Abstract

Biometric identification systems are increasingly deployed in large-scale applications, such as national identity programs, border security, financial authentication, and digital governance platforms. As database sizes grow to billions of enrolled identities, traditional one-to-many (1:N) matching strategies become computationally infeasible due to exhaustive search requirements and high-dimensional feature representations. This thesis addresses the fundamental challenge of designing scalable, transformation-invariant, and computationally efficient biometric recognition frameworks for fingerprint and iris modalities.

For fingerprint recognition, this work proposes an indirect feature extraction methodology derived from geometric relationships among minutiae points. Instead of relying on direct feature comparisons, which are sensitive to noise, partial capture, and distortion, invariant triangular features are encoded into a compact feature vector. These features are proven to be invariant to rotation, translation, scaling, and ordering, ensuring stability across varied conditions. Experimental validation on benchmark datasets demonstrates improved robustness and reduced computational complexity compared to conventional descriptors. Building upon this invariant representation, a novel indexing scheme is introduced. The method maps pairwise minutiae features into a discretised three-dimensional cubic space, enabling efficient candidate retrieval through a localized mini-cube search strategy. This structured indexing mechanism significantly reduces penetration rate while maintaining a high hit rate, making it suitable for large-scale fingerprint identification systems.

For iris recognition, a compact feature learning framework is proposed using a multi-branch channel-attentive convolutional neural network architecture. This approach focuses on learning discriminative features while minimising storage requirements, making it suitable for large-scale deployments. The architecture incorporates attention mechanisms to selectively emphasise informative channels, improving recognition performance under varying acquisition conditions. To further enhance the efficiency of iris recognition, this thesis explores scalable learning under limited data scenarios. A few-shot learning framework is developed using a deep convolutional feature extractor combined with Prototypical Networks for metric-based classification. Unlike traditional supervised classifiers that require retraining when new identities are enrolled, the proposed approach operates in an embedding space where classification is performed via distance to class prototypes. This design improves adaptability, supports dynamic enrolment, and demonstrates strong cross-dataset generalisation performance.

Keywords: Deep Learning, Computer Vision, Biometric Identification, Fingerprint Feature Extraction, Fingerprint Indexing, Iris Feature Extraction, Few-shot Learning