PARIS LODRON UNIVERSITY SALZBURG

Finger Vein Biometrics
An Analysis from Different Perspectives

Bernhard Prommegger
Supervisor: Andreas Uhl

Department of Computer Sciences
University of Salzburg

November 5, 2021

Finger Vein Biometrics

- Based on the structure of the blood vessels inside the human finger
- Only visible in NIR light
- Established in Asia and Eastern Europe
- Rising interest in Western Europe
  - Border Control
  - Financial sector

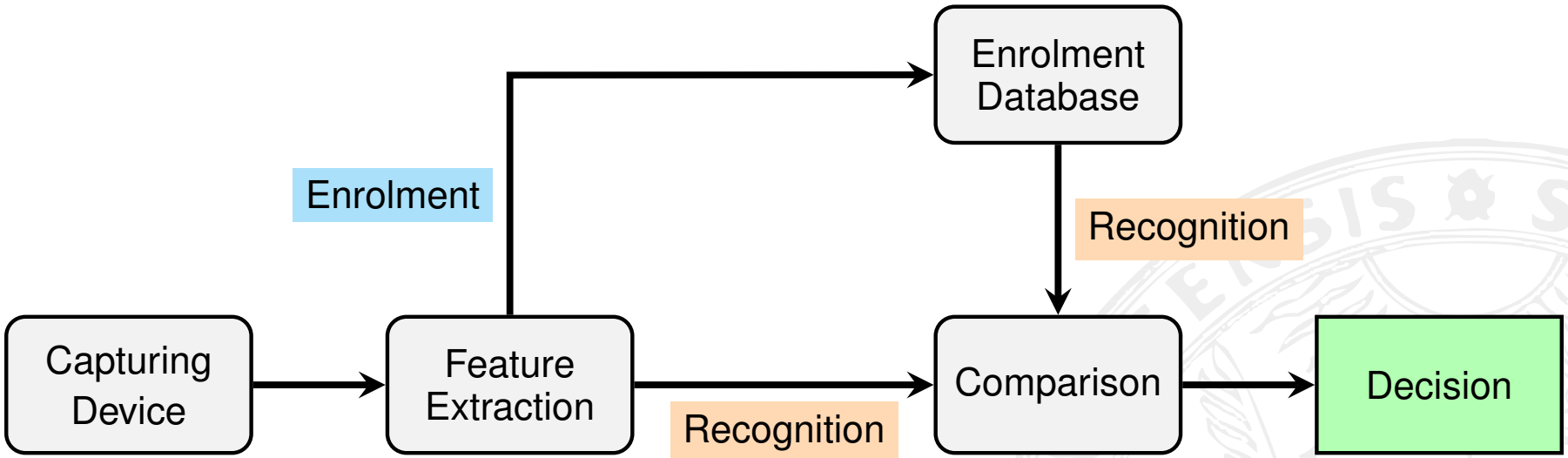
https://www.m2sys.com/

https://www.hitachi.com/

https://www.hitachi.com/

https://www.fujitsu.com

Biometric Recognition Systems



Introduction III

Contributions in three major areas:

1. Finger vein capturing devices and data set creation
2. Finger vein recognition from different perspectives
3. Rotation invariant finger vein recognition

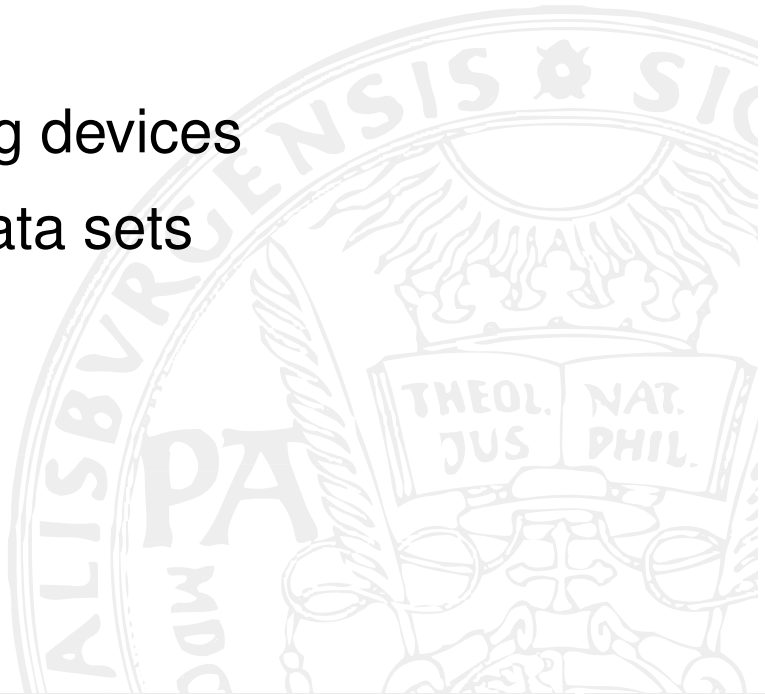
Publications

- 14 published in relevant peer reviewed journals and conferences
  - 3 journals: **T-BIOM**, **IET-Biometrics** and Sensors
  - 2 book chapters (Springer)
  - 9 conferences: 3x **BTAS**, 1x **ICB**, 1x IWBF, 1x **ICPR**, 3x BioSig

Capturing Devices and Data Set Creation I

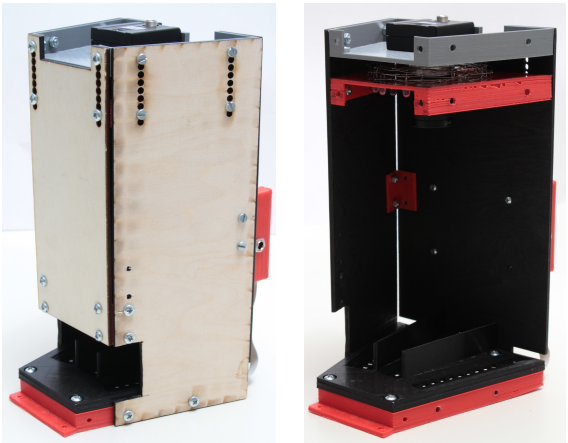
Finger vein capturing devices and data set creation [1, 2, 3, 4, 5]

- General problem in biometrics: availability of suitable datasets
- Even worse for vascular biometrics:
  - devices do not provide raw data
  - limited size
- Development of three different capturing devices
- Acquisition of three publicly available data sets

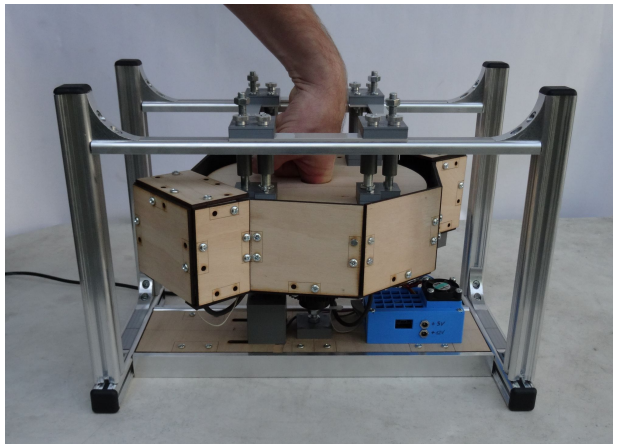


Capturing Devices and Data Set Creation II

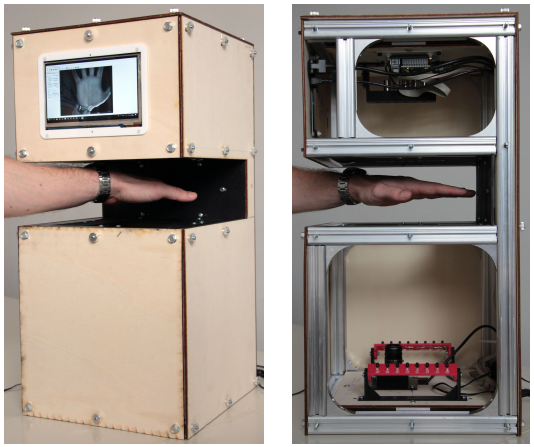
Self-developed capturing devices and acquired data sets



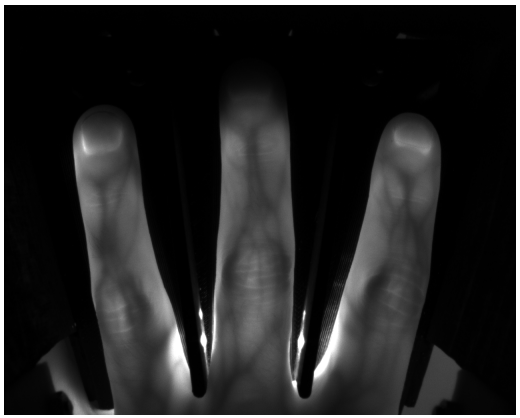
PLUS OpenVein [5]



3D Finger Vein Scanner [2]

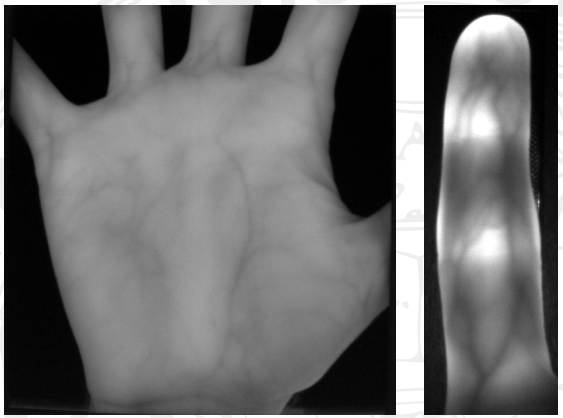


Contactless Scanner [4]



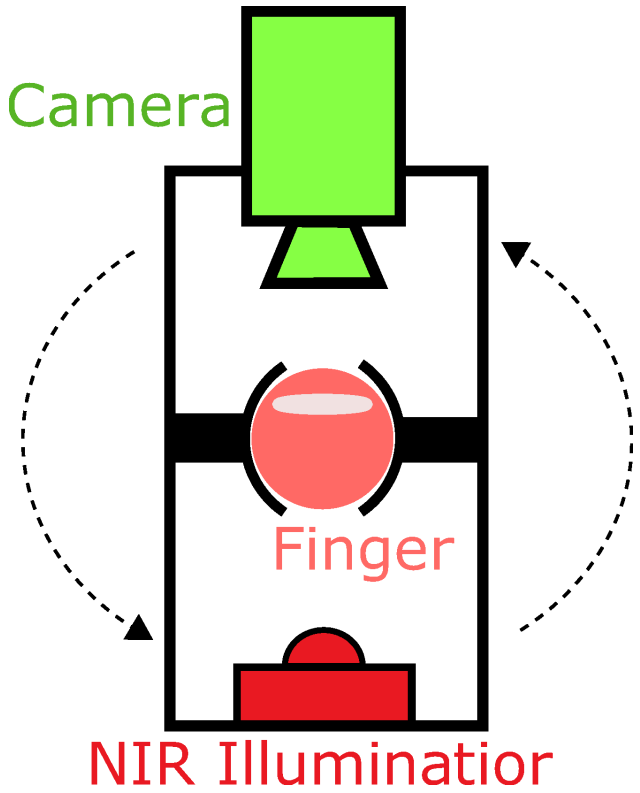
PLUSVein-FV3 [1, 3]

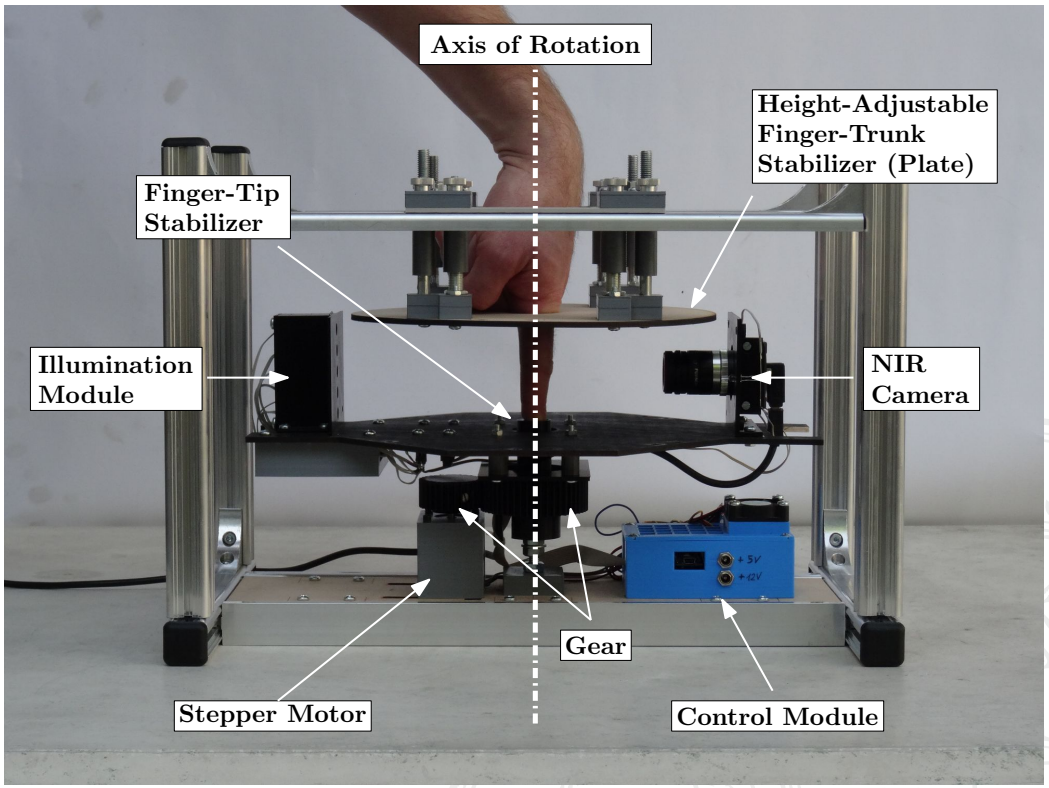
PLUSVein-FR [2, 6, 7]



PLUSVein-CL [4]

Multi-perspective finger vein scanner [2]



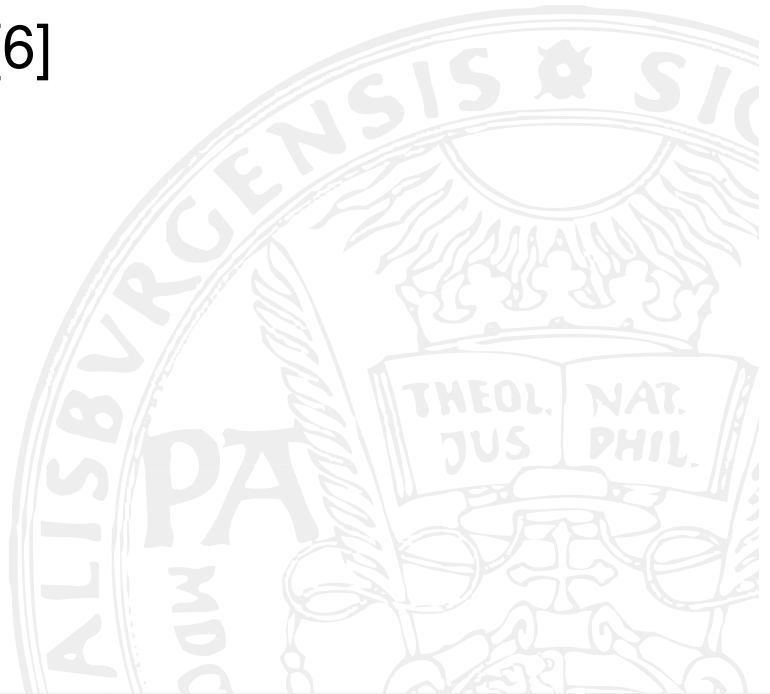


Left: Principle of the multi-perspective finger vein scanner, right: the scanner itself

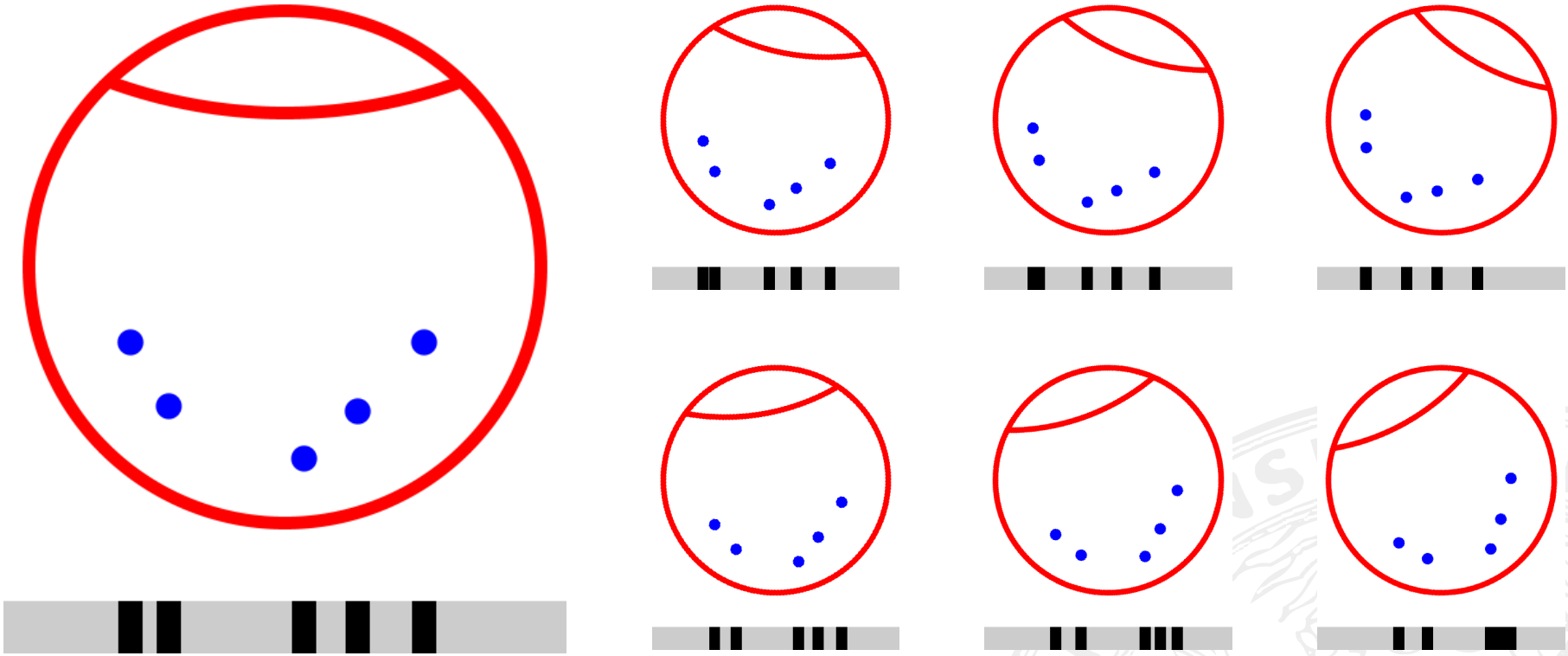
Recognition from Different Perspectives I

Finger vein recognition from different perspectives

- Intra perspective recognition performance [2, 6, 8]
- Effect of longitudinal finger rotation [9, 6]
- Rotation compensation and correction [6]
- Rotation detection [10, 11]

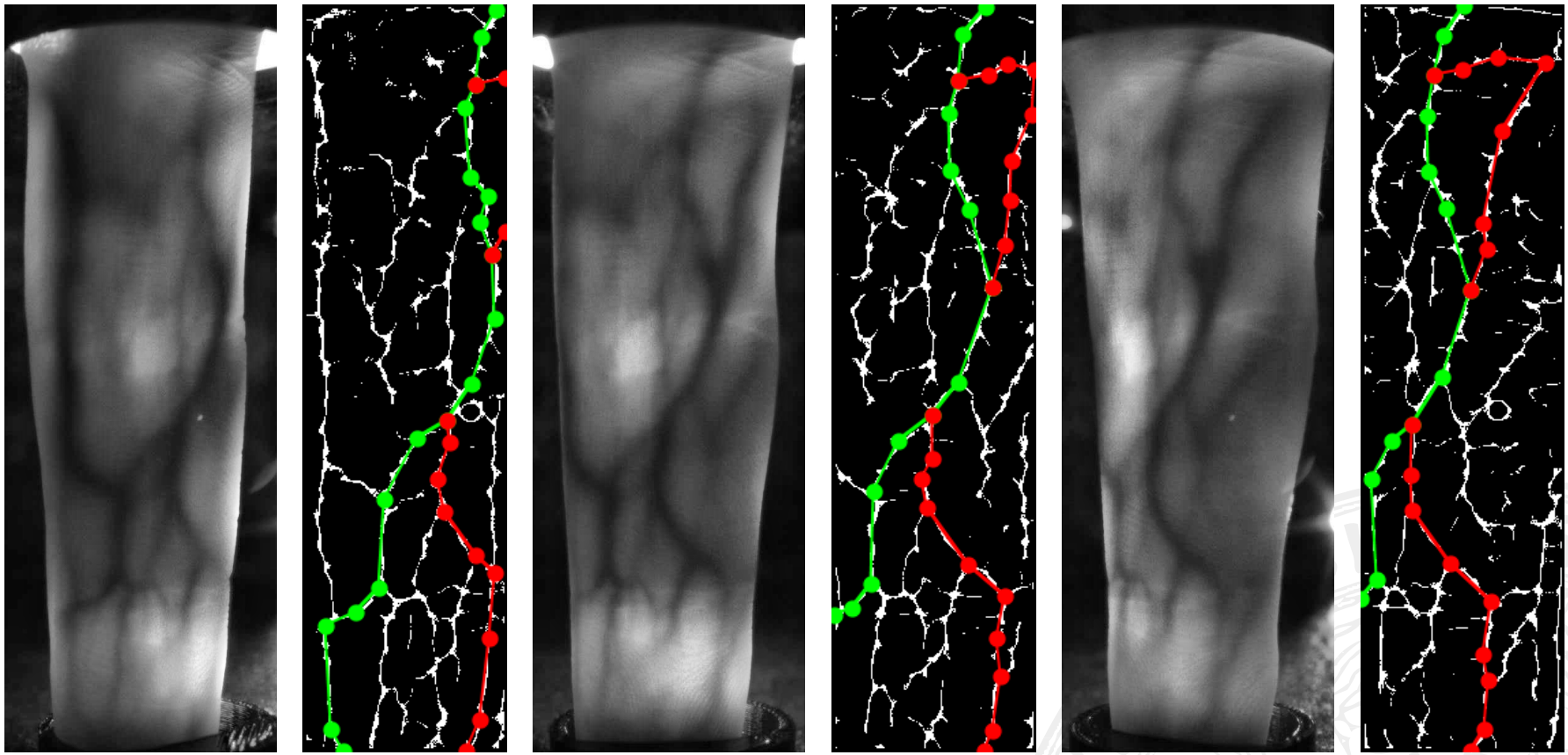


Longitudinal finger rotation



Finger longitudinal axis rotation principle: a schematic finger cross section showing five veins (blue dots) rotated from -10° to -30° (top row) and 10° to 30° (bottom row) in 10° steps. The projection of the vein pattern is different according to the rotation angle following a non-linear transformation [9].

Recognition from Different Perspectives III

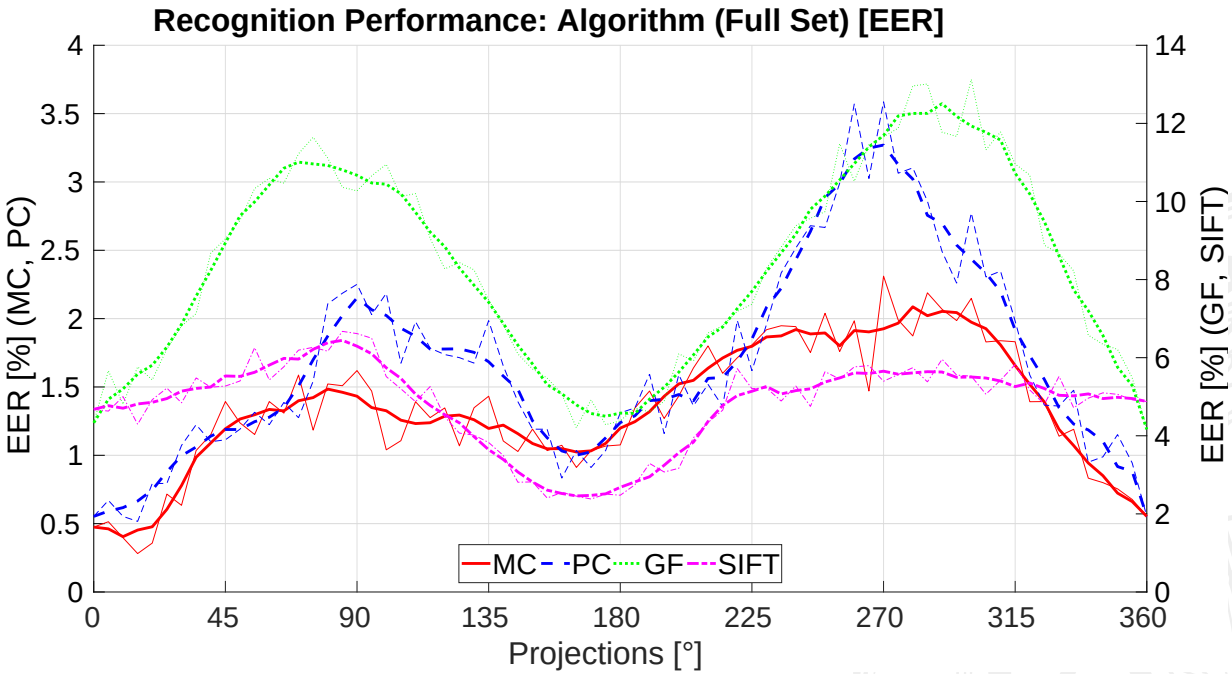


Examples of finger vein images and extracted MC features acquired at different longitudinal rotation angles. Left: -30°, middle: 0° (palmar view), right: 30° [9].

Recognition from Different Perspectives IV

Intra perspective recognition performance [2, 6, 8]

- Currently the palmar view is used nearly exclusively
- Analysis of all perspectives all around the finger
- Multi-perspective and multi-algorithm fusion

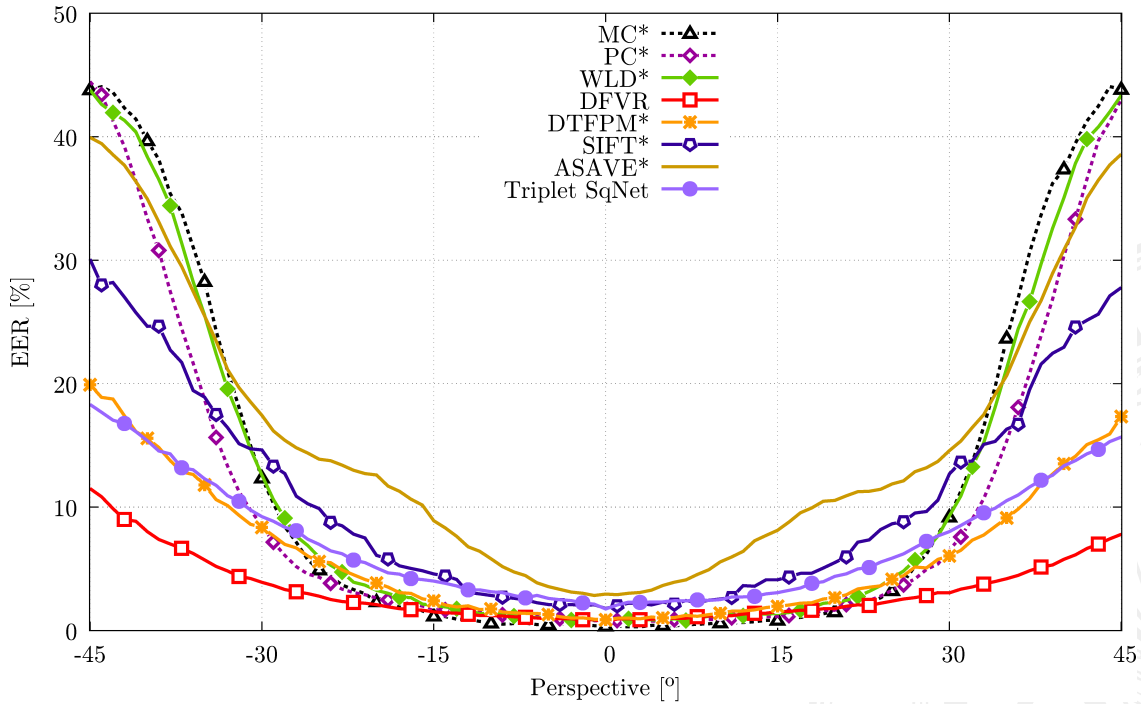


Recognition performance for different perspectives [2]

Recognition from Different Perspectives V

Effect of longitudinal finger rotation [9, 6]

- Systematic robustness analysis of several finger vein recognition schemes against longitudinal rotation.
- Cross-comparison of the rotated perspectives to the reference view

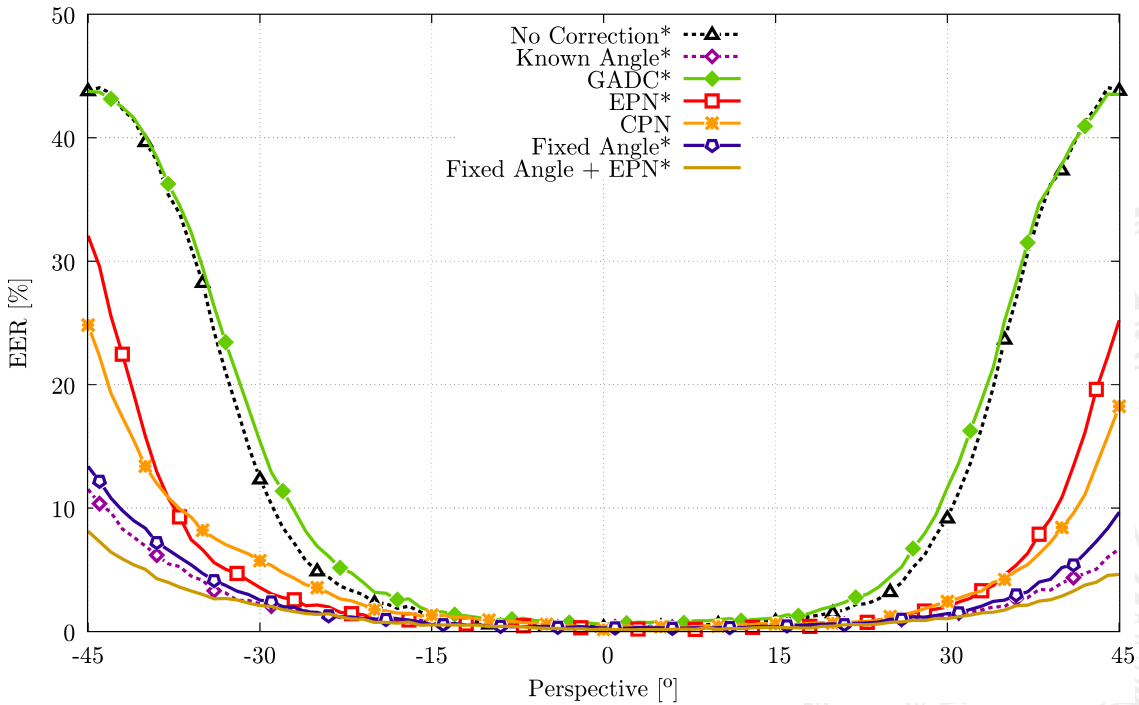


Decline in performance due to finger rotation [12]

Recognition from Different Perspectives VI

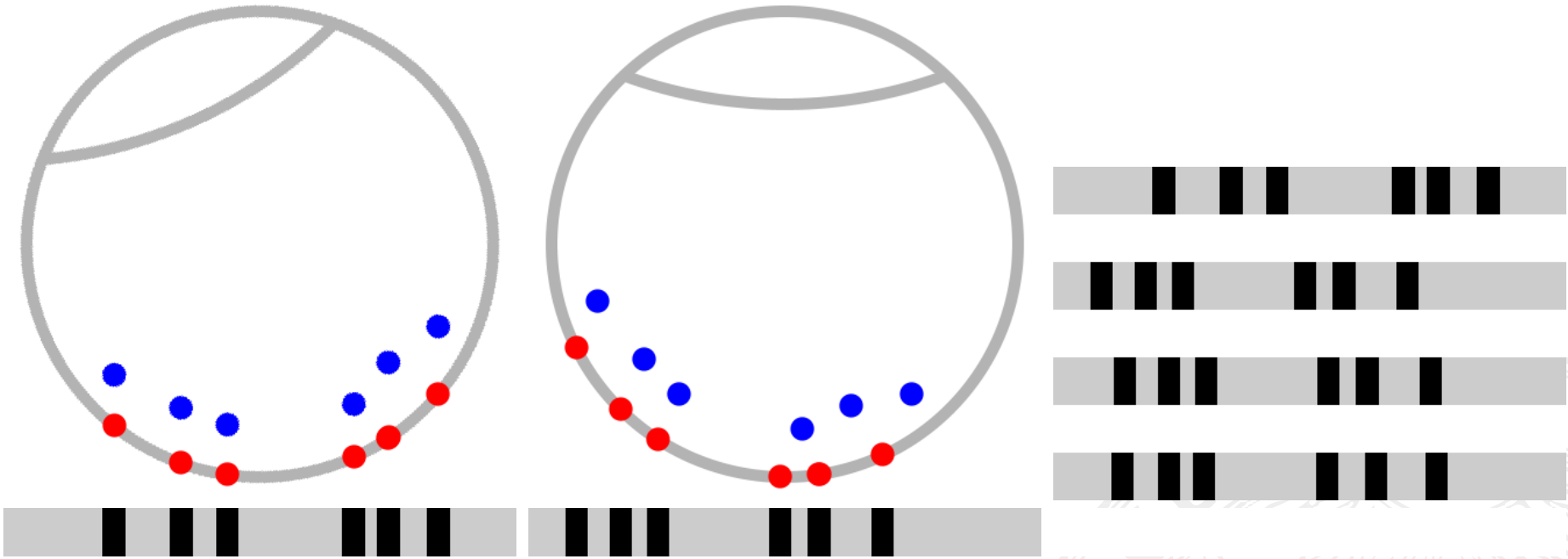
Rotation compensation and correction [6]

- Proposal of two rotation compensation approaches
  - using the known rotation angle
  - using predefined fixed angle
- Comparison to state-of-the-art rotation compensation schemes



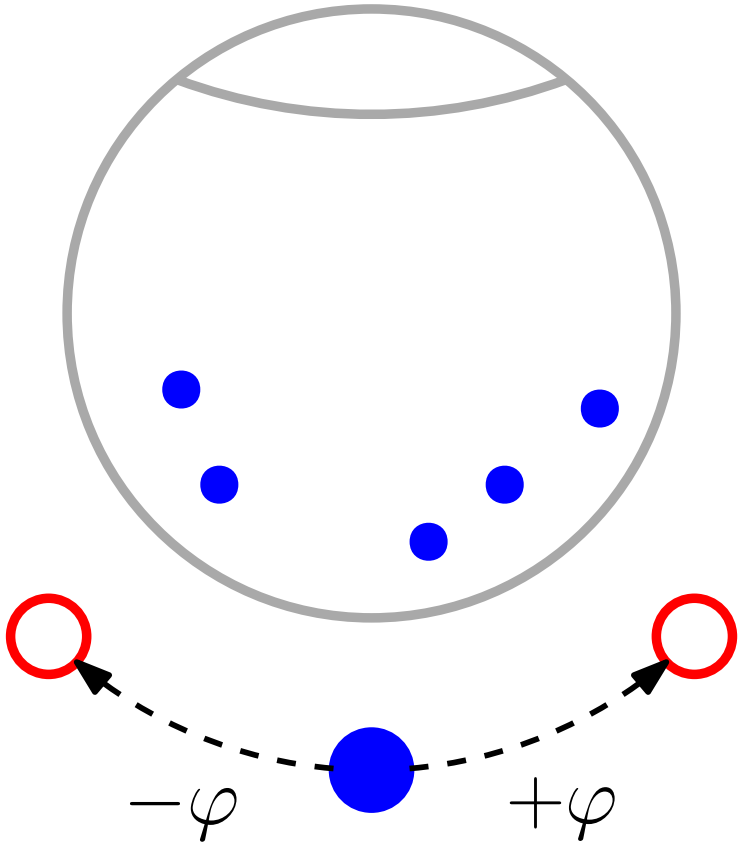
Recognition performance for different rotation correction schemes (MC) [6]

Known-Angle Approach [6]

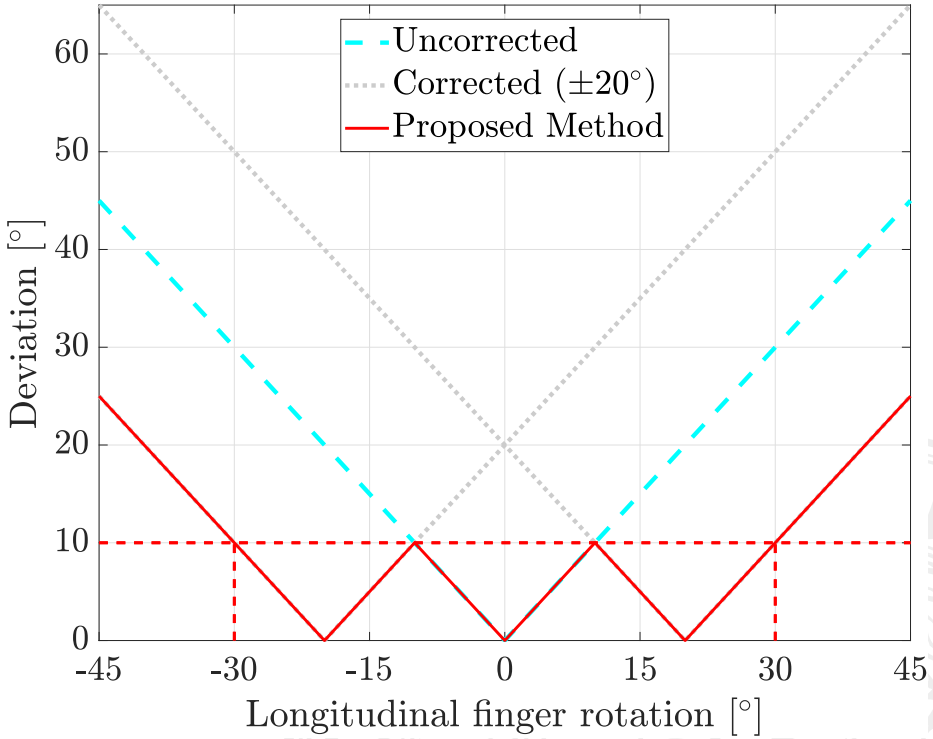


Left: finger rotated with 25°
Middle: the finger rotated into the palmar view
Right (from top to bottom): (1) rotated, (2) corrected, (3) corrected and shifted for the highest correlation to (4) original palmar pattern.

Fixed-Angle Approach [6]



Introducing pseudo-perspectives



Deviation of the rotated finger to the palmar view with an correction angle $\varphi_{corr} = 20°$

Recognition from Different Perspectives IX

Rotation detection [10, 11]

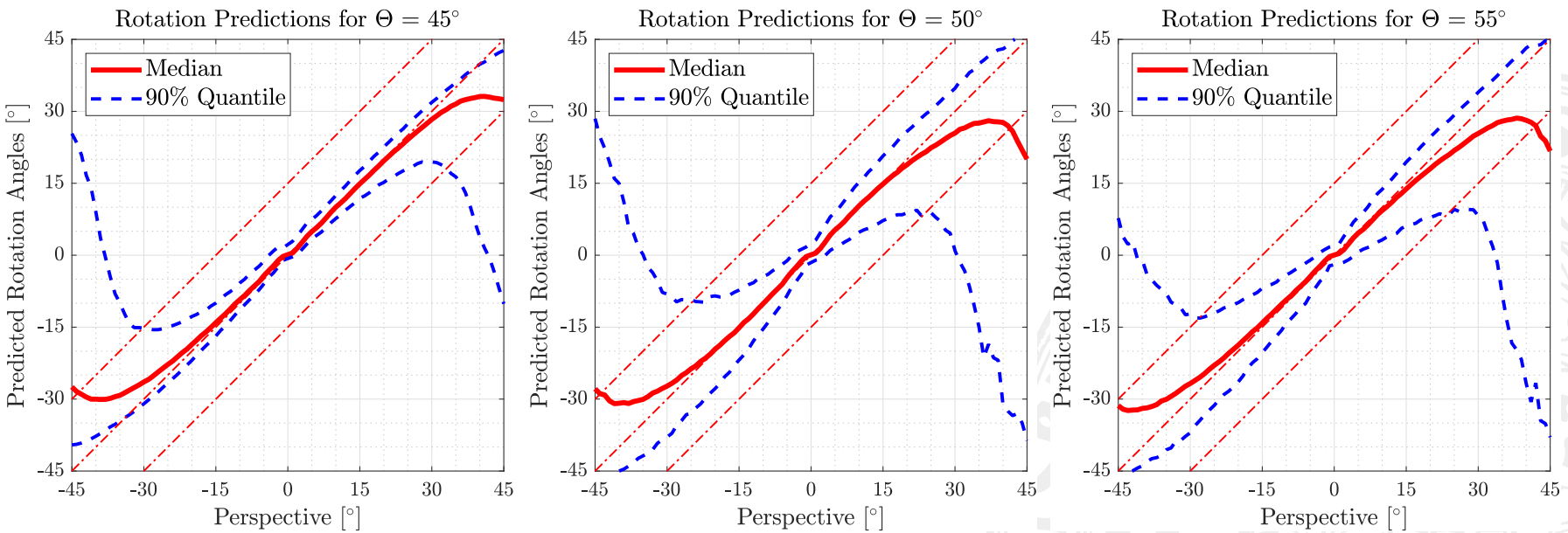
- Analysis of 4 publicly available FV data sets
- Two approaches for rotation estimation (RE):
  1. Comparison of rotated versions against reference (MC features, highest score wins) [10]
  2. CNN-based estimator, can be used in real-time systems [11]
- Not only a scientific problem !!!

Data Set	Abs. Dist. to Mean			Maximum Distance		
	Mean	Max	Std	Mean	Max	Std
SDUMLA-HMT	6.43	44.83	6.90	19.40	**77.00**	15.73
UTFVP	2.65	16.50	2.29	7.95	**29.50**	4.41
FV-USM	3.04	23.83	3.23	11.32	**41.00**	7.75
PLUSVein-FV3	1.37	8.60	1.24	4.46	12.50	2.44

Degree of rotation present in the data sets [10]

CNN-based rotation estimator [11]

- Architecture: ResNext + MSE
- Training:
  - DB: PMMDB
  - different rotational ranges Θ
- Evaluation:
  - DB: PLUSVein-FR
  - best results $\Theta = \pm 45°$
  - stable results up to 30°



Result Verification / Generalisability of Proposed CNN

- 4 publicly available finger vein data sets
- Recognition performance after applying rotation correction
- **CNN was not retrained for evaluated data sets!**
- Results close to [10] where rotation estimation was done on the data set

Data Set	Method	EER [%]	RPI [%]
SDUMLA-HMT	original	4.73	-
	aligned	1.30	263.40
UTFVP	original	0.42	-
	aligned	0.18	125.47
FV-USM	original	1.23	-
	aligned	0.52	137.03
PLUSVein-FV3	original	0.08	-
	aligned	0.05	61.23

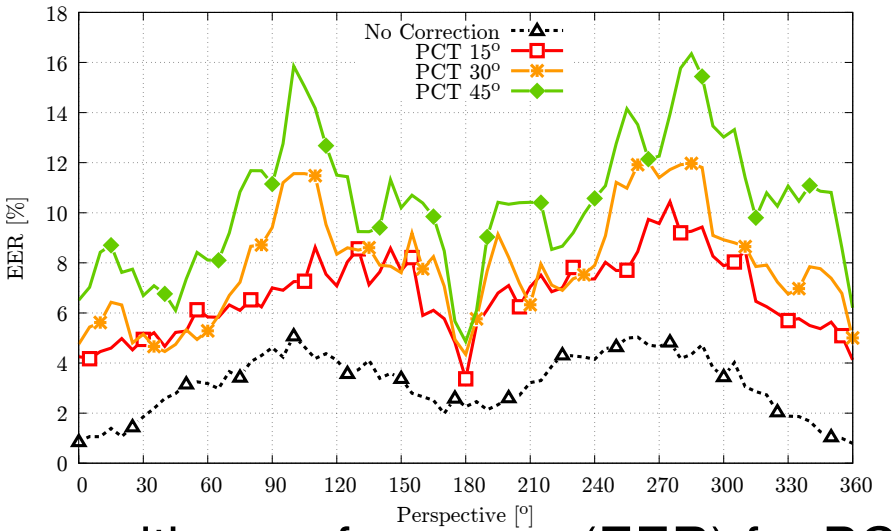
Rotation Invariant Finger Vein Recognition I

Rotation invariant finger vein recognition [7, 13, 14, 12]

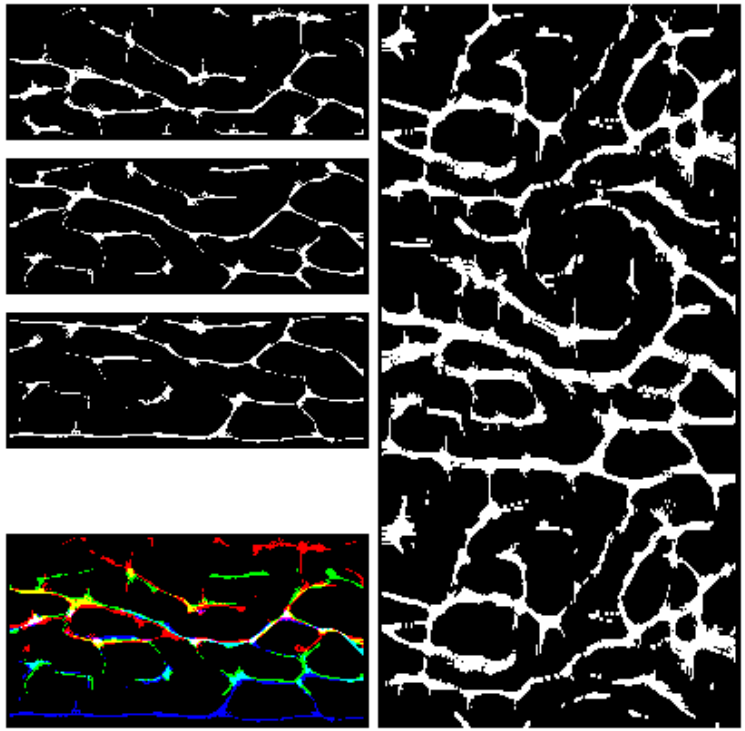
- Proposal of 4 rotation invariant multi-camera recognition systems
- Enrolment and/or recognition samples need to cover the complete (rotational) range of interest
- Two different approaches:
  1. Stitching of enrolment images to a large template
     - Perspective cumulative finger vein templates (PCT) [7]
  2. Independent comparison of multiple finger vein images (enrolment and recognition) combined with maximum score level fusion
     - Multi-perspective enrolment (MPE) [7, 14]
     - Perspective multiplication for MPE (PM-MPE) [10, 14]
     - Combined multi-perspective enrolment and recognition (MPER) [12]
- All 4 System are rotational invariance
- PCT shows a slightly inferior performance

Perspective Cumulative Finger Vein Templates (PCT) [7]

- Enrol subject using multiple perspectives
- Combine perspectives to a single PCT
- Verification: single perspective vs PCT
- Applied in the feature space



Recognition performance (EER) for PCT

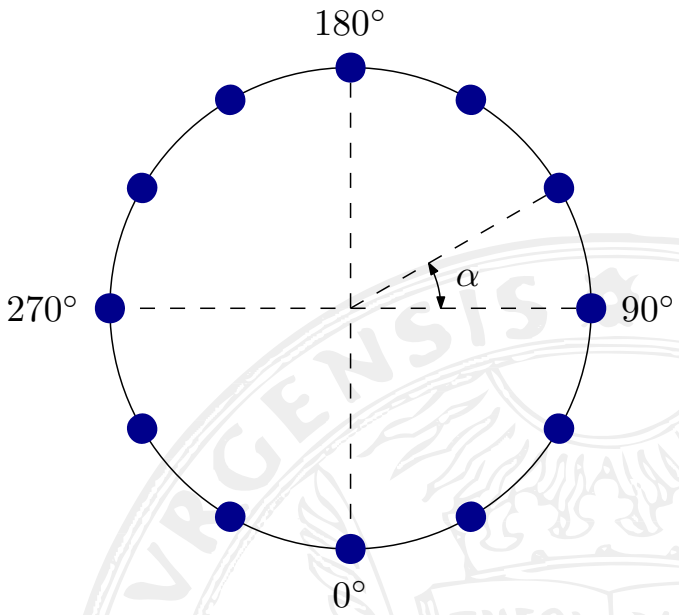


Top-left: single templates
Bottom-left: stitched templates
Right: full PCT

Rotation Invariant Finger Vein Recognition III

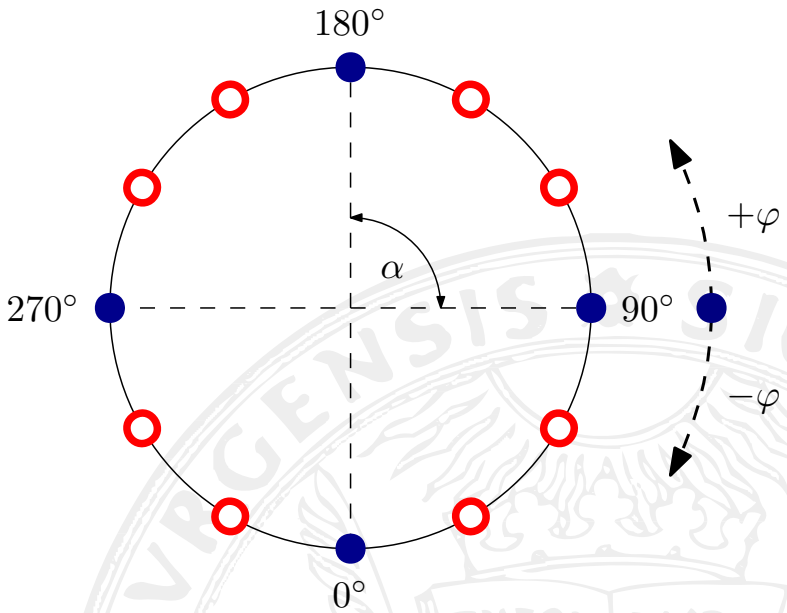
Mulit-Perspective Enrolment (MPE) [7, 14]

- Enrol subject using multiple perspectives
- Verification: single perspective vs all enrolled perspectives
- Maximum rule score level fusion for final result
- Invariant to rotation as enrolment covers complete (rotational) range of interest



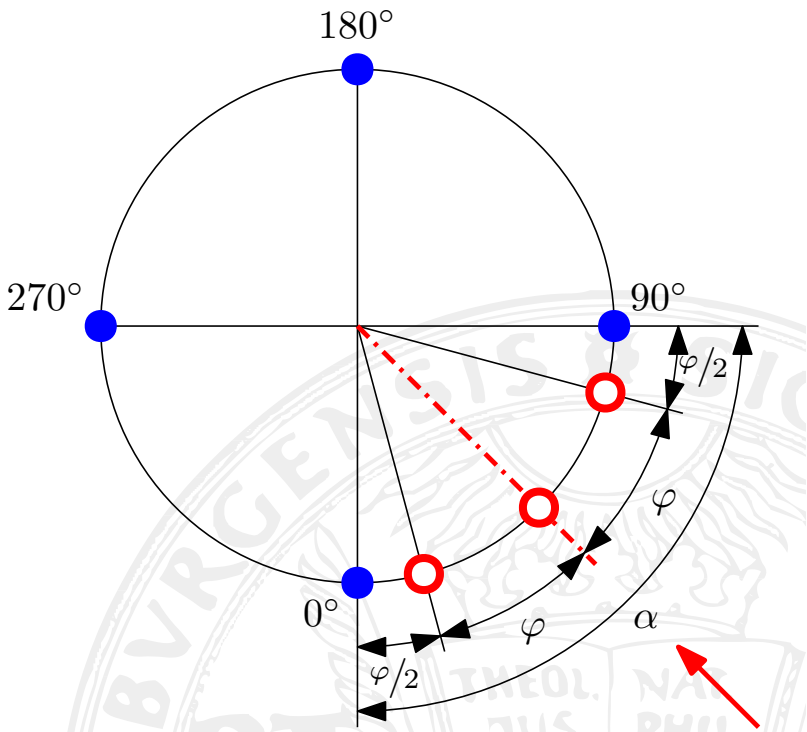
Perspective Multiplication for MPE (PM-MPE) [13, 14]

- Combination of ”fixed angle” approach and MPE
- Verification: single probe sample vs all enrolment and ”pseudo” perspectives
- Rotational distance between enrolment cameras can be increased while still achieving similar recognition rates

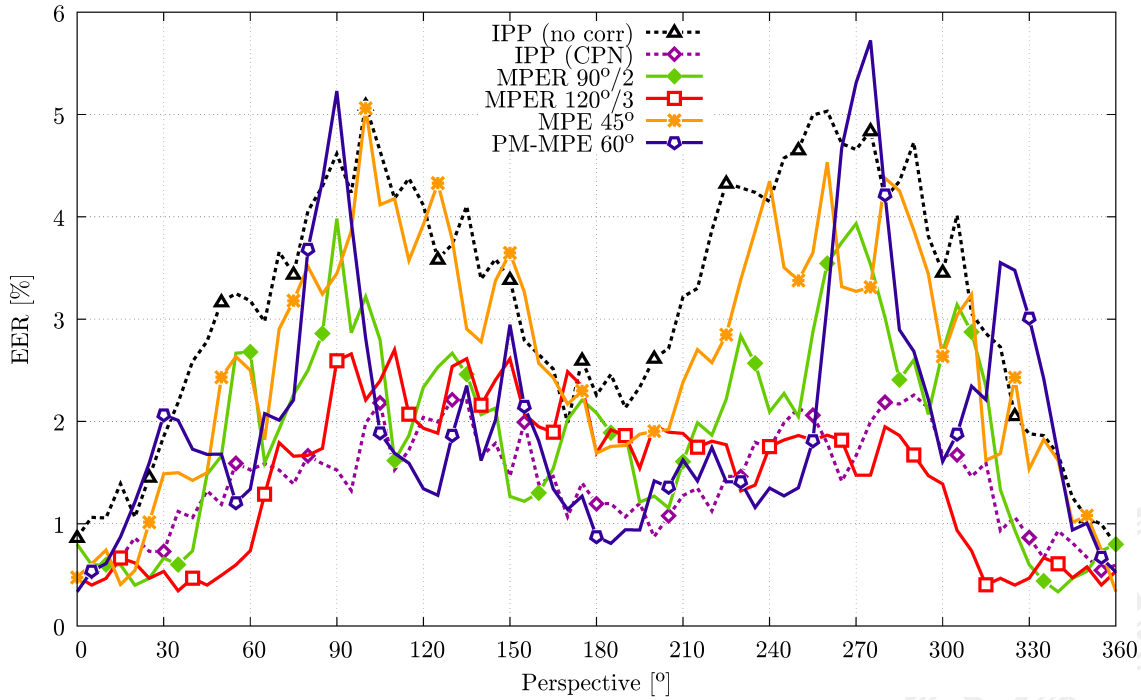


Multi-Perspective Enrolment and Recognition (MPER) [12]

- Multiple perspectives for enrolment and recognition
- Capturing devices for enrolment and recognition differ
- Important: keep max distance between closest enrolment and recognition perspective



Recognition performance for MPE, PM-MPE and MPER



Method	Number of perspectives involved		
	Enrolment	Recognition	Total
MPE 45°	8	1	9
PM-MPE 60°	6	1	7
MPER-90°/2	4	2	6
MPER-120°/3	3	3	6

Conclusion

- Perspectives other than the commonly used ones deliver enough information to perform biometric recognition
- Longitudinal finger rotation is a severe problem for finger vein recognition
- It is relevant for practical application
- We proposed several approaches to counterfight or eliminate the problem of longitudinal finger rotation
- Especially our PLUSVein-FR dataset enables many valuable research opportunities
- Since all of our data sets are publicly available, other researchers can also benefit from our work

The End

Thank you!

Q & A

Bibliography I

[1] C. Kauba, B. Prommegger, and A. Uhl, “Focussing the beam - a new laser illumination based data set providing insights to finger-vein recognition,” in *2018 IEEE 9th International Conference on Biometrics Theory, Applications and Systems (BTAS)*, Los Angeles, California, USA, 2018, pp. 1–9.

[2] B. Prommegger, C. Kauba, and A. Uhl, “Multi-perspective finger-vein biometrics,” in *Proceedings of the IEEE 9th International Conference on Biometrics: Theory, Applications, and Systems (BTAS2018)*, Los Angeles, California, USA, 2018.

[3] C. Kauba, B. Prommegger, and A. Uhl, “The two sides of the finger - an evaluation on the recognition performance of dorsal vs. palmar finger-veins,” in *Proceedings of the International Conference of the Biometrics Special Interest Group (BIOSIG’18)*, Darmstadt, Germany, 2018.

[4] ——, “Combined fully contactless finger and hand vein capturing device with a corresponding dataset,” *Sensors (Special Issue Biometric Systems)*, vol. 19(22), no. 5014, pp. 1–25, 2019.

[5] ——, *OpenVein—An Open-Source Modular Multipurpose Finger Vein Scanner Design*. Cham: Springer International Publishing, 2020, pp. 77–111. [Online]. Available: https://doi.org/10.1007/978-3-030-27731-4_3

Bibliography II

[6] B. Prommegger, C. Kauba, M. Linortner, and A. Uhl, "Longitudinal finger rotation - deformation detection and correction," *IEEE Transactions on Biometrics, Behavior, and Identity Science*, vol. 1, no. 2, pp. 123–138, 2019.

[7] B. Prommegger and A. Uhl, "Rotation invariant finger vein recognition," in *Proceedings of the IEEE 10th International Conference on Biometrics: Theory, Applications, and Systems (BTAS2019)*, Tampa, Florida, USA, 2019.

[8] B. Prommegger, C. Kauba, and A. Uhl, "Different views on the finger score-level fusion in multi-perspective finger vein recognition," in *Handbook of Vascular Biometrics*, A. Uhl, C. Busch, S. Marcel, and R. Veldhuis, Eds. Cham, Switzerland: Springer Nature Switzerland AG, 2019, ch. 10, pp. 261–305.

[9] ——, "Longitudinal finger rotation - problems and effects in finger-vein recognition," in *Proceedings of the International Conference of the Biometrics Special Interest Group (BIOSIG'18)*, Darmstadt, Germany, 2018.

[10] ——, "On the extent of longitudinal finger rotation in publicly available finger vein data sets," in *Proceedings of the 12th IAPR/IEEE International Conference on Biometrics (ICB'19)*, Crete, Greece, 2019, pp. 1–8.

Bibliography III

[11] B. Prommegger, G. Wimmer, and A. Uhl, “Rotation detection in finger vein biometrics using cnns,” in *Proceedings of the 25th International Conference on Pattern Recognition (ICPR)*, 2020, pp. 6531–6537.

[12] B. Prommegger and A. Uhl, “A fully rotation invariant multi-camera finger vein recognition system,” *IET Biometrics*, pp. 1–12, 2021. [Online]. Available: https://ietresearch.onlinelibrary.wiley.com/doi/abs/10.1049/bme2.12019

[13] ——, “Perspective multiplication for multi-perspective enrolment in finger vein recognition,” in *Proceedings of the 18th International Conference of the Biometrics Special Interest Group (BIOSIG’19)*, Darmstadt, Germany, 2019.

[14] ——, “Advanced multi-perspective enrolment in finger vein recognition,” in *Proceedings of the 8th International Workshop on Biometrics and Forensics (IWBF’20)*, Porto, Portugal, 2020, pp. 1–6.