Efficient 3D-Aware Face Frontalization via Lightweight Diffusion Adapters for Pose-Invariant Face Recognition

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Abstract

Face recognition performance in unconstrained environments is significantly challenged by extreme pose variations, which often lead to a drastic drop in accuracy. While face frontalization aims to mitigate this by synthesizing a canonical frontal view from a profile image, existing methods face a critical trade-off: GAN-based approaches frequently suffer from identity inconsistency and lack of photorealism, whereas modern Diffusion-based frameworks like ControlNet are computationally prohibitive for edge applications.

In this paper, we propose an efficient, identity-preserving face frontalization framework that leverages a lightweight T2I-Adapter guided by 3D Morphable Models (3DMM). By integrating 3D-aware geometric priors, our model effectively reconstructs facial structures even from extreme profile angles. To ensure biometric fidelity, we incorporate a specialized Identity-Preserving Loss based on ArcFace embeddings, which constrains the generation process to maintain high cosine similarity with the original subject.

We conduct extensive experiments on the challenging VGGFace2 dataset. Both qualitative and quantitative evaluations demonstrate that our proposed method achieves superior photorealism, measured by the Fréchet Inception Distance (FID), and significantly improves recognition accuracy (TAR@FAR) compared to state-of-the-art GAN-based and heavy diffusion-based baselines. Our work provides a scalable and robust solution for pose-invariant face recognition, balancing computational efficiency with high-fidelity identity preservation.

Keyword: Face Frontalization, Pose-Invariant Face Recognition, Diffusion Models, T2I-Adapter, 3DMM, Identity Preservation.