Fingerprint Feature Extraction using Empirical Mode Decomposition (EMD)

Abstract

Fingerprint recognition is one of the most widely used biometric authentication methods due to its uniqueness and reliability. This report presents a fingerprint feature extraction framework based on Empirical Mode Decomposition (EMD). The method decomposes fingerprint images into Intrinsic Mode Functions (IMFs), extracts ridge features, and detects minutiae points. Experimental results demonstrate the potential of EMD in enhancing ridge patterns and extracting reliable fingerprint features.

1 Introduction

Fingerprint recognition plays a critical role in biometric authentication systems. The unique ridge-valley structures in fingerprints serve as reliable features for identification. Traditional fingerprint feature extraction methods include Fourier transforms, Gabor filtering, and orientation field analysis. However, these methods may face limitations in noisy or low-quality images.

Empirical Mode Decomposition (EMD) is a data-driven method that adaptively decomposes signals into Intrinsic Mode Functions (IMFs). Unlike predefined basis functions (e.g., Fourier, wavelets), EMD is adaptive and suitable for non-linear and non-stationary data such as fingerprint patterns. This makes it a promising tool for fingerprint feature extraction.

2 Methodology

The proposed fingerprint feature extraction framework is implemented in MATLAB. The key steps are described below:

2.1 Preprocessing

The fingerprint image is first converted to grayscale (if RGB) and normalized to the range $[0, 1]$ for further processing.

2.2 EMD Decomposition

Since EMD is defined for 1D signals, the 2D fingerprint image is flattened before decomposition. The decomposition yields multiple IMFs, which capture oscillatory modes of varying frequency. The IMFs are reshaped back into the original image dimensions for visualization.

2.3 Ridge Feature Extraction

Higher frequency IMFs represent fine-scale structures such as ridges. A representative IMF is selected to enhance ridge details. Adaptive thresholding is applied to suppress noise, followed by contrast stretching to highlight ridge features.

2.4 Binarization

The enhanced ridge image is binarized using a threshold, ensuring clear separation of ridges from the background. This step facilitates minutiae detection.

2.5 Minutiae Detection

Minutiae points, including ridge endings and bifurcations, are extracted using morphological operations. In this study, a simple approach using MATLAB's `bwmorph` function is applied to detect ridge endpoints.

3 Results

Figure 2 shows the original fingerprint image and the extracted IMFs. The higher-order IMFs successfully capture the fine ridge structures. Figure 3 illustrates the enhanced ridge image, while Figure 4 demonstrates minutiae detection.

Figure 1: Original fingerprint image.

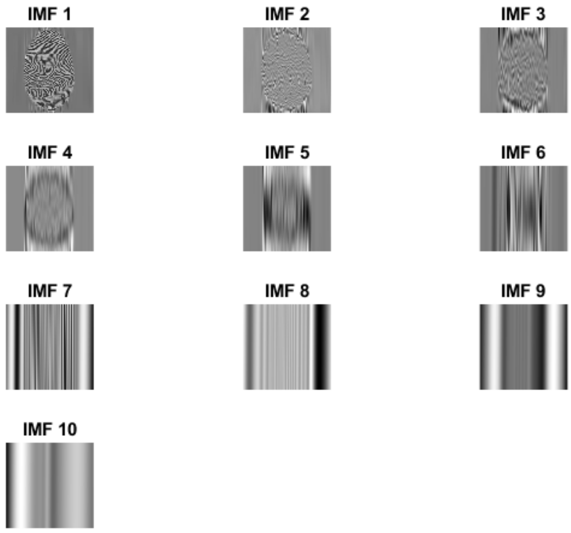

Figure 2: Sample IMFs obtained using EMD.

Figure 3: Enhanced ridge features from selected IMF.

Figure 4: Detected minutiae points (red markers).

4 Discussion

The results highlight the effectiveness of EMD in decomposing fingerprint images and isolating ridge structures. Compared to traditional frequency-domain methods, EMD provides a fully data-driven decomposition, making it robust against variations in fingerprint quality. However, challenges remain, particularly in noisy images where IMF selection may be ambiguous. Additionally, minutiae detection using simple morphological operators may result in spurious points.

5 Conclusion and Future Work

This work demonstrates a complete fingerprint feature extraction pipeline using EMD. The decomposition enhances ridge structures, while morphological analysis identifies minutiae points. Future work will explore Bidimensional EMD (BEMD), advanced ridge enhancement techniques, and robust minutiae matching algorithms for authentication.

References

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