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Information technology — Biometrics — Multimodal and other multibiometric fusion

Technologies de l'information — Biométrie — Fusion multimodale et autre fusion multibiométrique

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 37, *Biometrics*.

This third edition cancels and replaces the second edition (ISO/IEC TR 24722:2015), which has been technically revised.

The main changes are as follows:

— the content of Clause 3 has been removed and ISO/IEC 2382-37 has been listed as a normative reference;

— to enhance information accessibility, symbol descriptors have been paired with clear descriptions;

— the structure of the document has been updated, and various editorial modifications have been made, in order to improve technical accuracy and bring the document in line with the most recent edition of the ISO/IEC Directives Part 2.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

Introduction

Some applications of biometrics require a level of biometric performance that is difficult to obtain with a single biometric measure. Such applications include the prevention of multiple applications for national identity cards and security checks for air travel. In addition, provisions are needed for data subjects who are unable to give a reliable biometric sample for some biometric characteristic types.

Use of multiple biometric measurements from substantially independent biometric sensors, algorithms or characteristic types typically gives improved technical performance and reduces risk. This includes an improved level of performance where not all biometric measurements are available, such that decisions can be made from any number of biometric measurements within an overall policy on accept/reject thresholds.

Of the various forms of multibiometric systems, the potential for multimodal biometric systems, each using an independent measure, has been discussed in technical literature since at least 1974.[22],[45] Advanced methods for combining measures at the score level have been discussed in References [15] and [16]. At the current level of understanding, combining results at the score level typically requires knowledge of both mated and non-mated score distributions. All of these measures are highly application-dependent and generally unknown in any real system. Research on the methods not requiring previous knowledge of the score distributions is continuing and research on fusion at both the image and feature levels is still progressing.

Given the current state of research into these questions and the highly application-dependent and generally unavailable data required for proper fusion at the score level, work on multibiometric fusion can in the meantime be considered mature. By intention, this document is not issued as International Standard, in order not to force industrial solutions to conform to the methodology described herein. Rather, the present edition of this document provides a mature technical description for developments of multibiometric systems. It also provides a reference on multibiometric fusion for developers of other biometric standards and implementers.

Information technology — Biometrics — Multimodal and other multibiometric fusion

1 Scope

This document provides descriptions and analyses of current practices on multimodal and other multibiometric fusion, including (as appropriate) references to more detailed descriptions.

This document contains descriptions and explanations of high-level multibiometric concepts to aid in the explanation of multibiometric fusion approaches including: multi-characteristic-type, multi-instance, multi-sensorial, multialgorithmic, decision-level and score-level logic.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 2382-37, *Information technology — Vocabulary — Part 37: Biometrics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 2382-37 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
multialgorithmic
using multiple algorithms for processing the same biometric sample

3.2
multibiometrics
automated recognition of individuals based on their biological or behavioural characteristic and involving the use of biometric fusion

3.3
multi-characteristic-type
multi-type
using information from multiple types of biometric characteristic

EXAMPLE Biometric characteristic types include: face, voice, finger, iris, retina, hand geometry, signature/sign, keystroke, lip movement, gait, scent, vein, DNA, ear, foot, etc.

3.4
multi-instance
requiring two or more instances of a biometric characteristic

EXAMPLE Iris (left) + Iris (right), Fingerprint (left index) + Fingerprint (right index).

Note 1 to entry: [SOURCE: ISO/IEC 2382-37:2022, 37.03.47, modified — Note 1 to entry has been removed and an Example has been added.]

3.5
multipresentation
using either multiple presentation samples of one instance of a biometric characteristic or a single presentation that results in the capture of multiple samples.

EXAMPLE Several frames from video camera capture of a face image (possibly but not necessarily consecutive).

Note 1 to entry: Multipresentation biometrics is considered a form of multibiometrics if fusion techniques are employed. Many fusion and normalization techniques are appropriate to the integration of information from multiple presentations of the same biometric instance.

3.6
sequential presentation
capturing biometric samples in separate capture events to be used for biometric fusion

3.7
simultaneous presentation
capturing biometrics samples in a single capture event to be used for biometric fusion

4 Overview of multimodal and other multibiometric systems

4.1 General

In general, the use of the terms multimodal or multibiometric indicates the presence and use of more than one characteristic type, sensor, instance and/or algorithm in some form of combined use for making a specific biometric identification or verification decision. The methods of combining multiple samples, comparison scores or comparison decisions can be very simple or mathematically complex. For the purpose of this document, any method of combination will be considered a form of "fusion". Combination techniques will be covered in Clause 5 of this document.

Multimodal biometrics were first proposed, implemented and tested in the 1970s.[22,45] Combining measures was seen as a necessary future requirement for biometric systems. It was widely thought that combining multiple measures could increase either security by decreasing the false acceptance rate or data subject convenience by decreasing the false rejection rate. These systems did not seem to advance into practical applications.

The use of fusion and related methods has been a key tool in the successful implementation of largescale automated fingerprint identification systems (AFISs), starting in the 1980s, and was further expanded upon with the introduction of automated biometric identification systems (ABISs) in the 1990s. Most methods of fusion discussed elsewhere in this document have been successfully implemented using fingerprints alone. Some of the ways that fusion has been implemented in AFISs include:

— image fusion (also known as sample fusion), where a single "rolled" image is created from a series of plain impressions on a livescan device;

— template fusion, where features extracted from several presentations are combined into a single template;

— multi-instance fusion, which uses fingerprints from all ten fingers;

— multipresentation fusion, which uses rolled and slap (plain) fingerprints;

— algorithm fusion for the purpose of efficiency (cost, computational complexity, and throughput rate), where comparators are generally used as a series of filters in order of increasing computational complexity. These are generally implemented as a mix of decision and score-level fusion;

— algorithm fusion for the purpose of accuracy (decreasing false accept rate and/or false reject rate, lessening sensitivity to poor-quality data), where comparators are used in parallel, with fusion of resulting scores.

The use of fusion has made AFIS and ABIS possible because of fusion's potential in improving both accuracy and efficiency.

Most work to date on multibiometrics has focused only on improving false acceptance and false rejection error rates. Some research work considers the use of multibiometrics to flexibly improve usability, security or accuracy.[61] Further, multibiometrics also aims at decreasing the overall failure-to-enrol rate (FTE) especially in biometric systems where data subject cooperation is not expected (e.g. video surveillance systems). Multibiometrics is an effort to produce a biometric decision even if only a subset of the expected biometric characteristic were captured.[63]

To further develop the understanding of the distinction among the multibiometric categories, Table 1 illustrates the basic distinctions among categories of multibiometric implementation. The key aspect of the category that makes it multi-"something" is explained below the table.

Table 1 — Multibiometric categories illustrated by the simplest case of using 2 elements

Category	Characteristic type	Algorithm	Instance	Sensor	Presentation
Multi-characteristic-type	2 (always)	2 (always)	2 (always)	2 (usually)[b]	at least 1
Multialgorithmic	1 (always)	2 (always)	1 (always)	1 (always)	at least 1
Multi-instance	1 (always)	1 (always)	2 (always)	1 (usually)[c]	at least 1
Multi-sensorial	1 (always)	1 (usually)[a]	1 (always, and same instance)	2 (always)	at least 1
Multipresentation	1	1	1	1	at least 2

[a] It is possible that two samples from separate sensors could be processed by separate "feature extraction" algorithms, and then through a common comparison algorithm, making this "1.5 algorithms", or two completely different algorithms.

[b] An exception is a multi-characteristic-type system with a single sensor used to capture two different characteristic types. For example, a high resolution image used to extract face and iris or face and skin texture.

[c] An exception may be the use of two individual sensors to each capture one instance, for example possibly a two-finger fingerprint sensor.

— Multi-characteristic-type biometric systems — these systems take input from single or multiple sensors that capture two or more different types of biometric characteristic. For example, a single system combining face and iris information for biometric recognition would be considered a "multi-characteristic-type" system regardless of whether face and iris images were captured by different imaging devices or the same device. It is not required that the various measures be combined in any mathematically complex way. For example, a system with fingerprint and voice recognition would be considered "multi-characteristic-type" even if the "OR" rule was being applied, allowing data subjects to be verified using either of the characteristic types.

— Multialgorithmic biometric systems — these systems receive a single sample from a single sensor and process that sample with two or more algorithms. This technique could be applied to any characteristic type. Maximum benefit (theoretically) would be derived from algorithms that are based on distinctly different and independent principles such as either features they extract from the biometric sample (e.g. finger minutiae versus finger pattern) or approaches to comparison (e.g. different algorithms comparing minutiae).

— Multi-instance biometric systems — these systems use one (or possibly multiple) sensor(s) to capture samples of two or more different instances of the same biometric characteristic. For example, systems capturing images from multiple fingers are considered to be multi-instance rather than multi-characteristic-type. However, systems capturing, for example, sequential frames of facial or iris images are considered to be multipresentation rather than multi-instance.

— Multi-sensorial biometric systems — these systems sample the same instance of a biometric characteristic with two or more distinctly different sensors. Processing of the multiple samples can be done with one algorithm, or some combination of multiple algorithms. For example, a face recognition application could use both a visible light camera and an infrared camera coupled with a specific frequency (or several frequencies) of infrared illumination.

— Multipresentation — the biometric system uses multiple samples of one instance of a biometric characteristic.

For a specific application in an operational environment, there are numerous system design considerations and trade-offs that would need to be made, among factors such as improved performance (e.g. identification or verification accuracy, system speed and throughput, robustness and resource requirements), acceptability, circumvention, ease of use, operational cost, environmental flexibility and population flexibility.[40]

Especially for a large-scale human identification system, there are additional system design considerations, such as operation and maintenance, reliability, system acquisition cost, life cycle cost, and planned system response to identified susceptible means of attack, all of which will affect the overall deployability of the system.[40]

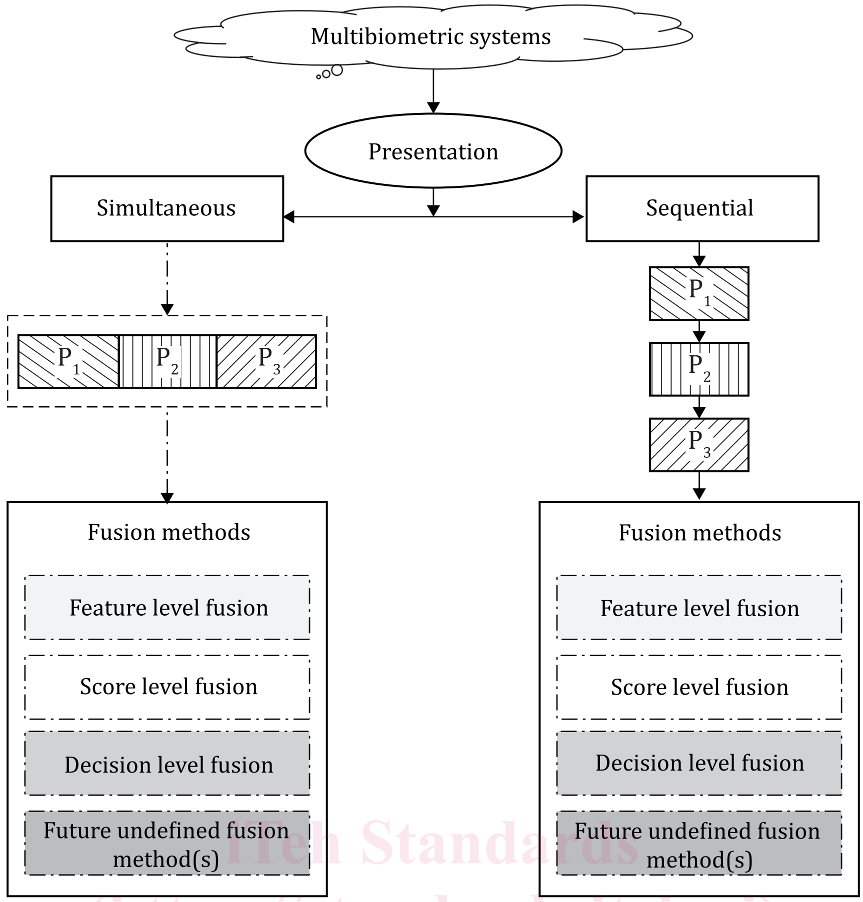
4.2 Simultaneous and sequential presentation

4.2.1 Overview

Dependent upon the system design, there are two methods of presenting a biometric characteristic for capture by the system:

1) simultaneous; and

2) sequential.



NOTE The presentation (simultaneous or sequential) method generally induces different fusion processes. The purpose of including this information is to illustrate considerations that can potentially influence multibiometric system design.

Figure 1 — Classification of multibiometric systems by simultaneity of presenting biometric characteristic

4.2.2 Simultaneous presentation

Simultaneous presentation (with successful capture) provides biometric sample(s) from multiple characteristic types in a single event (e.g. a face and iris taken from the same camera). System designs that utilize simultaneous acquisition would tend towards high throughput applications at the expense of possibly adding complexity (to synchronize sample collection) or difficulty of use (dual sensor interaction, data subject multi-tasking).

4.2.3 Sequential presentation

Sequential capture acquires biometric sample(s) from one or multiple characteristic types in separate events. Sequential capture may be utilized in the three concepts discussed in the literature.[65] The first is multi-instance, which is the use of two or more instances within one characteristic type for a subject, i.e. Fingerprint (left index) + Fingerprint (right index). In this example, one single digit fingerprint reader is used twice in sequence. The second concept is multi-characteristic-type, which is the use of multiple different biometric characteristic types captured from one or more sensors for a subject, i.e. Hand + Face in sequence. The third concept is multi-sensorial, which is the use of two or more distinct sensors for capturing the same biometric feature(s) (e.g. traits) for a subject, but not at the same time. To avoid confusion with multi-characteristic-type, which can also capture biometric instance(s) from two or more distinct sensors, multi-sensorial can be clarified as “uni-characteristic-type multi-sensorial”. Examples for face recognition are: infrared spectrum, visible spectrum, 2-D image, and 3-D image; for fingerprint recognition: optical, electrostatic and acoustic sensors.