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Color Transfer to Anonymized Gait Images While Maintaining Anonymization

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Outline

- Introduction
- Issue of our previous gait anonymization approach
- Proposed method
- Experimental results
- Demonstration
- Conclusion

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Introduction: Background

- Gait is a manner of walking and can be used to identify a person

- The internet users can easily upload and share their videos to the social network.
- People in those videos may be identified by gait identification systems
  ➔Posting videos increases the risk of privacy invasion:
  - Personal information may be revealed unintentionally
  - The shared videos may be used to generate fake videos

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Introduction: Gait identification system

- Gait identification systems
  - In our research, we adopted model-free gait identification systems [1]
  - These gait identification systems use the silhouettes of one gait cycle as the gait feature

[1] S. Zheng, J. Zhang, K. Huang, R. He, and T. Tan, "Robust View Transformation Model for Gait Recognition," in International Conference on Image Processing, Brussels, Belgium, 2011.

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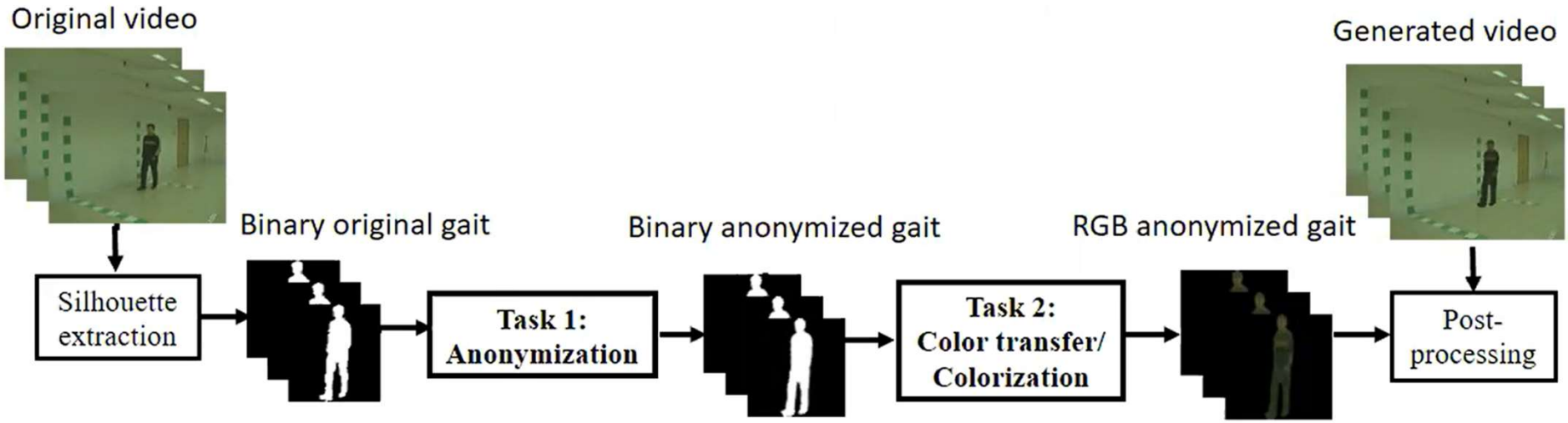
Introduction: Gait Anonymization



- Anonymization: Remove identity of people in videos
- Color transfer: Transfer the garment of the original gait image to the binary anonymized gait image

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Introduction: Research Objective

- Users want to share their videos with family or friends

  => they care about the quality of generated videos

- Propose a model to transfer color from an RGB original gait image to a binary anonymized gait image so that
  - The model is able to generate sharp and finely textured colors
  - The model is robust against silhouette quality
  - The success rate of anonymization remains

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Issue of our previous gait anonymization approach

- In our research, we define:
  - A complete silhouette is a seamless silhouette
  - An incomplete silhouette is a silhouette that misses one or some body parts due to the silhouette extraction process.

Complete silhouettes

Incomplete silhouettes

Original image

Silhouette

An incomplete silhouette caused by occultation [1]

[1] H. Kim, R. Sakamoto, I. Kitahara, T. Toriyama, and K. Kogure, "Robust Silhouette Extraction Technique Using Background Subtraction ", MIRU 2007

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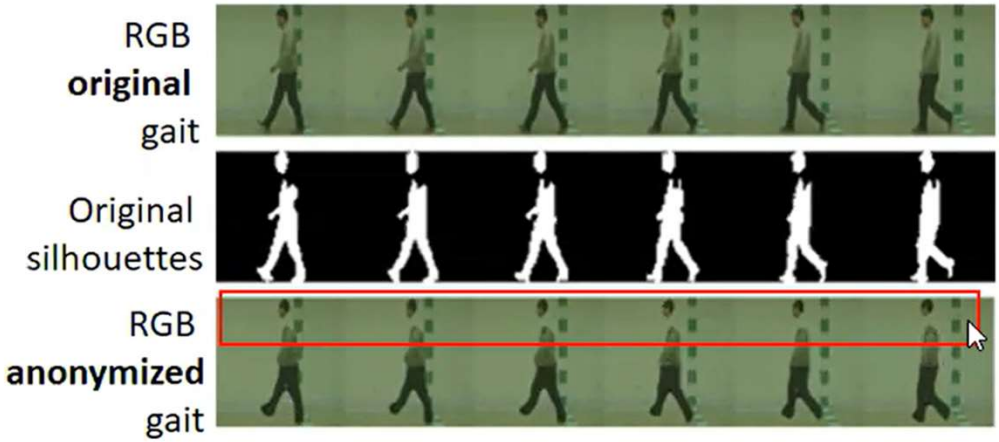
Issue of our previous gait anonymization approach: Model 1

- **Anonymization network**: anonymizes the binary gait based on the gait's contour
  - This model is an auto-encoder without the latent layer.
- **Colorization network**: We had to extract the color of the original gait image ➔ difficult for incomplete silhouettes
- Limitation: anonymized gaits generated from incomplete silhouettes look unnatural



[1] N.-D. T. Tieu, H. H. Nguyen, H.-Q. Nguyen-Son, and I. E. Junichi Yamagishi, "Spatio-temporal generative adversarial network for gait anonymization," Journal of Information Security and Applications, vol. 46, pp. 307–319, June 2019.

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Issue of our previous gait anonymization approach: Model 2

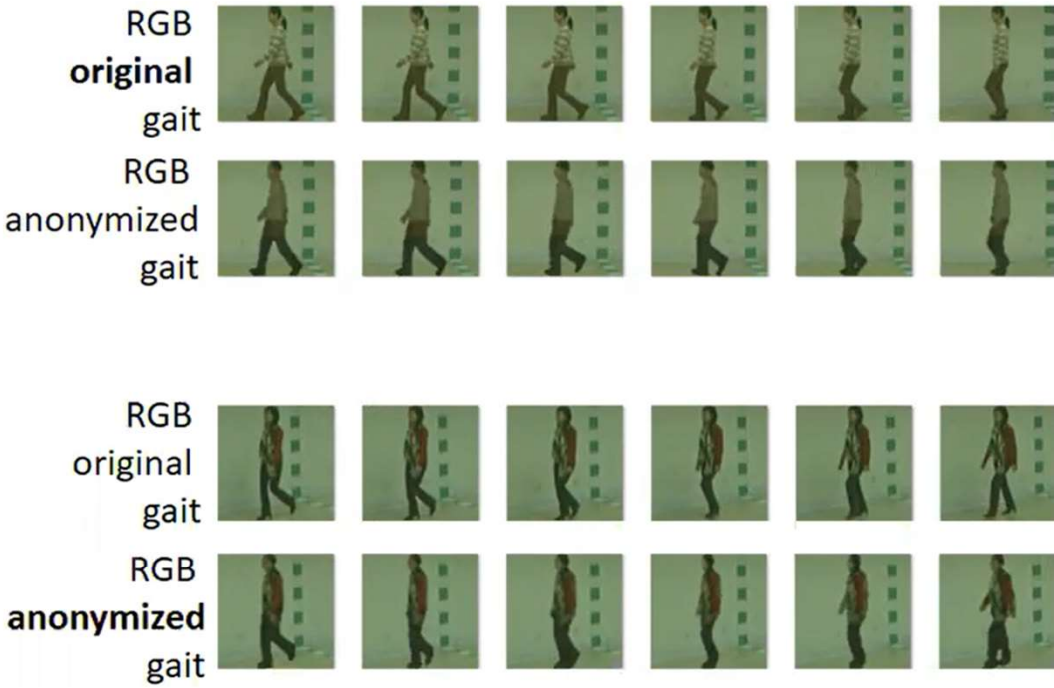
- **Anonymization network**: anonymizes the binary gait based on the gait's silhouette
  - The model architecture is based on DCGAN and trained on complete silhouette.

➔This model can generate the unbroken anonymized gait regardless of the silhouette quality of the original gait

- **Colorization network**: Use ground truths generated by the Model 1 to train the colorization network

➔ The generation results are affected by the artificial ground truths

- **Limitation**: this model was unable to generate sharp and finely textured colors



[1] N. T. Tieu, H. H. Nguyen, F. Fang, J. Yamagishi, and I. Echizen, "An rgb gait anonymization model for low-quality silhouettes," in 2019 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA ASC), 2019, pp. 1686–1693.

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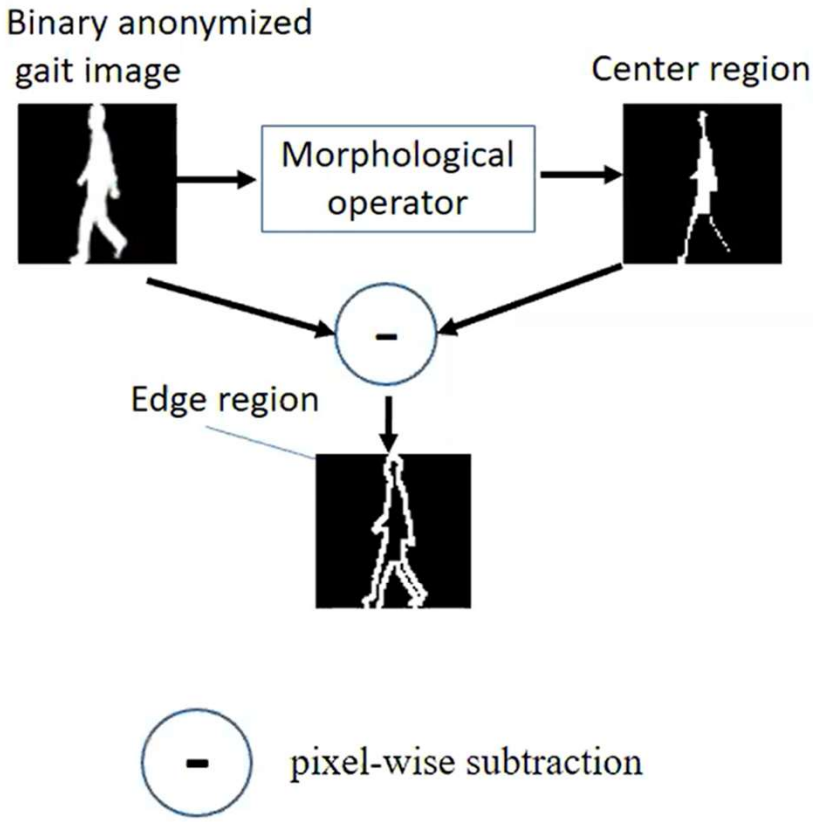
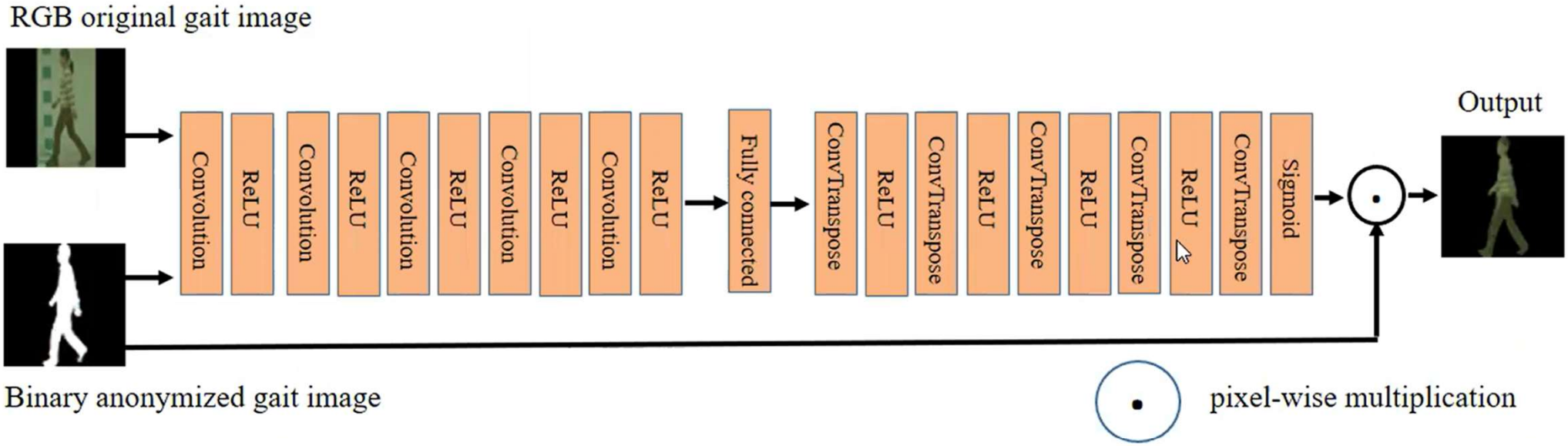
Proposed method

- We propose a loss function so that the model can generate the sharp and finely textured colors without using ground truths and without extracting the colors of the original gait images.
- We divide the binary anonymized gait image into 2 regions
  - Center region: the overlapping region between binary anonymized gait image and the RGB original gait image
  - Edge region: the remaining region
- Colors in center region are generated based on the color of the RGB original gait image
- Colors in the edge region are interpolated from the colors in the center region

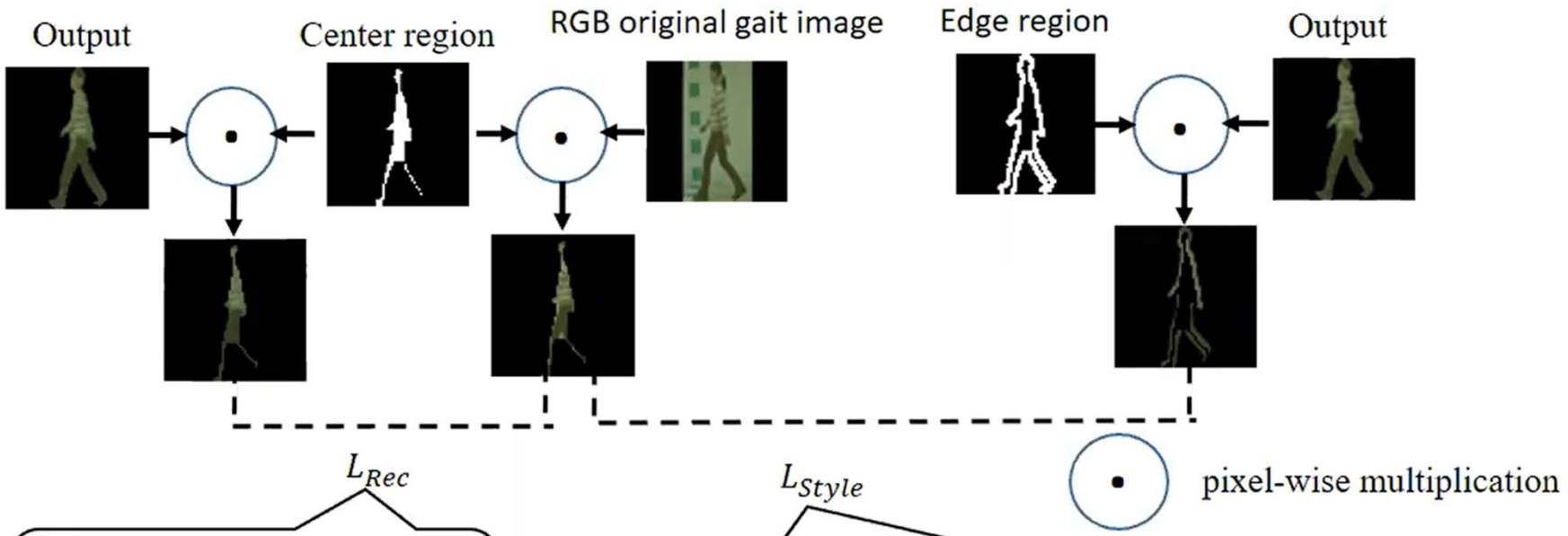


Proposed method: Network architecture



- The model takes RGB original gait image and binary anonymized gait image as two inputs
- pixel-wise multiplication forces the network to reform the shape of the output to that of the binary anonymized gait

Proposed method: Loss function



- The network is trained by loss: $L_{Rec} + L_{Style}$ (1)

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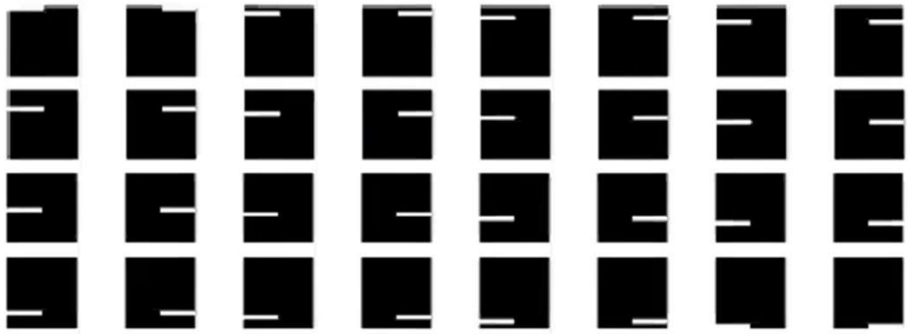
Proposed method: Style loss

- We divide the edge and center region into patches.
  - Create 32 masks that have the same size as the input images
  - Multiply each region by each mask

Masks



- The color of each patch in the edge region is generated based on the color of the nearest patch in the center region by matching the Gram matrix values of these two patches

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Proposed method: Style loss (cont.)

$$L_{Style} = \sum_{l} || \frac{1}{M_l} Gr(Mp(x_{bi}) \odot x_{rgb} \odot m_l) - \frac{1}{N_l} Gr((x_{bi} - Mp(x_{bi})) \odot \Phi(x_{bi}, x_{bi}) \odot m_l) ||_1 \quad (2)$$

- Gr: Gram matrix
- Mp: Morphological operator
- x_{bi}: binary anonymized gait image
- x_{rgb}: RGB original gait image
- M_l and N_l : the numbers of pixels in each patch
- l is the index of the mask l-th.

$$M_l = \sum_{p} (Mp(x_{bi}) \odot m_l) \quad (3)$$

$$N_l = \sum_{p} ((x_{bi} - Mp(x_{bi})) \odot m_l) \quad (4)$$

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Experimental results

- **Dataset**: Use dataset CASIA_B [1] containing 124 subjects (12,989 sequences):
  - Training the gait recognition system: 50 subjects (5,500 sequences)
  - Training the baseline: 30 subjects (1,100 sequences)
  - Testing: 40 subjects (4400 sequences) and is divided into 4 subset:
    - an incomplete silhouette set containing incomplete silhouette gaits,
    - a complete silhouette set containing complete silhouette gaits,
    - a plain color set containing images in which clothing with one color overlays the gait, and
    - a textural color set containing images in which clothing with multiple colors overlays the gait.
- **Evaluation**: Qualitative and quantitative evaluation
- **Gait identification system**: Use the method proposed by Zheng et al. [2].
- **Baseline**: We compare the proposed model with our previous model[3]

[1] http://www.cbsr.ia.ac.cn/english/Gait%20Databases.asp
[2] S. Zheng, J. Zhang, K. Huang, R. He, and T. Tan, "Robust View Transformation Model for Gait Recognition," in International Conference on Image Processing, Brussels, Belgium, 2011.
[3] N. T. Tieu, H. H. Nguyen, F. Fang, J. Yamagishi, and I. Echizen, "An rgb gait anonymization model for low-quality silhouettes," in 2019 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA ASC), 2019, pp.

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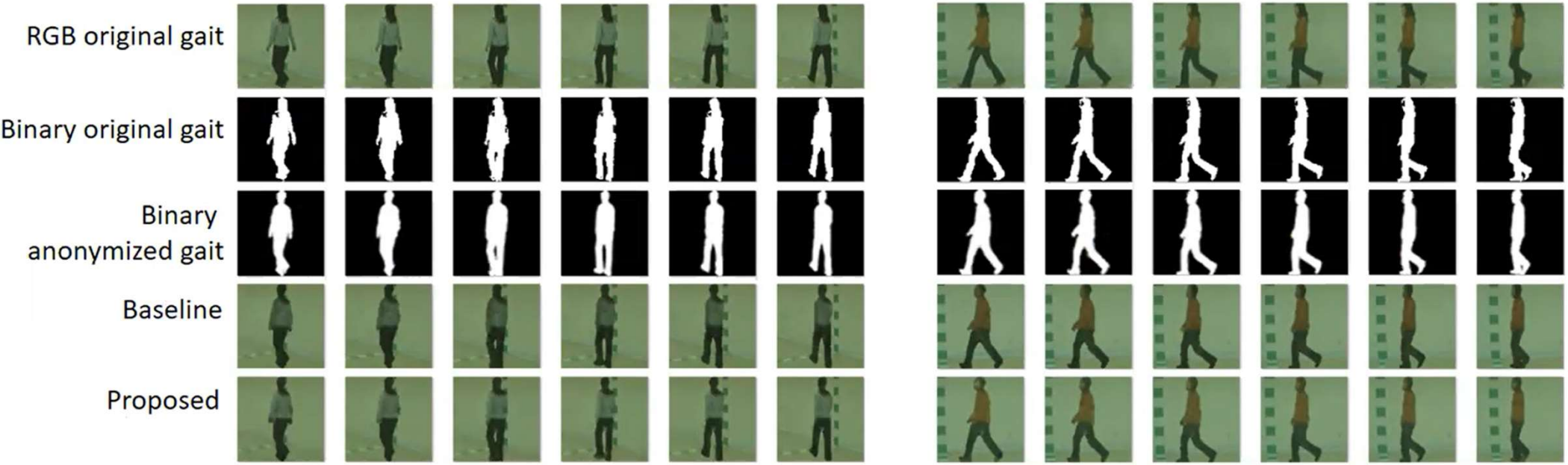
Experimental results: Qualitative evaluation

- Plain color set



➔ both models can transfer a plain color but the colors generated by the proposed model look more similar to the original colors

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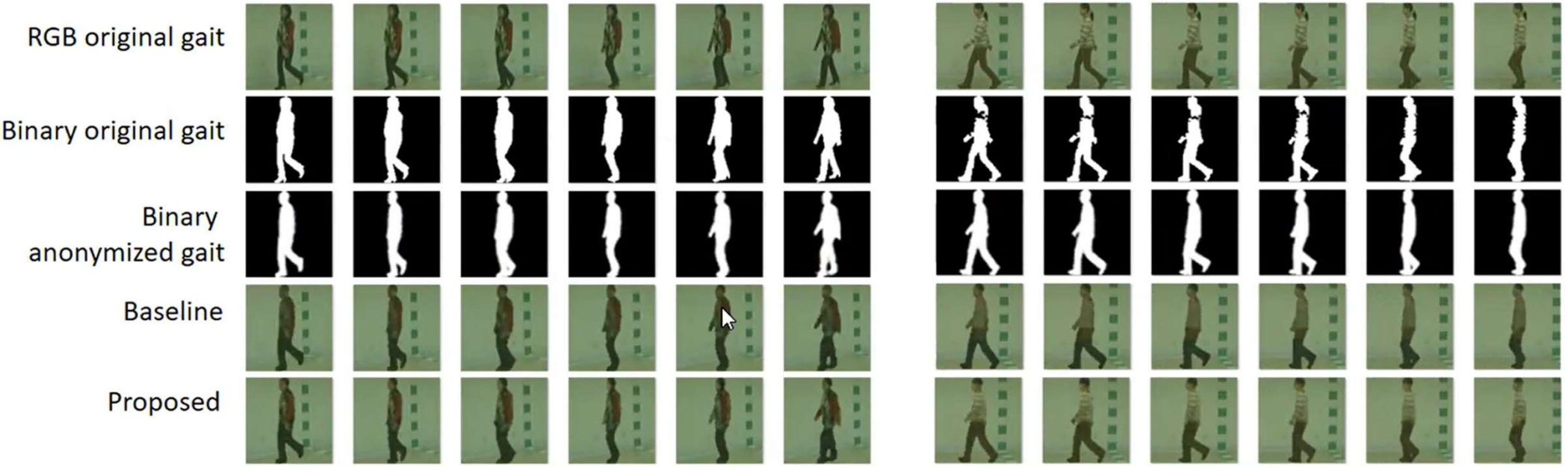
Experimental results: Qualitative evaluation (cont.)

- Textured color set



➔ The baseline model produced blurry and coarse images, while the proposed model can generate finely textured color.

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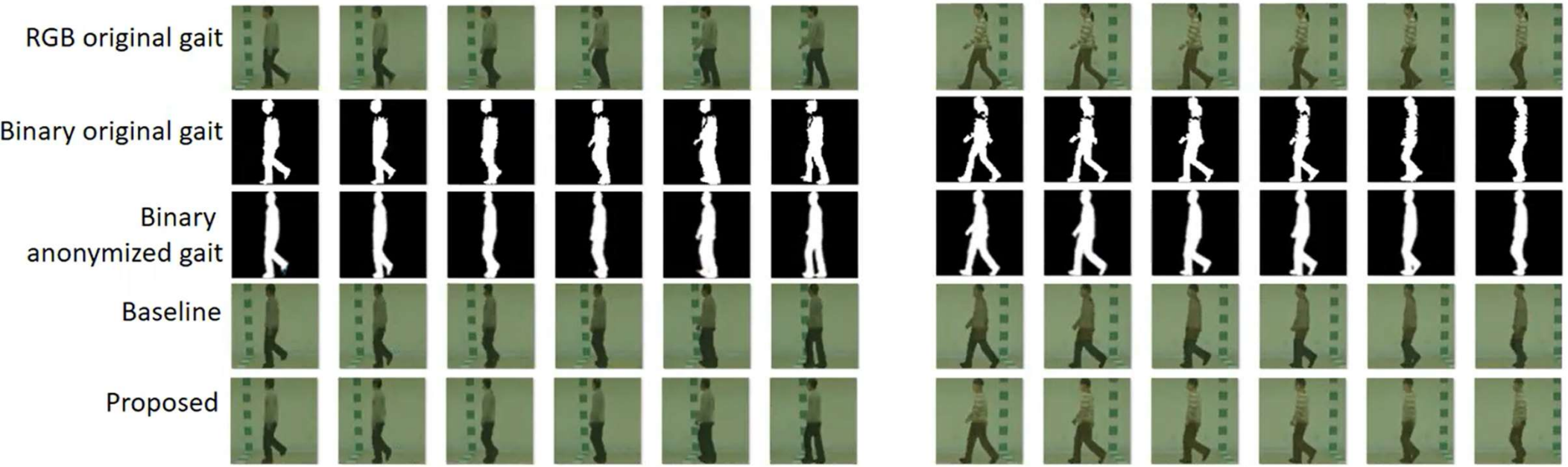
Experimental results: Qualitative evaluation (cont.)

- Complete and incomplete silhouette set



➔ the proposed model can generate images with either a plain color or a finely textured color regardless of the quality of the original gait silhouettes

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Experimental results: Quantitative evaluation

- The PSNR/SSIM of images generated by two models:

TABLE I: PSNR and SSIM of baseline and proposed models for plain and textural color sets.

Method	PSNR		SSIM	
	Plain color	Textural color	Plain color	Textural color
Baseline	24.2417	23.6273	0.9062	0.8970
Proposed	24.7302	24.2822	0.9142	0.9065

TABLE II: PSNR and SSIM of the baseline and proposed models for complete and incomplete silhouette sets.

Method	PSNR		SSIM	
	Incomplete silhouette	Complete silhouette	Incomplete silhouette	Complete silhouette
Baseline	23.9494	24.1035	0.9047	0.9042
Proposed	24.4664	24.8346	0.9126	0.9094

PSNR/SSIM of the proposed model are higher than the baseline model for all 4 sets.

➔ The quality of images generated by the proposed model is better than those generated by the baseline.

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Experimental results: Success rate

- Success rate is the ratio of the number of anonymized gaits that were not correctly identified by the gait recognition system and the total number of anonymized gaits

- S: the set of gaits that the gait identification system identifies correctly
- S': the anonymized gaits of S
- M: the number of gaits in S' that the gait identification system identifies incorrectly

$$\textbf{Success\_rate}\ (\%) = \frac{M}{|S|} \times 100 \qquad (5)$$

- We tested with the top-1 identification.
- The success rates for the two models were completely the same for every viewing angle and ranged from 79.04% to 93.61% depending on the viewing angle.

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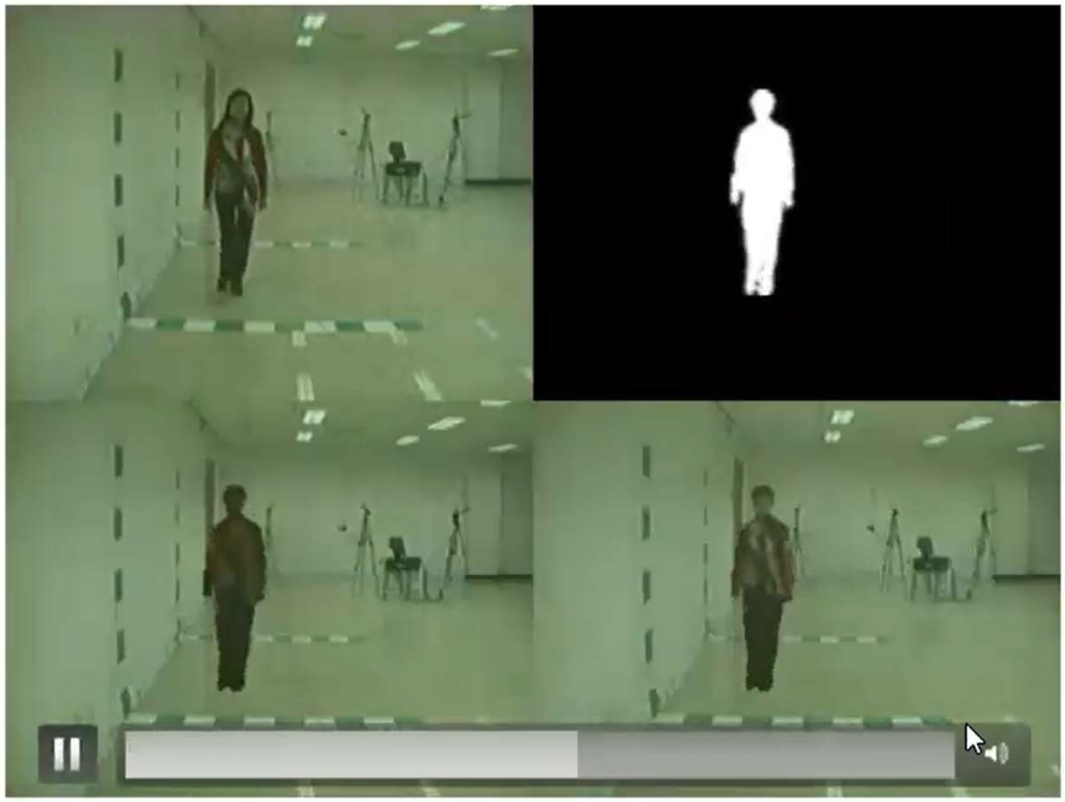
Demonstration

RGB original gait



Binary anonymized gait

RGB anonymized
Gait (baseline)

RGB anonymized
Gait (proposed)

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Conclusion

- We have introduced a model for color transfer in gait anonymization.
- We conducted extensive qualitative and quantitative evaluations on four sets of data: plain color, textural color, incomplete silhouettes, and complete silhouettes.
- Both evaluations demonstrated that the proposed model is more effective and more robust against silhouette quality for color transfer while preserving the success rate of anonymization.