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Fingerprint Systems: Sensors, Image Acquisition, Interoperability and Challenges

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Abstract: The fingerprint is a widely adopted biometric trait in forensic and civil applications. Fingerprint biometric systems have been investigated using contact prints and latent and contactless images which range from low to high resolution. While the imaging techniques are advancing with sensor variations, the input fingerprint images also vary. A general fingerprint recognition pipeline consists of a sensor module to acquire images, followed by feature representation, matching and decision modules. In the sensor module, the image quality of the biometric traits significantly affects the biometric system's accuracy and performance. Imaging modality, such as contact and contactless, plays a key role in poor image quality, and therefore, paying attention to imaging modality is important to obtain better performance. Further, underlying physical principles and the working of the sensor can lead to their own forms of distortions during acquisition. There are certain challenges in each module of the fingerprint recognition pipeline, particularly sensors, image acquisition and feature representation. Present reviews in fingerprint systems only analyze the imaging techniques in fingerprint sensing that have existed for a decade. However, the latest emerging trends and recent advances in fingerprint sensing, image acquisition and their challenges have been left behind. Since the present reviews are either obsolete or restricted to a particular subset of the fingerprint systems, this work comprehensively analyzes the state of the art in the field of contact-based, contactless 2D and 3D fingerprint systems and their challenges in the aspects of sensors, image acquisition and interoperability. It outlines the open issues and challenges encountered in fingerprint systems, such as fingerprint performance, environmental factors, acceptability and interoperability, and alternate directions are proposed for a better fingerprint system.

Keywords: finger biometrics; sensor; image acquisition; ultrasonic sensing; interoperability

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1. Introduction

Biometric systems are pervasive in people's lives and assist to authenticate their identity reliably in many applications. Automated processes such as identification or verification are involved in a biometric recognition system where physical or behavioral characteristics of a biometric trait are used. Fingerprint identification is one of the most authentic approaches for human identification [1], where ridges and minutiae (ridge ending and branch) of the fingerprint information play a significant role in the recognition process [2–7]. The fingerprint is the oldest and a widely adopted biometric trait in forensic and civilian applications [8]. Until the use of DNA profiling, fingerprints were the central identification tool in criminal investigation. Later, it was widely used in government-related verification, for instance, integration of finger and face in passport and border control systems [9]. The fingerprint as a biometric modality is now prevalent in multiple applications related to civil activities such as attendance systems, access control, cellular authentication, e-commerce and information security applications [6,10].

The fingerprint biometric system has been investigated using contact prints and latent and contactless images ranging from low to high resolution [2]. Contact-based fingerprint