Presentation Attack Detection und PAD Metrics

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TTT AG-Biometrie

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HOCHSCHULE DARMSTADT
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Fraunhofer IGD

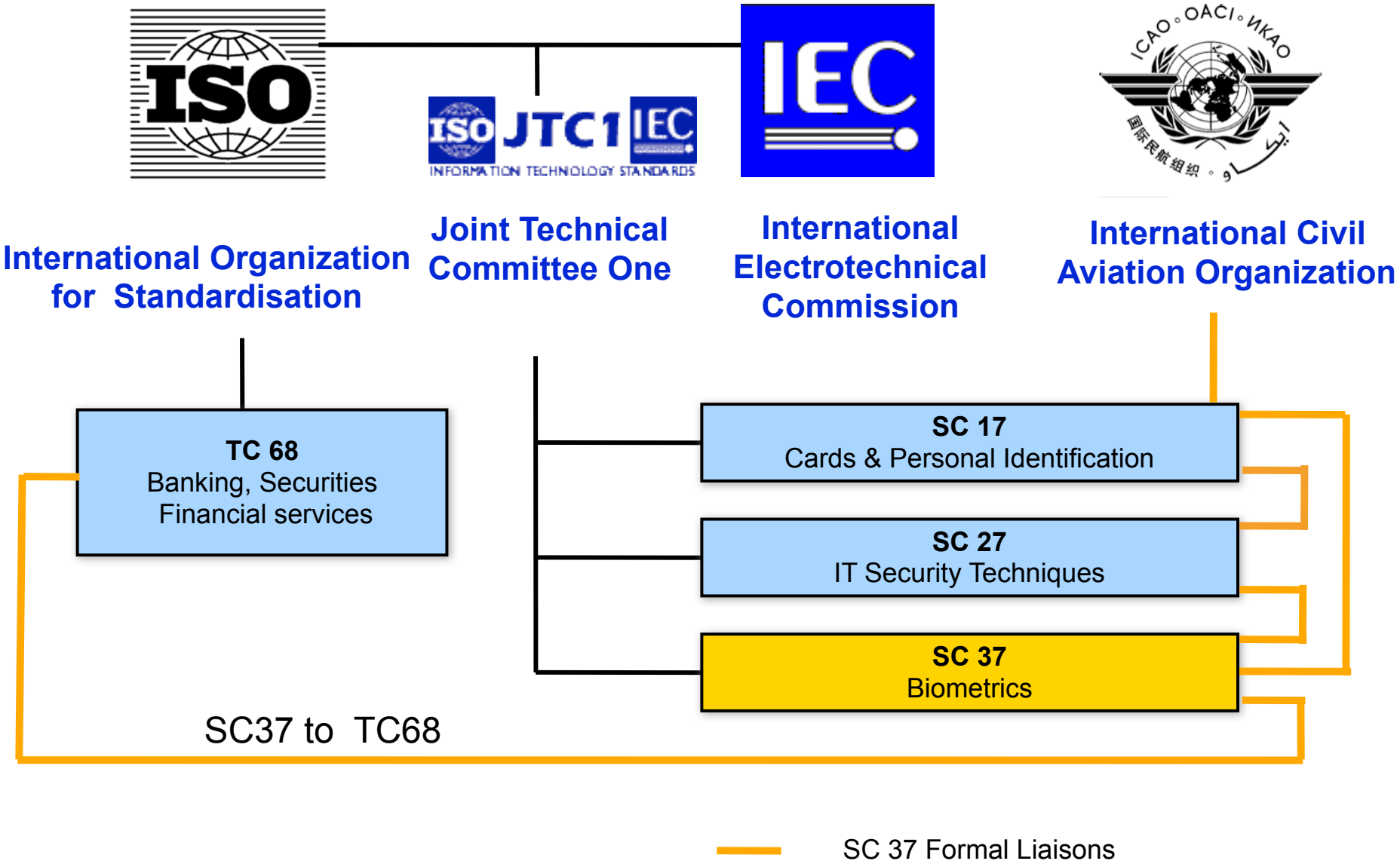
European Association for Biometrics
eab
Human Identity in Europe

Agenda

- Certification is important and requested
  - should one develop new standards to test against?
  - should one test against existing standards?
- Existing International Standardisation
- Performance Testing
- Vulnerability of Biometric Capture Devices
  - Development of the Presentation Attack Detection Standard

International Standardisation

Biometric Standardisation



ISO/IEC SC37 Biometrics

Established by JTC 1 in June 2002 to ensure

- a high-priority, focused and comprehensive approach worldwide for the rapid development of formal generic biometric standards

Scope of SC37

- *"Standardization of generic biometric technologies pertaining to human beings to support interoperability and data interchange among applications and systems. Generic human biometric standards include: common file frameworks; biometric application programming interfaces; biometric data interchange formats; related biometric profiles; application of evaluation criteria to biometric technologies; methodologies for performance testing and reporting and cross jurisdictional and societal aspects"*
- http://www.jtc1.org

Next two meetings: January 2015 in Spain
June 2015 in Gjøvik

Working Group 3

Title: Biometric Data Interchange

- Convenor: Christoph Busch (Germany)

Terms of Reference:

- To consider the standardisation of the content, meaning, and representation of biometric data formats which are specific to a particular biometric technology. To ensure a common look and feel for Biometric Data Structure standards, with notation and transfer formats that provide platform independence and separation of transfer syntax from content definition

“Getting equipment to understand each other”

Working Group 5

Title: Biometric Testing and Reporting

- Convenor: Nigel Gordon (UK)

Terms of Reference:

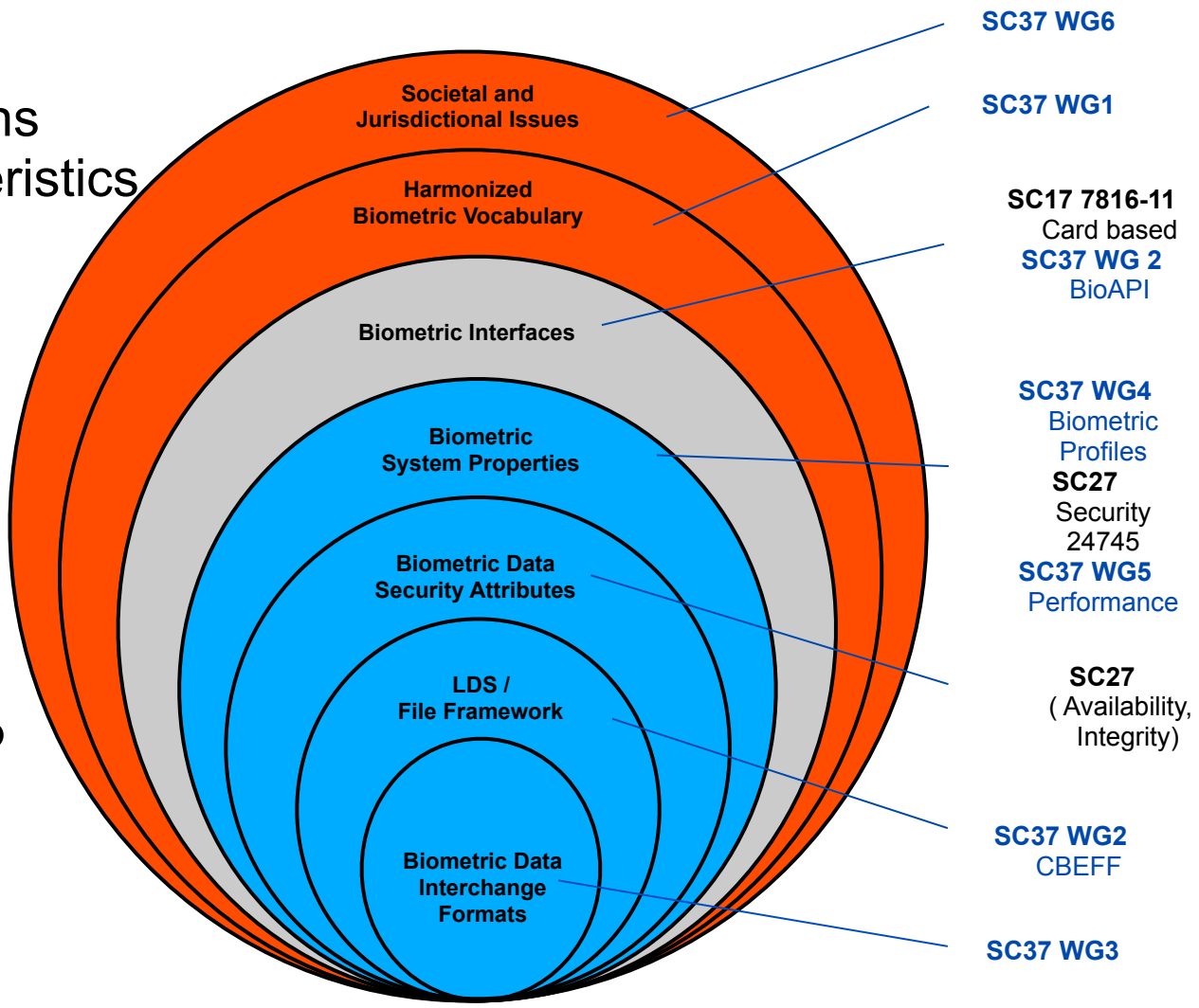
- To create testing and reporting methodologies and metrics that cover biometric technologies, systems and components
- To develop Working Drafts for approved projects on biometric testing and reporting.

“how to check it works”

Biometric Standardisation

Onion Layers

- Layer 1: BDIR
  - Digital representations of biometric characteristics
- Layer 2: LDS
  - CBEFF Meta-data
- Layer 3+4: System properties
  - Security
  - Performance
- Layer 5: BioAPI, BIP
  - System Integration



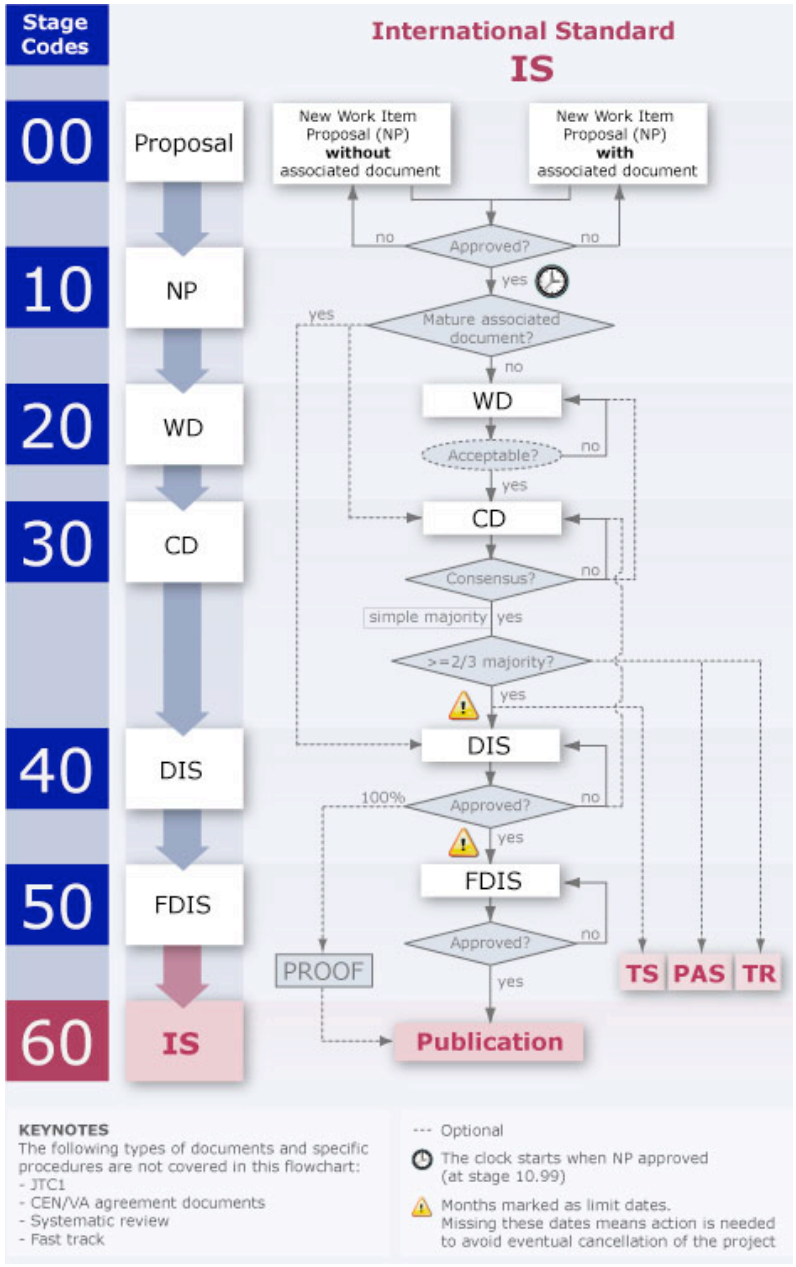
Levels of Development?

Progression levels

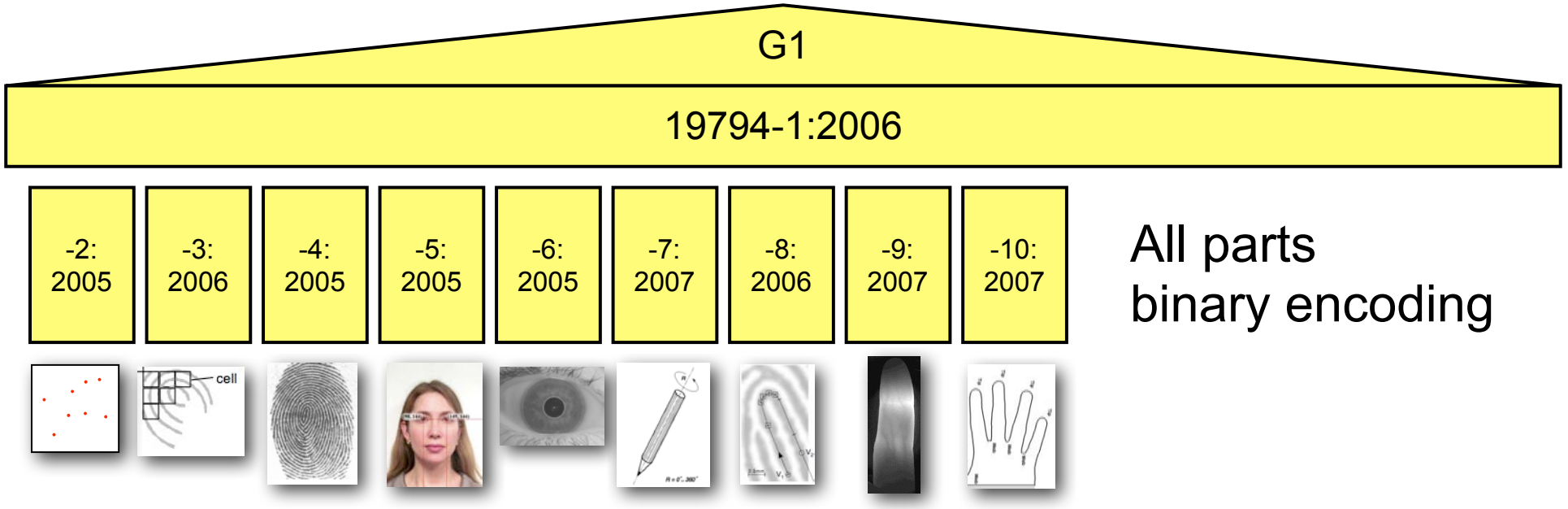
- Working Draft (WD)
- Committee Draft (CD)
- Darft International Standard (DIS)
- Final Draft International Standard (FDIS)
- International Standard (IS)

Issues to consider:

- Need for mature technology
- Decisions are made on consensus
- Commenting periods
- Potentially multiple loops at one level
- Need to progress
- Five year revision cycle



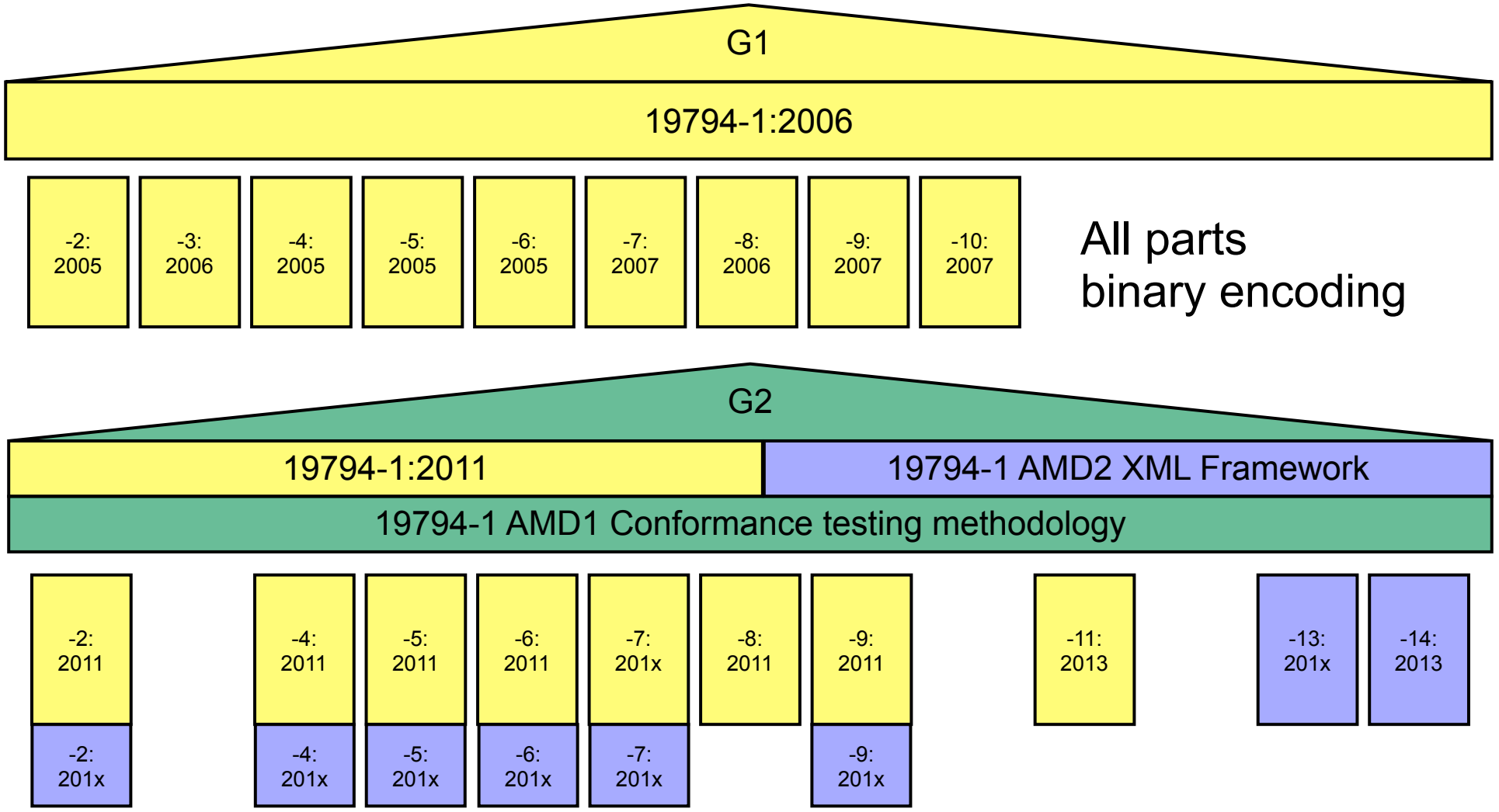
ISO/IEC Interchange Format Standards



All parts
binary encoding

The 19794-Family: Biometric data interchange formats

Generation 2 of ISO/IEC 19794

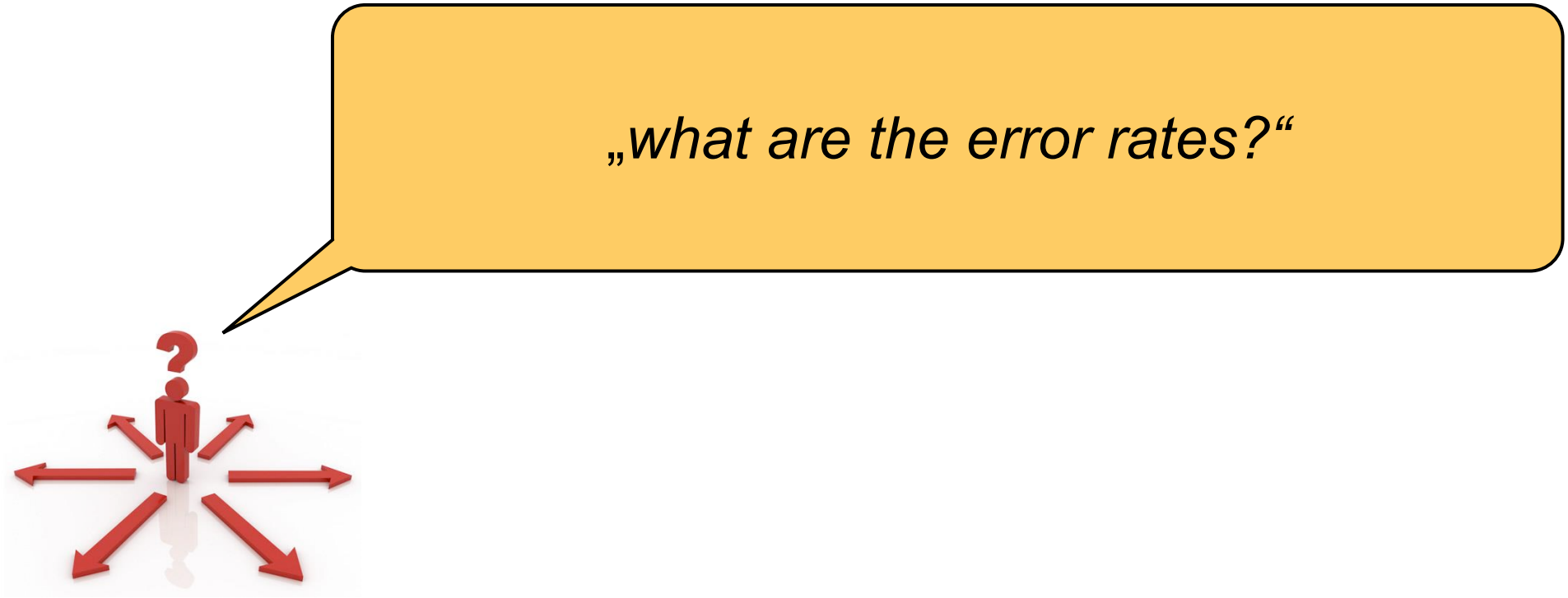


the semantic is equivalent for binary encoded and XML encoded records

Biometric Performance Testing
ISO/IEC 19795-1:2006

Biometric Performance Testing

Operators may think:



Biometric Performance Testing Standard

ISO/IEC 19795-x, Information technology - Biometric performance testing and reporting

- Part 1: Principles & Framework
  - Guidance applicable to the broad range of tests
- Part 2: Testing Methodologies for Technology and Scenario Evaluation
  - Multiple visits, habituation, enrolment
- Part 3: Modality-Specific Testing
  - Modality (& application) specific methodologies
- Part 4: Interoperability Performance Testing
  - Performance on other vendors data
- Part 5: Framework for biometric device performance evaluation for access control
- Part 6: Testing Methodologies for Operational Evaluation
- Part 7: Testing of ISO/IEC 7816-based Verification Algorithms
- Part 8: Performance Testing of Template Protection Schemes

Performance Metrics

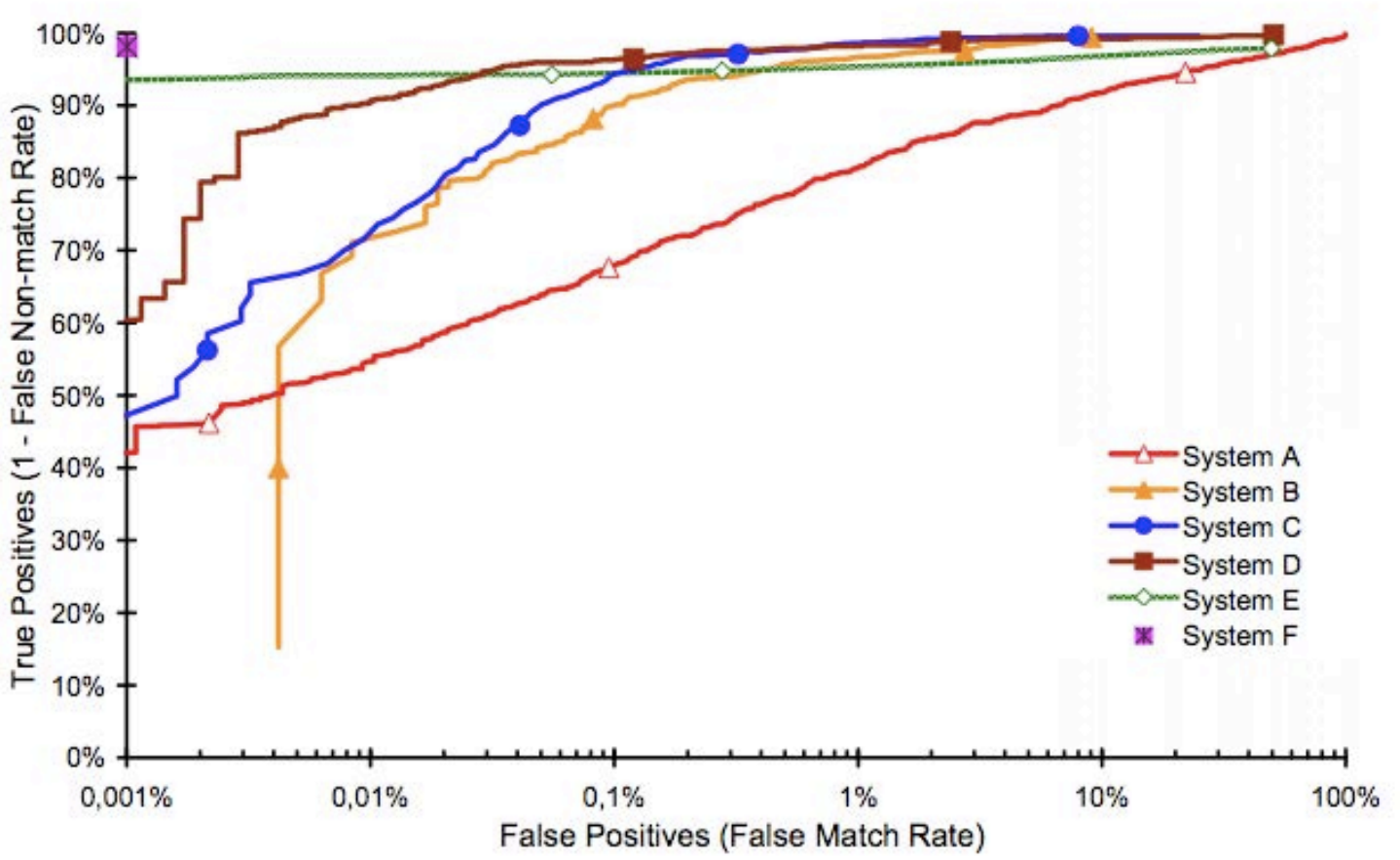
Categorization

- Technology testing
  - Algorithmic level verfication error
    - False-Match-Rate (FMR) - algorithm accepts „zero-effort“ imposter
    - False-Non-Match-Rate (FNMR) - algorithm rejects true identity
- Scenario testing and operartional testing
  - System level verification error
    - False-Accept-Rate (FAR)
    - False-Reject-Rate (FRR)
  - System level error requires observation of:
    - Sample generation: Failure-to-Capture (FTC)
    - Enrolment: Failure-to-Enrol (FTE) - no reference for this subject
    - Verification: Failure-to-Acquire (FTA) - no probe feature vector

Graphical Presentation

ROC curve (Receiver operating characteristic curve)

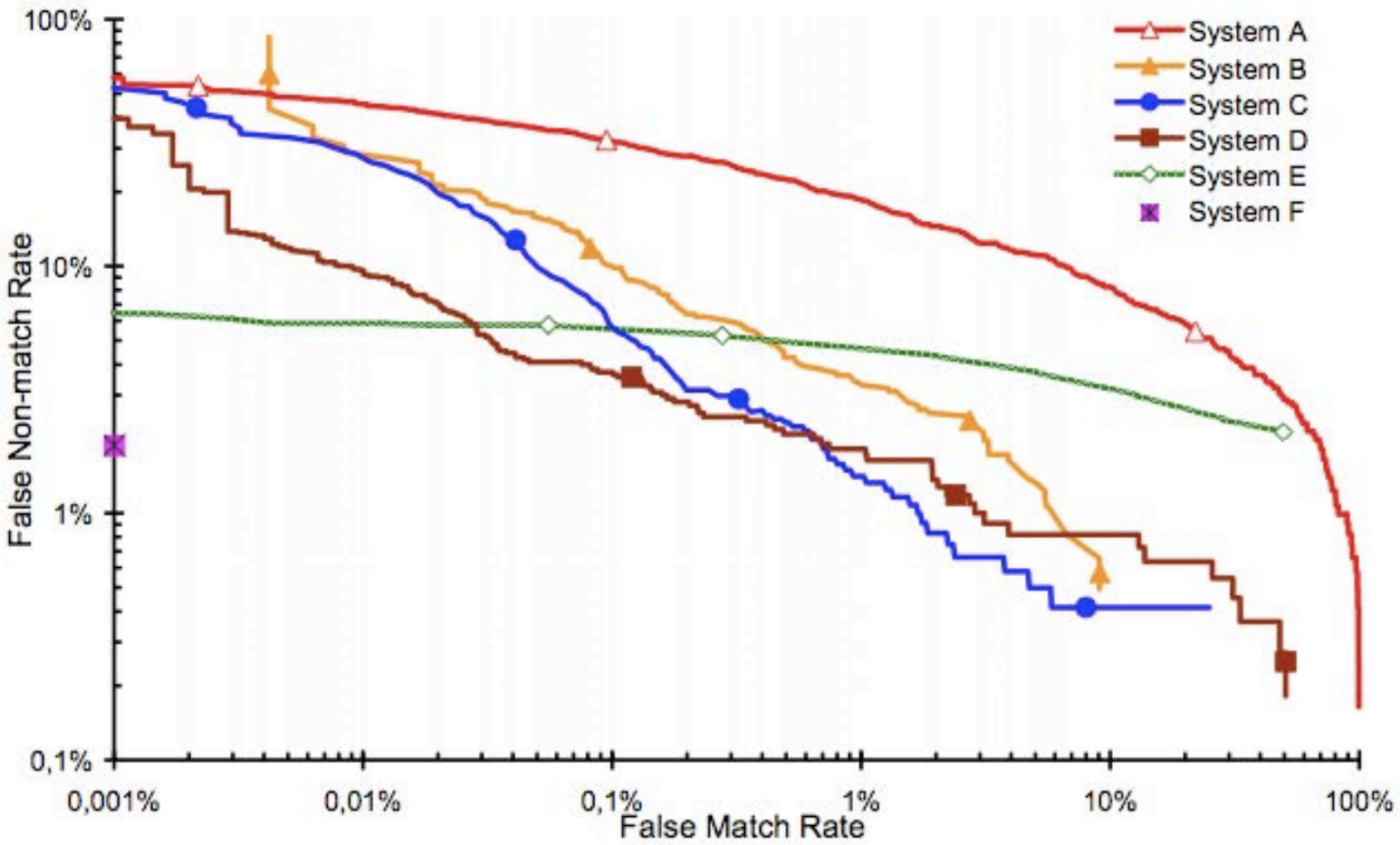
- Plot of the rate of false positives (i.e. impostor attempts accepted) on the x-axis against the corresponding rate of true positives (i.e genuine attempts accepted) on the y-axis plotted parametrically as a function of the decision threshold



Graphical Presentation

DET curve (detection error trade-off curve)

- modified ROC curve which plots error rates on both axes (false positives on the x-axis and false negatives on the y-axis)



Vulnerability Testing

Vulnerability Testing

Operators may think:

„Biometric sensors can not detect gummy and cut-off fingers“

Smart Phone Access Contol

- Presentation Attacks

Gummy Finger Production in 2000 !

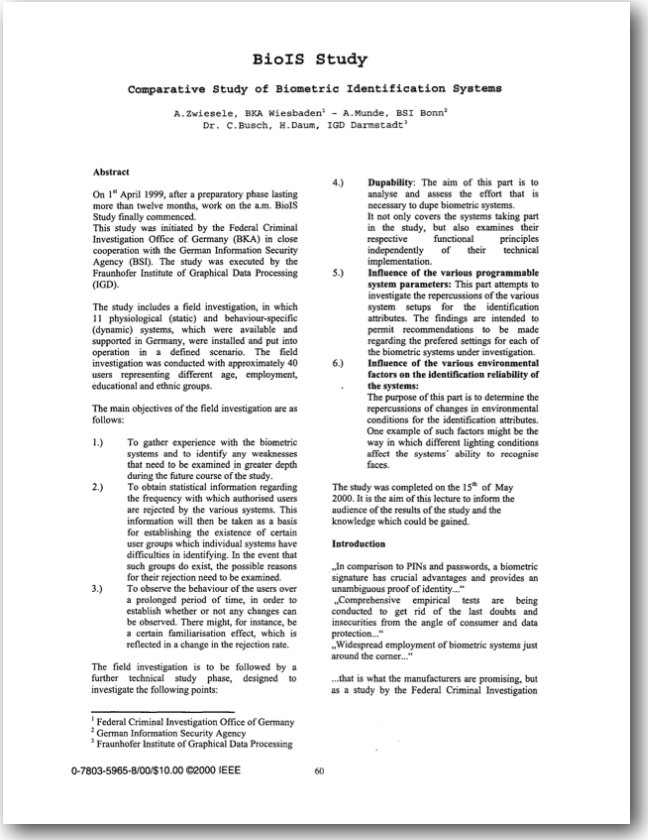
Attack without support of an enroled individual

- Recording of an analog fingerprint from flat surface material
  - z.B. glass, CD-cover, etc.
    with iron powder and tape
- Scanning and post processing:
  - Correction of scanning errors
  - Closing of ridge lines (as needed)
  - Image inversion
- Print on transparent slide
- Photochemical production of a platine

Gummy Finger Production in 2000 !

Reported in a publication by BKA

- A. Zwiesele et al. „BioIS Study - Comparative Study of Biometric Identification Systems“, In: 34th Annual 2000 IEEE International Carnahan Conference on Security Technology, Ottawa, pp. 60-63, (2000)



BioIS Study

Comparative Study of Biometric Identification Systems

A.Zwiesele, BKA Wiesbaden[1] - A.Munde, BSI Bonn[2]
Dr. C.Busch, H.Daum, IGD Darmstadt[3]

Abstract

On 1st April 1999, after a preparatory phase lasting more than twelve months, work on the a.m. BioIS Study finally commenced.
This study was initiated by the Federal Criminal Investigation Office of Germany (BKA) in close cooperation with the German Information Security Agency (BSI). The study was executed by the Fraunhofer Institute of Graphical Data Processing (IGD).

The study includes a field investigation, in which 11 physiological (static) and behaviour-specific (dynamic) systems, which were available and supported in Germany, were installed and put into operation in a defined scenario. The field investigation was conducted with approximately 40 users representing different age, employment, educational and ethnic groups.

The main objectives of the field investigation are as follows:

1.) To gather experience with the biometric systems and to identify any weaknesses that need to be examined in greater depth during the future course of the study.
2.) To obtain statistical information regarding the frequency with which authorised users are rejected by the various systems. This information will then be taken as a basis for establishing the existence of certain user groups which individual systems have difficulties in identifying. In the event that such groups do exist, the possible reasons for their rejection need to be examined.
3.) To observe the behaviour of the users over a prolonged period of time, in order to establish whether or not any changes can be observed. There might, for instance, be a certain familiarisation effect, which is reflected in a change in the rejection rate.

The field investigation is to be followed by a further technical study phase, designed to investigate the following points:

4.) **Dupability**: The aim of this part is to analyse and assess the effort that is necessary to dupe biometric systems.
It not only covers the systems taking part in the study, but also examines their respective functional principles independently of their technical implementation.
5.) **Influence of the various programmable system parameters:** This part attempts to investigate the repercussions of the various system setups for the identification attributes. The findings are intended to permit recommendations to be made regarding the prefered settings for each of the biometric systems under investigation.
6.) **Influence of the various environmental factors on the identification reliability of the systems:**
The purpose of this part is to determine the repercussions of changes in environmental conditions for the identification attributes. One example of such factors might be the way in which different lighting conditions affect the systems' ability to recognise faces.

The study was completed on the 15th of May 2000. It is the aim of this lecture to inform the audience of the results of the study and the knowledge which could be gained.

Introduction

„In comparison to PINs and passwords, a biometric signature has crucial advantages and provides an unambiguous proof of identity..."
„Comprehensive empirical tests are being conducted to get rid of the last doubts and insecurities from the angle of consumer and data protection..."
„Widespread employment of biometric systems just around the corner..."

...that is what the manufacturers are promising, but as a study by the Federal Criminal Investigation

[1] Federal Criminal Investigation Office of Germany
[2] German Information Security Agency
[3] Fraunhofer Institute of Graphical Data Processing

0-7803-5965-8/00/$10.00 ©2000 IEEE

Face Mask Production in 2013

Attack again without support of an enroled individual

- Frontal and profile photos are uploaded
- 3D face dataset rendered and produced

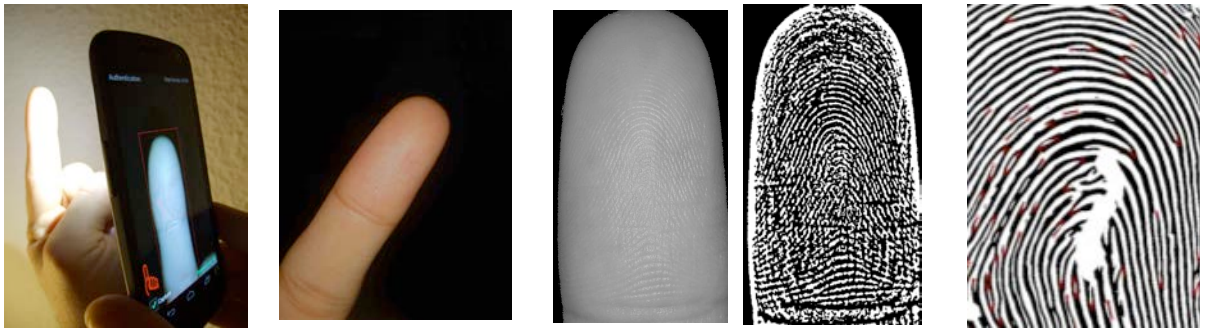
Smartphone Access Contol

Capture process

- Camera operating in macro modus

Preview image of the camera with LED on (left) and LED off (right)

- LED permanent on



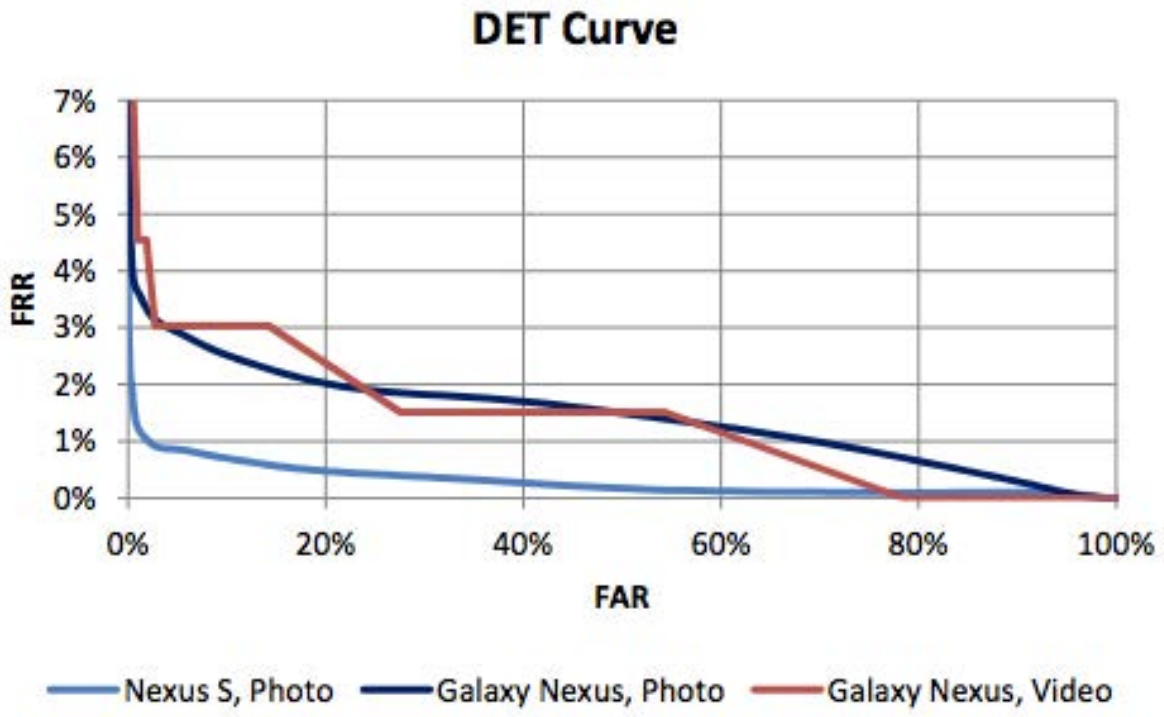
Finger illuminated

[SNB12] C. Stein, C. Nickel, C. Busch, „Fingerphoto Recognition with Smartphone Cameras“, Proceedings 11th Intern. Conference of the Biometrics Special Interest Group (BIOSIG 2012)

Smartphone Access Contol

Finger recognition study - 2012/2013

- Results: biometric performance at 1.2% EER



Capture Method and Device	EER from [SC-2012]	EER	FRR (FAR= 0.1%)
Photo, Nexus S	22.3%	1.2%	2.7%
Photo, Galaxy Nexus	19.1%	3.1%	6.7%
Video, Galaxy Nexus	-	3.0%	12.1%

[SBB13] C. Stein, V. Bouatou, C. Busch, „Video-based Fingerphoto Recognition with Anti-spoofing Techniques with Smartphone Cameras“, Proceedings 12th Intern. Conference of the Biometrics Special Interest Group (BIOSIG 2013)

Smartphone Access Contol

Finger recognition study - 2012/2013

- Presentation Attacks
  - 1: replay from Smartphone display (simple)
  - 2: self generated print-outs (not critical to detect)
  - 3: Ralph Breithaupt‘s / BSI best artefacts (very challenging)

Replay attack

Simple artefacts

Challenging artefacts

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Finger recognition study - 2012/2013

- Observation
  - significant strong light reflection near the fingertip
  - from the cameras LED
- Reflection depends on
  - Shape of the finger
  - Consistency of the finger
  - Angle of the finger to the camera

- Attack detection, as light reflection differs from artefacts to genuine fingers

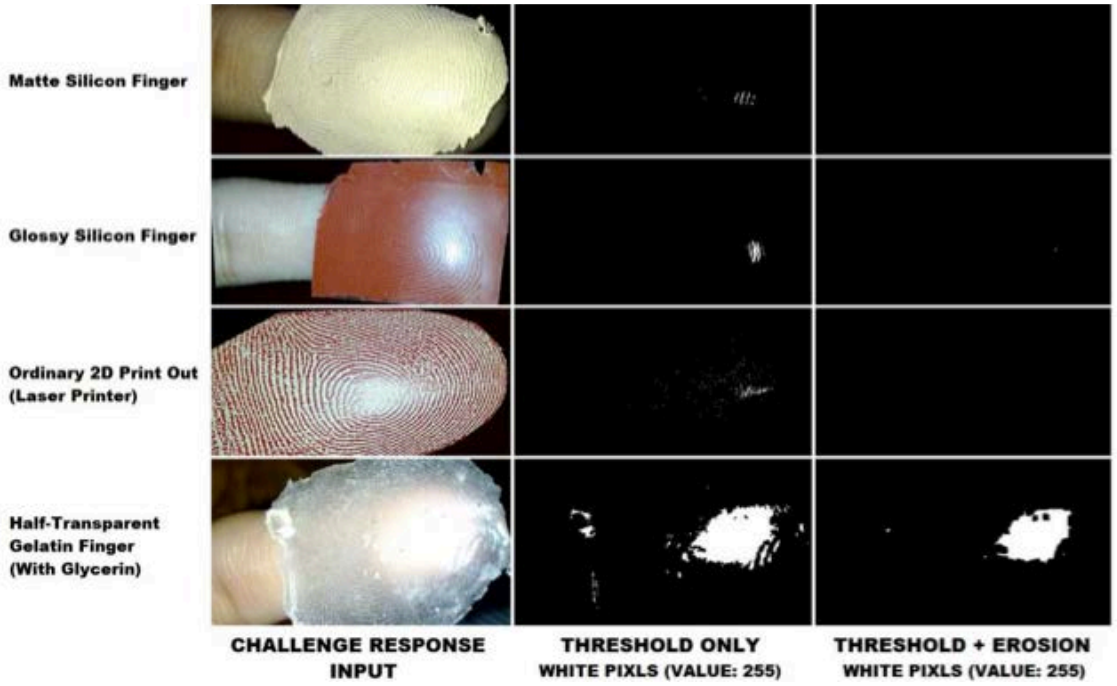
- [SBB13] C. Stein, V. Bouatou, C. Busch, „Video-based Fingerphoto Recognition with Anti-spoofing Techniques with Smartphone Cameras“, Proceedings12th Intern. Conference of the Biometrics Special Interest Group (BIOSIG 2013)

Smartphone Access Contol

Finger recognition study - 2012/2013

- Normal presentation with genuine finger

- Results: Presentation Attack Detection (PAD)

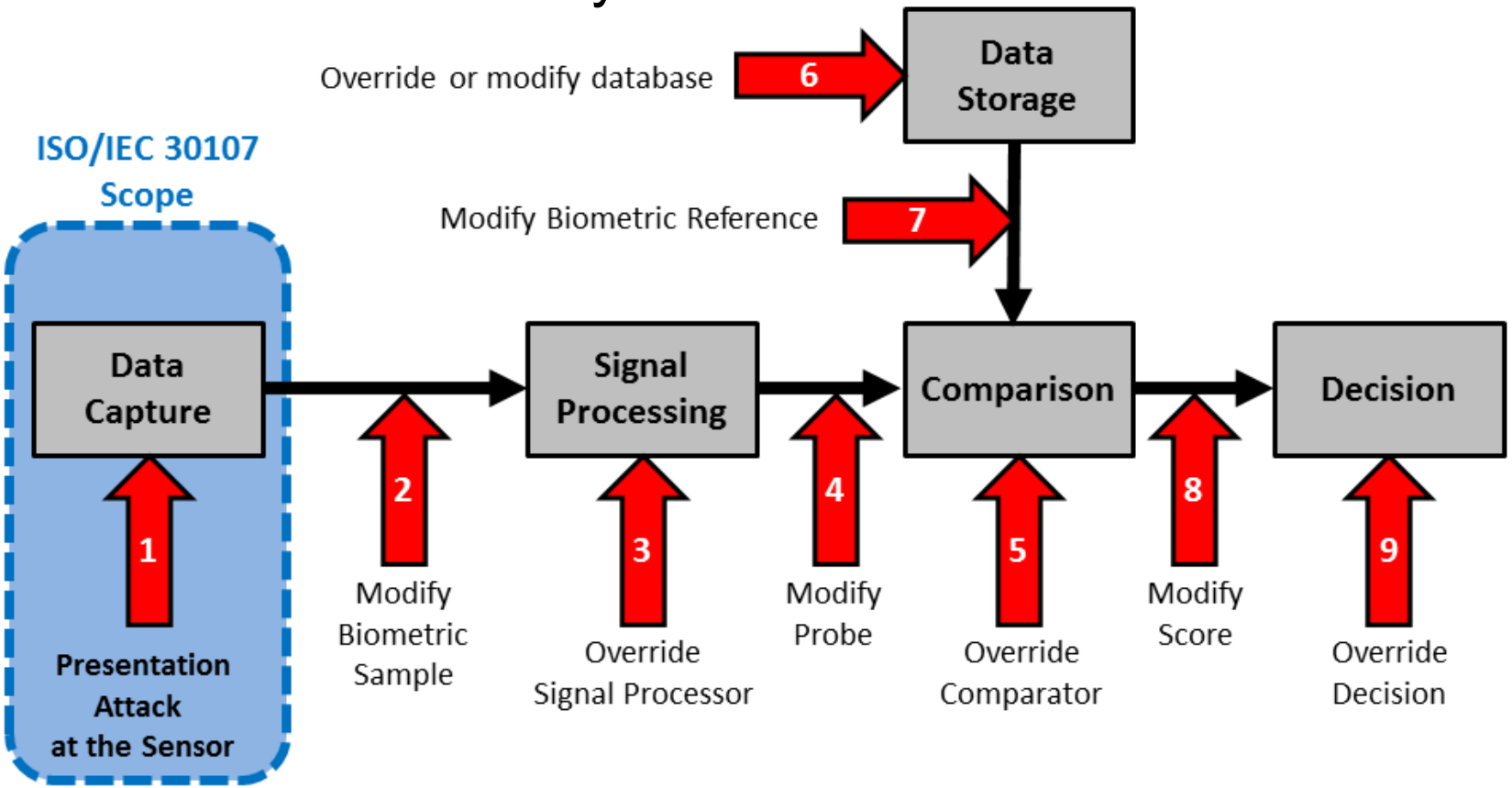


- Conclusion:
  better Presentation Attack Detection than capacitive sensors

Liveness Detection

ISO/IEC CD 30107 - Presentation Attack Detection

- Attacks on Biometric Systems



Source: ISO/IEC 30107-1 inspired by N.K. Ratha, J.H. Connell, R.M. Bolle, "Enhancing security and privacy in biometrics-based authentication systems," IBM Systems Journal, Vol 40. NO 3, 2001.

Presentation Attack Detection

ISO/IEC 30107 - Scope

- terms and definitions that are useful in the specification, characterization and evaluation of presentation attack detection methods;
- a common data format for conveying the type of approach used and the assessment of presentation attack in data formats;
- principles and methods for performance assessment of presentation attack detection algorithms or mechanisms; and

Outside the scope are

- standardization of specific PAD detection methods;
- detailed information about countermeasures (i.e. anti-spoofing techniques), algorithms, or sensors;
- overall system-level security or vulnerability assessment.

Presentation Attack Detection

30107 parts

- Part 1 (IS) - Framework
  - Elaine Newton
  - status: 2nd CD
- Part 2 (IS) - Data formats
  - Olaf Henniger
  - status: WD
- Part 3 (IS) Testing and Reporting
  - Michael Thieme
  - status: WD

Presentation Attack Detection

Definitions in ISO/IEC 30107 PAD - Part 1: Framework

- **presentation attack**
  presentation to the biometric capture subsystem with the goal of interfering with the operation of the biometric system
- **presentation attack detection (PAD)**
  automated determination of a presentation attack

Definitions in ISO/IEC 2382-37: Vocabulary
http://www.christoph-busch.de/standards.html

- **impostor**
  subversive biometric capture subject who attempts to being matched to someone else's biometric reference
- **identity concealer**
  subversive biometric capture subject who attempts to avoid being matched to their own biometric reference

Presentation Attack Detection

ISO/IEC 30107 -
Examples of Artificial and Human Attack Presentation

Artificial	*Complete*	gummy finger, video of face
	Partial	glue on finger, sunglasses, artificial/patterned contact lens, non-permanent make up
Human	*Lifeless*	cadaver part, severed finger/hand
	Altered	mutilation, surgical switching of fingerprints between hands and/or toes
	Non-Conformant	facial expression/extreme, tip or side of finger
	Coerced[1]	unconscious, under duress
	Conformant	zero effort impostor attempt

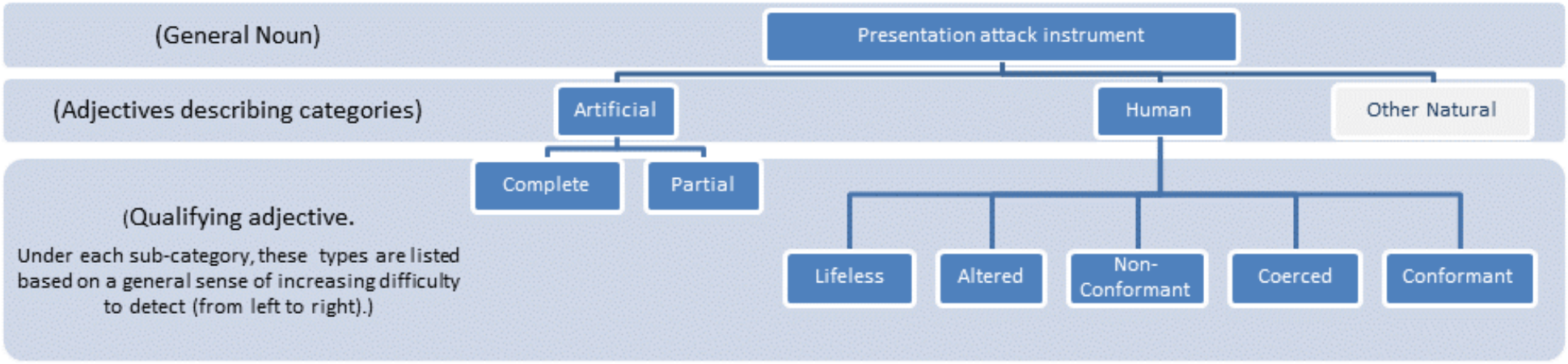
Source: ISO/IEC 30107

Presentation Attack Detection

ISO/IEC 30107 - Definitions

- **presentation attack instrument (PAI)**
  biometric characteristic or object used in a presentation attack
- **artefact**
  artificial object or representation presenting a copy of biometric characteristics or synthetic biometric patterns

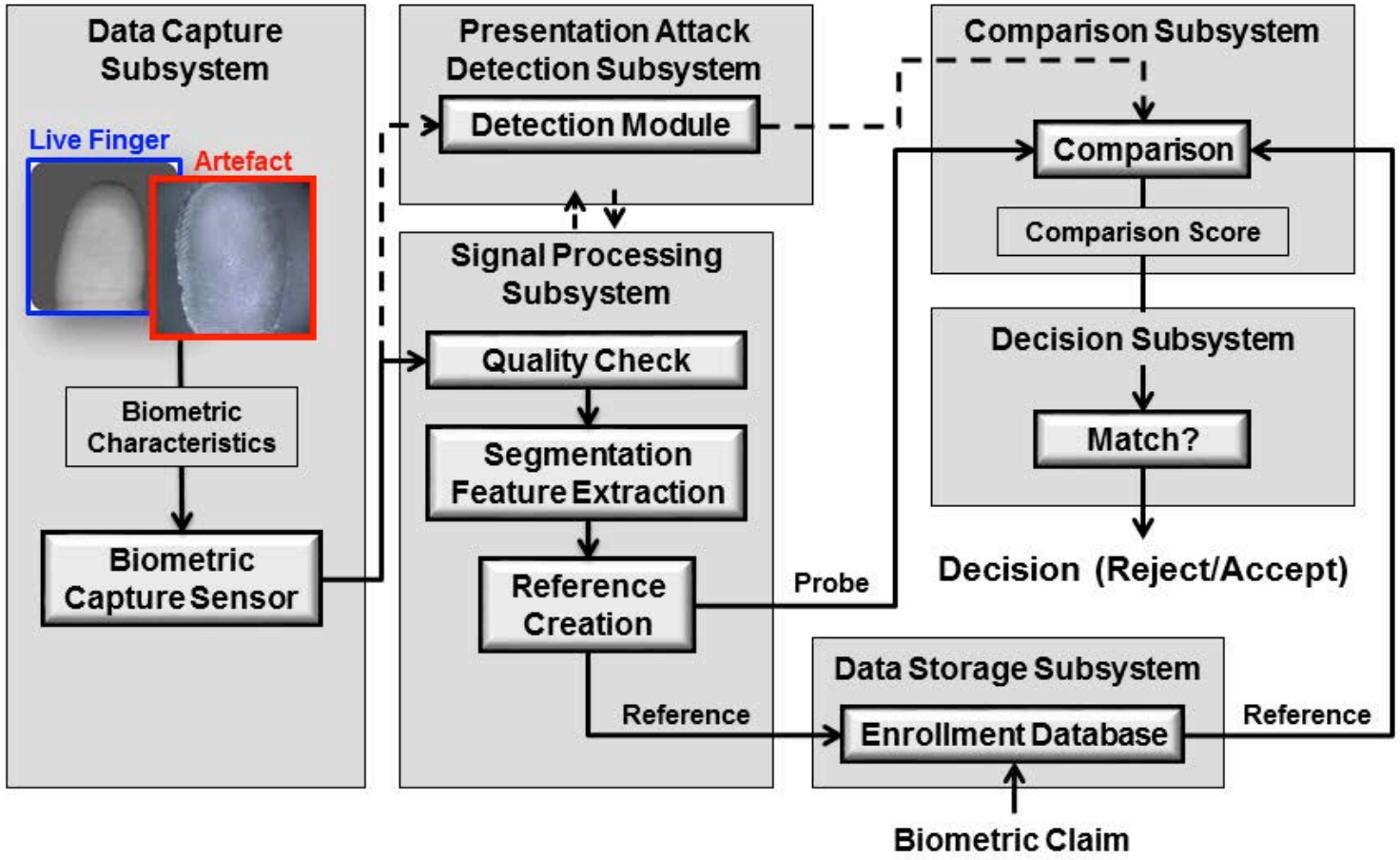
Types of presentation attacks



Source: ISO/IEC 30107-1

Presentation Attack Detection

Biometric framework with PAD



Source: ISO/IEC 30107

Reporting about the PAD using ISO/IEC 30107-3

PAD-Standard

Methodology in ISO/IEC 30107 Presentation Attack Detection - Part 3: Testing and reporting

- Security Evaluation
  - for evaluations using the Common Criteria Framework
  - Protection Profile (PP) (e.g. from German BSI)
  - Security Target (ST)
  - Evaluation Assurance Level (EAL)
  - Assessment of the attack potential
  - *„if there is at least one aretefact that can reproducibly successful attack the PAD-component - then the PAD failed the test“*
- Other approaches
  - for evaluations in academic and technology development
  - tolerating the limited statistical significance of small test set
    - the statistical distribution is unknown and for sure not normal
  - *„ a score based metric can tell us, if the method improved“*

PAD-Standard

Metrics in ISO/IEC 30107 Presentation Attack Detection - Part 3: Testing and reporting

- **Attack presentation classification error rate (APCER)**
  proportion of attack presentations incorrectly classified as normal presentations at the component level in a specific scenario
- **Normal presentation classification error rate (NPCER)**
  proportion of normal presentations incorrectly classified as attack presentations at the component level in a specific scenario

Applying ISO/IEC 30107-3 Metrics

Do the metrics currently in ISO/IEC 30107 PAD - Part 3: serve to provide a meaningful report?

- [SBB13] - Publication:
  The reported number of attack presentations incorrectly classified as normal presentations was one out of four artefacts
- Thus the APCER to be reported is

$$APCER = \frac{1}{4} = 0.25$$

- but there were in fact 27 artefact species, that were used in the background but not reported as they are not challenging

$$APCER = \frac{1}{27} = 0.04$$

Thoughts for improving ISO/IEC WD 30107

Refining ISO/IEC 30107-3 Metrics

Trust in a biometric sensor relates to risk

Apply classical risk assessment ?

- *Risk = Impact of Risk event x Probability of Occurrence*
- we do not know the impact!

Modified assessment

- *Vulnerability = Attack Potential x Probability of Occurrence*

Refining ISO/IEC 30107-3 Metrics

Needed Change

- The size of the corpus with the artefact species is essential
- The CC-related attack potential should be included in the metric definition for non-cc evaluations
  - 30107-1: **attack potential** - *attribute of a biometric presentation attack expressing the effort expended in the preparation and execution of the attack in terms of elapsed time, expertise, knowledge about the capture device being attacked, window of opportunity and equipment, graded as "no rating", "minimal", "basic", "enhanced-basic," "moderate" or "high.*
- The known success rate of a presentaion artefact instrument is relevant and might be an approximation for the probability of occurrence

Refining ISO/IEC 30107-3 Metrics

Suggested augmented metric for ISO/IEC 30107-3

- **Attack presentation classification error rate (APCER)**
  proportion of attack presentations incorrectly classified as normal presentations at the component level a specific scenario -
  taking the attack potential and the known
  attack instrument success rate into account.
- **Attack potential (AP)** = {0.2 for “minimal”, 0.4 for “basic”, 0.6 for "enhanced-basic,” 0.8 for “moderate”, 1.0 for “high.}
- **Presentation attack instrument success rate (PAISR)**
  Proportion of evaluated capture devices
  that could be spoofed by the specific PAI (i.e. artefact).
  - would start with a value of 1 for a new discovered artefact species and could be reduced over time (as more sensors become robust)

Refining ISO/IEC 30107-3 Metrics

Suggested refined metrics for ISO/IEC 30107-3

- The APCER could thus be expressed as

$$APCER = \frac{\sum_{i=1}^{N_{AS}} (RES_i * AP_i * PAISR_i)}{N_{AS}}$$

N_{AS}	number of presentation attack instruments (PAI) (i.e. artefact species) in the corpus
RES_i	result of attack with ith PAI {0 for detected attack, 1 for successful attack}
AP_i	attack potential of the ith PAI (close to zero, if artefact is easy to produce)
$PAISR_i$	presentation attack instrument success rate (close to zero, if all sensor can detect this artefact)

Refining ISO/IEC 30107-3 Metrics

Suggested refined metrics for ISO/IEC 30107-3

- **Normal presentation classification error rate (NPCER)**: *proportion of normal presentations incorrectly classified as attack presentations at the component level in a specific scenario*
- The NPCER could thus be expressed as

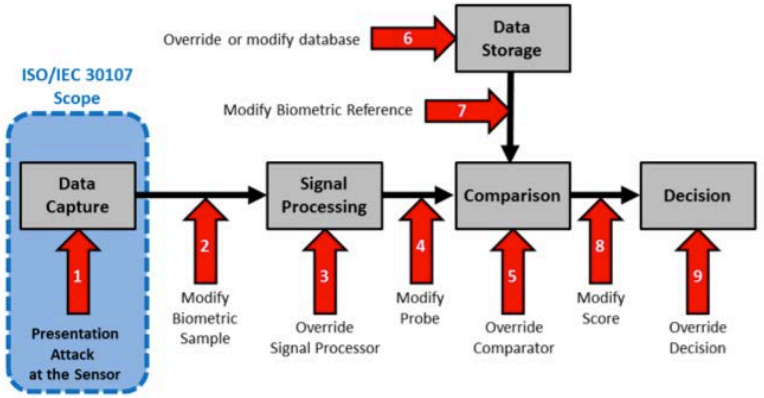
$$NPCER = \frac{\sum_{i=1}^{N_{GPA}} RES_i}{N_{GPA}}$$

- N_{GPA} number of normal presentations from a genuine subject
- RES_i result of presentation detection component for the ith attempt {0 for no detected attack, 1 for false alarm}

Conclusion

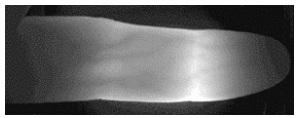
The standardisation process is open process

- Register and contribute to ISO/IEC 30107 Presentation Attack Detection
- Open question:
  - should PAD metrics and performance metrics be merged ?



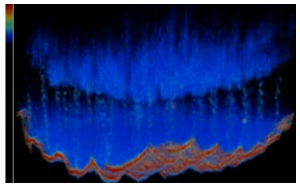
Recent research provides effective countermeasures to detect artefacts

- Vein recognition



Fingervein image

- Fingerprint Recognition with Optical Coherence Tomography (OCT)



3D Finger OCT scan

References

Web

- WG3 onvenors website with latest news
  http://www.christoph-busch.de/standards-sc37wg3.html
- ISO/IEC JTC SC37
  http://isotc.iso.org/livelink/livelink?func=ll&objId=2262372&objAction=browse&sort=name
- Wikipedia
  http://en.wikipedia.org/wiki/ISO/IEC_JTC_1/SC_37
- Published ISO Standards
  http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_tc_browse.htm?commid=313770&published=on
- ISO/IEC 19795-1:2006, Biometric performance testing and reporting - Part 1:Principles and framework
- ISO/IEC 24745:2011, Biometric information protection
- ISO/IEC CD 30107-1, Biometric presentation attack detection - Part 1: Framework
- ISO/IEC WD 30107-3, Biometric presentation attack detection - Part 3: Testing and reporting

Visit Norway in 2015

Norwegian Biometrics Laboratory Workshop 2015

- Presentation Attack Detection in Biometrics: Solved and Unsolved Challenges
- Chair: Dr. Raghavendra Ramachandra
- Monday, March 2, 2015
- please follow us at: http://nislab.no/biometrics_lab

ISO/IEC JTC1 SC37 Conference

- Working Group Meetings
- June 22 to 26, 2015 in GUC
- Standards Norge
- We are seeking Sponsors for the ISO - conference

Contact

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