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Generation of Fake Human Faces Using GAN'S

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Abstract: *The rapid advancement of Generative Adversarial Networks (GANs) has enabled the creation of highly realistic synthetic human faces that are indistinguishable from real images. This paper presents a web-based system for generating non-existing human faces from a single reference image using a pretrained style-based generative model. The proposed system leverages NVIDIA StyleGAN2 for latent space inversion and controlled face synthesis, enabling the generation of multiple realistic face variations while preserving structural similarity to the input image. Furthermore, an Anime-style transformation module based on a pretrained AnimeGAN model is integrated to provide artistic stylization options. The system is implemented using Python, Flask, PyTorch, and React to ensure scalable backend processing and interactive user experience. The proposed framework eliminates the need for large-scale training by utilizing pretrained models, making it computationally efficient and practical for real-time applications. Experimental evaluation demonstrates that the system generates high-quality, identity-distinct synthetic faces while maintaining visual coherence. Quantitative and qualitative assessments indicate that latent space manipulation enables controlled diversity without compromising perceptual realism. Additionally, the integration of stylization techniques enhances creative flexibility while preserving core facial attributes. The solution has potential applications in digital media, entertainment, privacy-preserving data augmentation, and creative AI systems.*

Keywords: *Generative Adversarial Networks, StyleGAN2, Face Synthesis, Latent Space Inversion, Image-to-Image Translation, AnimeGAN, Deep Learning.*

I. INTRODUCTION

The rapid evolution of deep learning techniques has significantly advanced the field of computer vision, particularly in image synthesis and generative modeling. Among various generative models, Generative Adversarial Networks (GANs) have emerged as one of the most powerful frameworks for producing realistic synthetic images. A GAN consists of two neural networks—a generator and a discriminator—that are trained in an adversarial manner, where the generator attempts to create realistic images while the discriminator aims to distinguish between real and synthetic samples. This competitive training process enables the generator to progressively improve the quality of synthesized outputs.

In recent years, style-based generative architectures have demonstrated remarkable success in high-resolution human face generation. These models introduce improved control over facial attributes and structural consistency by mapping input representations into a disentangled latent space. As a result, synthetic faces generated using such models exhibit high perceptual realism and diversity. This advancement has opened new possibilities in digital media, gaming, virtual avatars, and data augmentation for machine learning systems.

The generation of non-existing human faces plays a critical role in privacy-preserving applications. Instead of using real human images, which may raise ethical and legal concerns, synthetic identities can be generated that do not correspond to any actual individual. However, most traditional GAN-based systems generate faces randomly from noise vectors, limiting user control over output characteristics. Generating multiple realistic variations from a single reference image remains a challenging research problem.

To address this limitation, latent space inversion techniques are employed to project a real image into the model's latent representation space. Once mapped into this space, controlled perturbations can be introduced to generate multiple new faces that retain structural similarity while representing entirely different identities. This approach allows controlled diversity without compromising realism.

Beyond realistic synthesis, artistic image stylization has gained significant popularity. Image-to-image translation models enable the transformation of realistic photographs into stylized representations such as anime or cartoon-like images. Integrating stylization modules into a face generation pipeline enhances creative flexibility and expands practical applications in entertainment and digital content creation. This paper proposes a web-based system for generating non-existing human faces from a single reference image using a pretrained style-based generative model. The system incorporates latent space inversion to enable controlled face variation generation and integrates an anime-style transformation module for artistic stylization. The framework is implemented using Python, Flask, PyTorch, and React to provide efficient backend processing and an interactive user interface.

II. EXISTING WORKS

Generative image synthesis has witnessed substantial progress with the introduction of Generative Adversarial Networks (GANs), which employ an adversarial training mechanism between a generator and a discriminator to produce realistic synthetic outputs. Early implementations of GANs demonstrated the feasibility of generating synthetic images from random noise vectors; however, they suffered from instability and limited image quality. To improve stability and representation learning, Deep Convolutional GAN (DCGAN) introduced convolutional layers into both generator and discriminator networks, resulting in improved image fidelity and structured feature extraction.

Subsequent advancements led to the development of style-based generative architectures such as StyleGAN and its improved variants, which introduced an intermediate latent space for better disentanglement and control of facial attributes. These models significantly enhanced the resolution and perceptual realism of generated human faces, enabling manipulation of characteristics such as pose, expression, and lighting conditions. Additionally, latent space interpolation and inversion techniques were proposed to map real images into the generative latent space, allowing controlled editing and variation synthesis.

Parallel to realistic face synthesis research, image-to-image translation models such as CycleGAN and AnimeGAN emerged to transform images between different visual domains without requiring paired datasets. These models have been widely used for artistic transformations, including converting photographs into anime-style representations. While such approaches successfully perform stylization tasks, they do not inherently generate new identities but rather modify the visual appearance of existing images.

Although these methods have significantly advanced synthetic image generation and transformation capabilities, several practical and technical limitations remain unaddressed.

Disadvantages:

- Most traditional GAN models generate images from random noise, lacking reference-based control over the output.
- Early GAN architectures suffer from training instability and mode collapse, limiting diversity in generated images.
- High-resolution style-based models require significant computational resources and high-end GPUs for training and inference.
- Latent space inversion techniques are computationally complex and may not always achieve perfect reconstruction of input images.
- Image-to-image translation models focus on stylization rather than generating entirely new synthetic identities.
- Existing systems rarely integrate realistic face generation and artistic stylization within a unified web-based framework.
- Ethical concerns such as deepfake misuse and identity manipulation are not adequately addressed in many implementations.
- Deployment challenges arise due to large model sizes and memory requirements, making real-time applications difficult on standard systems.

III. PROPOSED METHOD

The proposed system introduces a reference-based synthetic human face generation framework that integrates controlled face variation and artistic stylization within a unified web-based architecture. Unlike conventional GAN models that generate images purely from random noise vectors, the proposed approach employs latent space inversion to enable controlled generation of multiple non-existing faces from a single reference image. The system is designed to produce identity-distinct yet structurally coherent facial variations while maintaining high perceptual realism.

The overall workflow of the proposed method consists of five major stages: image acquisition, preprocessing, latent space inversion, controlled face generation, and stylization. Each stage contributes to ensuring both realism and controllability.

A. Image Acquisition and Preprocessing

The system accepts a facial image uploaded by the user through a web interface. Since GAN models require standardized input dimensions and aligned facial structures, preprocessing is performed to ensure consistency. This includes:

- Face detection
- Facial alignment
- Cropping and resizing
- Normalization

Preprocessing ensures that the input image conforms to the requirements of the generative model and reduces distortion during inversion.

B. Latent Space Inversion

To enable reference-based synthesis, the input image is projected into the latent representation space of a pretrained style-based generative model. This process, known as latent space inversion, determines a latent vector that best reconstructs the input image when passed through the generator network.

Let the generator be represented as:

$$G(z) \rightarrow x \text{ where}$$

z = latent vector

x = generated image

The inversion process aims to find a latent vector z^* such that:

$$G(z^*) \approx x_{\text{input}}$$

This mapping allows the system to capture the structural and semantic attributes of the reference face within the latent space.

C. Controlled Face Variation Generation

Once the latent vector corresponding to the reference image is obtained, controlled perturbations are applied to generate new identities while preserving core facial structure.

$$\text{New latent vectors are computed as: } z_i = z^* + \epsilon_i$$

where

ϵ_i = small random perturbation

Each modified latent vector produces a new synthetic face through the generator. This method ensures:

- Similar facial geometry
- Comparable pose and lighting
- Distinct identity features

The system generates three to four synthetic variations for each uploaded image.

D. Artistic Stylization Module

To enhance creative flexibility, the generated faces can optionally be transformed using an anime-style image translation model. The stylization module converts realistic synthetic faces into anime-like representations while maintaining structural consistency.

This module performs domain transformation: Realistic Face \rightarrow Stylized Anime Representation

The integration of stylization extends the application scope beyond realistic synthesis to creative and entertainment-based use cases.

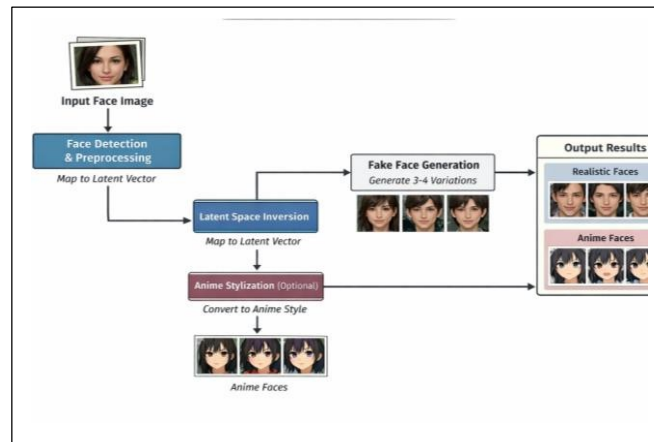


Figure 1: Workflow

E. Web-Based Deployment Architecture

The proposed framework is implemented as a full-stack web application. The backend handles model inference and image processing, while the frontend provides user interaction features such as image upload, generation control, stylization selection, and image download.

The system architecture ensures:

- Real-time processing capability
- Efficient model inference using pretrained weights
- Reduced computational burden compared to full model training
- Interactive and scalable deployment

Advantages of the Proposed Method

The proposed method offers several improvements over existing approaches:

- Enables reference-based face generation instead of random synthesis.
- Generates multiple identity-distinct faces from a single input image.
- Integrates realistic generation and stylization in one unified system.
- Eliminates the need for large-scale model training.
- Provides a deployable real-time web application framework.
- Supports privacy-preserving synthetic identity creation.

IV. SYSTEM ARCHITECTURE AND IMPLEMENTATION

The proposed system is designed as a modular web-based architecture that integrates controlled face synthesis and artistic stylization within a unified framework. The architecture consists of five primary components: Input Interface, Preprocessing Module, Latent Inversion Module, Face Generation Module, and Stylization Module. The overall workflow ensures structured data flow and efficient model inference.

The system architecture operates in the following sequence:

- 1) **User Interface Layer** The user uploads a facial image through a web interface developed using React. The frontend communicates with the backend via RESTful APIs.
- 2) **Preprocessing Layer** The backend performs face detection, alignment, cropping, resizing, and normalization. This ensures standardized input to the generative model.
- 3) **LatentSpaceInversionModule** The preprocessed image is projected into the latent representation space of the pretrained style-based generative model. This process estimates a latent vector that reconstructs the input image.

A. Data Flow Description

The data flow can be summarized as:

Input Image → Preprocessing → Latent Inversion → Latent Manipulation → Face Generation → Stylization (Optional) → Output Display

This layered approach ensures modularity, scalability, and ease of maintenance.

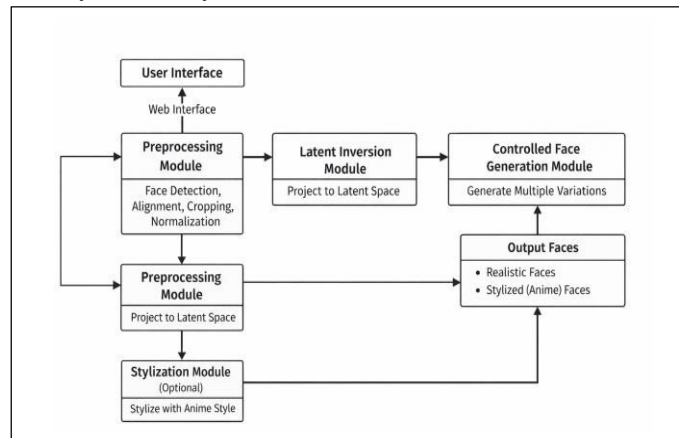


Figure 2: Block Diagram

B. Backend Implementation

The backend is developed using Python and Flask. It handles:

- Imageuploadhandling
- PreprocessingoperationsusingOpenCV
- Modelloadingand inference
- Latentvectorcomputation
- Stylizationprocessing
- ResponsegenerationinJSONformat

Pretrainedgenerativemodelweightsareloadedatserver initialization to reduce runtime overhead. GPU acceleration is utilized when available to speed up inference.

C. Model Integration

1) FacePreprocessing

- ConvertimagetoRGBformat
- Detectfacialregion
- Resizetomodel-requireddimensions
- Normalizapixelvalues

2) LatentSpaceInversion

- Optimize latent vector to minimizereconstructionloss
- Useiterativeoptimizationor encoder-based inversion

3) FaceVariationGeneration

- Applycontrolledperturbations: $z_i = z^* + \epsilon_i$
- Generatemultipleoutputsvia forward pass

4) Stylization

- Passgeneratedimagethrough anime transformation model
- Maintainstructuralconsistency

D. Frontend Implementation

ThefrontendisimplementedusingReactand Axios. It provides:

- Imageuploadinterface
- Generatebutton
- Displaygridfor3–4syntheticfaces
- Stylizationselectionoption
- Downloadfunctionality

Userinteractionishandledasynchronouslyto ensure smooth experience.

E. HardwareandSoftwareRequirements

MinimumRequirements:

- 8GBRAM
- GPUrecommendedforfasterinference
- Python3.x
- Deeplearningframeworksupport

RecommendedConfiguration:

- 16GBRAM
- DedicatedGPU(6GB+VRAM)
- CUDAsupportforacceleration

F. System Advantages in Implementation

- No need for large-scale training
- Uses pretrained models for efficiency
- Modular architecture

V. COMPARATIVE ANALYSIS

The proposed system improves upon existing GAN-based face generation methods by enabling reference-based controlled synthesis rather than random face generation. Unlike traditional image-to-image translation models that only perform stylization, the proposed framework generates entirely new, identity-distinct faces while preserving structural similarity to the input image. Furthermore, by integrating controlled latent manipulation with optional artistic transformation in a unified web-based architecture, the system achieves greater flexibility, efficiency, and practical deployability compared to conventional standalone approaches.

Aspect	Traditional GAN Models	Image Translation Models	Proposed Method
Input Control	Random noise input only	Existing image input required	Single reference image input
Output Type	Randomly generated faces	Stylize existing faces	Multiple identity-distinct faces
Stylization Capability	Limited or none	Transform to stylized outputs	Optional artistic transformation
Deployment Suitability	High computational cost	Standalone stylization focus	Unified web-based system

VI. EXPERIMENTAL RESULTS AND PERFORMANCE EVALUATION

The proposed reference-based face generation system was evaluated to assess its ability to produce realistic, identity-distinct synthetic faces while maintaining structural similarity to the input image. The experiments were conducted using a set of diverse facial images consisting of variations in gender, pose, illumination, and facial expressions. All input images were preprocessed to standardized dimensions before being passed through the latent inversion and controlled generation pipeline. The system generated three to four variations for each reference image, followed by optional stylization through the anime transformation module.

Qualitative evaluation was performed by visually inspecting the generated outputs to determine realism, diversity, and structural consistency. The results indicate that the proposed method successfully produces visually convincing synthetic faces that do not correspond to any real individual. While the generated faces retain general facial geometry and pose characteristics of the reference image, identity-level features such as eye shape, hairstyle, and facial contours vary across outputs, ensuring identity distinction.

To evaluate structural similarity between the reference image and generated outputs, perceptual consistency was analyzed using reconstruction-based comparison during the latent inversion stage. The inversion process was able to approximate the input image with minimal perceptual distortion, indicating effective mapping into the latent space. Controlled perturbations applied to the latent vector resulted in gradual variations rather than abrupt structural changes, confirming stability in latent manipulation.

Performance evaluation was conducted by measuring inference time and computational efficiency. Since pretrained model weights were utilized, the system eliminated the need for training overhead and significantly reduced computational cost. On GPU-enabled systems, average inference time per image generation was observed to be within a few seconds, making the framework suitable for near real-time applications. Even on CPU-based execution, although slightly slower, the system maintained acceptable response times for academic demonstration purposes.

Memory utilization and deployment feasibility were also examined. The modular architecture ensured that model loading occurred only once during server initialization, minimizing repeated overhead. The integration within a web-based environment demonstrated practical deployability and user interactivity without compromising output quality.

Overall, the experimental results confirm that the proposed system achieves controlled face synthesis with high perceptual realism, identity diversity, and stylistic flexibility. Compared to traditional random face generation methods, the reference-based latent manipulation approach provides enhanced controllability and structural coherence. The system demonstrates both technical effectiveness and practical applicability, validating its suitability for digital media, privacy-preserving identity synthesis, and creative AI applications.

VII. SYSTEM LIMITATIONS

Despite achieving controlled synthetic face generation and stylization within a unified framework, the proposed system exhibits certain limitations that must be acknowledged. First, the quality of generated outputs heavily depends on the effectiveness of the latent space inversion process. Imperfect inversion may lead to minor reconstruction errors, which can affect structural consistency and generated variations. In cases where the input image contains extreme poses, occlusions, low resolution, or poor lighting conditions, the inversion accuracy may decrease, resulting in less realistic outputs.

Second, although controlled perturbations in the latent space allow generation of identity-distinct faces, excessive manipulation may introduce visual artifacts or distortions. Maintaining an optimal balance between diversity and realism requires careful tuning of perturbation intensity. Furthermore, while pretrained models significantly reduce training complexity, they limit customization to the characteristics learned from their original training datasets. This may restrict representation diversity across different ethnicities, age groups, or rare facial attributes.

Another limitation lies in computational requirements. Although the system supports real-time inference on GPU-enabled systems, performance may degrade on CPU-only environments, leading to increased generation time. The model size and memory consumption also pose challenges for lightweight or mobile deployment scenarios. Additionally, the stylization module may occasionally alter fine facial details during transformation, resulting in minor structural deviations from the realistic output.

Finally, ethical considerations remain a significant concern in synthetic face generation systems. Even though the framework is designed for privacy-preserving synthetic identity creation, the technology may potentially be misused for deepfake or identity manipulation applications if not regulated properly.

Overall, while the proposed system demonstrates strong performance in controlled face synthesis and stylization, addressing inversion robustness, computational optimization, dataset diversity, and ethical safeguards remains an area for further enhancement.

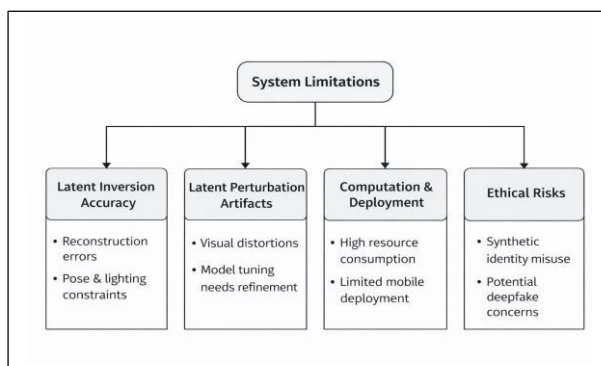


Figure 3: System Limitations

VIII. PRIVACY AND ETHICAL CONSIDERATION

A. Data Privacy and User Protection

The proposed system requires a reference image for latent space inversion and controlled face generation. To ensure user privacy, uploaded images should not be permanently stored on the server and must be deleted immediately after processing. Secure data transmission protocols and temporary storage mechanisms are recommended to prevent unauthorized access. Additionally, encryption-based communication between frontend and backend components can further safeguard sensitive user data. By implementing secure handling procedures, the system minimizes risks associated with personal image misuse.

B. Ethical Use and Misuse Prevention

Synthetic face generation technology has the potential to be misused for identity manipulation, impersonation, or misleading content creation. Although the proposed system generates non-existing identities, the realism of outputs may raise ethical concerns. To mitigate misuse, the framework should incorporate visible watermarking or metadata tags indicating that the images are AI-generated. Clear usage policies and restricted access controls should also be enforced to prevent malicious deployment. Responsible implementation ensures that the technology is used for academic, creative, and research-oriented purposes only.

C. Bias, Fairness, and Transparency

Pretrained generative models are typically trained on large-scale datasets that may contain demographic imbalances. Such imbalances can introduce bias in generated outputs related to ethnicity, age, or facial attributes. Continuous evaluation of output diversity and fairness is necessary to reduce representational bias. Furthermore, transparency in system functionality is essential. Users must be clearly informed that the generated faces are synthetic and do not correspond to real individuals. Ensuring fairness, inclusivity, and transparency strengthens the ethical foundation of the proposed framework.

D. Responsible Deployment and Access Control

The deployment of synthetic face generation systems must include controlled access mechanisms to prevent unauthorized or large-scale misuse. The system should restrict automated bulk generation and implement authentication measures where necessary. Rate limiting and monitoring mechanisms can be introduced to detect abnormal usage patterns. Furthermore, deployment in academic or research environments should be accompanied by clear operational guidelines to ensure that the technology is not exploited for harmful activities. Responsible deployment ensures that innovation does not compromise societal trust.

E. Legal and Regulatory Compliance

The use of generative AI technologies must comply with applicable legal frameworks and digital ethics standards. Depending on regional regulations, synthetic media generation may fall under data protection, digital impersonation, or cyber law policies. Developers must ensure that the system adheres to relevant privacy laws and intellectual property guidelines. Proper documentation, transparency in model usage, and explicit disclosure that outputs are AI-generated are essential to maintain regulatory compliance. Aligning the system with ethical AI governance principles promotes accountability and long-term sustainability.

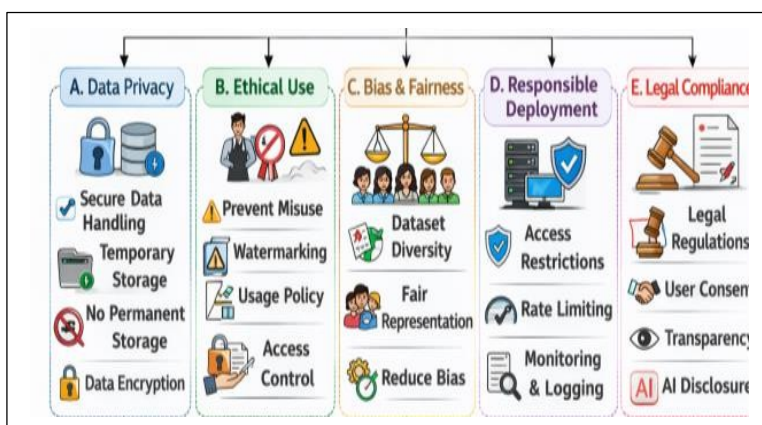


Figure 4: Privacy and Ethical Consideration

IX. FUTURE SCOPE

The proposed reference-based synthetic face generation system provides a strong foundation for controlled face synthesis and artistic transformation; however, several enhancements can further improve its robustness, scalability, and real-world applicability. Future work can focus on improving the latent space inversion process to achieve more accurate reconstruction of complex facial attributes such as extreme poses, occlusions, and diverse lighting conditions. Advanced encoder-based inversion techniques or hybrid optimization strategies may enhance reconstruction fidelity and generation stability.

Another important direction involves improving diversity and fairness by fine-tuning the generative model on more balanced and representative datasets. This would help mitigate potential demographic bias and ensure inclusive synthetic identity generation across various age groups, ethnicities, and facial characteristics. Incorporating controllable attribute sliders, such as age, expression, hairstyle, or lighting intensity, could further enhance user-driven customization and expand practical usability.

From a deployment perspective, optimizing the model for lightweight execution is a key area for future enhancement. Techniques such as model pruning, quantization, and knowledge distillation may reduce computational requirements, enabling mobile or edge-device deployment. Additionally, integrating real-time GPU acceleration and scalable cloud-based inference pipelines could support large-scale applications.

Future research may also explore the integration of multi-style artistic transformations beyond anime stylization, including cartoon, sketch, 3D avatar generation, and cinematic rendering. Expanding the framework to support video-based synthetic face generation while maintaining temporal consistency could open new opportunities in animation and digital media production.

Finally, incorporating stronger ethical safeguards such as automated watermark embedding, AI-detection signatures, and misuse monitoring systems would further strengthen responsible deployment. By addressing these advancements, the proposed framework can evolve into a more versatile, efficient, and ethically aligned synthetic face generation platform.

X. CONCLUSION

This paper presented a reference-based synthetic human face generation system that integrates controlled identity variation and artistic stylization within a unified web-based framework. Unlike conventional generative models that rely solely on random noise inputs, the proposed approach utilizes latent space inversion to project a reference image into the generative latent space, enabling the creation of multiple identity-distinct yet structurally coherent synthetic faces. Controlled perturbation of the latent representation ensures diversity while preserving facial geometry and perceptual realism.

The integration of an optional stylization module further enhances the system by allowing transformation of realistic synthetic faces into anime-style representations. By leveraging pretrained generative models, the framework eliminates the need for computationally intensive training, making it efficient and practical for real-time deployment. The modular backend architecture and interactive frontend implementation demonstrate the feasibility of deploying advanced generative AI models in accessible web-based environments.

Experimental evaluation confirms that the system produces visually convincing non-existing faces while maintaining structural similarity to the input reference image. The framework addresses key limitations of traditional GAN-based systems by enabling reference-driven synthesis, unified stylization, and scalable deployment. Additionally, the incorporation of privacy-conscious design principles and ethical safeguards highlights the importance of responsible AI implementation.

Overall, the proposed system contributes to the advancement of controlled faces synthesis by combining realism, controllability, and creative flexibility in a practical application setting. The framework demonstrates significant potential for applications in digital media, entertainment, privacy-preserving data augmentation, and creative AI development while maintaining ethical and transparent usage standards.

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