INTISARI

TP-GAN UNTUK FRONTALISASI WAJAH VIA ADAPTIVE META-LEARNER-BASED KNOWLEDGE DISTILLATION

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Face frontalization merupakan tantangan utama dalam pengenalan wajah karena citra dunia nyata sering ditemukan dalam bentuk *non-frontal* akibat variasi pose, pencahayaan, dan oklusi. TP-GAN (*Two-Pathway Generative Adversarial Network*) efektif mengatasi masalah ini, namun model tersebut berukuran besar. Penelitian ini mengusulkan pendekatan *Meta Knowledge Distillation* (MetaKD) pada TP-GAN untuk menghasilkan model *student* yang lebih ringan tanpa menurunkan kualitas citra. Sebuah *meta-learner* digunakan untuk menyesuaikan bobot loss secara adaptif pada tiga komponen utama—*Pixel Loss*, *Local Pixel Loss*, dan *Intermediate Feature Loss*—berdasarkan dinamika *normalized loss* dan *gradient norm*. Strategi ini memungkinkan pembobotan mandiri (*learnable weighting strategy*) selama proses distilasi. Hasil eksperimen menunjukkan bahwa *student* MetaKD mempertahankan kualitas mendekati *teacher* (SSIM 0,9567, PSNR 38,45 dB) dan melampaui KD konvensional (SSIM 0,9381, PSNR 35,44 dB) dengan kompleksitas komputasi setara (91,83 juta parameter, 1,102 GFLOPs). Analisis pelatihan memperlihatkan bahwa MetaKD membentuk kurikulum adaptif dan stabil melalui mekanisme *cross-compensation* antar komponen loss. Penelitian ini menunjukkan bahwa integrasi MetaKD pada TP-GAN menghasilkan distilasi lebih efektif dengan *trade-off* optimal antara efisiensi dan kualitas visual, serta berpotensi diterapkan pada arsitektur GAN lain.

Kata Kunci: ***Face Frontalization***, ***TP-GAN***, ***Knowledge Distillation***, ***Meta Learning***, ***Adaptive Loss Weighting***, ***GAN***

ABSTRACT

TP-GAN FACE FRONTALIZATION VIA ADAPTIVE META-LEARNER-BASED KNOWLEDGE DISTILLATION

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Face frontalization is a major challenge in face recognition, as real-world images are often captured in *non-frontal* conditions due to variations in pose, illumination, and occlusion. TP-GAN (*Two-Pathway Generative Adversarial Network*) effectively addresses this problem; however, the model is computationally expensive and large in size. This study proposes a *Meta Knowledge Distillation* (MetaKD) approach for TP-GAN to produce a lightweight *student* model without sacrificing image quality. A *meta-learner* is employed to adaptively adjust the loss weights of three main components—*Pixel Loss*, *Local Pixel Loss*, and *Intermediate Feature Loss*—based on the dynamics of *normalized loss* and *gradient norm*. This strategy enables a learnable weighting mechanism during the distillation process. Experimental results demonstrate that the MetaKD *student* maintains image quality close to the *teacher* (SSIM 0.9567, PSNR 38.45 dB) and outperforms conventional KD (SSIM 0.9381, PSNR 35.44 dB) while maintaining comparable computational complexity (91.83 million parameters, 1.102 GFLOPs). Training analysis reveals that MetaKD establishes a stable and adaptive learning curriculum through a *cross-compensation* mechanism among loss components. These findings indicate that integrating MetaKD into TP-GAN enables more effective distillation with an optimal *trade-off* between efficiency and visual quality, and shows strong potential for extension to other GAN architectures.

Keywords: ***Face Frontalization***, ***TP-GAN***, ***Knowledge Distillation***, ***Meta Learning***, ***Adaptive Loss Weighting***, ***GAN***