NDSS SYMPOSIUM/2025

山东大学 SHANDONG UNIVERSITY

EMIRIS: Eavesdropping on Iris Information via Electromagnetic Side Channel

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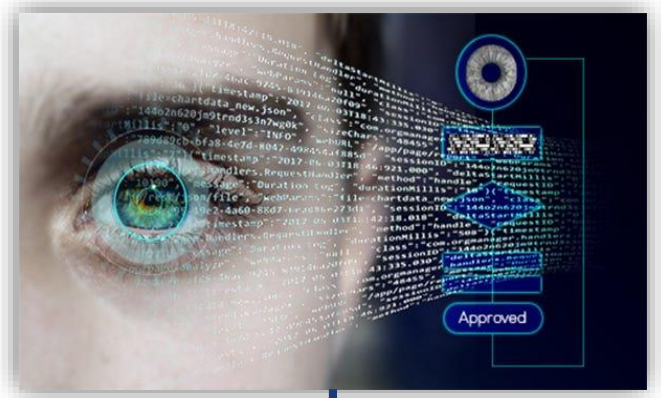
Shandong University

February 2025

Iris Recognition & Its Hidden Risks

- ✅ High-entropy biometric authentication method
- ✅ Widely Used in various authentication scenarios
- ✅ Typically uses near-infrared (NIR) sensors



ID Recognition

Airport Security

Bank ATMs

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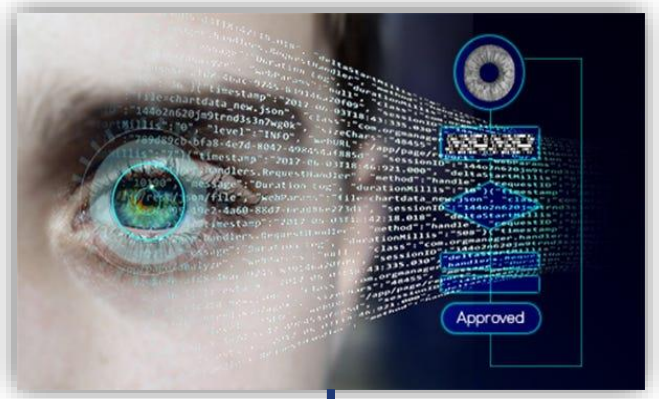
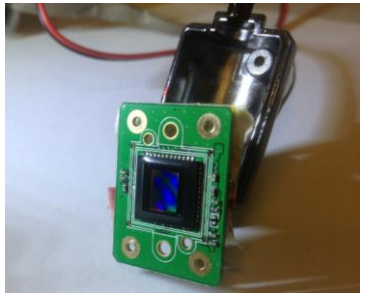




Electromagnetic Emissions

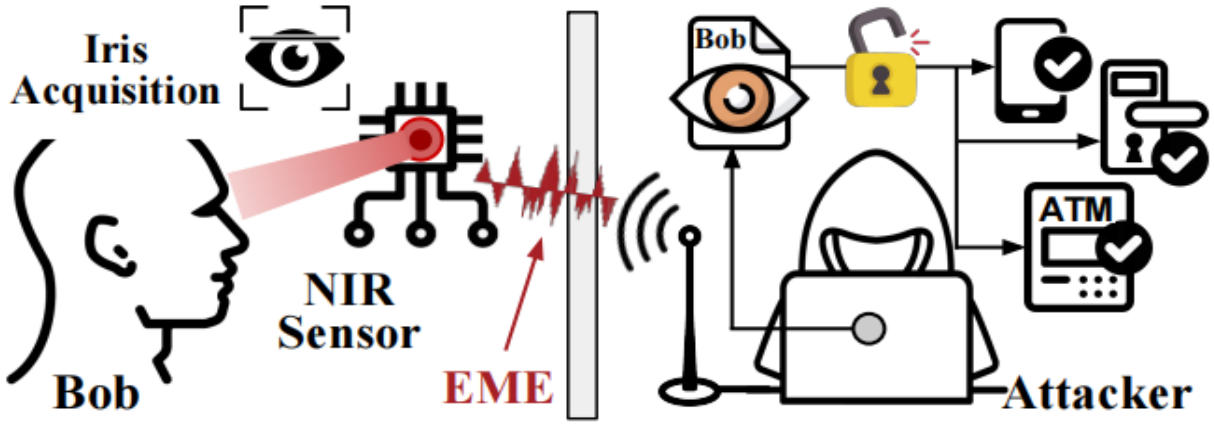
ID Recognition

Airport Security

Bank ATMs

Threat Model

- No physical access to device
- No prior knowledge of victim
- Only capture EM signal at a distance



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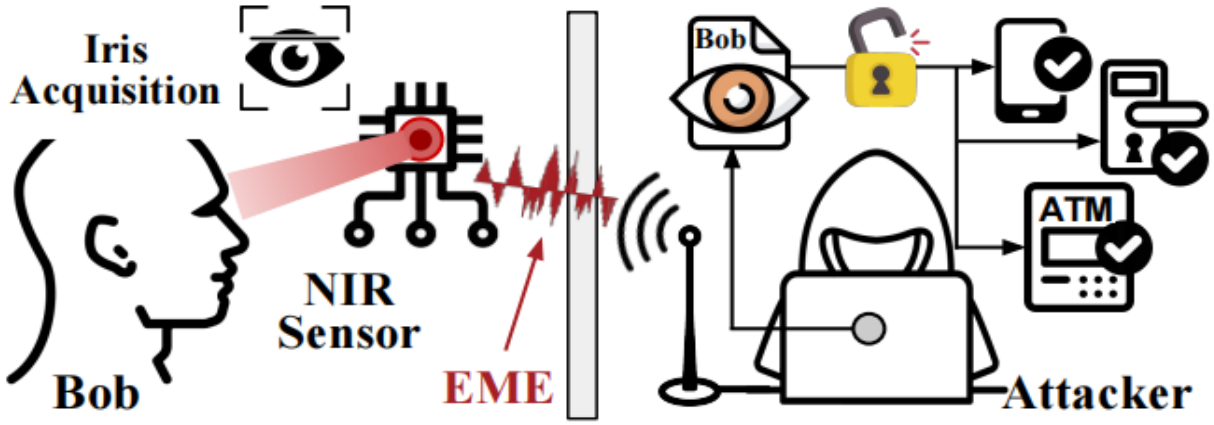
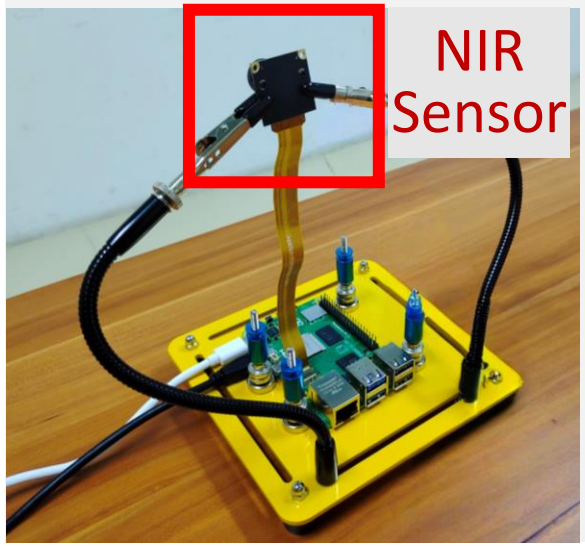
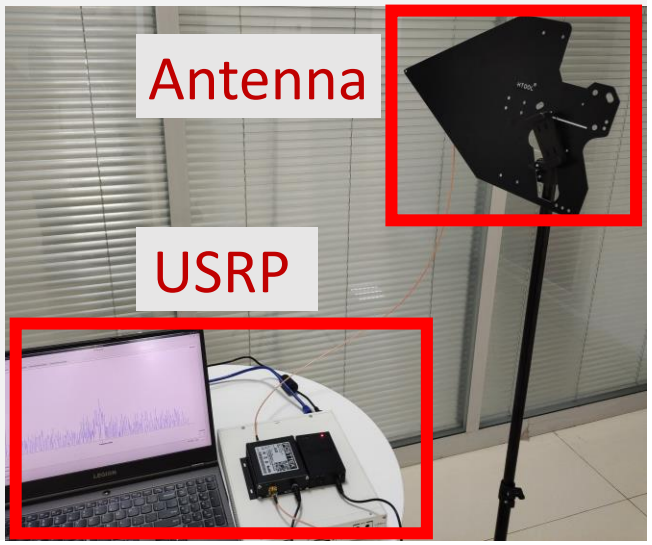


Target Device



Attacker Equipment



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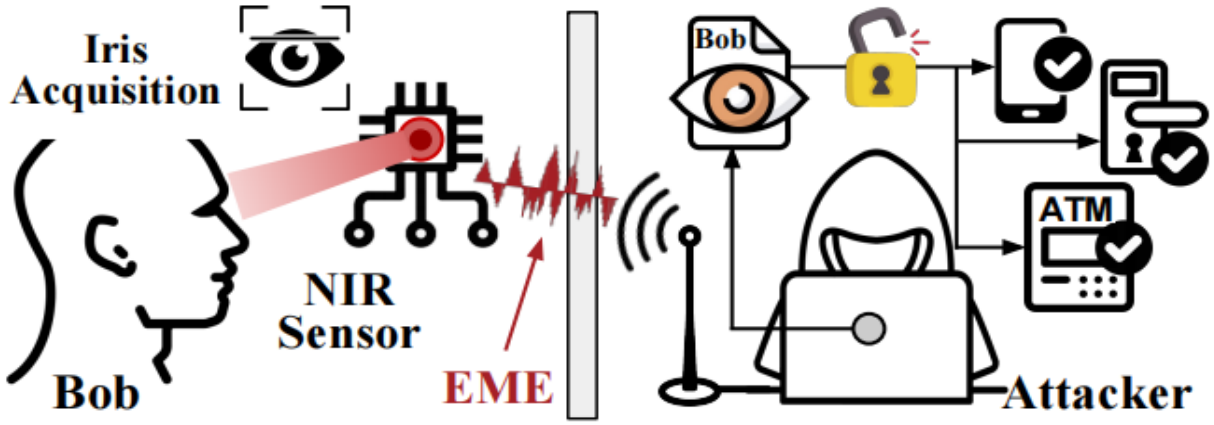

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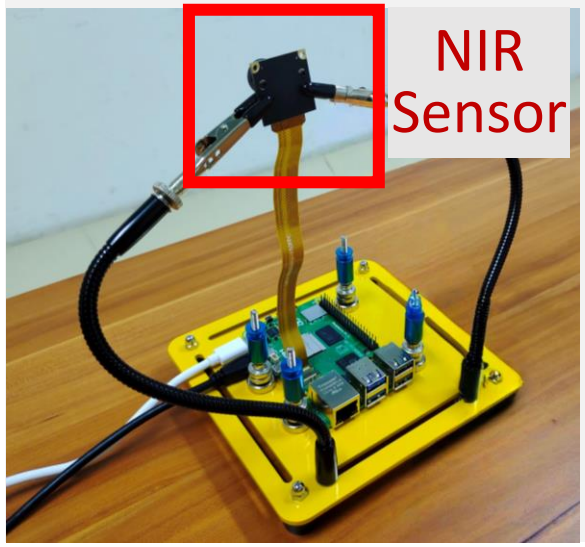
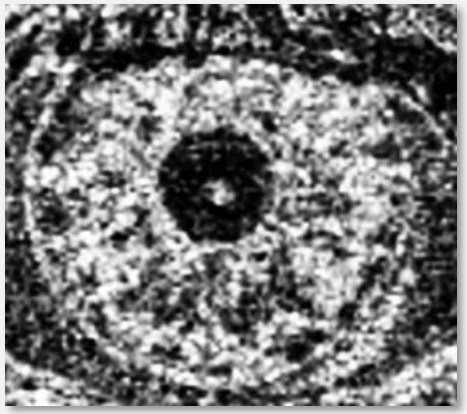


Attacker Equipment

Original Iris

Reconstructed Iris



Iris Reconstruction from EM signal

$$\mathrm{IRIS}_{\mathrm{raw}}(f) = M_{E2I}\{f, E, M_{D2I}(D_{\mathrm{digi}}, G)\} + W(f)$$

Iris grayscale matrix 

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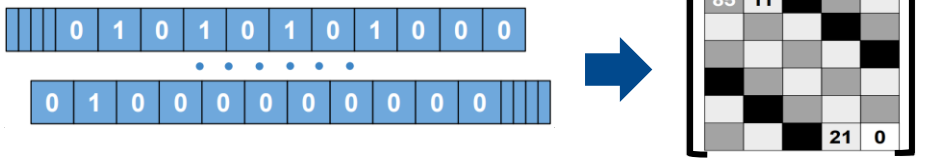
Digital signal to iris data mapping function



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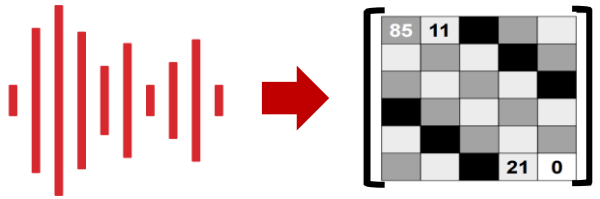

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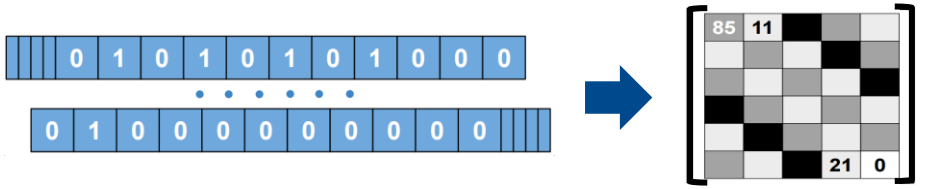
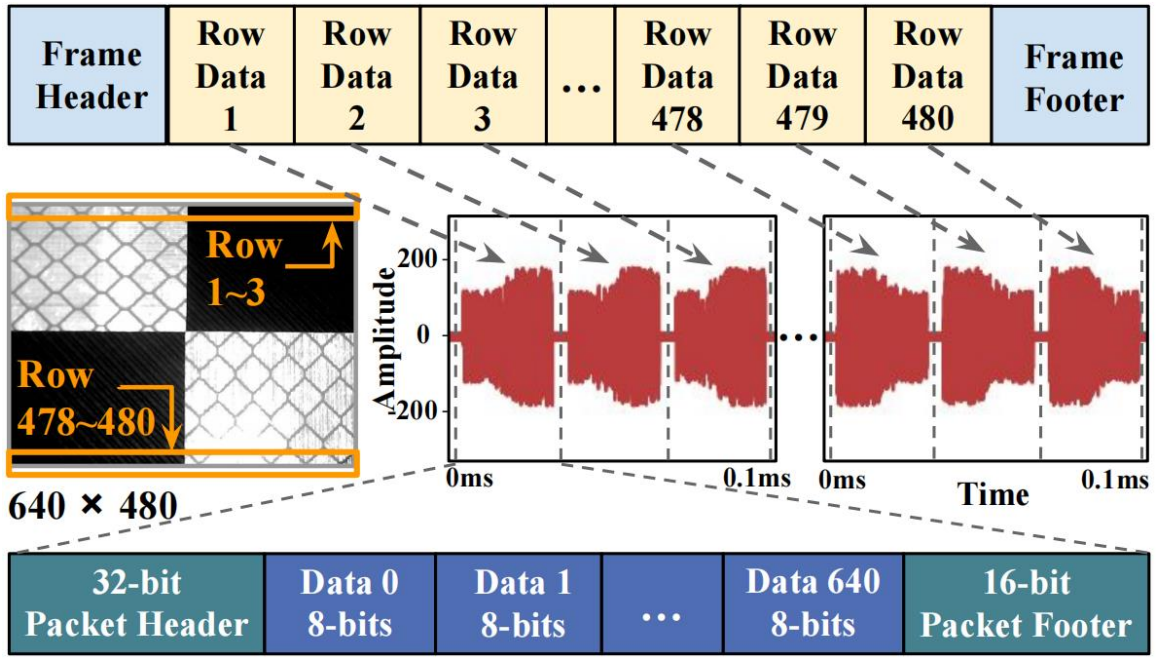


Iris Reconstruction from EM signal

📌Example: Electromagnetic Leakage & Data Format



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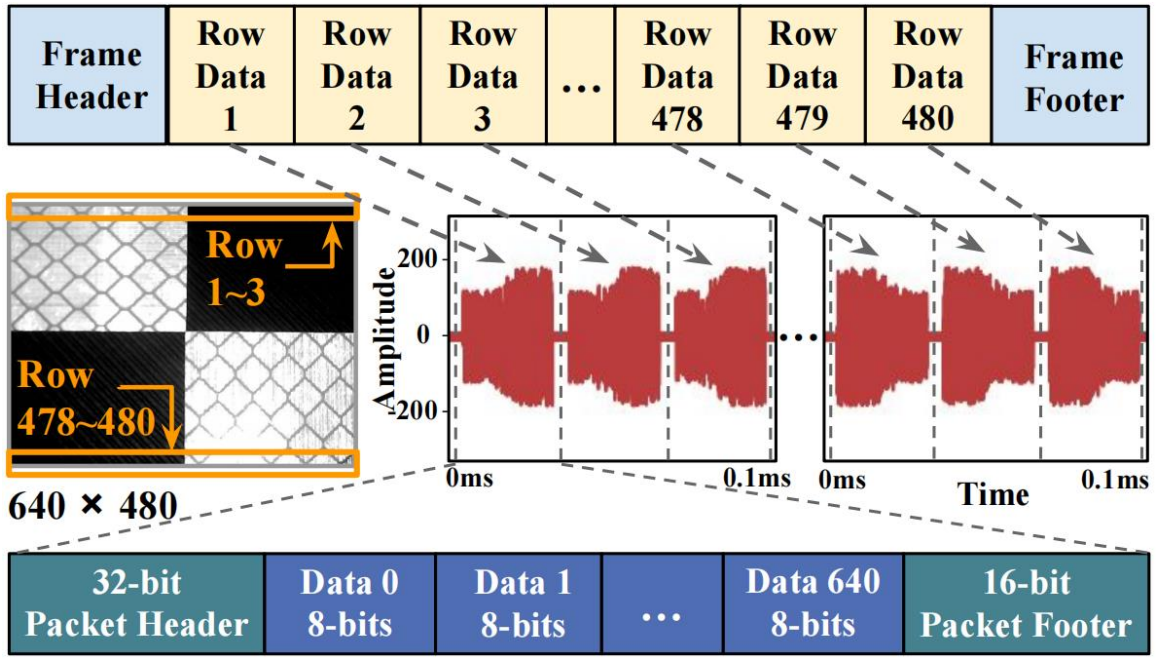
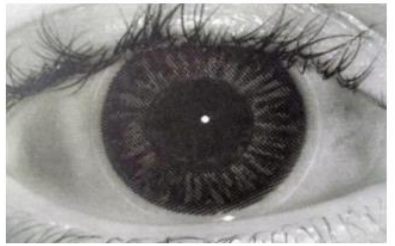
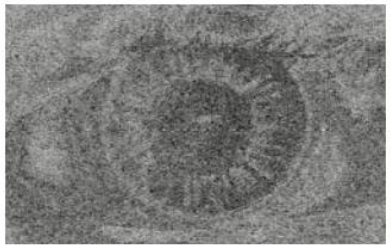
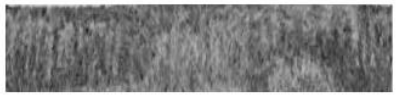




(a) Ground truth



(b) Reconstructed iris



Segmentation and normalization

Iris Reconstruction from EM signal

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Noise introduced by the channel

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Noise introduced by the channel

Denoising:

Digital domain

$$\tilde{E}[n] = \sum_{m=0}^{L-1} b_m E[n-m]$$

$$\hat{E}[n] = \mathrm{IDFT}\{\mathrm{DFT}(\tilde{E}[n])H[k]\}$$

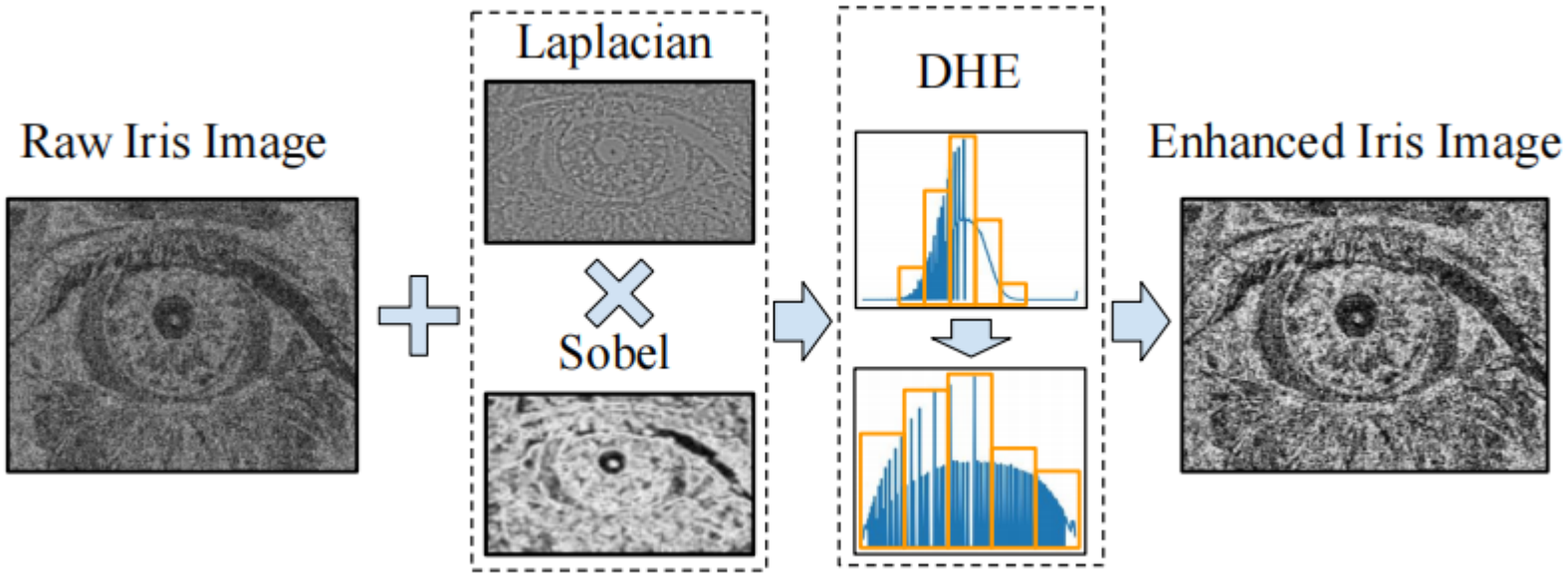
+

Physical domain

Low-Noise Amplifiers (LNA)

Enhancing Iris Structure

- Emphasize key structural components:

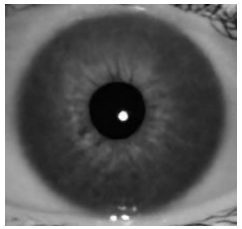


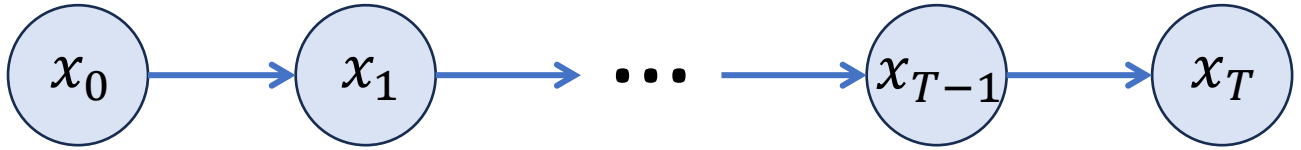
Iris Denoising and Detail Generation

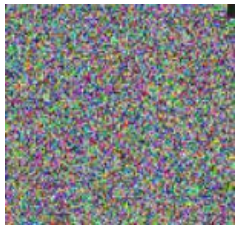
- Diffusion Model:

Forward process

Additive gaussian noise

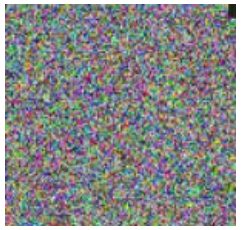


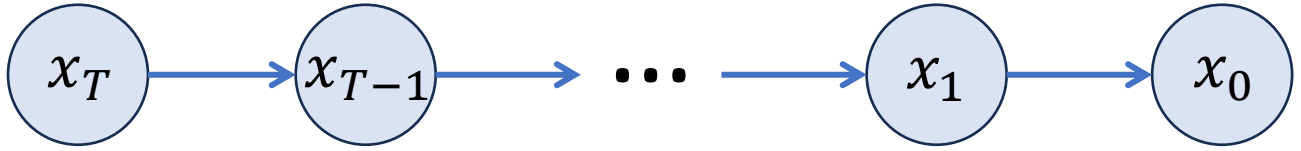


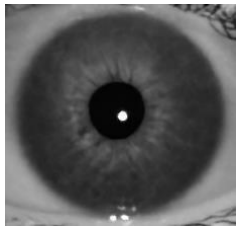


Reverse process

Denoising







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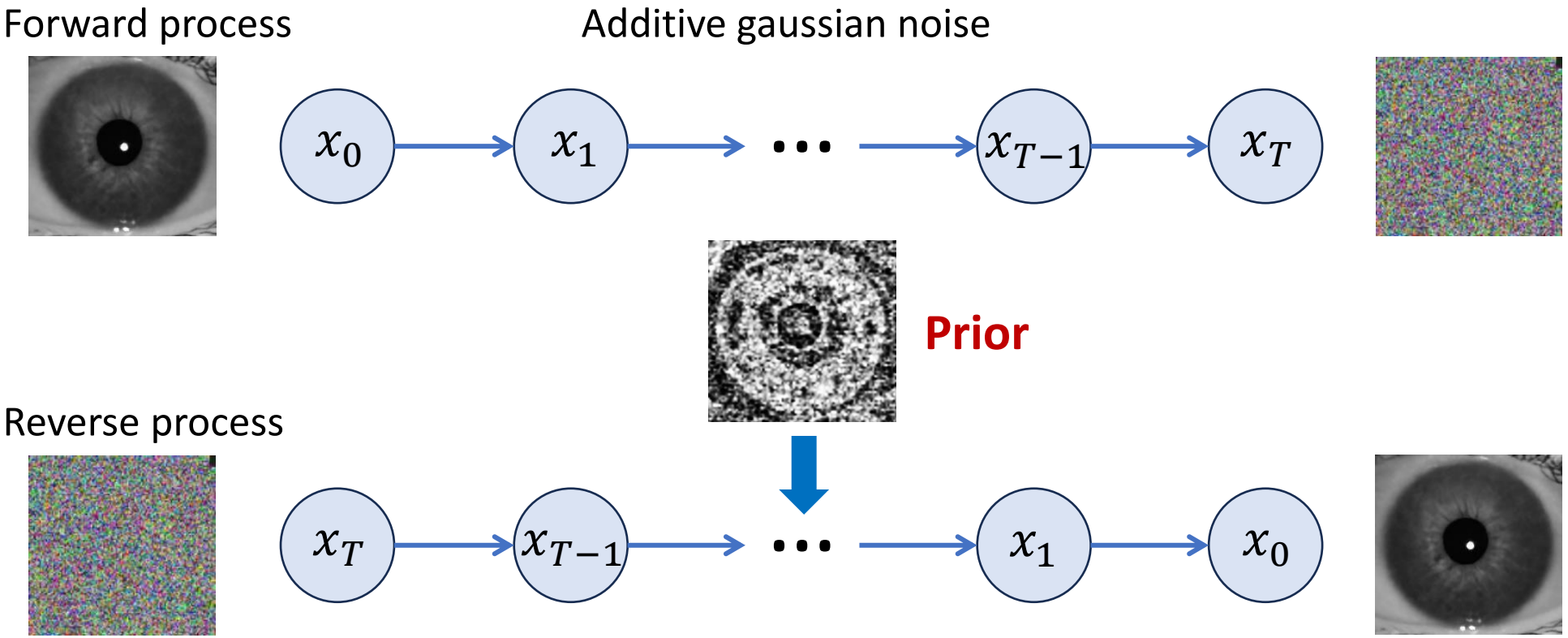

Iterative Denoising with HQS

💡 Enforcing consistency between x and the captured EM-based iris reconstruction

Subiteration:

$$(1) \quad z_t = \arg\min_z \frac{1}{2\sigma_t^2} ||z - x_t||^2 + P(z)$$

Prior

Iterative Denoising with HQS

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Prior

(2) $$x_{t-1} = \arg\min_x ||y - H(x)||^2 + \lambda||x - z_t||^2$$

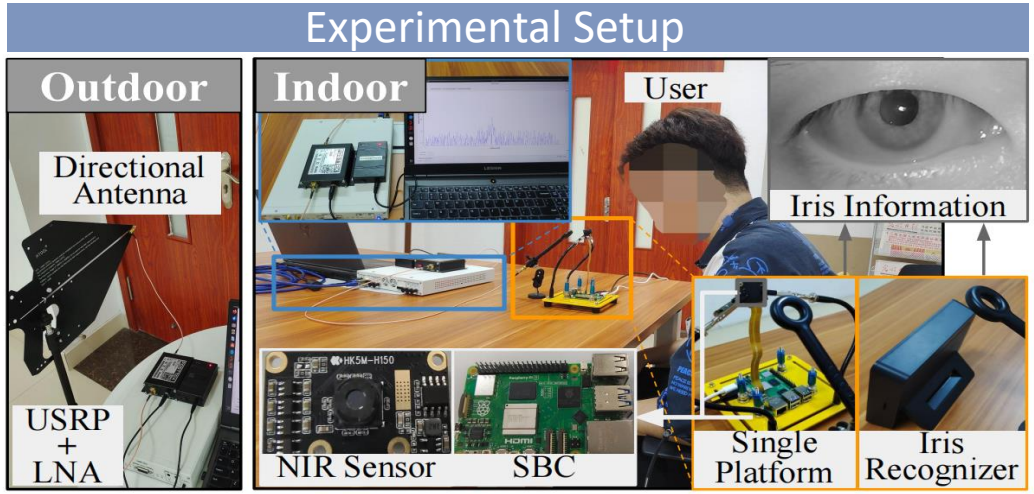
Enforce x to stay close to z_t

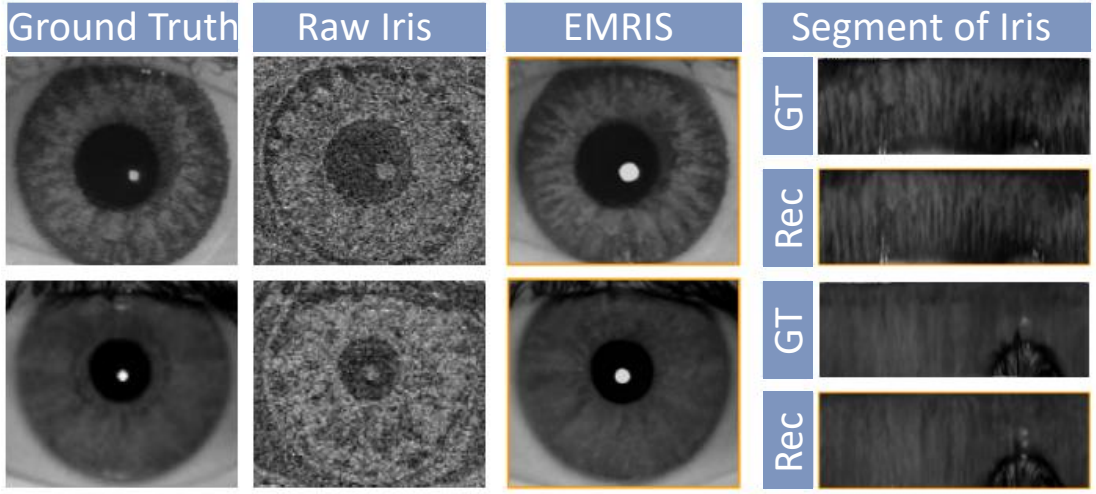
Diffusion Model

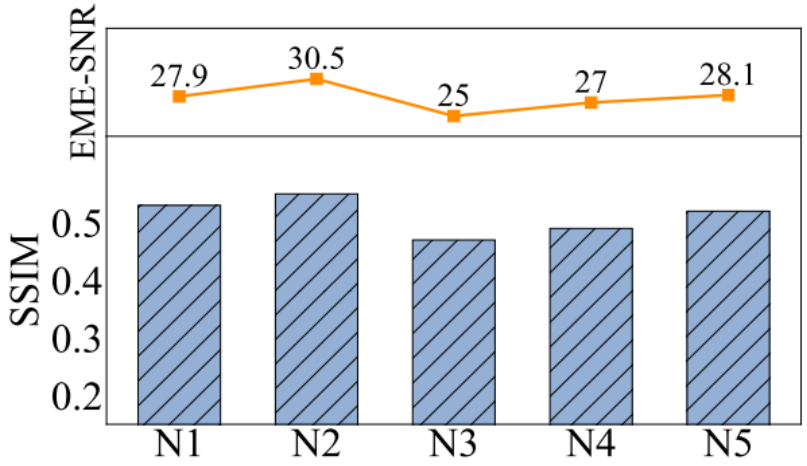
- Model Training:
  - 4 different datasets
  - 46,451 iris images in total
  - Diffusion model: DDPM
  - Optimizer: AdamW
  - Epochs: 50
  - Diffusion steps: 1000

Datasets	CASIA-IrisV4	ND-IRIS-0405	IITD v1	LivDet-Iris 2020
Subjects	1,800	356	224	118
Image format	JPEG	JPEG	BMP	PNG
Environment	Variety	Standard light	Standard light	Standard light
Devices	IrisKing IKEMB-100	LG 2200	JIRIS, JPC1000	Iris ID iCAM7000
Sensors	NIR	NIR	NIR	NIR
Liveness detection	No	No	No	Yes
Age	-	18-75	14-55	-
Resolution	640×480	640×480	320×480	640×480
Images for training	54,601(20,000)	64,980(20,000)	1,120(all)	5,331(all)

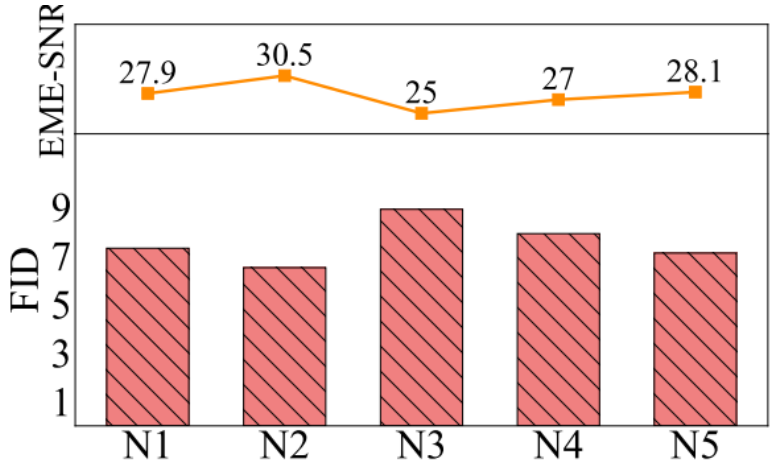
Iris Reconstruction Results







SSIM for different NIR sensors

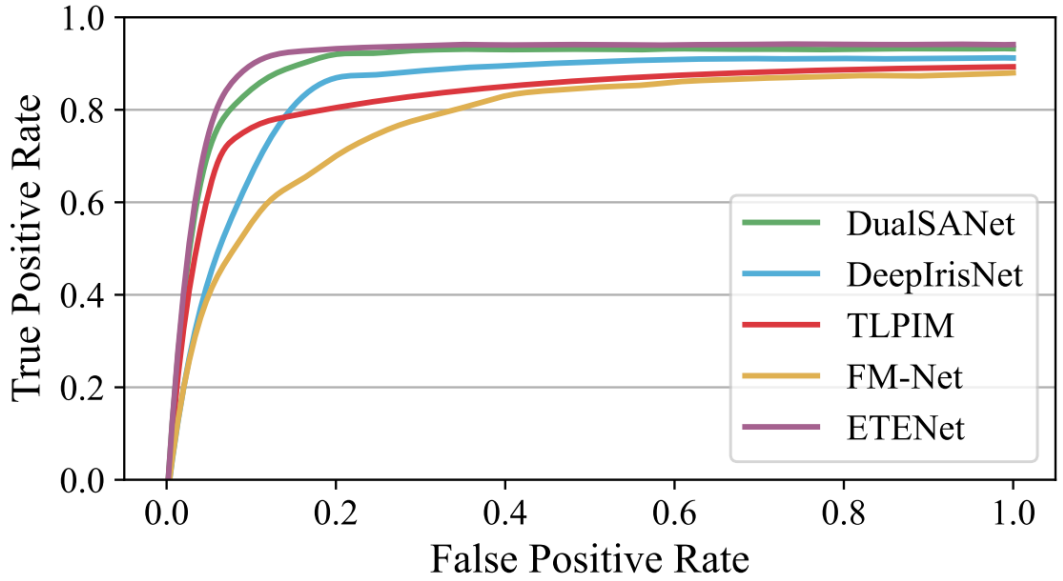


FID for different NIR sensors

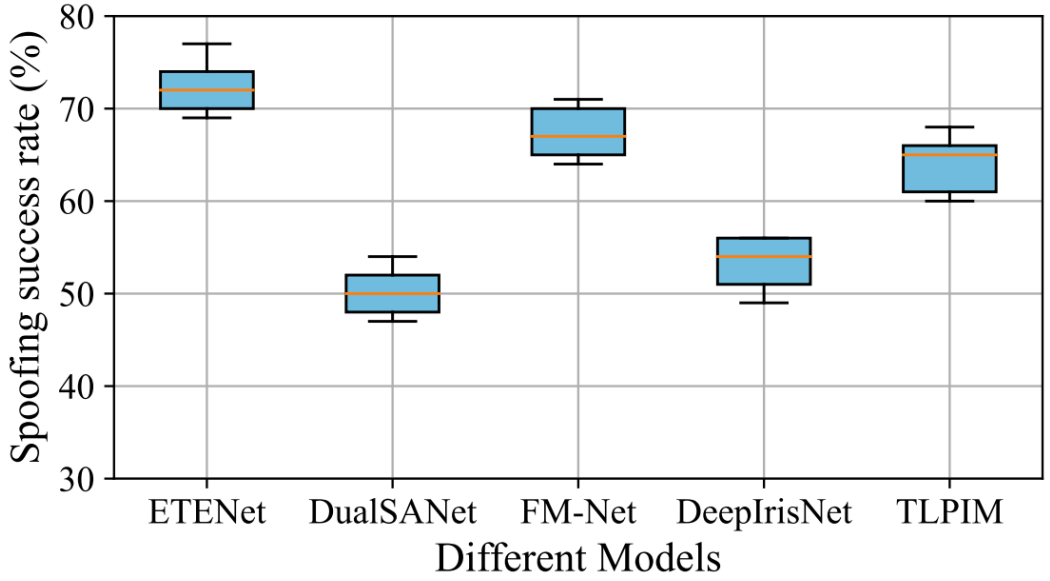
Spoofing Iris Recognition Models

➢ Target models

Models		Input Size	Activation Function	Optimizer	Learning Rate	Datasets	FRR (FAR=0.1%)	Accuracy* (%)
DeepIrisNet [30]	DCNN	128×128	ReLU	SGD	0.01	ND-iris-0405, ND-CrossSensor-Iris-2013	0.008	97.31
FM-Net [31]	FCN+MCNN	28×28	ReLU	SGD	0.01	CASIA-Iris-Thousand	4.27	95.63
ETENet [32]	DNN	160×120	ReLU	Adam	0.0001	CASIA-IrisV4, IITD	0.75	99.76
DualSANet [33]	CNN	64×512	ReLU	SGD	0.001	CASIA-IrisV4,IITD	0.58	99.69
TLPIM [34]	ResNet	256×256	ReLU	Adam	0.00001	CASIA-Iris-Thousand	0.8	96.00



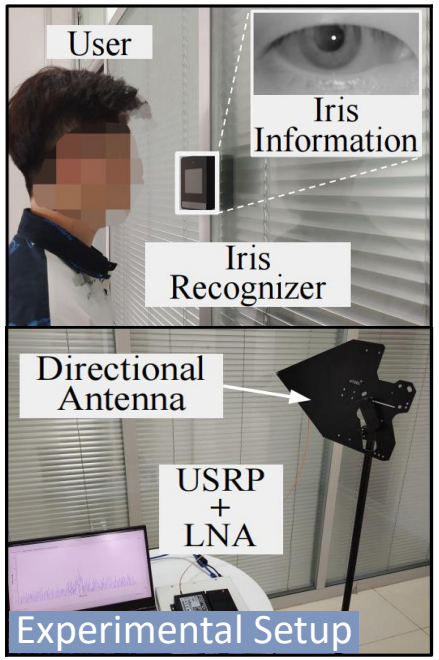
ROC curves of different models

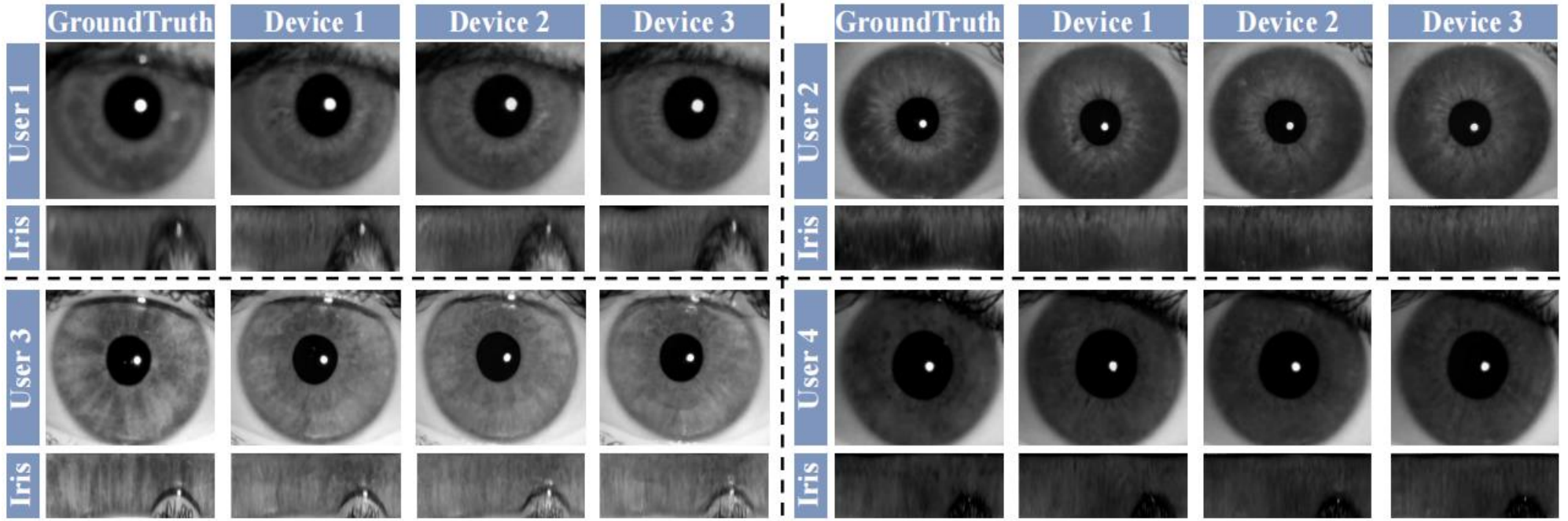


SSR for different models

Iris Reconstruction Results

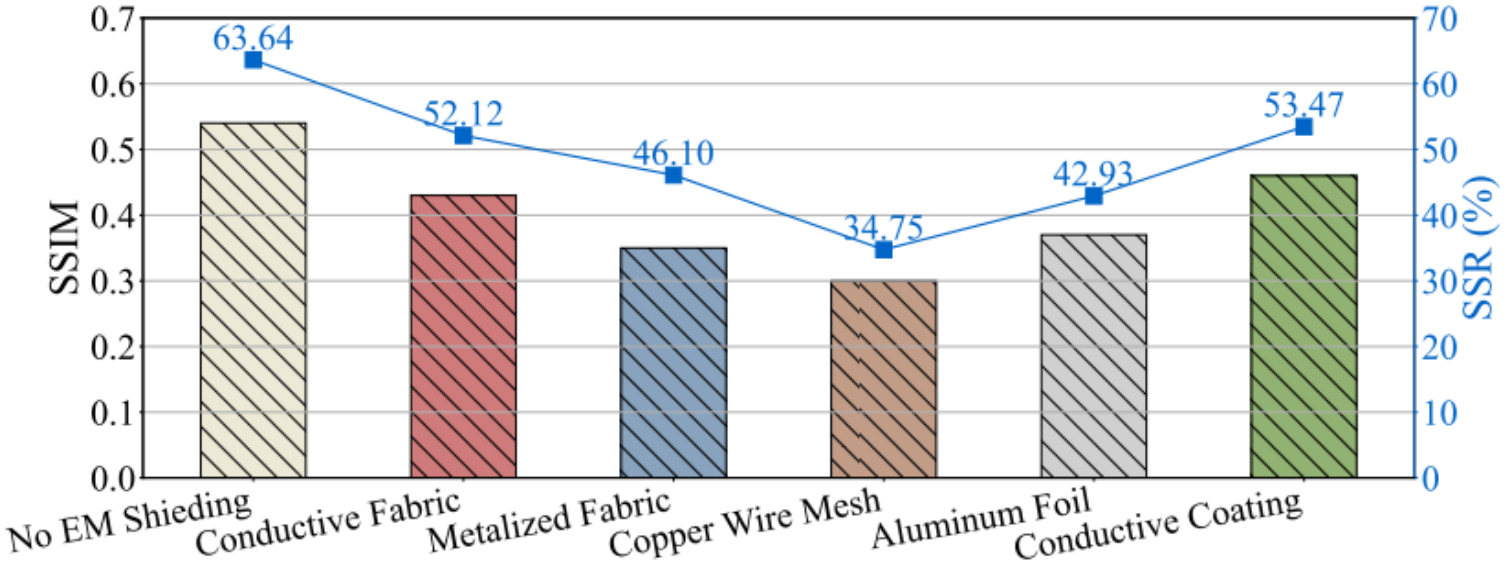
- Target different iris recognition devices





- How to against EMIRIS?

  Enhancing EM Shielding.

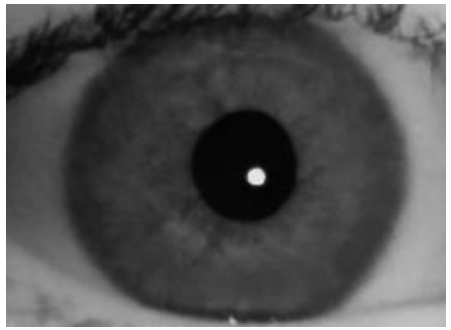


Discussion: Limitations

- Limitations

EMIRIS may not bypass liveness detection.

Two-dimension Iris



Liveness detection

- Pupil response detection
- Blink detection

Discussion: Future work

- Future work

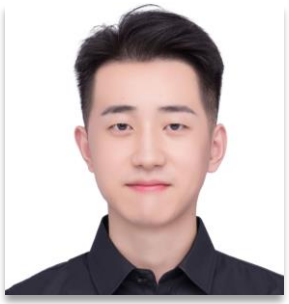
Apply reconstructed iris information to bionic eyes or contact lenses.

Bionic eye

Contact lenses

Thank You! Questions and Discussions Are Welcome!

Our Team



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