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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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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

In exceptional circumstances, the joint technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when the joint technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC TR 24722, which is a Technical Report of type 2, was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 37, *Biometrics*.

Introduction

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

Use of multiple biometric measurements from substantially independent biometric sensors, algorithms or modalities 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 the technical literature since at least 1974 [22, 49]. Advanced methods for combining measures at the score level have been discussed [15, 16]. At the current level of understanding, combining results at the score level typically requires knowledge of both genuine and impostor 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 those questions and the highly application-dependent and generally unavailable data required for proper fusion at the score level, work on multimodal and other multibiometric fusion was considered not sufficiently mature to initiate an International Standard on the subject. Instead, it was considered appropriate to publish a Technical Report on the subject. This Technical Report is meant to provide information for future development of standards on multibiometric systems, in particular regarding the various aspects of fusion. It will also provide a reference on multibiometric fusion for developers of other biometric standards and implementers.

Information technology — Biometrics — Multimodal and other multibiometric fusion

1 Scope

This Technical Report contains descriptions of and analyses of current practices on multimodal and other multibiometric fusion, including (as appropriate) references to more detailed descriptions. It also discusses the need for, and possible routes to, standardisation to support multibiometric systems.

This Technical Report contains descriptions and explanations of high-level multibiometric concepts to aid in the explanation of multibiometric fusion approaches including multimodal, multiinstance, multisensorial, multialgorithmic, decision-level and score-level logic.

2 Terminology issues

The primary motivation in addressing the terms and definitions in Clause 3 is to draw a distinction between "multibiometric" and "multimodal" terms that appeared to be used in the literature interchangeably. To support defining this terminology, the term "modality" is a key, and Table 1 provides a listing of modalities based on CBEFF [30]. The distinction between conventional and unconventional categories is subjective, and based on past and current biometric products.

Table 1 — Terms for biometric modalities or data types

Category	Biometric Type
Other	No Value Available
Multiple	Multiple Biometric Types
Conventional	Face
	Voice
	Finger
	Iris
	Retina
	Hand Geometry
	Signature or Sign
Unconventional	Keystroke
	Lip Movement
	Gait
	Vein
	DNA
	Ear
	Foot
	Scent

(Source: ISO/IEC 19785-1: 2006, *Information technology — Common Biometric Exchange Formats Framework — Part 1: Data element specification,* Table 1 — Abstract values for BDB_biometric_type.)

3 Terms and definitions

Note: Two categories of terms are defined here:

- terms that are specific to multimodal and multibiometric systems;
- terms that are not specific to multimodal and multibiometric systems, but are required to define the terms in the first category and not defined in the latest revision of ISO/IEC JTC 1/SC 37 Standing Document 2 [33].

For definitions of other terms in the subject field of biometrics, refer to ISO/IEC JTC 1/SC 37 Standing Document 2 [33].

For the purposes of this document, the following terms and definitions apply.

3.1
biometric characteristic
biometric (deprecated)
biological and behavioural characteristic of an individual that can be detected and from which distinguishing, repeatable biometric features can be extracted for the purpose of automated recognition of individuals

Note 1: Biological and behavioural characteristics are physical properties of body parts, physiological and behavioural processes created by the body and combinations of any of these.

Note 2: Distinguishing does not necessarily imply individualization.

Examples: Galton ridge structure, face topography, facial skin texture, hand topography, finger topography, iris structure, vein structure of the hand, ridge structure of the palm, and retinal pattern.

3.2
biometric modality
the biometric characteristic which is used in a biometric process

3.3
biometric process
automated process using one or more biometric characteristics of a single individual for the purpose of enrollment, verification or identification

3.4
biometric fusion
combination of information from multiple sources, i.e. sensors, modalities, algorithms, instances or presentations

3.5
cascaded system
system where pass/fail thresholds of biometric samples are used to determine if additional biometric samples are required to reach an overall system decision

3.6
layered system
system where individual biometric scores are used to determine the pass/fail thresholds of other biometric data processing

3.7
multialgorithmic
using multiple algorithms for processing the same biometric sample

3.8
multibiometric
pertaining to multibiometrics

Note: Multibiometric has five distinct subcategories: multimodal, multiinstance, multisensorial, multialgorithmic and multipresentation

3.9
multibiometric process
biometric process involving the use of biometric fusion

3.10
multibiometrics
automated recognition of individuals based on their biological or behavioral characteristics and involving the use of biometric fusion

3.11
multiinstance
using multiple biometric instances within one biometric modality

Examples: Iris (left) + Iris (right), Fingerprint (left index) + Fingerprint (right index).

3.12
multimodal
using multiple different biometric modalities

Example: Fingerprint + Face.

3.13
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: Multipresentation biometrics is considered a form of multibiometrics, if fusion techniques are employed. Many fusion and normalisation techniques are appropriate to the integration of information from multiple presentations of the same biometric instance.

3.14
multisensorial
using multiple sensors for capturing samples of one biometric instance

Examples: For face: infrared spectrum, visible spectrum, 2-D image and 3-D image. For fingerprint: optical, electrostatic and acoustic sensors.

3.15
sequential presentation
capturing biometric samples in separate capture events to be used for biometric fusion

3.16
simultaneous presentation
capturing biometric 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 modality, 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, matching scores or matching 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. 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 user 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 large scale automated fingerprint identification systems (AFISs), starting in the 1980s. Until recently, multiple modalities have not been used in AFIS; however, most methods of fusion discussed elsewhere in this report have been successfully implemented using fingerprints alone. Some of the ways that fusion has been implemented in AFISs include:

— Image (AKA sample) fusion in creating a single “rolled” image from a series of plain impressions on a livescan device;

— Template fusion in the use of multiple feature extraction algorithms on each fingerprint image;

— Multiinstance fusion in the use of fingerprints from all ten fingers;

— Multipresentation fusion in the use of rolled and slap (plain) fingerprints;

— Algorithm fusion for the purpose of efficiency (cost, computational complexity, and throughput rate); generally matchers are 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); matchers are used in parallel, with fusion of resulting scores.

The use of fusion has made AFISs possible, because of fusion’s increase in both accuracy and efficiency.

Most work to date on multibiometrics has focused only on improving false acceptance and false rejection error rates. Work at University of Kent, on project IAMBIC (Intelligent Agents for Multimodal Biometric Identification and Control) is notable as it considers the use of multibiometrics to flexibly improve usability, security or accuracy [65].

To further the understanding of the distinction among the multibiometric categories, Table 2 illustrates the basic distinctions among categories of multibiometric implementation. The key aspect of the category that makes it multi-“something” is shown in boldface.

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

Category	Modality	Algorithm	Biometric characteristic (e.g., body part)	Sensor
Multimodal	**2 (always)**	2 (always)	2 (always)	2 (usually)[b]
Multialgorithmic	1 (always)	**2 (always)**	1 (always)	1 (always)
Multiinstance	1 (always)	1 (always)	**2 instances of 1 characteristic (always)**	1 (usually)[c]
Multisensorial	1 (always)	1 (usually)[a]	1 (always, and same instance)	**2 (always)**
Multipresentation	1	1	1	1

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 Exception: a multimodal system with a single sensor used to capture two different modalities. For example a high resolution image used to extract face and iris or face and skin texture.

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

Multimodal biometric systems take input from single or multiple sensors that capture two or more different modalities of biometric characteristics. For example, a single system combining face and iris information for biometric recognition would be considered a "multimodal" 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 mathematically combined in anyway. For example, a system with fingerprint and voice recognition would be considered "multimodal" even if the "OR" rule was being applied, allowing users to be verified using either of the modalities.

Multialgorithmic biometric 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 modality. Maximum benefit (theoretically) would be derived from algorithms that are based on distinctly different and independent principles (such algorithms may be called "orthogonal").

Multiinstance biometric 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 multiinstance rather than multimodal. However, systems capturing, for example, sequential frames of facial or iris images are considered to be multipresentation rather than multiinstance.

Multisensorial biometric 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.

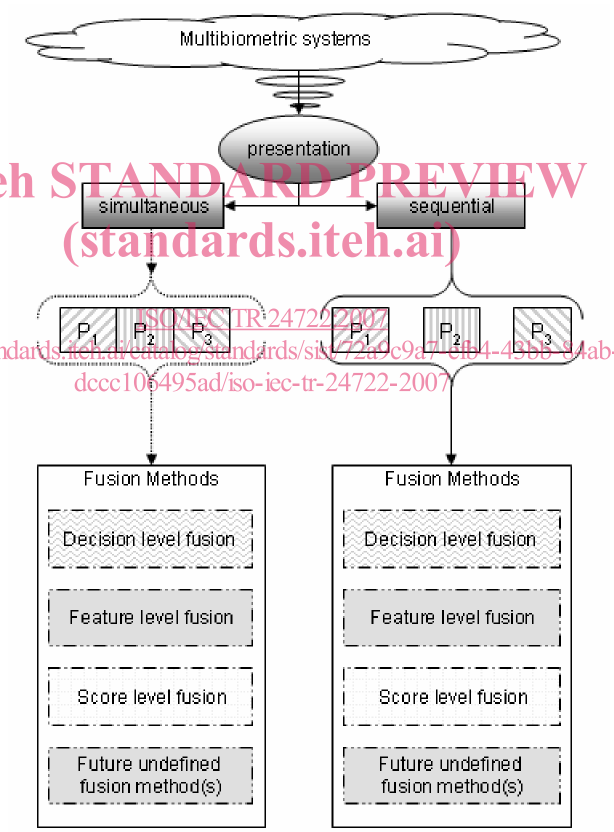
For a specific application in an operational environment, there are numerous system design considerations, and trade-offs that must be made, among factors such as improved performance (e.g., identification or verification accuracy, system speed and throughput, robustness, and resource requirements), acceptability, circumvention, ease of use, operational cost, environmental flexibility, and population flexibility [44].

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 [44].

4.2 Simultaneous and sequential presentation

4.2.1 General multibiometric system model

A general multibiometric system model is shown in Figure 1. For explanatory purposes, this model uses three biometric samples (P_1, P_2, P_3) from 3 unique biometric modalities, except for where specified differently. At the topmost level a subject presents their biometric characteristic(s) to the system. Dependent upon the system design, there are two methods of presenting characteristics for acquisition by the system: 1) **simultaneous** and 2) **sequential**.



Note: the presentation method (simultaneous or sequential) is distinct from the fusion process itself. The purpose of including this information is to illustrate considerations that may influence multibiometric system design.

Figure 1 — Multibiometric system model

