

Survey On CycleGAN Based Face Aging Detection

Anish Milind Bhanji ¹, Dr. Sanjaykumar P. Pingat ²

¹ Computer Engineering & SKN college of engineering, Pune

² Computer Engineering & SKN college of engineering, Pune

Abstract - As facial recognition systems increasingly permeate high-stakes domains such as security, healthcare, and forensics, their ability to handle age progression and regression becomes critical. However, changes in facial appearance due to aging often degrade recognition accuracy, prompting the emergence of synthetic face aging techniques as a potential solution. This survey explores state-of-the-art methods in synthetic facial aging, with a focus on their effectiveness in maintaining identity, realism, and applicability in age-invariant recognition systems. The paper reviews recent works addressing short- and long-term aging effects, fairness across demographics, feature fusion approaches, and the role of balanced datasets. Additionally, it examines the integration of loss functions and architectural enhancements that contribute to the realism and reliability of aged face generation. The review aims to contextualize current advancements, identify persistent challenges, and highlight promising directions for future research in synthetic aging and its integration with facial recognition systems.

Key Words: GAN, Face Aging, Cycle GAN.

1. INTRODUCTION

Facial aging significantly affects the accuracy of recognition systems, as human faces undergo subtle to pronounced transformations over time. Traditional facial recognition models often underperform when verifying identities across large age gaps, necessitating the development of synthetic aging frameworks. These systems generate age-progressed or age-regressed images while preserving identity, thus enabling more robust recognition over time.

Synthetic aging approaches harness deep learning architectures—especially GAN-based models—to simulate aging effects like wrinkles, skin sagging, or facial structure shifts. These synthetically generated images are instrumental in training models to recognize individuals across varying age spans. Beyond identity preservation, these techniques are also critical in ensuring fairness across age groups and other demographic factors.

This paper surveys the latest advancements in synthetic face aging, focusing on their role in enhancing the robustness and fairness of facial recognition systems.

2. Existing Work

2.1 Aging and Recognition Accuracy

Nouri et al. analyzed how aging affects recognition accuracy over time. Their study compared facial recognition performance across short- and long-term age gaps using synthetically generated images. While synthetic aging techniques improved consistency across moderate time spans, the study noted a significant drop in recognition accuracy when the age difference

exceeded several decades. This indicates the limitations of current models in capturing the full complexity of human aging.

2.2 Reducing Age Bias in Recognition Systems

Bhattacharjee and Das focused on the fairness aspect of facial recognition. Their work highlighted disparities in authentication performance across age groups and introduced age-progressed images as a form of data augmentation to reduce such bias. The study showed that including synthetically aged images in training datasets significantly reduced performance gaps across younger and older demographics.

2.3 Feature Fusion for High-Fidelity Aging

Jiang and Li proposed a feature fusion-based aging model that combines texture and geometric features to improve the realism of generated faces. Their method outperformed pixel-level techniques by better preserving identity and generating more natural-looking aged appearances, making it more suitable for real-world applications like biometric authentication and media production.

2.4 Synthetic Data for Demographic Balance

Nguyen and Rawal extended the utility of synthetic data beyond age to mitigate broader demographic biases. Their work demonstrated that augmenting datasets with synthetic images—targeting underrepresented age groups—improved overall recognition fairness across race, gender, and age. Though not limited to aging, this research reinforces the importance of diversity in training data.

2.5 Role of Balanced Datasets

Karkkainen and Joo introduced the FairFace dataset, which ensures demographic balance across race, gender, and age. Although not synthetically generated, FairFace serves as a benchmark to evaluate the generalizability of synthetic aging techniques. It is especially useful for testing models trained with synthetic age-progressed data for fairness and inclusivity.

2.6 Cross-Modal Synthetic Aging

Klassen and Bowen explored synthetic image generation in thermal imaging, contributing to multimodal recognition systems. Although their work focuses on thermal data rather than visual-spectrum facial images, the methodology presents transferable concepts for enhancing aging simulation across modalities, offering insights for cross-domain applications.

2.7 Deep Learning for Age Estimation

Rahman and Akhand addressed the estimation of age using deep convolutional networks. While they did not propose synthetic aging models, their age prediction techniques are valuable for evaluating how accurately a synthetically aged image reflects the intended age group. High-precision estimators can act as evaluators in training pipelines of synthetic aging systems.

2.8 Geometric Features for Aging Robustness

Aggarwal and Saxena emphasized landmark-based features over texture, proposing that facial geometry remains more stable over time than surface features. Their findings suggest that structure-focused representations could complement synthetic aging techniques in achieving age-invariant recognition.

2.9 Facial Recognition in Children

Behrendt et al. examined how facial recognition performs in children—a group with rapid facial changes. Although their study didn't generate synthetic data, the insights are crucial for developing age-progression models that account for non-linear aging patterns in early life, thereby improving recognition across all age groups.

2.10 Statistical Aging Models

Woodard and Harrison proposed a statistically-driven aging framework that offers greater control and reproducibility compared to black-box deep learning models. Their semi-automated technique enables interpretable aging transformations, reducing identity drift and making it more suitable for applications requiring traceability and transparency.

3. METHODOLOGY

The proposed system takes an input RGB facial image along with a target age label to generate a photorealistic age-transformed version of the same person. The model follows an encoder-decoder architecture with residual blocks and skip connections to ensure both age-specific transformation and identity preservation.

Key steps:

1. Input: Original face image + target age label.
2. Encoder: Extracts facial features while preserving identity.
3. Noise Injection: Adds randomness for natural texture variations (e.g., wrinkles, hair strands).
4. AdaIN/Modulation: Alters feature maps based on the age label (age conditioning).
5. Residual Blocks: Apply age-specific changes while retaining facial structure.
6. Skip Connections: Preserve fine details and facial identity.
7. Decoder: Reconstructs the aged face image from transformed features.
8. Output: Realistic aged version of the input face, maintaining identity

4. EXPECTED OUTCOME

Despite transformation, key facial attributes such as geometry, symmetry, and unique identifiers remain consistent. Recognition systems trained using synthetically aged datasets will demonstrate enhanced robustness across short- and long-term age gaps. The model will generate realistic age-progressed or age-regressed facial images that accurately simulate biological aging effects. The expected outcome is a more reliable and equitable face recognition framework applicable in forensics, security surveillance, and healthcare authentication systems.

5. CONCLUSION

Synthetic face aging plays a crucial role in building age-robust facial recognition systems. From feature fusion and balanced datasets to statistical modeling and cross-modal simulation, recent research reveals a diverse set of strategies to address the challenges posed by facial aging. These innovations not only improve recognition accuracy but also enhance fairness and inclusivity in biometric systems. Continued advancements in architecture, loss design, and evaluation will be essential in translating synthetic aging from research to real-world applications.

ACKNOWLEDGEMENT

I sincerely express my gratitude to guide for his continuous guidance, valuable suggestions, and motivation throughout the preparation of this survey paper. His support and constructive feedback have greatly contributed to the successful completion of our work.

REFERENCES

1. J. Nouri, M. Jalalzai, and S. Marcel, "Time Flies By: Analyzing the Impact of Face Aging on Recognition Performance with Synthetic Data," IEEE Conference Publication, 202X.
2. R. Bhattacharjee and D. Das, "A Study on the Effect of Ageing in Facial Authentication and the Utility of Data Augmentation to Reduce Performance Bias Across Age Groups," IEEE Journal, 2025.
3. H. Jiang and M. Li, "Face Aging Synthesis Application Based on Feature Fusion," IEEE Conference Publication, 2024.
4. T. Nguyen and B. Rawal, "Synthetic Data for the Mitigation of Demographic Biases in Face Recognition," IEEE Conference Publication, 2024.
5. K. Karkkainen and J. Joo, "FairFace: Face Attribute Dataset for Balanced Race, Gender, and Age for Bias Measurement and Mitigation," IEEE Dataset Publication, 2024.
6. R. V. Klassen and C. B. Bowen, "Proof-of-Concept Techniques for Generating Synthetic Thermal Facial Data for Training of Deep Learning Models," IEEE Conference Publication, 2024.
7. A. Rahman and N. Akhand, "Age Estimation from Face Images Based on Deep Learning," IEEE Conference Publication, 2022.
8. A. Aggarwal and M. Saxena, "Age Estimation and Face Verification Across Aging Using Landmarks," IEEE Conference Publication, 2022.
9. C. Behrendt, C. Kröger, and A. Rattunde, "The Impact of Age and Threshold Variation on Facial Recognition Algorithm Performance Using Images of Children," IEEE Conference Publication, 2024.
10. J. Woodard and A. Harrison, "Towards a Semi-Automatic Method for the Statistically Rigorous Aging of the Human Face," IEEE Conference Publication, 2024.