

Comparative Study on Fingerprint Recognition Systems – Project BioFinger

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Abstract: This paper describes a comparative study on fingerprint recognition systems – the project BioFinger. The goal of this study is to investigate the capability characteristics of biometric systems in the ongoing discussion regarding integration of biometric features in personnel documents such as IDcards and Visa application documents. Thus the designed test has the focus on performance testing of selected algorithms and systems with dedicated investigations on side effects such as independence of matching rates and results from the scanning device or dependability of received operator characteristics from aging effects. The project is carried out in close collaboration between Federal Bureau of Criminal Investigation (Bundeskriminalamt, BKA), the Federal Office for Information Security (Bundesamt für Sicherheit in der Informationstechnik, BSI) and the Fraunhofer-IGD.

Introduction

Biometric fingerprint recognition systems are the most common used biometric technology due to their long tradition. Fingerprint identification systems have been developed for more than hundred years and the identification of persons through their unique fingerprint [PAN01] is widespread in criminal investigations. Nowadays international criminal investigation offices are using standardized data formats [NIST00] to support the exchange of fingerprint images among distributed Automated Fingerprint Identification Systems (AFIS). Furthermore biometric fingerprints recognition sensors are well suited for convenience applications in the consumer market in mobile phones or Personal Digital Assistants (PDAs). The sensors are in general extremely small in their size and inexpensive to produce and thus well suited for mass production.

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In the discussion on anti-terror measures the German legislation does now allow the inclusion of further biometrical features in ID cards and passports, in order to verify the identity of an ID card holder. The goal of the project BioFinger [BIOF03] is to analyze potential constraints for the implementation of the new legal situation [BMI02]. Therefore this study should investigate the capability characteristics of biometric systems or their components. In contrary to International Competitions for Fingerprint Verification Algorithms [FVC00, FVC02] only those systems were considered in this study that are commercially available on the German market and do provide adequate product support. Furthermore, both the underlying hardware respectively sensors and used algorithms are investigated with respect to their performance in the verification scenario. This paper reports on the series of tests, that were designed recently. One major objective of the study is to conduct a biometric performance testing of selected algorithms and systems. As such the independence of matching rates and results from the scanning device is of high importance. For the potential operator as replacement of components in large numbers is cost-intensive and thus not feasible. Further interest is given to aging effects. As personnel documents are valid up to ten years, the constancy of recognition rates should be verified, if current impressions are matched against outmoded templates.

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Goals of the Investigation

According to the *Best Practices in Testing and Reporting of Biometric Devices* [BP02] the conducted investigations in BioFinger may be classified as a technology investigation, in order to identify the most suitable component of competing sensors and algorithms. The overall goal of this study is to analyze whether fingerprint recognition systems or combination of components can fulfill the requirements for fingerprint verification in an large scale passport or visa application scenario. Thus the investigation should prove that verification results are within a given tolerance bound. As it is highly desirable to exchange single components of a biometric system, the impact of the individual components (sensor, preprocessing, feature extraction) should be analyzed such that performance measures are available for numerous combinations of components. Performance measures are given in compliance with the *Best Practices* document [BP02] namely

- False Match Rates (FMR) / False Accept Rates (FAR)
- False Non Match Rates (FNMR) / False Reject Rates (FRR)

while further reporting of the results is given with Receiver Operating Characteristics curves (ROC) and Detection Error Trade-Of Curves (DET) which are a well established standard to describe the capabilities of a detector in a pattern recognition system. Moreover the ROC curves provide independence of the used threshold in the special system and report the overall performance of the fingerprint system (see figure below).

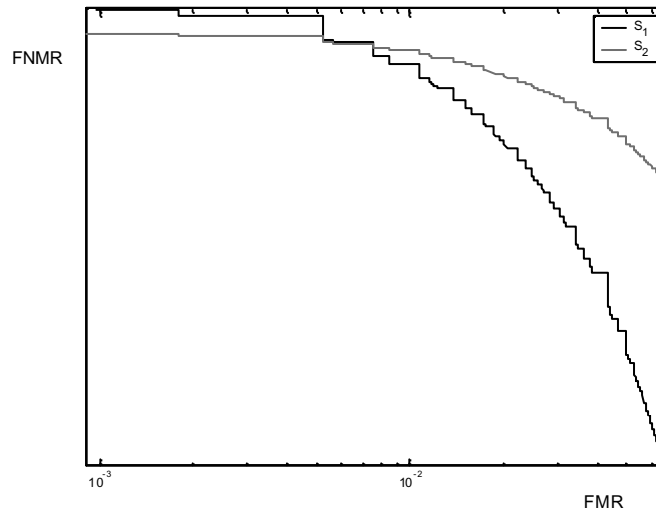


Figure 1 ROC curves for two different sensors.

The investigations in the study BioFinger are addressing the following questions:

1. What is the impact of the sensors on the matching score? – assuming that all sensors are generating images under comparable environment conditions.
2. What is the impact of the fingerprint image quality on the matching score? – assuming that the one sensor does provide various image qualities caused by changing environmental conditions such as dirty sensors or unusual dry or moist skin conditions of the test persons.
3. What is the impact of a feature extraction on the matching score? – assuming that a *standardized sensor* (scanning device) has been in use.
4. What is the impact of the matching algorithm (MSA) on the score?

Data Collection

As for the data collection the BioFinger study is conducted on three independent data collections. For all three segments of the data base no synthetic fingerprints were accepted [CAP00]. The major data base is composed with fingerprints from numerous volunteers that provided multiple impressions of eight finger (the small finger of the left and right hand are not considered in the investigation). In order to address the investigation target – as described in the previous section – volunteers are expected to provide the impression to all available sensors. The data collection is repeated at various milestones in the project. Thus statistical independence of the probes is improved and potential impacts with varying environmental conditions may be detected.

A second database is composed with fingerprints from more than 100 persons, whose impressions were recorded for a long period comparable to the current lifetime of personal documents (10 years). From a theoretical point of view it is common sense in the literature that aging may not impact the characteristics of fingerprints [HEI27]. However for practical purposes, scaling effects of minutiae based matching algorithms may render older templates useless. This second database should give some insight, were for practical applications with low cost scanner practical threshold should be defined—if there is any such threshold.

The third collection is composed of impressions from different persons that show in their fingerprints similar features in terms of specific combinations of arches, delta and whirls. The persons providing these fingerprints can be considered as biometric twins and are of high interest for the investigations in BioFinger as they represent a worst case test for the algorithms and may cause numerous False Matches. The performance of the used algorithms will be investigated regarding this critical data set by measuring the FMR(t) as a function of the threshold t .

Biometric Performance Testing in BioFinger

At the time of this writing the set up of the BioFinger benchmarking laboratory is still ongoing. Therefore we can report here only on the intended performance tests, that have been designed so far.

1.) Sensor Impact

The given application scenario with possibly large number of enrolment stations requires, that acceptable performance rates can be obtained with low cost sensor hardware. Therefore the first experiment is designed such that for each sensor a DET curves is elaborated based on the three databases. For this experiment the choice of the feature extraction algorithm and the choice of the matching score algorithm is assumed to be a fixed parameter to enable a relative comparison of the devices.

2.) **Image Quality Impact**

It can be assumed that the quality of fingerprint images has a significant impact on Matching Scores of the biometric system. While reliable metrics for the comparable quality measures of a fingerprint image are hard to define² adequate indicators for the level of quality are somehow straightforward and may be derived from signal processing. On the one hand the geometric resolution can be indicated in terms of dots per inch (DPI) describing the scanning capabilities of the sensor. On the other hand from the signal processing domain we may apply indicators, that describe the dynamic of the image signal as for instance approximated with measures derived from the image histogram or signal-to-noise-ratio of the image (SNR). Fortunately for our experiments we can simulate specific image characteristics with the help of signal processing toolkits, that provide resampled images in low resolution or images with poor image dynamic. Thus we can generate a test set with continuously degrading image quality and measure the system performance rates accordingly.

3.) **Feature Extraction Impact**

The characteristics of the feature extraction component are crucial for the entire systems performance. Detailed investigations of the feature extraction impact require sensors that can be operated with a variety of feature extraction methods and also one selected matching score algorithm. It is intended to perform this test with the most capable sensor, that was determined in test 1.) in combination with an mean value for the matching score as derived from all MSA cooperating with the feature extraction component under test.

4.) **Matching Score Algorithm Impact**

For many vendors of biometric system the matching algorithm can not be separated from the feature extraction component and consequently only for a very limited number of systems it is possible to provide receiver operating characteristics in dependence of varying score algorithms. However for those components that do provide a proper interface a test unit is scheduled that operates on the best performing sensor data and gives score algorithm characteristics based on average calculations for interoperable feature extraction algorithms.

² Metrics for fringerprint image quality are currently subject to discussions within the standardization body ISO-SC37

Conclusion

This paper introduces the project BioFinger and the application scenario that has defined the scope of this project, namely to investigate biometric sensors and algorithms and systems. In order to reach the goals of this project three independent databases are currently under composition with fingerprints from various sources and volunteers. As separability of system components is a high priority in the underlying application scenario four test tracks have been designed to elaborate the impact of sensor properties, image degradations, feature extraction methods and matching score algorithms. Results of the investigations in the BioFinger project may be expected for the third quarter 2003.

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