Available online at www.sciencedirect.com
ScienceDirect
Forensic Science International 167 (2007) 154–159
Forensic Science International
www.elsevier.com/locate/forsciint

Multimodal biometrics for identity documents (MBioID)

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Received 9 June 2006; accepted 14 June 2006
Available online 4 August 2006

Abstract

The MBioID initiative has been set up to address the following germane question: *What and how biometric technologies could be deployed in identity documents in the foreseeable future?* This research effort proposes to look at current and future practices and systems of establishing and using biometric identity documents (IDs) and evaluate their effectiveness in large-scale developments.

The first objective of the MBioID project is to present a review document establishing the current state-of-the-art related to the use of multimodal biometrics in an IDs application. This research report gives the main definitions, properties and the framework of use related to biometrics, an overview of the main standards developed in the biometric industry and standardisation organisations to ensure interoperability, as well as some of the legal framework and the issues associated to biometrics such as privacy and personal data protection. The state-of-the-art in terms of technological development is also summarised for a range of single biometric modalities (2D and 3D face, fingerprint, iris, on-line signature and speech), chosen according to ICAO recommendations and availabilities, and for various multimodal approaches. This paper gives a summary of the main elements of that report.

The second objective of the MBioID project is to propose relevant acquisition and evaluation protocols for a large-scale deployment of biometric IDs. Combined with the protocols, a multimodal database will be acquired in a realistic way, in order to be as close as possible to a real biometric IDs deployment. In this paper, the issues and solutions related to the acquisition setup are briefly presented.

Keywords: Biometrics; Multimodality; Identity documents; Electronic passport; Acquisition protocol; Evaluation protocol

1. Introduction

The issues associated with identity usurpation are currently at the heart of numerous concerns in our modern society. Establishing the identity of individual person is recognized as fundamental to the numerous administrative operations. Identity documents (IDs) are tools that permit the bearers to prove or confirm their identity with a high degree of certainty. In response to the challenges posed by theft or fraudulent use of IDs and security threats, a wide range of biometric technologies is emerging, covering, e.g. face, fingerprint and iris recognition. They are also proposed to enforce border control and check-in procedures. These are positive developments and they offer specific solutions to enhance document integrity and ensure that the bearer designated on the document is truly the person holding it. Biometric identifiers – conceptually unique attributes – are often portrayed as the panacea for identity verification.

In many countries, IDs is increasingly associated with biometry. Most modern identity cards are proposed associated with chips embedding biometric identifier. Under the impetus of the United States of America, a large number of countries (all EU countries) are developing and piloting if not delivering biometric passports. The International Civil Aviation Organization (ICAO, a United Nations specialised agency) issued specific recommendations for travel documents inviting members to use facial images and optionally fingerprint or iris as biometric modalites. The Swiss government is currently conducting a pilot study testing and evaluating the next generation of passport developed according to the ICAO recommendations.

2. Purpose of the initiative

This project has been triggered by the frenetic technological promises and claim of simplicity of biometric technology

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doi:10.1016/j.forsciint.2006.06.037

applied to IDs. We believe that the deployment of such technology is a complex task that should receive proper research attention from various perspectives (technological, economical and legal). The MBioID research initiative aims at addressing the following germane question: *What and how biometric technologies could be deployed in identity documents in the foreseeable future?* This research proposed to look at current and future practices and systems of establishing and using IDs and evaluates their effectiveness in large-scale deployments it takes advantage of an acquired multimodal database specifically designed for exploring IDs biometric recognition efficiency. Indeed, most research today has been focused on studying single modalities independently, making difficult comparisons between various biometric solutions; a multi-modal approach is favoured in this initiative.

3. MBioID research report [1]

At the outset of the initiative, it was felt that all relevant information should be gathered in a review document, in order to establish the current state-of-the-art related to the use of multimodal biometrics in an IDs application. In such a rapidly evolving field, it is of paramount importance to conduct a state-of-the-art review to guide our next steps into the elaboration of acquisition and evaluation protocols and the establishment of a multimodal biometric research database. The MBioID research report [1] gives the main definitions, properties and the framework of use related to biometrics, an overview of the main standards developed in the biometric industry and standardisation organisations to ensure interoperability, as well as some of the legal framework and the issues associated to biometrics, such as privacy and personal data protection. The state-of-the-art in terms of technological development is also summarised for a range of single biometric modalities (face, fingerprint, iris, on-line signature and speech), chosen according to ICAO recommendations and availabilities, and for various multi-modal approaches. Discussion of the cost and whether or not the deployment of biometrics in this context will ensure adequate security or improves border controls is one that requires political involvement. Such considerations have been left out of the report. In the following sections, we present briefly the main elements of this research report.

3.1. Biometric modalities

The state-of-the-art in the different biometric modalities is summarised in this section, according to the following criteria: error rates, inter-session variability, universality, noise sensitivity, architectural features such as feasibility of distributed template storage, sensor cost, choice of vendors, pre-existing smartcard match-on-card implementations, susceptibility to covert acquisition. We roughly classify each attribute into low (L), medium (M), or high (H) and present the results in Table 1 to the best of our knowledge.

It should be strongly emphasised that, at least in terms of biometric performance metrics such as error rates or inter-session variability, these results are comparing evaluations made using very different populations and protocols. Therefore, Table 1 is at best a broad approximation and will need to be confirmed through rigorous experiments using a controlled population and corresponding acquisition and evaluation protocols.

Table 1
Broad summary of modalities according to several criteria

Criterion	2D face	FP	Iris	Signature	Speech
Error rates	M–H	L	Very L	L	M–H
Inter-session variability	M	L	Very L	M	M–H
Universality	H	H	H	M–H	M–H
Risk of failure to enroll	L	M–L	L	L	L
Noise sensitivity	H	M–L	M–L	L	H
Time to enroll	L	L	L	M	M
Distributed templates	H	H	H	H	H
Sensor cost	M–L	L	H	M	L
Choice of vendors	H	H	Very L	M	H
Match-on-card implementation	L	H	L	None	None
Covert acquisition	H	M–H	L	M–L	H

3.2. Multimodality

For IDs application, multimodality may be an effective tool to reduce the Failure to Enroll (FTE) rate. The sequential use of multiple modalities guarantees that the non-enrollable population is reduced drastically. Furthermore, sequential use of modalities permits fair treatment of persons that do not possess a certain biometric trait. We also aim at investigating multimodal fusion with partial templates, at the score and decision levels, to provide better privacy protection to the enrolled users, as partial templates by themselves (i.e. not in combination) would yield very low identification power.

3.3. International standards

International standards relating to biometrics are maturing quickly and many are already available. They support interoperability and data exchange between applications and systems, thus avoiding problems and costs stemming from proprietary systems. For IDs such as passports, international standards, such as those proposed by the International Organization for Standardization (ISO) [2,3] and the International Civil Aviation Organization [4], are essential so that biometric verification can be performed, independently to the location of the transaction.

3.4. Privacy, legal and societal aspects

As part of the feasibility study and before deployment, a full privacy impact assessment should be carried out, under the leadership of the states' data protection commissioners.

The collection and the process of biometric data should be only conducted in accordance with the requirements of data protection basic principles (e.g. lawfulness, good faith, purpose-link, data security, proportionality and rights of persons concerned). An important issue to address is whether or not biometrics in IDs should serve for verification or their scope could be extended to incorporate identification with a central database.

3.5. Integration to identity documents

Technical requirements for the integration of biometrics to IDs were proposed by the International Civil Aviation Organization [5–9] and the National Institute of Standards and Technology (NIST) [10,11]. Furthermore, the European Council has adopted since 2003 six regulations and proposals related to the introduction of biometrics in IDs [12–17]. All European countries have to follow these requirements for their biometric IDs projects.

4. MBioID database

The second objective of the MBioID project is to propose relevant acquisition and evaluation protocols for a large-scale deployment of biometric IDs. The MBioID acquisition protocol has been adapted to a multimodal database size where the number of transactions and enrollment acquisitions has been chosen in order to estimate reliably the error rates of each modality to a certain level of confidence. Furthermore, the acquisition procedure, which depends on the acquisition environment, is also conducted in a realistic way, in order to be as close as possible to a real biometric IDs deployment. Finally, when consistent with our usage scenarios, the acquisition devices and the acquisition procedure of the MBioID database were chosen in order to be as interoperable as possible with publicly available databases. Indeed, many biometric databases exist, with virtually every research laboratory in the field defining and recording their own dataset. Due to limited resources, this approach has led to the development of a vast number of small databases, which taken on their own, can often not be used to predict performance on large populations due to the large confidence intervals induced by small sample sizes. The definition of this database follows the principle established by the MyIDea database [18] that interoperability with publicly available databases is a good way to increase the number of subjects with very limited investment. Therefore, where possible, the MBioID database has been made compatible with leading multimodal and monomodal databases (such as CiTER, MyIDea, XM2VTS, CASIA, BIOMET and MCYT) so that these can be extended with our data and vice-versa.

The political choice of using biometric information in travel documents of a specific nation is echoed on the whole population of this nation. In order to evaluate this large-scale introduction, a pilot project, on a smaller scale, has to be conducted [19]. Two databases are needed for such an evaluation: a background and a search database, for simulating the system database and the applicants, respectively. The background database has to contain at least several hundred thousand subjects.[1] Both data sets have to be statistically representative of the relevant population (in this case the whole population of the nation) and be large enough in order to infer validly the results of the test evaluation to the potential population of the future application. In order to satisfy this requirement, either a random sampling of subjects from the relevant population should be performed or a sampling using quota (i.e. sex, age, social and professional category, demography, etc.) which represents best the characteristics of the population. For the MBioID database, all these restrictive recommendations cannot be met; most of our contributors are staff of student volunteers. However, we have chosen a priori the number of subjects and the number of acquisition per subject we need for evaluating specific errors rates, in a specific confidence level, following the methodology proposed by Schuckers [20].

Table 2
Content of the database for one session

Modality	Enrollment data	Transaction data
Face 2D	5	5
Face 3D	5	5
Fingerprint	4×5	4×5
Iris	2×5	2×5
On-line signature	10	10
Speech	10 (~1 min)	10 (~1 min)

Schuckers proposes a sample size calculation in function of the error rate to estimate, the maximum error rate allowed, the number of acquisitions per subject, the confidence level and a correlation parameter. This correlation parameter is estimated for face and fingerprint from the data in Ref. [21]. Those for 3D face, iris, signature and speech are guessed from our experience. The program (and the documentation related to this tool) is publicly available.[2]

The acquisition procedure is conducted in two different sessions, separated in time, where both enrollment and transaction data will be acquired. According to the methodology described above, the level of performance that we want to achieve for each modality and the fact that about 120 subjects will be able to be acquired, Tables 2 and 3 presents for each modality the content (enrollment and transaction data) of the MBioID database, as well as the expected and maximum expected errors for a specific confidence level in transaction conditions.

4.1. Environmental conditions

The enrollment procedure, as it is the case with the Swiss biometric passport, will be set in enrollment centres, in order to obtain biometric data of best quality. Indeed, each biometric data can be acquired in standardised conditions, the same standardised conditions in each enrollment centre. Furthermore, "active" operator will probably be present during the acquisitions, in order to avoid any variability introduced by

[1] Indeed, "background databases smaller than a few hundred thousand people are not suitable for reliable speed/throughput extrapolation" [19].

[2] PRESS calculation tool available online at http://it.stlawu.edu/~msch/biometrics/downloads.htm.

Table 3
Expected and maximum expected FAR and FRR in transaction conditions

Modality	Expected transaction FAR (%)/FRR (%)	Maximum expected transaction FAR (%)/FRR (%)	Confidence level (%)
Face 2D	2.0/10.0	2.3/13.3	99
Face 3D	1.5/6.0	1.8/8.8	99
Fingerprint	0.4/5.0	0.4/7.1	99
Iris	0.0/0.8	0.0/2.1	99
On-line signature	4.0/5.0	5.5/6.8	99
Speech	4.0/4.0	4.3/5.3	99

each subject. Here are some examples of standardised conditions: position, distance to sensor, environmental noise, acquisition noise, etc.

The transaction procedure will be set at border controls, such as airports, ports and embassies. The environmental conditions of these places will be less controllable than the enrollment centres. ‘‘Passive’’ operators will also be present during the acquisition procedure, but will probably not have a sufficient skill level for controlling this stage. Furthermore, some environmental conditions cannot be standardised at border control, such as position, distance from sensor, environmental noise, acquisition noise, etc.

In order to acquire the data of the MBioID database in a realistic way (mimicking the operational scenario described above), the environmental conditions will be recreated to some extent. The enrollment and the transaction acquisitions will be performed in a same room, in which these environments will be recreated. For the enrollment acquisitions, an ‘‘active’’ operator will give all the necessary instructions during the acquisition procedure to the subjects. Each acquisition will be standardised in a particular way, identically for all subjects during the enrollment procedure: seated, without background noise, standardised illumination, without glasses, etc. For the transaction acquisitions, the ‘‘passive’’ operator will not give any instruction during the acquisition procedure, but all devices will have a display board with all necessary written instructions. Each of these latter acquisitions will be less controlled, but conducted identically for all subjects during the transaction procedure: standing, with jacket, window curtain open, with glasses, windows and door opened, etc.

4.2. Acquisition devices

In a large-scale biometric deployment, such as IDs, each acquisition device should follow the standards proposed by international organisations, in order that all data acquired be interoperable with the acquisition devices selected by other countries. The acquisition devices used for the MBioID project, and thus the acquired data, meet the standards and requirements of international organisations (e.g. ISO and ICAO). Table 4 presents the acquisition devices used for the MBioIDdatabase.

4.3. Acquisition protocol

Biometric data are personal data and have thus to be treated in an appropriate way. A ‘‘personal data protection document’’ is signed by each subject in order to give them the guarantee that their data will be anonymised, that these data will only be transmitted to other institutions for research purposes only if the concerned country benefits from a law on data protection at least equivalent to that existing in Switzerland and that they have a challenge right if they want to be removed from the database. The MBioID acquisition protocol for each modality and each session is as follows.

4.3.1. 2D face

- *Enrollment session*: Five frontal face shots will be taken using a high-quality Fuji Finepix S2 pro camera. Three flashes will be used to remove shadows and ensure even lighting. The background, distance, facial expression, head pose and illumination will be strictly controlled. The shots will comply with ISO photograph regulations.
- *Transaction session*: Five frontal face shots will be taken using the same camera. The background will not be controlled, the distance to the camera will be roughly indicated using a mark on the ground, no pose requirements will be in place and the illumination will be provided using the standard energy-saving light bulbs in use in the room.

4.3.2. 3D face

- *Enrollment session*: Every subject will be enrolled five times with the A4Vision technology, in the best possible conditions (e.g. sitting position, without glasses, hat, etc.). The raw data corresponding to these enrollments will be automatically stored.
- *Transaction session*: Five raw data recordings (called ‘‘attempts’’) per subject will be acquired additionally in a less controlled way. These attempts will be used during the evaluation process as transaction data. If the subject is wearing glasses, five additional recordings, with glasses, will be acquired during the session.

Table 4
Acquisition devices used for the database

Modality	Model	Applicable standard
Face 2D	FinePix S2 pro (FujiFilm)	ISO/ICAO
Face 3D	A4Vision	ISO
Fingerprint	ACCO 1394 (SHB)	FBI/ISO
Iris	BM-ET 300 (Panasonic)	ISO
On-line signature	Wacom Intuos 2 A4/Intuos 2 inking pen	None
Speech	AT3031 (audio-technica)	None

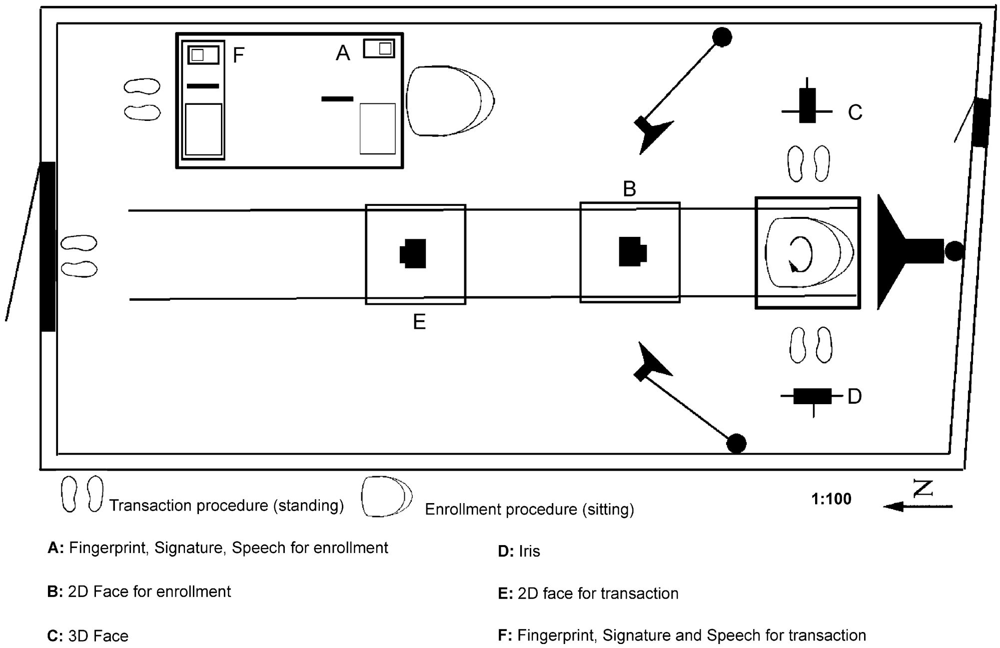

Fig. 1. MBioID acquisition room.

4.3.3. Fingerprint

- *Enrollment session*: For both indexes and thumbs of each subject, five samples will be acquired in controlled conditions (e.g. sitting position, indication for the finger position on the acquisition device, support cleaning after each subject, etc.) with the Acco 1394 device of Smith & Heinmann Biometrics.
- *Transaction session*: Five additional samples of these fingers will be acquired in a less controlled way (e.g. standing position, no oral indication for the finger position, support not cleaned after each subject, etc.).

4.3.4. Iris

- *Enrollment session*: Five samples per eye will be acquired in controlled conditions (e.g. sitting position, controlled illumination conditions, etc.) for every subject with the BM-ET 300 camera of Panasonic.
- *Transaction session*: Five other samples per eye, in less controlled conditions (standing position, without any oral indication from the operator for the positioning, etc.), will be acquired. If the subject is wearing glasses, five additional transaction data, with glasses, will be acquired during each session.

4.3.5. On-line signature

- *Enrollment session*: Ten signatures will be required with a Wacom Intuos 2 A4 tablet with two inking pen. The angle of the writing tablet, as well as the seating height, can be freely adjusted by each subject to ‘‘what feels comfortable for writing’’. A sheet of paper is placed on the tablet to allow visual feedback and to give a usual feel to the friction between pen-tip and paper. Additionally, expert forgers will be trained to forge enrollment signatures using purpose-built software from the University of Fribourg [22].
- *Transaction session*: Ten signatures will be required. The angle of the writing tablet, as well as the height of the tablet, is fixed. The subject has to stand up to sign, and is told to keep his or her jacket on.

4.3.6. Speech

- *Enrollment session*: A group of 10 phonetically balanced sentences in French, followed by 2 PINs in French and 2 PINs in English will be recorded by an audio-technica AT3031 microphone. The user is seated, and the directional microphone is positioned laterally with respect to the mouth to prevent excessive pressure gradients on plosives. The distance to the head is kept constant during recording. The acquisition room is padded with absorbing foam to decrease its reverberation time.
- *Transaction session*: The same speech material is recorded, but the door (opening into an office corridor) and the window (opening on a busy road) are opened, and the distance to the microphone is not controlled.

4.4. Acquisition room

The MBioID acquisition room is illustrated below. Fig. 1 presents the relative positioning of the acquisition devices in the room and between them.

5. Database evaluation

The comparison process will be made offline, after the acquisition procedure. Commercial recognition systems and publicly available algorithms will be used for the evaluation of the MBioID database. The performance metrics which will be used are those proposed by Mansfield and Wayman [23].

6. Conclusion

The MBioID initiative proposes to look at current future practices and systems of establishing and using IDs and evaluates their effectiveness in large-scale deployments. At the outset of the initiative, it was felt the need for gathering, all relevant information for establishing the current state-of-the-art related to the use of multimodal biometrics in an IDs application. This research report [1] is publicly available on the European Biometrics Portal (http://www.europeanbiometrics.info). The proposal of relevant acquisition and evaluation protocols for large-scale deployment of biometric IDs is the second milestone of the initiative. Indeed, there is a need of realistic acquired data for the scientific community in order to impact the political choice about the modality(ies) choice, the performance requirements and the system architecture of a biometric IDs deployment. For this purpose, the MBioID project has started an acquisition procedure for a multimodal biometric database, conduced in a realistic way. These data will be available for the scientific community at the end of the acquisition step.

Acknowledgements

We take this opportunity to thank the University of Lausanne, the EPFL and the Foundation BCV, for the financial support to this research initiative. We also wish to thank Eric Dürst and Eric Sapin, for the setup of the acquisition room.

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