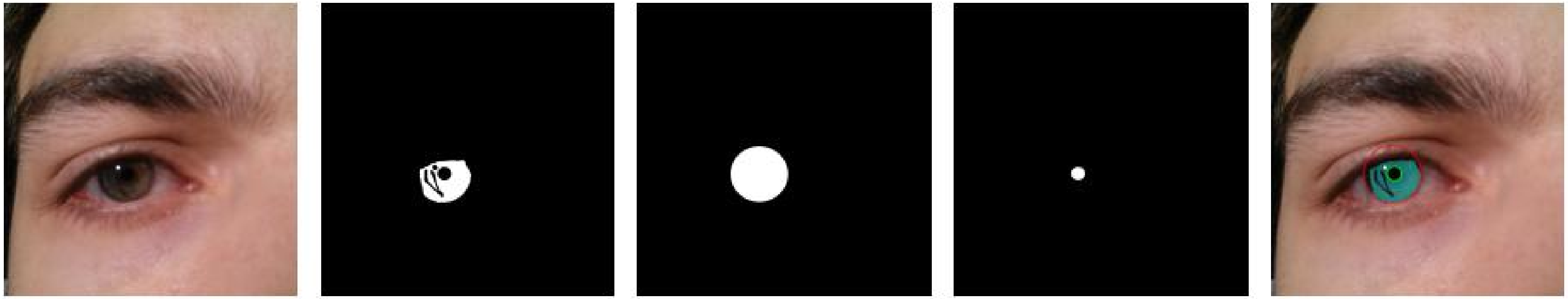
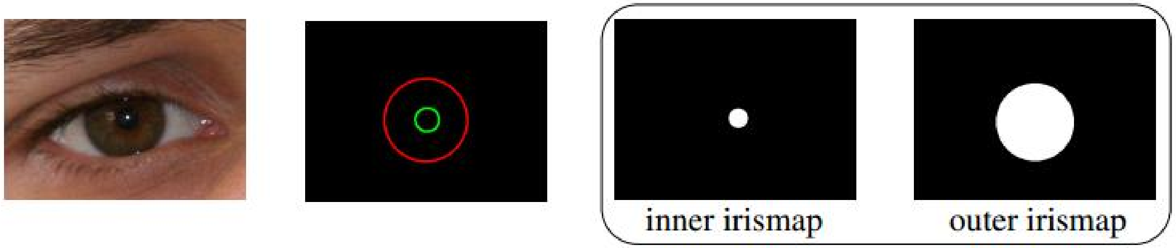
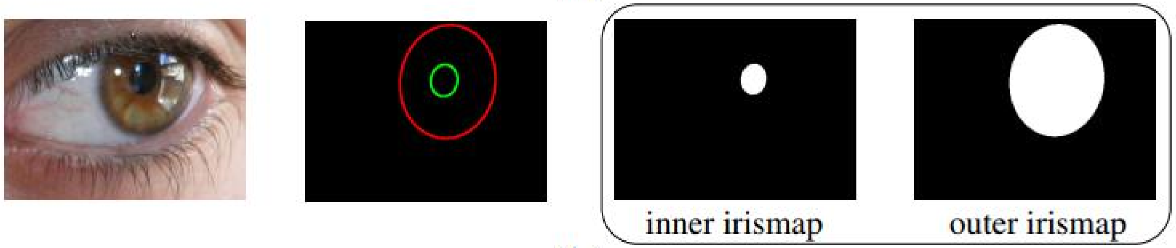
➢ Multi-label learning



- ❖ Iris mask, inner irismap, and outer irismap are overlapping from each other.
- ❖ The model needs to assign each pixel to multiple binary labels.



(a)



(b)

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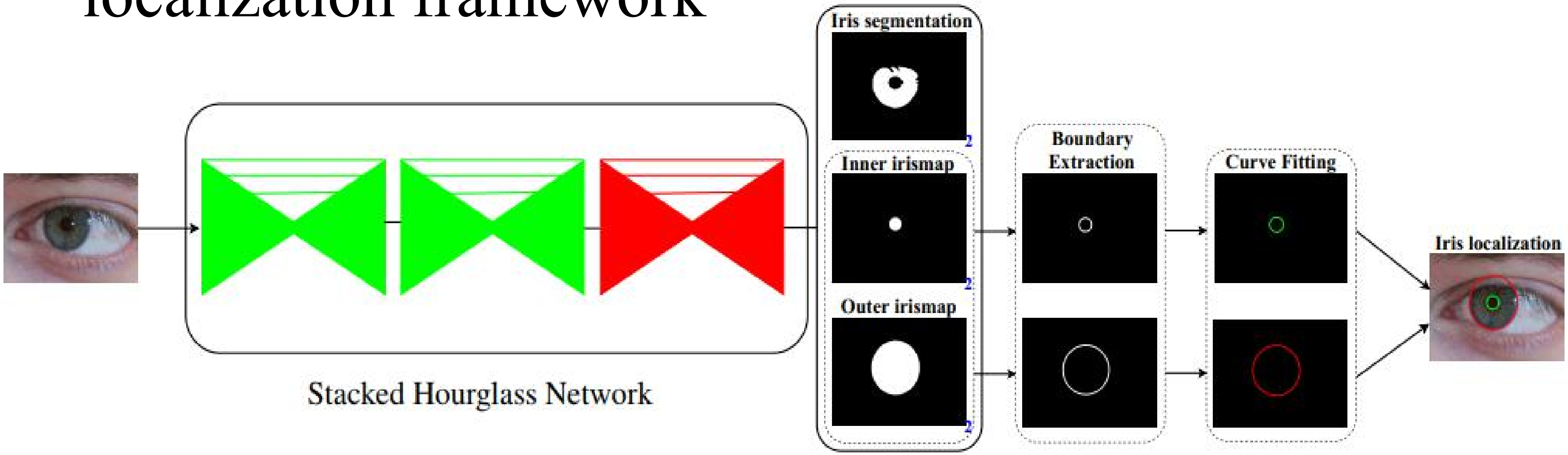
- The proposed unified iris segmentation and localization framework



- Lightweight stacked hourglass network
  - The stride of the initial convolutional layer with kernel size 7 × 7 is changed from 2 to 1.
  - The initial max-pooling layer is removed.
  - The per-layer channel number of the network is reduced from 256 to 64.
  - Each hourglass module is processed at 4 different image scales, and stacked 3 times.

Multi-label loss function

$$\mathcal{L} = \lambda_1 \mathcal{L}_{seg} + \lambda_2 \mathcal{L}_{inner} + \lambda_3 \mathcal{L}_{outer}$$

- $\mathcal{L}_{seg}, \mathcal{L}_{inner}, \mathcal{L}_{outer}$ are implemented as cross-entropy loss over two classes (foreground vs. background).
- The coefficients λ_1, λ_2 and λ_3 are all set to 1 to make these loss value ranges comparable.
- The loss is applied to the output of the last hourglass module without intermediate supervision.

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➢ Experimental Settings

❖ Database:

Database	Illumination	Resolution	Training set	Testing set
CASIA-Iris-M1	NIR	400×400	1500	1500
MICHE-I	VIS	Various	680	191

CASIA-Iris-M1-S1 CASIA-Iris-M1-S2 CASIA-Iris-M1-S3 MICHE-I

Experimental Settings

Evaluation Protocols:

- Iris segmentation (from NICE.I competition)

$$E1 = \frac{1}{n \times c \times r} \sum_{c'} \sum_{r'} G(c', r') \otimes M(c', r')$$

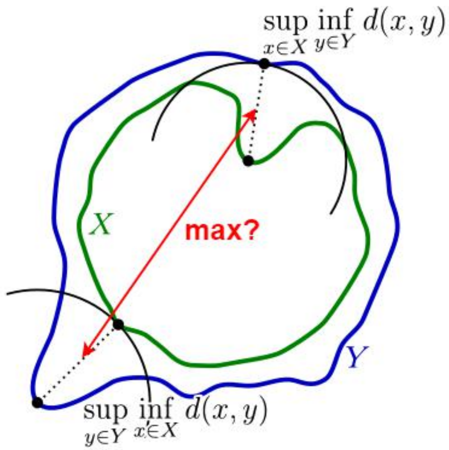
which evaluates the inconsistent pixels between G and M.

The value of E1 is bounded in [0,1], where the ***smaller value*** indicates the ***better segmentation*** result.

Experimental Settings

Evaluation Protocols:

- Iris localization (from Hausdorff distance)



$$H(G,B)=\max\{\sup_{x\in G}\inf_{y\in B}\parallel x-y\parallel,\sup_{y\in B}\inf_{x\in G}\parallel x-y\parallel\}$$

which measures the shape similarity between the predicted iris inner or outer boundaries and its ground truth.

➡ ***Smaller Hausdorff distances*** correspond to ***higher shape similarity*** between predicted iris boundary and its ground truth, suggesting ***higher detection accuracy***.

➡ Percentage of Correct Localization (PCL) curve, AUC@τ about varing distance threshold

➢ Experimental Results

Method	Database	$E1$ (%)	Overall mHdis (%)	AUC@0.3
RTV-L^1 [20]	MICHE-I	2.42	4.3852	0.2522
MFCNs [4]	CASIA-Iris-M1	0.77	N/A	N/A
	MICHE-I	**0.74**	N/A	N/A
CNNHT [7] (RefineNet)	CASIA-Iris-M1	**0.71**	1.7245	0.2803
	MICHE-I	0.80	3.6824	0.2559
Proposed	CASIA-Iris-M1	0.72	**0.5517**	**0.2987**
	MICHE-I	0.82	**1.1107**	**0.2910**

Table 1. Comparison of iris segmentation and localization (circular boundary) for different approaches.

➢ Experimental Results

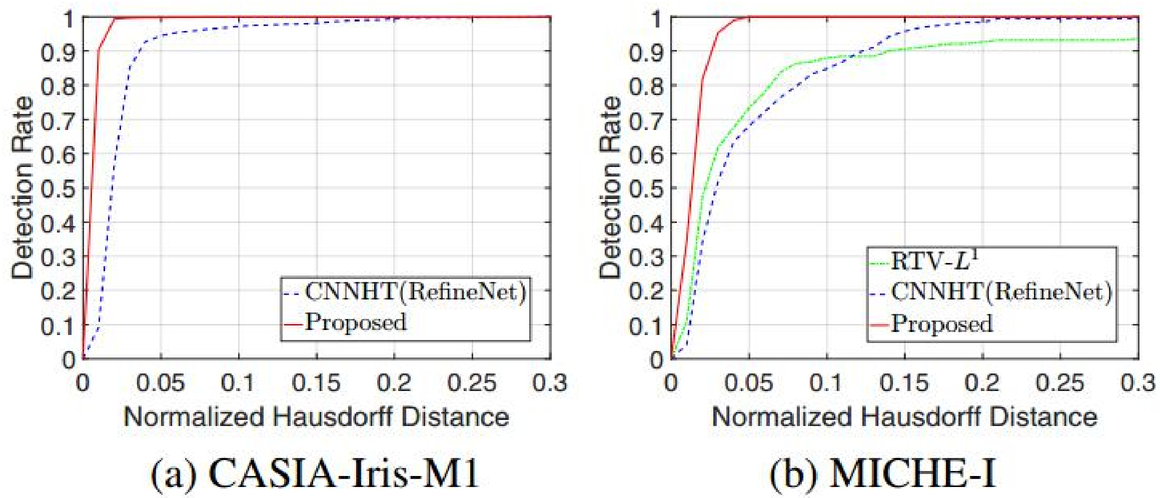
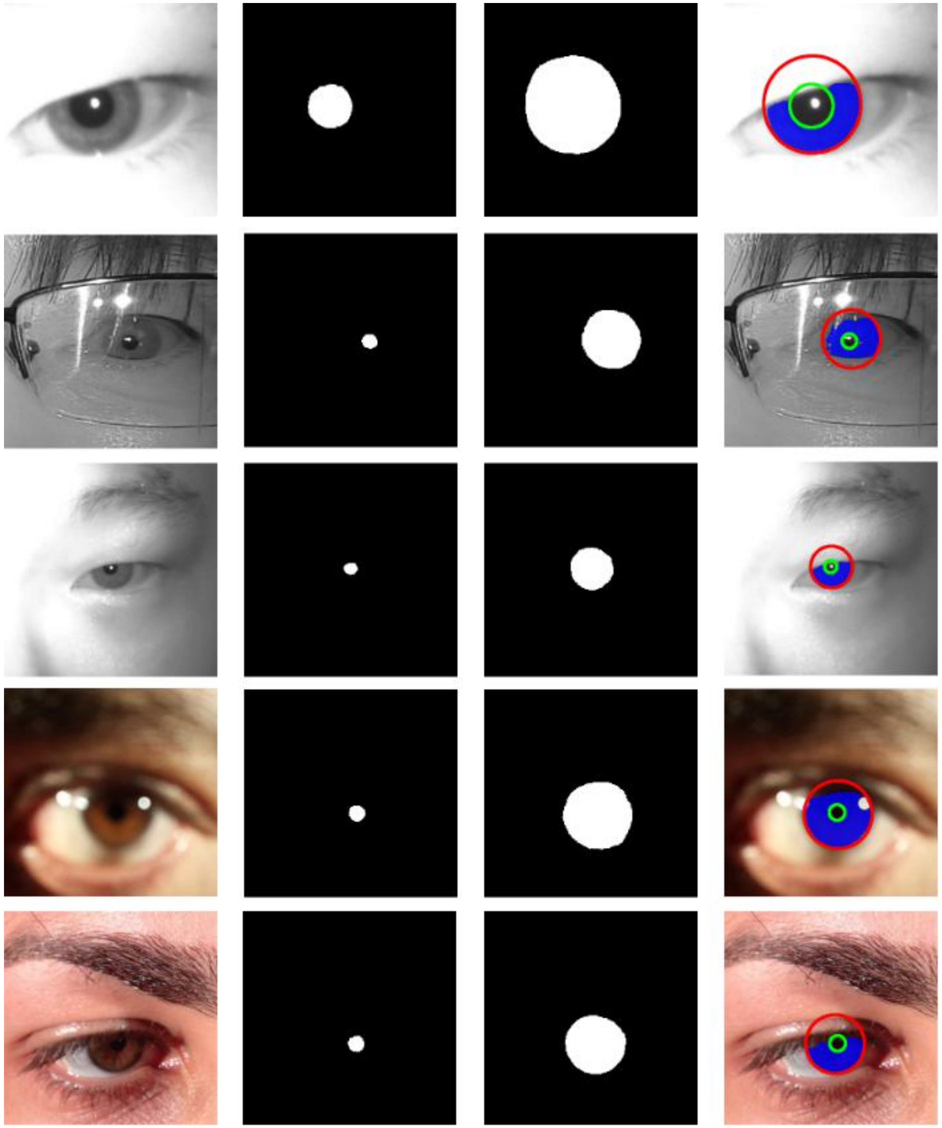


Fig. 3. Comparison of iris localization for different approaches using the proposed PCL curve.

- ✓ For iris segmentation, the proposed method achieves comparable results ***compared with the current state-of-the-art method***.

- ✓ For iris localization, the proposed method ***consistently outperforms other methods*** by a large margin in all metrics across all databases.

➢ Experimental Results



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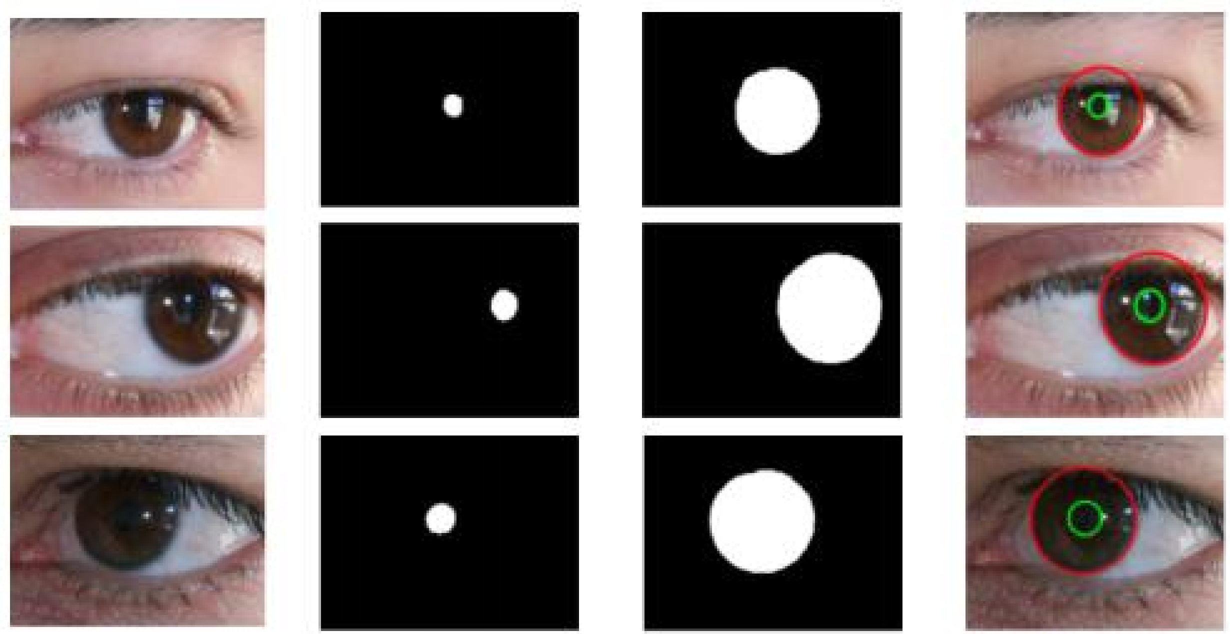

(a) (b) (c) (d)

✓ The proposed method ***makes full use of the original iris images to learn complete inner and outer iris boundaries*** so it can achieve much more robust and accurate iris localization results.

Model complexity

Method	Params (M)	FLOPs (G)†	Storage (MB)
MFCNs [4]	21.68	156.35	82.70
CNNHT(RefineNet) [7]	61.87	144.79	236.00
Proposed	**0.69**	**74.27**	**2.83**

† The FLOPs is calculated with the resolution of 640×480.

Table 2. Comparison of model complexity for different approaches.

- ✓ The proposed model is lightweight and high-efficiency.

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➢ Conclusion

- ✓ This paper proposes a ***lightweight multi-label learning*** framework for ***complete iris segmentation*** on mobile devices.
- ✓ The proposed method achieves ***competitive or state-of-the-art performance*** in ***both iris segmentation and localization*** on two challenging mobile iris datasets.

➢ References

1. Z. He, T. Tan, Z. Sun, and X. Qiu, “Toward accurate and fast iris segmentation for iris biometrics,” IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 31, no. 9, pp. 1670–1684, 2008.

2. H. Hofbauer, E. Jalilian, and A. Uhl, “Exploiting superior cnn-based iris segmentation for better recognition accuracy,” Pattern Recognition Letters, vol. 120, pp. 17–23, 2019.

3. C. Wang, J. Muhammad, Y. Wang, Z. He and Z. Sun, "Towards Complete and Accurate Iris Segmentation Using Deep Multi-Task Attention Network for Non-Cooperative Iris Recognition," in IEEE Transactions on Information Forensics and Security, vol. 15, pp. 2944-2959, 2020.

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Thank you!