TURBINE Performance Evaluation

From Benchmarks to Airport Deployment

Christoph Busch

Davrondzhon Gafurov, Bian Yang and Patrick Bours

Gjøvik University College, NORWAY

Jan 17, 2011

christoph.busch@hig.no

FP7 Integrated Project TURBINE (TrUsted Revocable Biometric IdeNtitiEs)

Outline

- Testing framework
- GUC 100 fingerprint database
- First round testing results
- Second round testing results
- Conclusion

TURBINE Performance Evaluation

Two rounds of performance evaluation

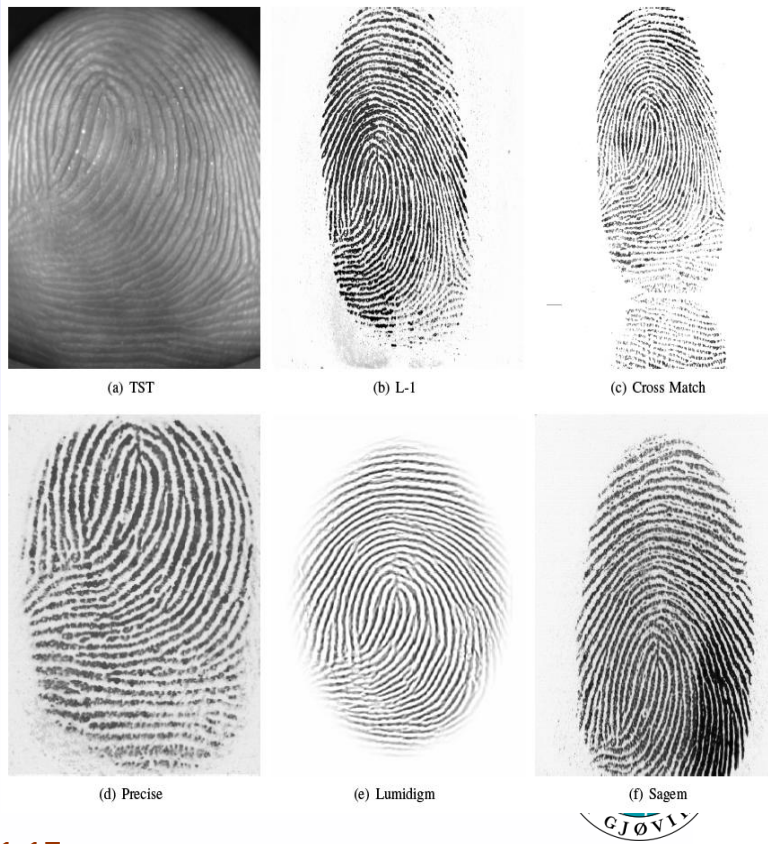
- 2009 and 2010
- In this presentation *biometric performance* per se
  - Performance report *algorithm* and *system* performance
  - No *security* performance -
    this will be covered by Koen Simoens in the next talk

TURBINE

- Algorithm developers
  - Morpho (France)
  - Precise Biometrics AB (Sweden)
  - Philips Research Europe (The Netherlands)
  - University of Twente (The Netherlands)
- Biometric performance evaluator
  - Gjøvik University College (Norway)
- Security performance evaluator
  - K.U.Leuven (COSIC) (Belgium)

TURBINE Database

- GUC 100 - primary test database
  - 6 scanners,
  - 100 subjects, all 10 fingers,
  - 12 sessions, ~ 72000 images
  - Sequestered database (no access granted to algorithm developers)



GUC 100 Database

- 12 sessions (on separate days)
  - Temperature variation (Norway 2008/09)
  - Large intra-class variation
  - Uncontrolled
    - No image quality control
  - Controlled
    - Quality was controlled to some extend visually (e.g. by wetting fingers if necessary)
- Sequestered database
  - No access granted to algorithm developers
  - Disjunct database provided for training
- ISO 29159 Dataset ID #56 for GUC 100

Performance Metrics

- According to ISO/IEC 19795-1
- Algorithm performance
  - FMR vs. FNMR
- System performance
  - FAR vs. FRR
- Metrics
  - FAR = FMR*(1-FTA)
  - FRR = FNMR*(1-FTA) + FTA
  - **FTA = FTC + FTX*(1-FTC)**

$$FTX = \frac{\#\text{–}of - not - encoded - images}{total\text{–}\#\text{–}of - images - submitted - to - encoder}$$

Performance Reporting

- Performance in terms of
  - DET curves
  - EER and FRR@FAR0.1%
  - *result = f (algorithm, sensor, data subjects, environment)*
- Target performance:
  - FRR of 1% at FAR of 0.1%

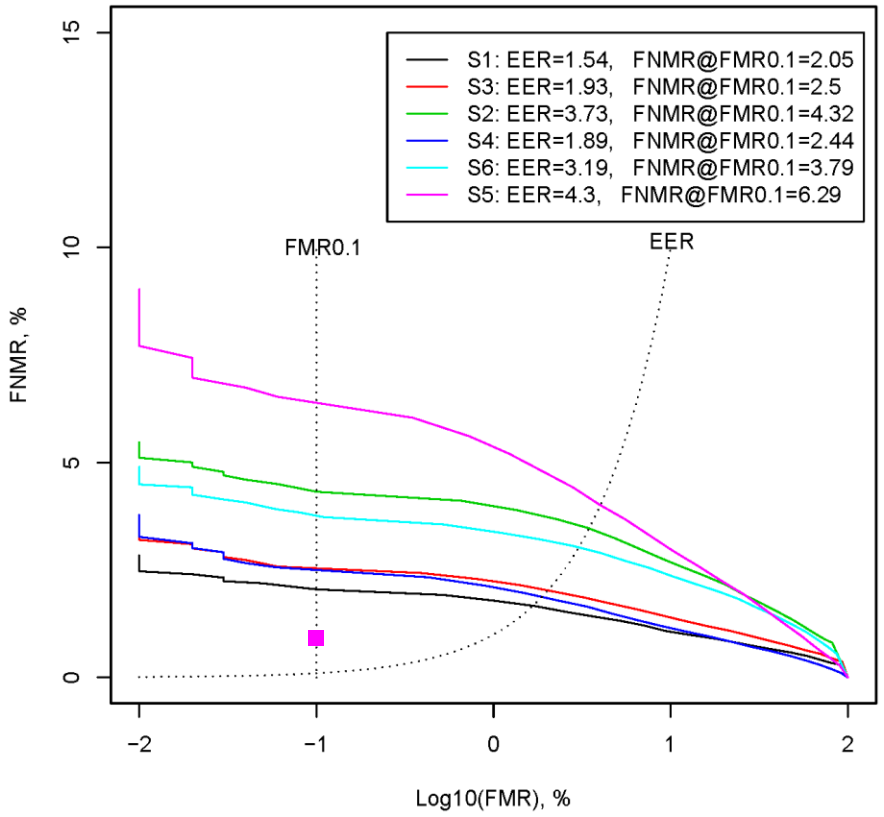
Performance report

- Minutiae level
  - Without considering image quality
  - With image quality (NFIQ > 3 counted in FTC)
- Pseudonymous Identifier (PI) level
  - Intensive computations
  - Less points in DET curves

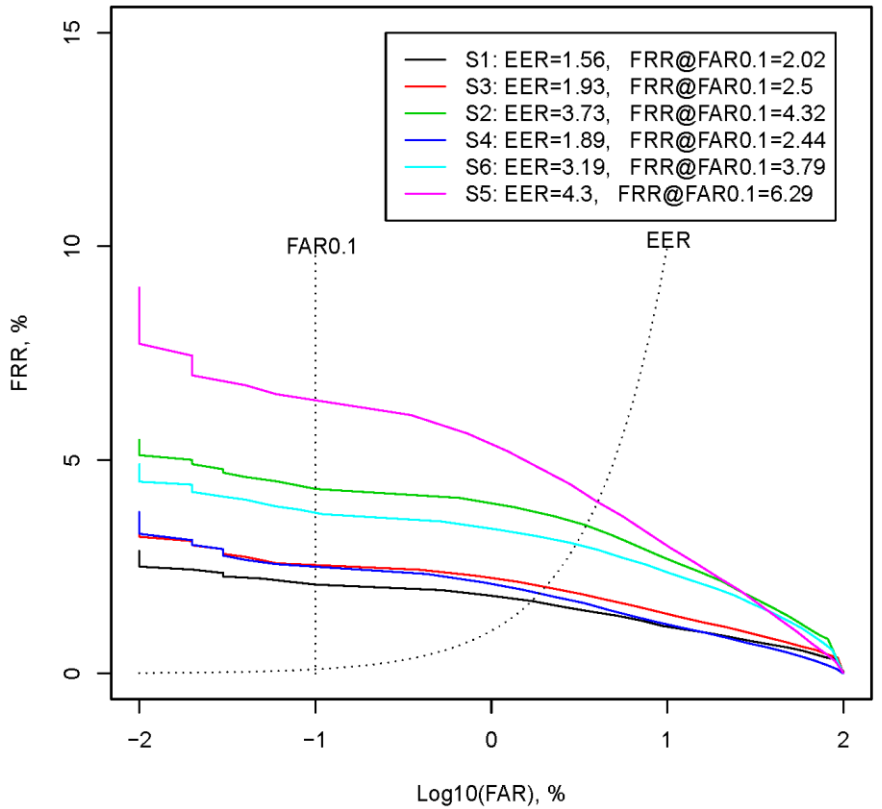
Minutiae level:

Benchmarking of Sensors using COTS Neurotechnology without considering image quality

Algorithm performance



System performance

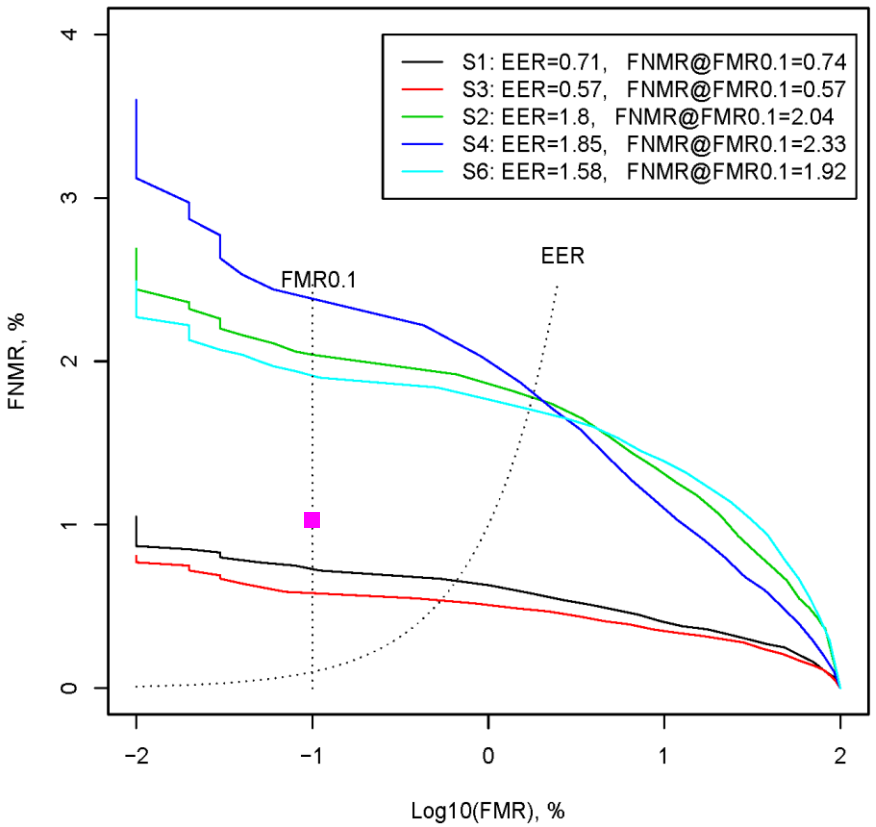


Minutiae level:

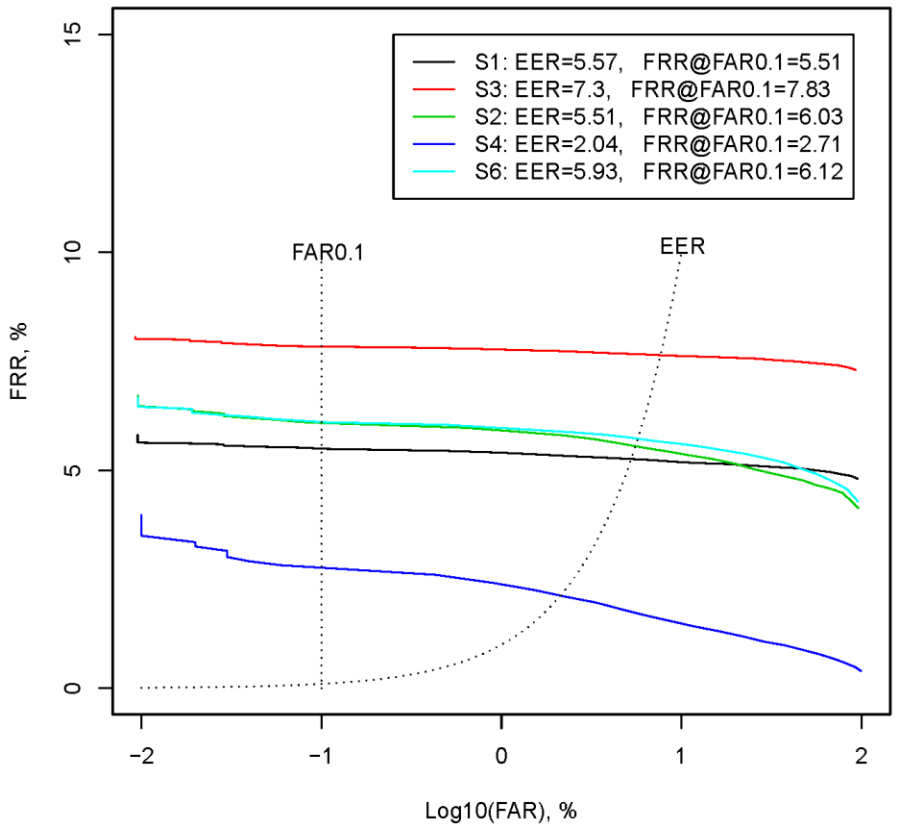
Benchmarking of Sensors using COTS Neurotechnology

with considering image quality (NFIQ<3 is FTC)

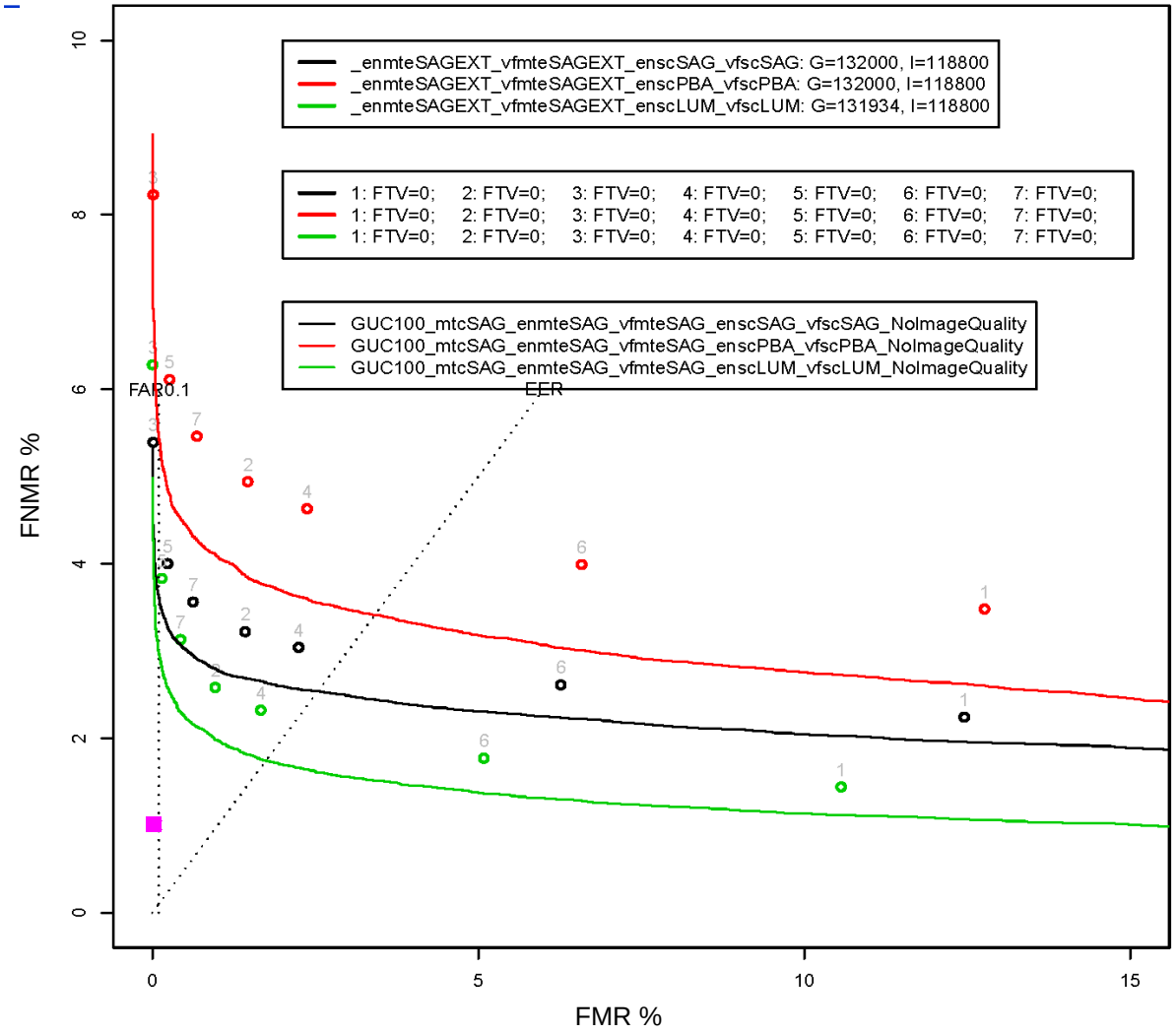
Algorithm performance



System performance



PI level: Protection vs. Performance



2nd Round Testing

- Minutiae algorithms
  - PBAISO2 (extractor and comparator)
  - PBAEXT2 (extractor and comparator)
  - MPHEXT2 (extractor only)
- PI algorithms
  - MPHPI2b (software only)
  - MPHPI2a: (On-Card-Comparison alias match on card)
  - PREPI2: (software only)
  - GUCPI2: (software only)
- More than 200 test scenarios in total

Algorithms in 2nd Round

- Publications in TURBINE
  - http://www.turbine-project.org/publications_2010.php

Publications resulting from TURBINE in year 2010

- Davrondzhon Gafurov, *"Independent Performance Evaluation of Fingerprint Verification at the Minutiae and Pseudonymous Identifier Levels"*. Accepted to the 2010 IEEE Conference on Systems, Man and Cybernetics (SMC2010), Istanbul, Turkey, 10-13 October, 2010.
- Bian Yang, Christoph Busch, Davrondzhon Gafurov, Patrick Bours *"Renewable Minutiae Templates with Tunable Size and Security"* Accepted to the 20th International Conference on Pattern Recognition (ICPR2010), Istanbul, Turkey, 23-26 August, 2010.
  http://www.icpr2010.org/ICPR10_ContentListWeb_2.html#tuat7_02
- Haiyun Xu, Raymond N. J. Veldhuis *"Binary representations of Fingerprint Spectral Minutiae Features"*. Accepted to the 20th International Conference on Pattern Recognition (ICPR2010), Istanbul, Turkey, 23-26 August, 2010.
  http://www.icpr2010.org/ICPR10_ContentListWeb_2.html#tuat9_23
- Bian Yang, Davrondzhon Gafurov, Christoph Busch, Patrick Bours, *"Encrypting Fingerprint Minutiae Templates by Random Quantization"* Accepted to the Special Session on Real Time Biometric Solutions for Networked Society (RT-BioS 2010) at the Second International Conference on Networked Digital Technologies 2010, Prague, Czech Republic, 7-9 July, 2010.
  http://www.dirf.org/ndt2010/realtime.asp
- Haiyun Xu, Raymond N. J. Veldhuis, *"Complex Spectral Minutiae Representation For Fingerprint Recognition"*. Accepted to CVPR 2010, the Twenty-third IEEC Conference on Computer Vision & Pattern Recognition, San Francisco, CA, 13-18 June 2010.
  http://cvl.umiacs.umd.edu/conferences/cvpr2010
- Emile J. C. Kelkboom, Gary Garcia Molina, Jeroen Breebaart, Raymond N. J. Veldhuis, Tom A. M. Kevenaar, and Willem Jonker, *"Binary Biometrics: An Analytic Framework to Estimate the Performance Curves Under Gaussian Assumption"* IEEE transactions on systems, man, and cybernetics—part a: systems and humans, vol. 40, no. 3, May 2010
  http://doc.utwente.nl/71010/
- Davrondzhon Gafurov, Patrick Bours, Bian Yang and Christoph Busch, *"GUC100 Multi-scanner Fingerprint Database for In-House (Semi-Public) Performance and Interoperability Evaluation"* International Conference on Computational Science and Its Applications (ICCSA), Fukuoka, Japan, 23-26 March, 2010, IEEE.
  http://www.computer.org/portal/web/csdl/doi/10.1109/ICCSA.2010.71
- Davrondzhon Gafurov, Bian Yang, Patrick Bours and Christoph Busch, *"Independent Performance Evaluation of Biometric Systems"* International Biometric Performance Testing Conference, National Institute of Standards and Technology (NIST), Gaithersburg, USA, 2-4 March, 2010. http://biometrics.nist.gov/cs_links/ibpc2010/pdfs/Gafurov2_SupportingTwoPageAbstractForPresentation.pdf
- Kelkboom, E. J. C., Breebaart, J., Buhan, I., Veldhuis, R. N. J., *"Analytical template protection performance and maximum key size given a Gaussian modeled biometric source"* Proc. SPIE defense, security and sensing, 2010
  http://www.jeroenbreebaart.com/papers/spie/spie2010.pdf
- Els KINDT, *"The use of privacy enhancing technologies for biometric systems analysed from a legal perspective"* in M. Bezzi et al. (Eds.). Privacy and Identity, IFIP International Federation for Information Processing AICT 320, 2010, pp. 134--145.
- Bian, Y., Busch, C., Bours, P. and Gafurov, D. Gjøvik Univeristy College, *"Robust Minutiae Hash for Fingerprint Template Protection"* Proc. SPIE, Vol. 7541, 75410R (2010); doi:10.1117/12.838998 , Jan., 2010 http://dx.doi.org/10.1117/12.838998
- Haiyun Xu, Raymond N. J. Veldhuis, Tom A. M. Kevenaar, and Ton A. H. M. Akkermans *"A Fast Minutiae-Based Fingerprint Recognition System"* Systems Journal, IEEE. DOI 10.1109/JSYST.2009.2034945. Date of current version: 26 janvier 2010. Volume: 3 Issue: 4 - page(s): 418 - 427

Publications resulting from TURBINE in year 2009

- Haiyun Xu, Raymond N. J. Veldhuis, Tom A. M. Kevenaar, and Ton A. H. M. Akkermans, "*A Fast Minutiae-Based Fingerprint Recognition System*" *IEEE Systems Journal*, Volume 3, Issue:4, pp. 418-427, December 2009
  http://dx.doi.org/10.1109/JSYST.2009.2034945
- Xu, H. and Veldhuis, R.N.J. "*Spectral Representations of Fingerprint Minutiae Subsets*" 2nd International Congress on Image and Signal Processing, 2009. CISP '09, October 2009
  http://dx.doi.org/10.1109/CISP.2009.5302445
- Yang, B. and Busch, C., "*Parameterized Geometric Alignment for Minutiae-Based Fingerprint Template Protection*", IEEE Third International Conference on Biometrics: Theory, Applications and Systems (BTAS 09), September 2009
  http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5339058
- Kelkboom, E.J.C., Zhou, X., Breebaart, J., Veldhuis, R.N.J. and Busch, C. "*Multi-algorithm fusion with template protection*" IEEE 3rd International Conference on Biometrics: Theory, Applications, and Systems, 2009. BTAS '09, September 2009
  http://dx.doi.org/10.1109/BTAS.2009.5339045
- Kelkboom, E.J.C., de Groot, K.T.J., Chen, C., Breebaart, J. and Veldhuis, R.N.J., "*Pitfall of the Detection Rate Optimized Bit Allocation within Template Protection and a Remedy*", IEEE 3rd International Conference on Biometrics: Theory, Applications, and Systems, 2009. BTAS '09, Digital Object Identifier: 10.1109/BTAS.2009.5339046, September 2009
  http://www.jeroenbreebaart.com/papers/btas/btas2009_2.pdf
- Xu, H. and Veldhuis, R.N.J. "*Spectral minutiae representations of fingerprints enhanced by quality data*" IEEE 3rd International Conference on Biometrics: Theory, Applications, and Systems, 2009. BTAS '09, September 2009
  http://dx.doi.org/10.1109/BTAS.2009.5339064
- Bringer, J., Chabanne, H., Kevenaar. Tom A. M. and Kindarji, B. "*Extending Match-On-Card to Local Biometric Identification*", lecture notes in Computer Science, Springer Berlin / Heidelberg, Volume 5707/2009, pp. 178-186, September 2009
  http://www.springerlink.com/content/[illegible]
- Kindt E., "*Privacy by design? The case of biometrics*", published in the pre-proceedings of the IFIP/PrimeLife Summerschool 2009 with theme : Privacy and identity management for emerging Internet applications throughout a person's life, September 7-11, 2009, Nice, France
- Buhan, I., Breebaart, J., Guajardo, J., de Groot, K., Kelkboom, E., Akkermans, T., "*A Quantitative Analysis of Indistinguishability for a Continuous Domain Biometric Cryptosystem*", September 2009
  http://www.jeroenbreebaart.com/papers/dpm/dpm2009.pdf
- Yang, B., Busch, C., Derawi, M., Bours, P. and Gafurov, D., "*Geometric-Aligned Cancelable Fingerprint Templates*", lecture notes in Computer Science, ISSN: 0302-9743 (Print) 1611-3349 (Online), Springer, Berlin / Heidelberg, August 2009
  http://www.springerlink.com/content/6347bg582w2u1224/
- Breebaart, J., Akkermans, T. and Kelkboom, E., "*Intersubject Differences in False Nonmatch Rates for a Fingerprint-Based Authentication System*", EURASIP Journal on Advances In Signal Processing, Volume 2009 (2009), Article ID 896383, Hindawi Publishing Corporation, July 2009
  http://www.hindawi.com/journals/asp/2009/896383.abs.html
- Chen, C. and Veldhuis, R.N.J."*Binary Biometric Representation through Pairwise Polar Quantization*", lecture notes in Computer Science 5558, Springer Verlag, Berlin, pp. 72-81, June 2009
  http://dx.doi.org/10.1007/978-3-642-01793-3_8
- Koen Simoens, Pim Tuyls and Bart Preneel, "*Privacy Weaknesses in Biometric Sketches*", May 2009
  http://www.cosic.esat.kuleuven.be/publications/article-1205.pdf
- Breebaart, J., Yang, B., Buhan, B., Busch, C, "*Biometric template protection The need for open standards*", Datenschutz und Datensicherheit - DuD, Volume 33, number 5, pp. 299-304, May 2009
  http://www.springerlink.com/content/[illegible]
- Bian Yang, Christoph Busch, Patrick Bours, and Davrondzhon Gafurov, "*Non-invertible Geometrical Transformation for Fingerprint Minutiae Template Protection*", Norwegian Information Security Laboratory at Gjøvik University College, Norway, May 2009
  http://www.q2s.ntnu.no/iwscn2009/
- Kindt, E. "Biometric Applications and the Data Protection Legislation", in *Biometrics : Techno-Legal Issues*, M.N.Bhavani (ed.), Icfai University Press, Punjagutta (India), 2008-2009, pp. 170- 182.
  https://www.law.kuleuven.be/icri/publications/880DuD3_2007_166.pdf
- Chen, C. and Veldhuis, R.N.J. and Kevenaar, T.A.M. and Akkermans, A.H.M. "*Biometric Quantization through Detection Rate Optimized Bit Allocation*" EURASIP Journal on Advances in Signal Processing, Volume 2009 (2009), Article ID 784834, Hindawi, April 2009
  http://dx.doi.org/10.1155/2009/784834
- Xu, H. and Veldhuis, R.N.J. and Bazen, A.M. and Kevenaar, T.A.M. and Akkermans, A.H.M. and Gokberk, B. "*Fingerprint Verification Using Spectral Minutiae Representations*" IEEE Transaction on Information Forensics and Security, Volume: 4 Issue:3, pp. 397 – 409, April 2009
  http://dx.doi.org/10.1109/TIFS.2009.2021692
- Kindt, E. "*Nieuwe Identificatietechnologieën, Persoonsgegevens en Privacy : de uitdaging van de 21ste eeuw*", Jubileum-editorialComputerrecht 2009/3, p. 109 (uitgeverij Kluwer BV, ISSN 0771-7784), March 2009
  http://law.kuleuven.be/icri/all_pubs.php?action=pubs_staff&staffid=39
- Kindt, E. & van der Hof, S., "*Identiteitsgegevens en Identiteitsbeheer in een digitale omgeving*", Publication in legal journal (for the Netherlands and Belgium) :Computerrecht 2009/2, publisher Kluwer BV, ISSN 0771-7784, pp. 44-52, March 2009
  http://law.kuleuven.be/icri/all_pubs.php?action=pubs_staff&staffid=39

Publications resulting from TURBINE in year 2008

- E. Kindt, J. Dumortier, "*Biometrie als herkenning- of identificatiemiddel? Enkele juridische beschouwingen*", in Legal journal for the Netherlands and Belgium: Computerrecht 2008/5, 185 - 198, n 132, October 2008
  https://lirias.kuleuven.be/handle/123456789/202599?mode=full&submit_simple=Show+full+item+record
- B. Yang, "*Norwegian Contribution on 3rd WD 24745*", circulated by ISO as document SC27N4805, 16 September 2008
- E. Kindt, J. Breebaart, C. Busch, J. Grave, "*A Reference Architecture for Biometric Template Protection based on Pseudo Identities*", in proceedings BIOSIG 2008, GI-LNI, 2008, Darmstadt, Germany, 11-12 September 2008
  http://www.cast-forum.de/en/workshops/infos.html/106
- Delvaux, N. Chabanne, H. Bringer, J. Kindarji, B. Lindeberg, P. Midgren, J. Breebaart, J. Akkermans, T. van der Veen, M. Veldhuis, R. Kindt, E. Simoens, K. Busch, C. Bours, P. Gafurov, D. Bian Yang Stern, J. Rust, C. Cucinelli, B. Skepastianos, D., "*Pseudo Identities Based on Fingerprint Characteristics*", in proceedings of the IEEE IIH-MSP 2008, Harbin - China, pages 1063-1068, 15-17 August 2008
  http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=4604230
- Haiyun Xu, R.N.J. Veldhuis, T.A.M. Kevenaar, A.H.M. Akkermans, A.M.Bazen, "*Spectral Minutiae: A Fixed-length Representation of a Minutiae Set*", in proceedings CVPR 2008, Volume , Issue , 23-28 June 2008, Page(s): 1 - 6
  http://ieeexplore.ieee.org/Xplore/login.jsp?url=/iel5/4558053/4562948/04563120.pdf?arnumber=4563120
- C.Chen, R.N.J. Veldhuis, T.A.M. Kevenaar, A.H.M Akkermans, "*Biometric Binary String Generation with Detection Rate Optimized Bit allocation*", in proceedings CVPR 2008, 23-28 June 2008
  http://ieeexplore.ieee.org/xpl/abs_print.jsp?arnumber=4563112&page=FREE
- H. Xu, R. N. J. Veldhuis, T. A. M. Kevenaar, A. H. M. Akkermans, and A. M. Bazen, "*Spectral minutiae: A fixed-length representation of a minutiae set.*", In 2008 IEEE Computer Society Conference on Computer Vision and Pattern Recognition. Workshop on Biometrics, Anchorage, Alaska, US, pages 1-6, Los Alamitos, June 2008. IEEE Computer Society Press.

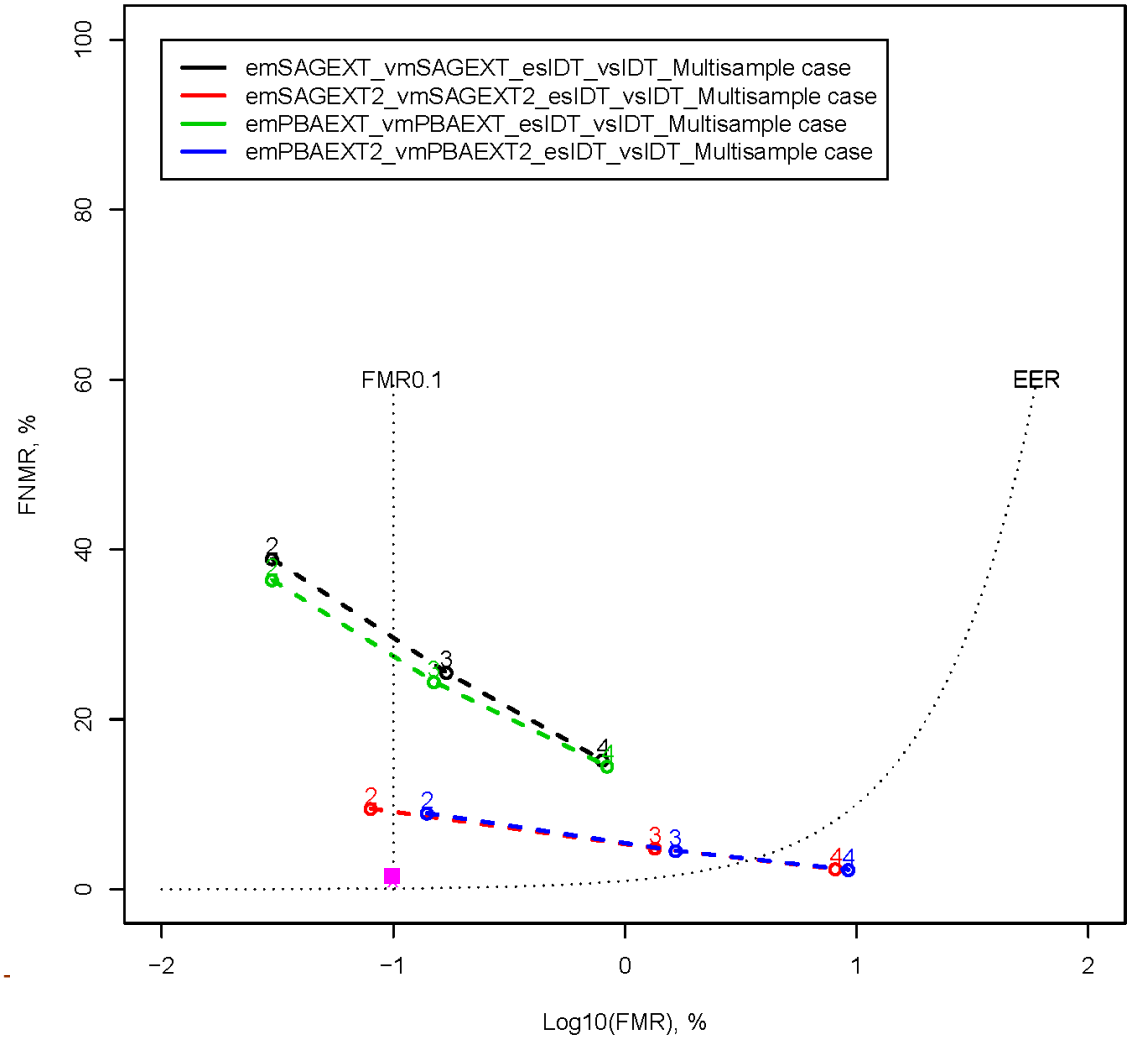
SEVENTH FRAMEWORK PROGRAMME

Fusion in 2nd Round Testing

- Multi-scanner
- Multi-sample
- Multi-instance
- Multi-sample-instance
- Multi-sample-instance-algorithm

Improvement from round #1 to #2

- Reflecting research from 06’2009 to 06’2010
- Multi-sample Enrolment



SEVENTH FRAMEWORK PROGRAMME

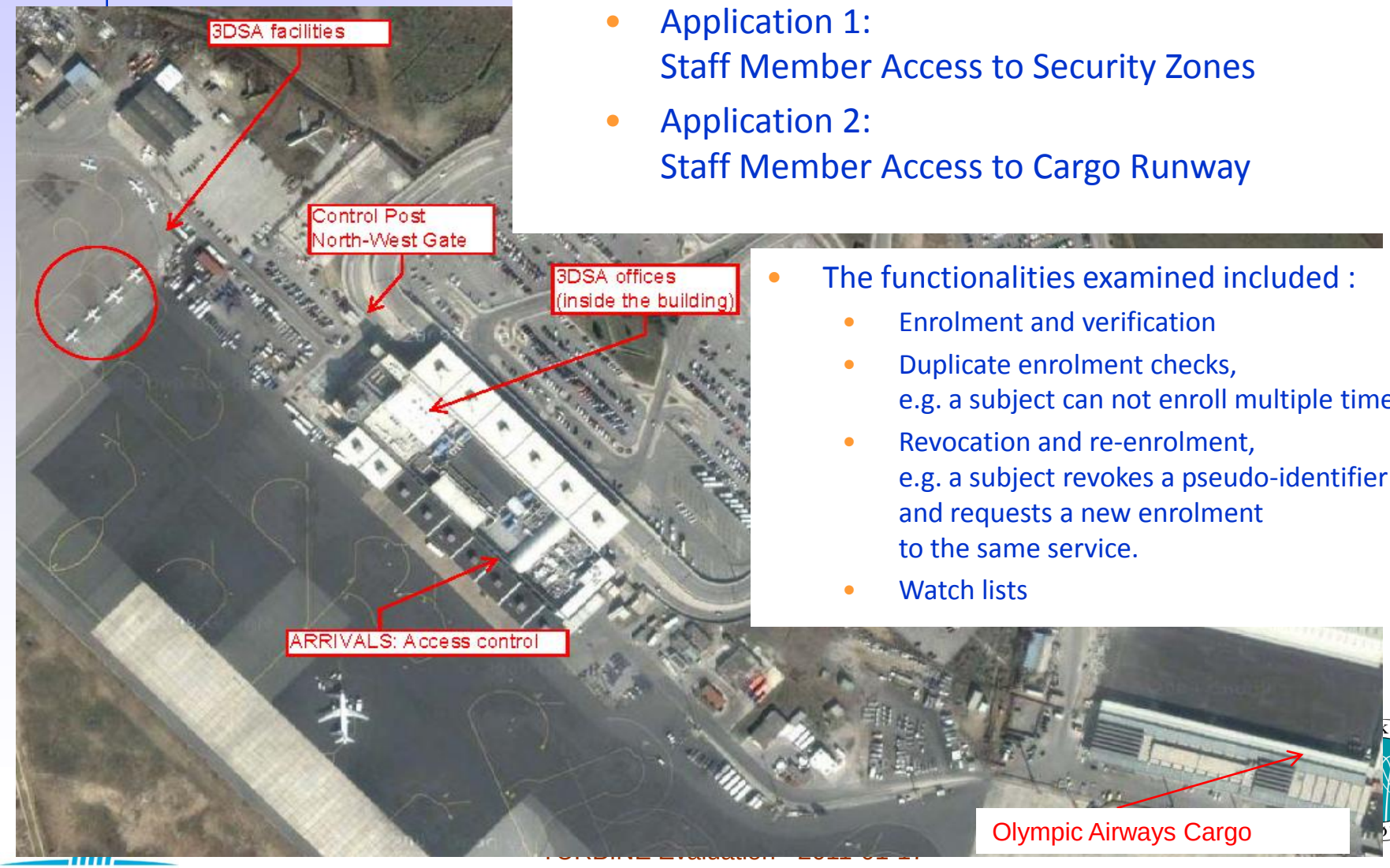
Best Biometric Performance

Algo-rithm	Test parameter	Best performance
MTE1	Image quality & single sample enrolment	FNMR= 0.57% @ FMR=0.1%
PI1	No image quality & single sample enrolment	FNMR=31.28% @ FMR=0.07%
PI2	No image quality & single sample enrolment	FNMR=31.30% @ FMR=0.02%
PI2	Image quality & multisample enrolment	FNMR= 8.96% @ FMR=0.14%
PI3	No image quality & single sample enrolment	FNMR=12.30% @ FMR=0.1%
PI3	Image quality & multisample enrolment	FNMR= 3.89% @ FMR=0.1%
PI1+ PI2+ PI3	Three layer fusion at decision level: multi-sample-instance-algorithm	FNMR= 0.60% @ FMR= 0.1%

Performance evaluation: from benchmarks to airport deployment

The field trial at Thessaloniki International Airport

- Demonstrator in a real-life environment:
  - Application 1:
    Staff Member Access to Security Zones
  - Application 2:
    Staff Member Access to Cargo Runway



- The functionalities examined included :
  - Enrolment and verification
  - Duplicate enrolment checks,
    e.g. a subject can not enroll multiple times
  - Revocation and re-enrolment,
    e.g. a subject revokes a pseudo-identifier
    and requests a new enrolment
    to the same service.
  - Watch lists

Summary and Conclusion

- PI level verification provides gain with respect to privacy
- We observe some degradation of the biometric performance
- Security analysis must also be taken into account in order to select good algorithms
  - See next presentation by Koen Simoens
  - In the future: ranking of algorithms
- Operational evaluation validates performance and throughput
  - See tomorrows presentation by Odysseas Spyroglou

Questions and Answers