IDloop®

QuaPik

BSI Comissioned Project

Introduction

Quality and Testing Metrics (Qualitäts- und Prüfmetriken: QuaPik) was a study contracted by Germany's Federal Office for Information Security (Bundesamt für Sicherheit in der Informationstechnik: BSI) from 2023-2024.

The goal of QuaPik was to establish metrics and testing methodologies for evaluating rolled- and camera-captured fingerprints, as well as 2D- and 3D-camera systems and their technical capabilities.

These results lay the foundation for new quality metrics and methodologies that can be integrated into BSI technical guidelines and international standards. An additional result of the project was a software framework, a command line interface (CLI), and a graphical user interface (GUI), that allows the uploading of biometric data that can be then interactively visualized and evaluated. The software allows the BSI to directly implement the new quality metrics and methodology findings.

The project consortium was led by **IDloop GmbH** and consisted of the *Austrian Institute of Technology (AIT)*, *Darmstadt University (Hochschule Darmstadt: HDA)*, *Fraunhofer Institute for Applied Optics and Precision Engineering (Fraunhofer-Institut für Angewandte Optik und Feinmechanik: IOF)*, and *Mehnert GmbH*.

Testing methodology of rolled fingerprints

A rolled fingerprint, also called a nail-to-nail fingerprint, is when fingerprint data is collected from the entire skin pad of the finger. Because a larger portion of the finger's surface is captured in a rolled fingerprint in comparison to a flat fingerprint (see Figure 1), rolled fingerprints are preferred (and usually required) by law enforcement and in the criminal justice system. Rolled fingerprints provide a more complete set of fingerprint features, while flat fingerprints can miss critical details that may exist near fingerprint edges, making fingerprint matching more difficult.

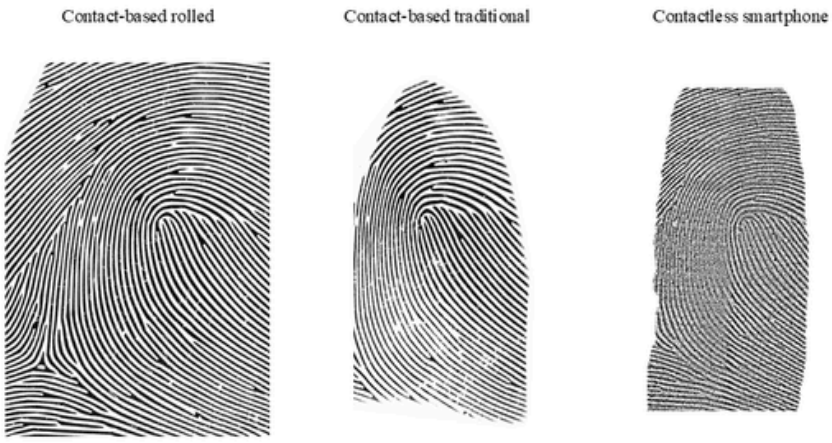

Figure 1: A contact-based rolled fingerprint, a contact-based traditional fingerprint, and a contactless fingerprint from a smartphone.

Currently, the standard is to collect rolled fingerprints on contact-based 2D scanners, where the finger is pressed onto a surface and physically rolled side-to-side, from nail-to-nail, to obtain contact with the entire fingerprint surface. However, the **movement of rolling the finger can introduce artifacts into the image**, such as smearing of the fingerprint or introduction/change of minutiae. Therefore, an aspect within the project was to **characterize how such artifacts can affect the accurate representation of the fingerprint**. To accomplish this, a 2D rolled fingerprint was evaluated against a true representation of the 3D finger (commonly called a "ground truth").

To establish ground truth representation of a fingerprint, synthetic 3D finger models were developed and evaluated for likeness to real fingers[1]. Next, multiple 3D systems were used to image the surface of the synthetic finger models. The 3D surface data from the 3D models was transformed into 2D renderings using mapping algorithms. Finally, the 2D renderings were compared with the 2D rolled fingerprints taken from traditional 2D scanners. This comparison resulted in the establishment of quality and error metrics for the 2D recording of rolled fingerprints (see Figure 2).

[1] Ruzicka, L., Strobl, B., Bergmann, S., Nolden, G., Michalsky, T., Domscheit, C., Priesnitz, J., Blümel, F., Kohn, B., & Heitzinger, C. (2024). Toward Synthetic Physical Fingerprint Targets. Sensors, 24(9), 2847. https://doi.org/10.3390/s24092847

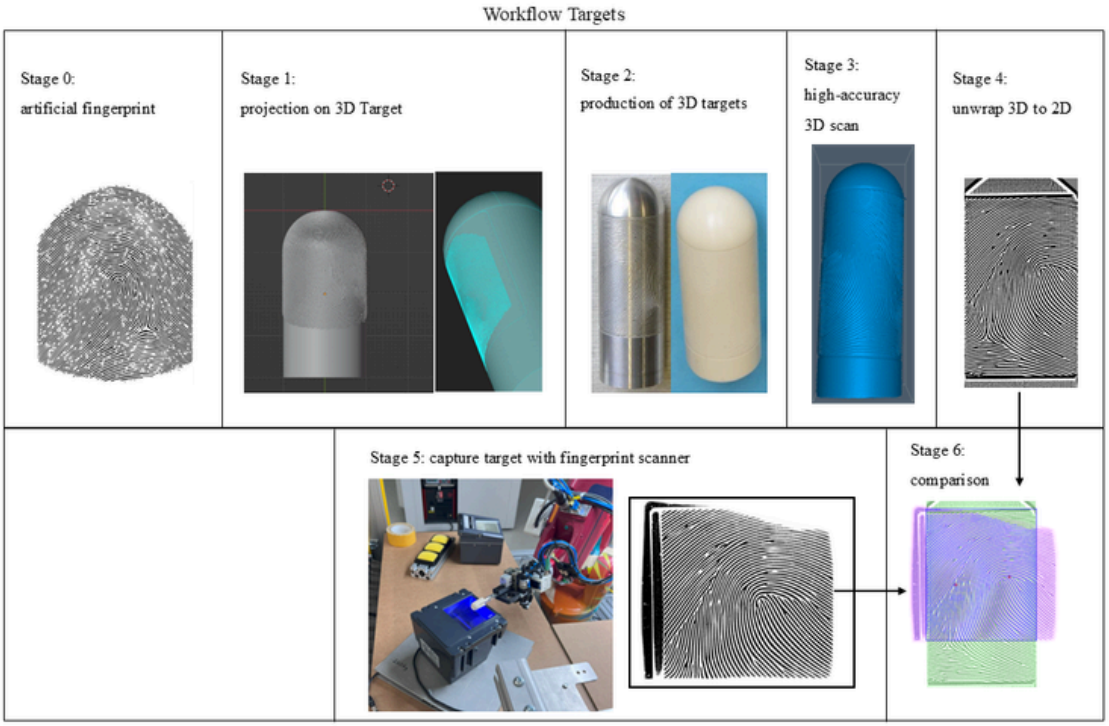

Figure 2. Diagram of the workflow: the artificial fingerprint is projected onto a 3D target. The 3D target is then produced, and a high-accuracy 3D scan is made of the target. The 3D data is unwrapped to 2D data (our 'ground truth'). A rolled fingerprint of the 3D target is then compared with our 'ground truth'.

Development and construction of an automatic fingerprint acquisition device

When evaluating rolled fingerprints, the accuracy of the fingerprint scanners acquiring the print must be considered. Since there are several parameters to consider during the acquisition of rolled fingerprints, the evaluation of a scanner's accuracy is not trivial. The rolling process requires hand and arm movement, introducing variation in rolling speed, in the applied pressure of the finger on the scanner, and in the angle the finger is presented. All these factors can change the resulting fingerprint image and therein lies the challenge: decoupling a scanner's performance from the influence of human behavior.

When different devices are compared against each other, it is challenging for humans to reliably reproduce the rolling process and eliminate movement variations. Therefore, a robotic measurement apparatus that mimics the human motion of rotating a finger on a surface for a rolled fingerprint capture was designed and constructed. Together with the synthetic 3D finger targets already developed, a **method and system for fully automating rolled fingerprint acquisition was established (Figure 3), thereby facilitating rolled fingerprint scanner evaluation by allowing identical rolled fingerprint motions to be performed on different scanners**.

Figure 3. Experimental set-up: a robotic arm wielding a finger target for fingerprint acquisition with two contact-based 2D fingerprint scanners.

In contrast to human subjects testing fingerprint scanners, the fully automated testing set-up allowed for the control of all movement parameters. Therefore, the scanner itself, its repeatability, accuracy, reaction to disturbances, etc. now can all be quantified in a standardized manner to obtain an accurate appraisal of device quality.

Testing methodology of contactless fingerprint acquisition

Contactless fingerprint capture has distinct advantages over contact-based capture. In comparison to contact-based scanners, fingerprints acquired with contactless scanners can be more hygienic (less likely to transfer bacteria, viruses, or chemicals between users), more robust and reliable (no latent prints left on the surface), faster (no contact to the scanner's surface is necessary and no surface cleaning needed between users) and can reduce wear-and-tear on the scanning device overall. Additionally, capturing contactless fingerprints using a smartphone camera as a fingerprint scanner is especially attractive because of the widespread use of smartphones.

The quality of the fingerprint captured by a contactless smartphone fingerprint scanner depends on the internal imaging system of the smartphone and the post-processing of the finger images. However, smartphone camera optics and internal image processing are usually not fully disclosed by the manufacturers, therefore, it cannot be assumed that the final fingerprint image is a true representation of the fingerprint. Taking this uncertainty into account, part of the project **developed reference-based and non-reference-based quality metrics for fingerprint images captured with smartphones**.

The technical requirements, test metrics and methodologies for evaluating smartphone camera systems were derived with the aim of interoperability with legacy, contact-based prints. Therefore, smartphone camera systems were also evaluated to determine if the resulting images were good enough to use, for example, in verification. Additionally, the image specifications and quality metrics were tested on images created by the smartphone camera and using the synthetic finger targets developed in the first part of the project (Figure 4). The results of the testing led to the quantification of detection, evaluation, and distortion correction in smartphone cameras due to finger geometry, camera optics and internal image processing. As a result, in certain application scenarios and environmental conditions, fingerprints acquired by contactless smartphones fingerprint scanners may not provide sufficient quality and reliability.

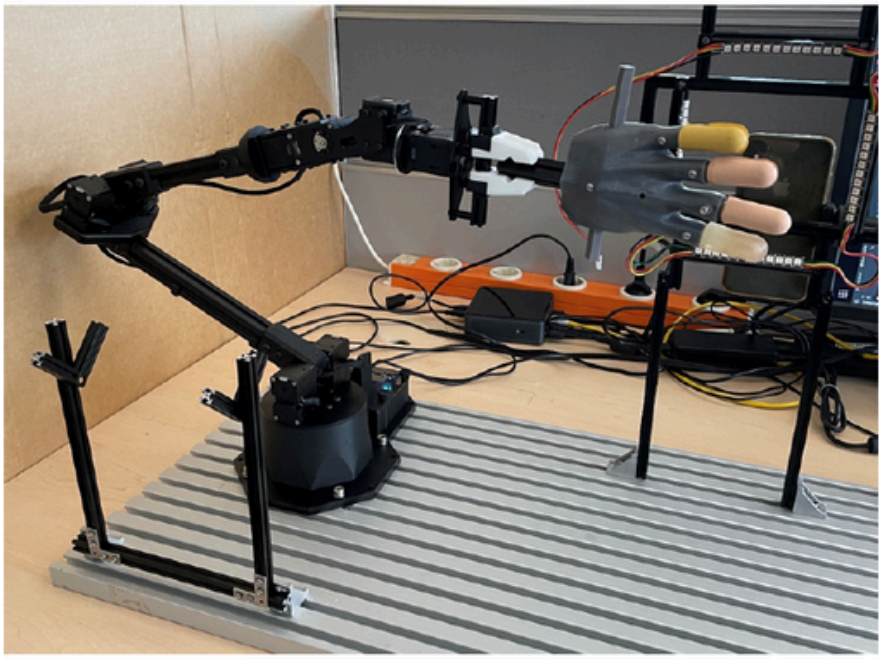

Figure 4. Testing set-up: the robotic arm is holding a hand with synthetic fingers in front of smartphone for contactless fingerprint capture.

Testing methodology for 2D and 3D camera systems

Biometric facial recognition systems are currently deployed in diverse environments, such as locations with low ambient light or high glare. Furthermore, the systems themselves are diverse, as facial recognition can be performed by both 2D and 3D camera set-ups. Therefore, **a part of the project established technical requirements and a testing methodology for biometric facial recognition performed by 2D and 3D camera systems.**

With the benchmark being 1:1 face verification/authentication with sufficient accuracy, the minimum requirements for 2D and 3D cameras were defined. The influence of external interference factors, such as varying lighting conditions (Figure 5) and motion, were evaluated on both the 2D and 3D camera systems. Additionally, a comprehensive test methodology was developed to evaluate biometric facial recognition with 2D and 3D camera systems.

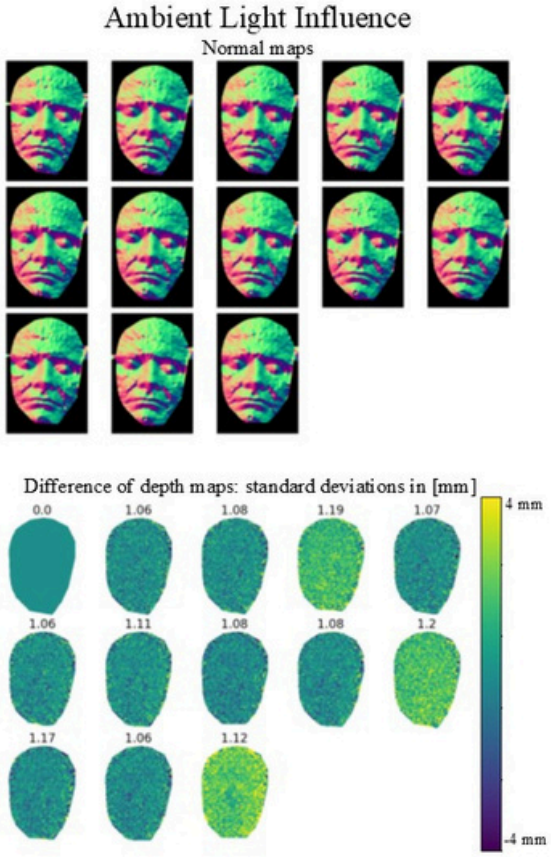

Figure 5. Facial 3D image results captured with a time-of-flight camera system under varying ambient light conditions. The upper panel shows the visualizations of the normal maps of face scans. In the lower panel, the differences of depth maps are shown with respect to the standard illumination case. The number above each image refers to the standard deviation in millimeters.

Key Takeaways

The BSI is dedicated to thoroughly evaluating biometric systems to ensure that they conform to the highest security standards. Prior to QuaPik, there were no adapted testing methodologies available specifically for rolled fingerprint scanners, smartphone camera-based fingerprint scanners or 3D facial scanners. Upon the completion of QuaPik, quality and testing metrics were developed in these three areas with the intention to integrate the results in current technical guidelines and standards. These results will help to establish comparability of biometric scanning devices from different vendors. Furthermore, QuaPik results are the first steps towards enabling interoperability of fingerprints taken with different methods (contact-based, contactless, rolled and pressed).

As consortium leader, IDloop demonstrated its skills in understanding, developing, and applying common standards for biometric systems throughout the project. Using technical knowledge combined with analytical skills, IDloop envisions contributing to similar projects in other biometric modalities, such as iris-scanning, vein patterns, and palm-scanning, in the future. IDloop fully supports the high standards that BSI perpetuates in the field of biometrics and is proud to help advance these standards through testing and research.

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