RPG-Palm: Realistic Pseudo-data Generation for Palmprint Recognition

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EE798R: INTELLIGENT PATTERN RECOGNITION

Introduction and Motivation

Background

Palmprint recognition has gained traction as a biometric authentication method due to its advantages in privacy and security over traditional biometric modalities such as fingerprint and face recognition. The unique texture of palmprints, including ridges and creases, makes it particularly resistant to spoofing.

Problem Statement

However, one major limitation in palmprint recognition is the scarcity of large-scale labeled datasets, which hampers the development of robust, generalizable recognition models. Collecting and labeling large numbers of palmprint images is challenging, both logistically and ethically.

Objective

Our research aims to address this data limitation by generating realistic, synthetic palmprint images that maintain identity consistency and diversity without relying heavily on real-world data.

Methodology

Model Overview

The proposed Realistic Pseudo-Palmprint Generation (RPG) model is designed to generate high-quality synthetic palmprints. It incorporates innovative features that enhance both intra-class diversity and ID consistency across generated images, setting it apart from existing generation methods.

Key Components

1. **Conditional Modulation Generator**

A core feature of RPG, the conditional modulation generator adjusts generation parameters dynamically to improve intra-class variability within synthetic palmprints, allowing for more diverse samples that better represent real-world data.

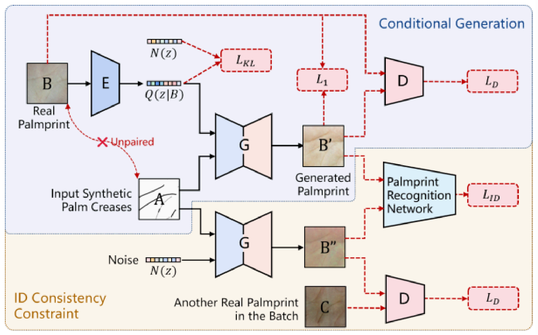
2. **ID-aware Loss**

To ensure that synthetic images retain ID consistency, we introduce an ID-aware loss function. This approach allows unpaired training with real palmprints while preserving unique identity characteristics across generated samples.

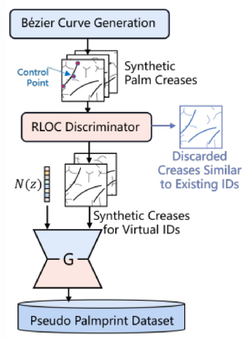
3. **Improved Bezier Palm Crease Generation**

Traditional methods for generating palm creases are limited in realism and identity representation. We introduce an enhanced Bezier curve synthesis that generates realistic creases based on statistical variations observed in real palmprints. This improvement helps create synthetic palmprints with visually accurate and unique creases.

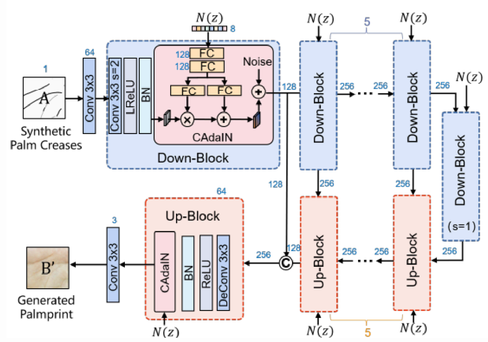
Framework



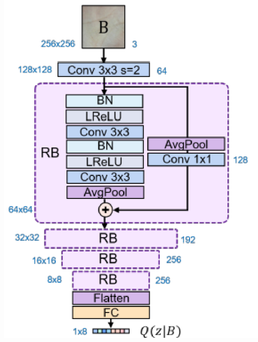
Training stage



Forward pseudo palmprint generation stage



Structure of Generator



Structure of Encoder

Experimental Results

Datasets

RPG was evaluated on multiple datasets, including:

- MPD (Multi-spectral Palmprint Dataset)
- TCD (Touchless Palmprint Dataset)
- HDP (High-resolution Digital Palmprint Dataset)

Evaluation Metrics

Two primary metrics were used to assess performance:

- TAR@FAR: Measures True Acceptance Rate at a given False Acceptance Rate.
- Open-set Protocol: Evaluates model performance on unseen identities, a crucial aspect for biometric applications.

Performance

Our RPG model demonstrates substantial improvements over baseline models, such as BezierPalm and ArcFace, particularly when limited real data is available. These results indicate that RPG's synthetic images are realistic enough to support high recognition accuracy.

Ablation Study

We conducted an ablation study to assess the impact of each key component in our model.

- ID-aware Loss: Improved ID retention and reduced variability within the same identity class.
- Conditional Modulation Generator: Increased diversity among synthetic palmprints while maintaining intra-class consistency.
- Enhanced Bezier Crease Generation: Allowed for more realistic and unique crease structures, enhancing recognition performance.

Conclusion

The Realistic Pseudo-Palmprint Generation (RPG) model addresses the lack of large-scale palmprint datasets by generating high-quality, identity-preserving synthetic palmprints. RPG's superior performance in both recognition and open-set scenarios underscores its potential to enable more effective palmprint recognition systems, particularly when real data is scarce.