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Information technology — Biometrics — Multimodal and other multibiometric fusion

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TECHNICAL REPORT

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Second edition
2015-12-15

Information technology — Biometrics — Multimodal and other multibiometric fusion

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

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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The committee responsible for this document is ISO/IEC JTC 1, *Information technology*, Subcommittee SC 37, *Biometrics*.

This second edition cancels and replaces the first edition (ISO/IEC/TR 24722:2007), which has been technically revised with the following changes:

— the original Clause 2 (Terminology issues) and Clause 7 (Scope and options for standardisation) are removed in this edition;

— Clause 2 (Terms and definitions) is aligned with ISO/IEC 2382-37;

— the current Clause 3, Clause 4, and Clause 5 have been technically revised in terminology, the state of arts updates, and other aspects. Such modifications have also been reflected in the bibliography.

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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 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 the technical literature since at least 1974.[22][45] Advanced methods for combining measures at the score level have been discussed in Reference [15] and Reference [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 multibiometric fusion can, in the meantime, be considered mature. By intention, this Technical Report is not issued as an International Standard, in order not to force industrial solutions to conform to the methodology described herein. However, this Technical Report revision provides a mature technical description for developments of multibiometric systems. It will also provide a reference on multibiometric fusion for developers of other biometric standards and implementers.

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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.

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

2 Terms and definitions

The following 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 2382-37.

For definitions of other terms in the subject field of biometrics, refer to ISO/IEC 2382-37. For the purposes of this document, the terms and definitions given in ISO/IEC 2382-37 and the following apply.

2.1
biometric data source
information channel (e.g. sensors, characteristic types, algorithms, instances or presentations) that is the origin of data (e.g. captured biometric sample, extracted features, comparison score, rank or decision) treated in fusion algorithms

2.2
biometric process
automated process using one or more biometric characteristics of a single individual for the purpose of enrolment, verification, or identification

2.3
biometric fusion
combination of information from multiple sources, i.e., sensors, characteristic types, algorithms, instances or presentations

2.4
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

2.5
layered system
system where individual biometric scores are used to determine the pass/fail thresholds of other biometric data processing

2.6
multialgorithmic
using multiple algorithms for processing the same biometric sample

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2.7
multibiometric
uses multiple biometrics that can be combined at image, feature, score and/or decision level

Note 1 to entry: Multibiometric has five distinct subcategories: *multi-characteristic-type* (2.10), *multiinstance* (2.11), *multisensorial* (2.13), *multialgorithmic* (2.6) and *multipresentation* (2.12).

2.8
multibiometric process
biometric process (2.2) involving the use of *biometric fusion* (2.3)

2.9
multibiometrics
automated recognition of individuals based on their biological or behavioral characteristics and involving the use of *biometric fusion* (2.3)

2.10
multi-characteristic-type
multi-type
using information from multiple types of biometric characteristics

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

2.11
multiinstance
using multiple biometric instances within one biometric characteristic type

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

2.12
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* (2.9), 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.

2.13
multisensorial
using multiple sensors for capturing samples of one biometric instance

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

2.14
sequential presentation
capturing biometric samples in separate capture events to be used for *biometric fusion* (2.3)

2.15
simultaneous presentation
capturing biometrics samples in a single capture event to be used for *biometric fusion* (2.3)

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3 Overview of multimodal and other multibiometric systems

3.1 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 Technical Report, any method of combination will be considered a form of "fusion". Combination techniques will be covered in Clause 4.

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 characteristic types have not been used in AFIS; however, most methods of fusion discussed elsewhere in this Technical Report have been successfully implemented using fingerprints alone. Some of the ways that fusion has been implemented in AFISs include the following:

— image (also known as 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, comparators 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); comparators are used in parallel, with fusion of resulting scores.

The use of fusion has made AFIS 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.[64] Further, multibiometrics also aims at decreasing the overall failure-to-enrol rate (FTE) especially in biometric systems where user 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 characteristics were captured.[66]

To further 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 shown in boldface.

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