Be Recognised by the Layout of Your Blood Vessels !

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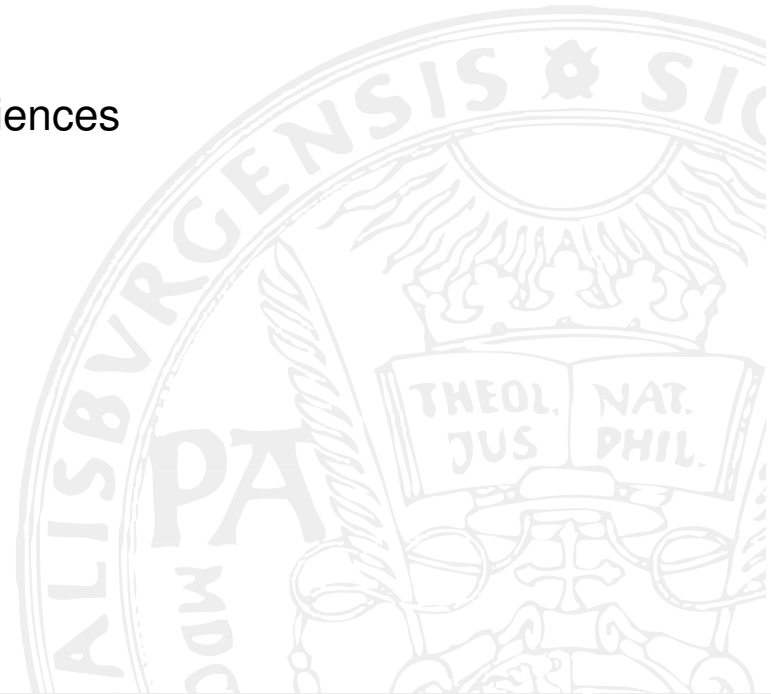
June 18th, 2021



Overview

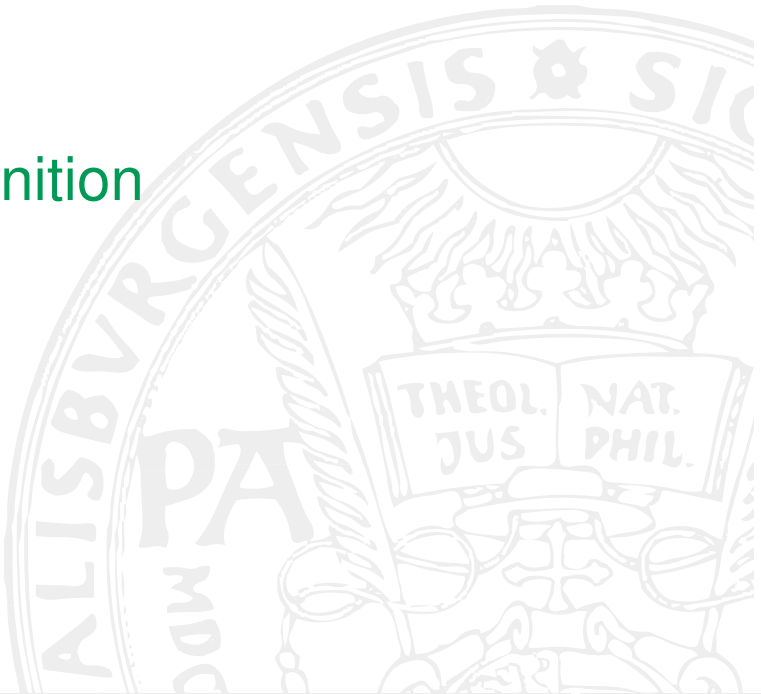
1 Introduction & Motivation

2 Security of Vascular Hand Biometrics

3 Scanners for Vascular Hand Biometrics

4 Towards unconstraint Finger Vein Recognition

5 Conclusion



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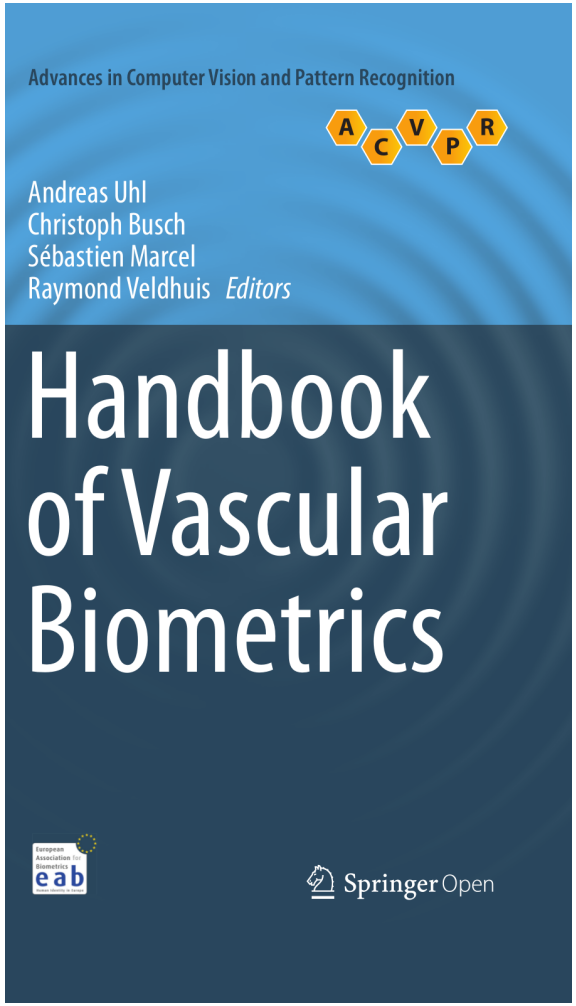
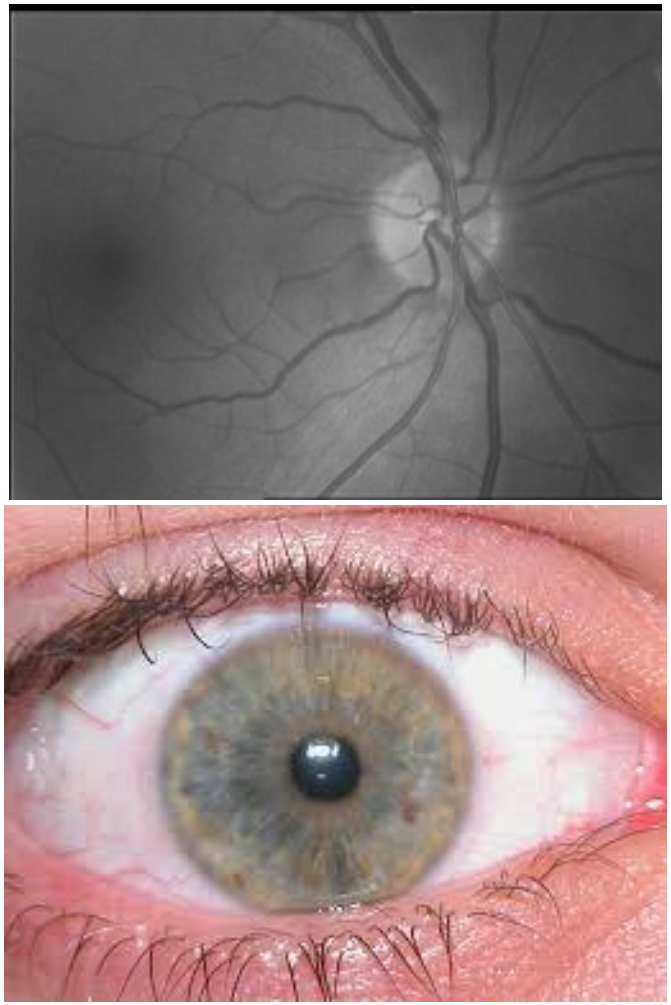
Handbook of Vascular Biometrics



- Human blood vessels as biometric trait
- All vascular biometric traits covered
- Invited and contributed chapters, rigorously reviewed (3 rounds)
- Focus on reproducible research (open datasets, open source code)
- OPEN ACCESS !!

Eye-based Vascular Biometrics



- Retina and sclera recogniton
- Blood vessels of the human eye as biometric trait
- Intrinsic biometric trait (no degradation to be expected)
- Visible in visible (VIS) light
- Dedicated, custom sensors for retina (fundus) capturing, consumer cameras for sclera vessel imaging
- Alternative to iris, face and periocular recognition

Pros and Cons of Vascular Eye Biometrics

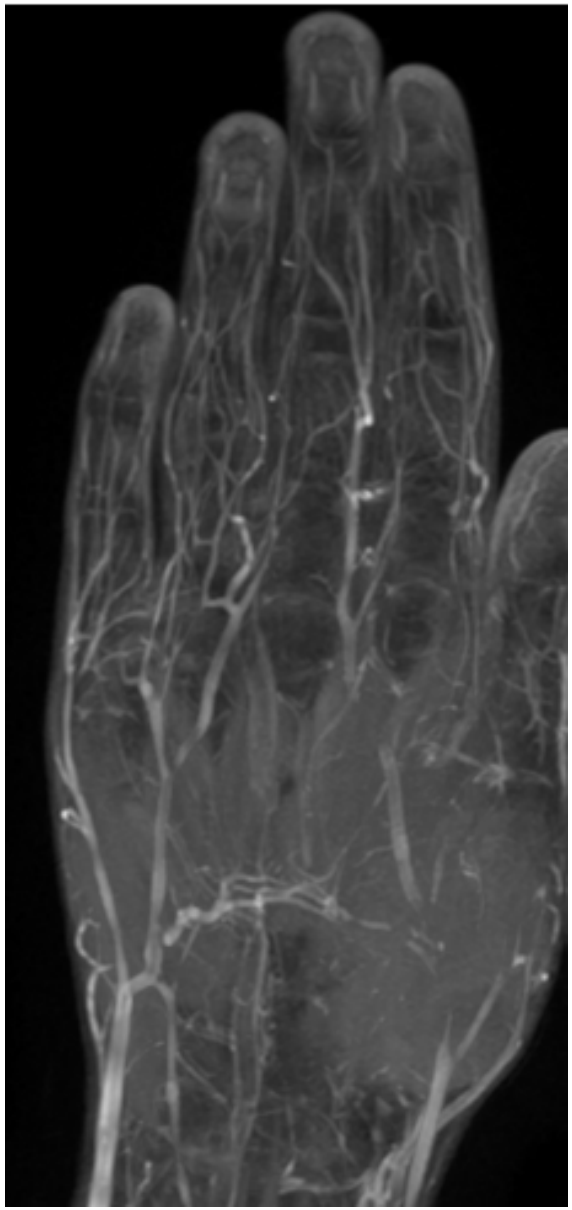
Advantages

- Captured in VIS domain (as opposed to NIR iris imaging)
- Spoofing and presentation attacks are almost impossible
- Liveness detection “easily” possible (blood flow)

Disadvantages

- Retina vessel capturing requires to illuminate the background of the eye which feels like ophthalmological treatment.
- Vessel structure / width in both retina and sclera is influenced by diseases or pathological conditions.
- Sclera recognition is extremely difficult due to the fine vessel network.
- Retina capturing devices originate from ophthalmology and are thus expensive
- Difficult (sclera) or impossible (retina) acquisition from a distance or on the move
- No commercial solutions that could prove the practicality of these two modalities.

Hand-based Vascular Biometrics



- Fingervein, handvein, palmvein, wristvein recognition
- Blood vessels inside the human hand as biometric trait
- Intrinsic biometric trait
- Only visible in near-infrared (NIR) light
- Haemoglobin inside the blood flowing through the vessels absorbs NIR light
- Veins appear as dark lines
- Alternative to fingerprint and palmprint recognition

Pros and Cons of Vascular Hand Biometrics

Advantages

- Insensitive to finger surface conditions (dryness, dirt, lotions) and abrasion (cuts, scars)
- Contactless sensing possible
- More resistant against forgery (i.e. spoofing, presentation attacks) as the vessels are only visible in infrared light
- Liveness detection easily possible due to detectable blood flow (video analysis)

Disadvantages

- Large capturing devices (compared to fingerprint readers) at least for transillumination imaging
- Images having low contrast and quality
- Vein structure may be influenced by temperature, physical activity, as well as by ageing and injuries / diseases
- Current commercial sensors do not allow to access imagery – evaluation only black-box

Commercial Hand (Palm) Vein Scanners – Fujitsu

Commercial Finger Vein Scanners

Figure: Hitachi: Transillumination

Figure: Mofira: Side-Transillumination

Figure: XPO Tech: Side-Transillumination

Deployments Finger Vein Scanners

Figure: Finger vein home banking.

Figure: ATM with finger vein authentication (e.g. Poland).

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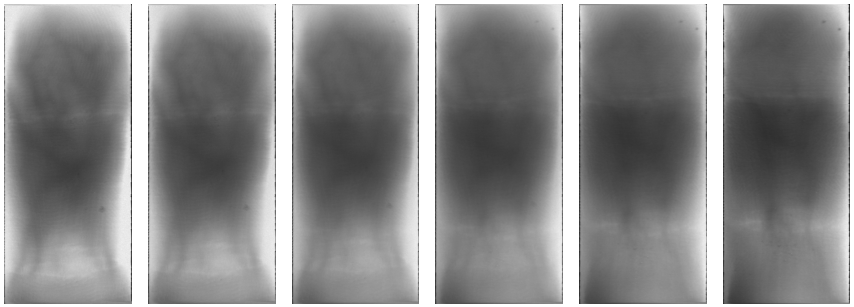
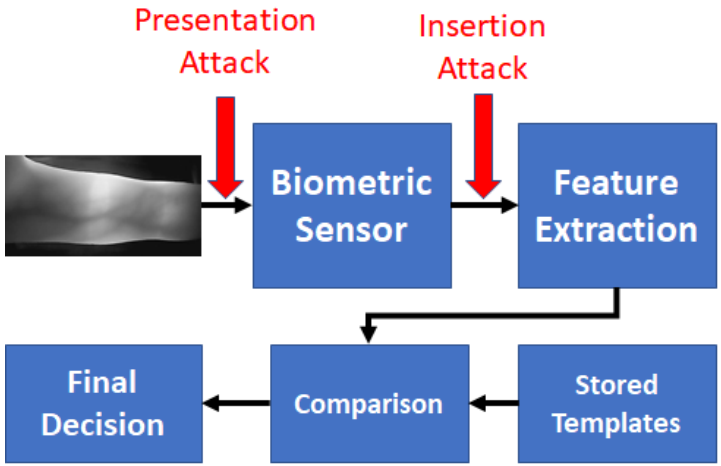
Spoofing Resistance of Vascular Hand Biometrics

- Face (and visible wavelength iris) imagery is public data (Flickr, SnapChat). From these, more advanced spoofing artefacts like 3D masks can be generated.
- Fingerprint images have been reconstructed from latent fingerprints on a water glass (BM Schäuble by CCC in 2008) and telephoto shots (BM von der Leyen by CCC in 2014). From those, spoofing artefacts like gummi-fingers can be produced.
- In 2015, spoofing against commercial fingervein [1] and palmvein scanners [2] has been demonstrated.
- Several presentation attack detection techniques have been published since [3,4].

[1] P. Tome, M. Vanoni, S. Marcel. On the vulnerability of finger vein recognition to spoofing. 2014 International Conference of the Biometrics Special Interest Group (BIOSIG'14).
[2] P. Tome, S. Marcel. On the vulnerability of palm vein recognition to spoofing attacks. 2015 IAPR/IEEE International Conference on Biometrics (ICB'15).
[3] J. Schuiki, A. Uhl. Vulnerability Assessment and Presentation Attack Detection Using a Set of Distinct Finger Vein Recognition Algorithms. 2021 IEEE/IAPR International Joint Conference on Biometrics (IJCB'21).
[4] A. P. S. Bhogal, D. Söllinger, P. Trung, J. Hämmerle-Uhl, A. Uhl. Non-reference image quality assessment for fingervein presentation attack detection. 2017 Scandinavian Conference on Image Analysis (SCIA'17).

Morphing Attack against Vascular Biometrics [1]

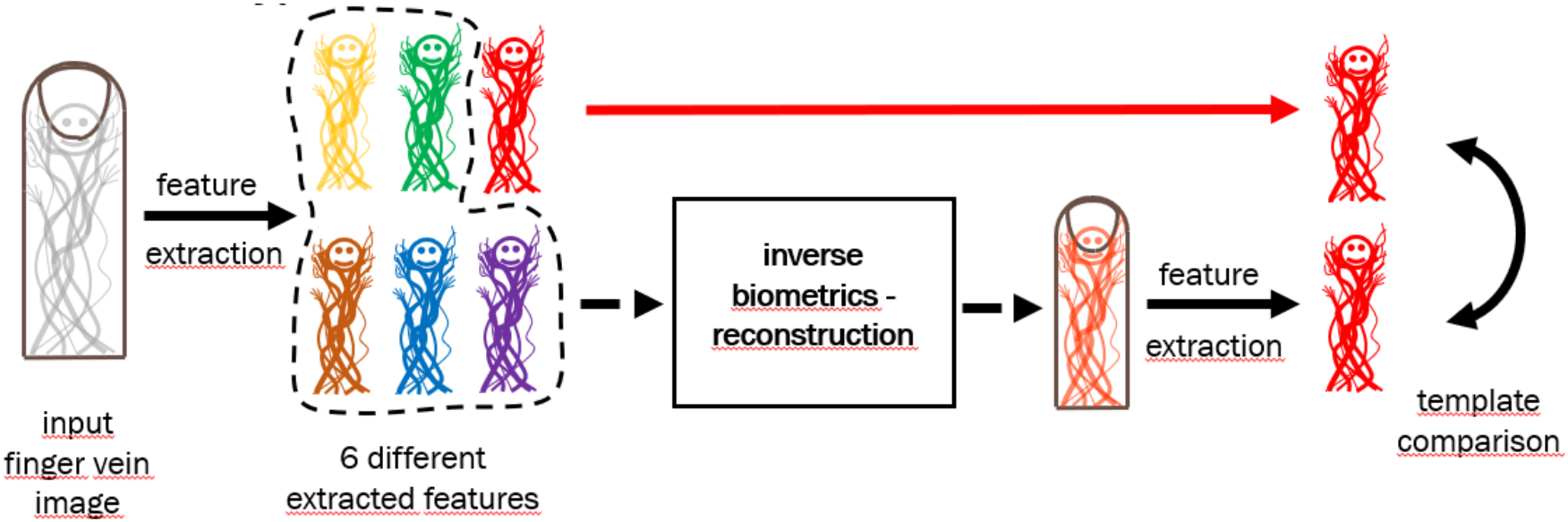




- Similar to the “Magic Passport” allowing two persons to pass border control due to a morphed portrait in the passport, morphing can be applied to vascular biometrics.
- However, as there is no passport, placing the morphed sample is supposed to happen during enrollment.
- Depending on the point of attack, a digital morph (insertion) or an artefact with morphed sample (presentation) is used.

[1] Altan A. Aydemir, J. Hämmerle-Uhl, A. Uhl. Feasibility of Morphing-Attacks in Vascular Biometrics. 2021 IEEE/IAPR International Joint Conference on Biometrics (IJCB’21).

Creating Vascular Samples from Binary Templates [1]



[1] Christof Kauba, Simon Kirchgasser, Vahid Mirjalili, Arun Ross, Andreas Uhl. Inverse Biometrics: Reconstructing Grayscale Finger Vein Images from Binary Features. 2020 IEEE/IAPR International Joint Conference on Biometrics (IJCB'20).

Results of the Inversion Process

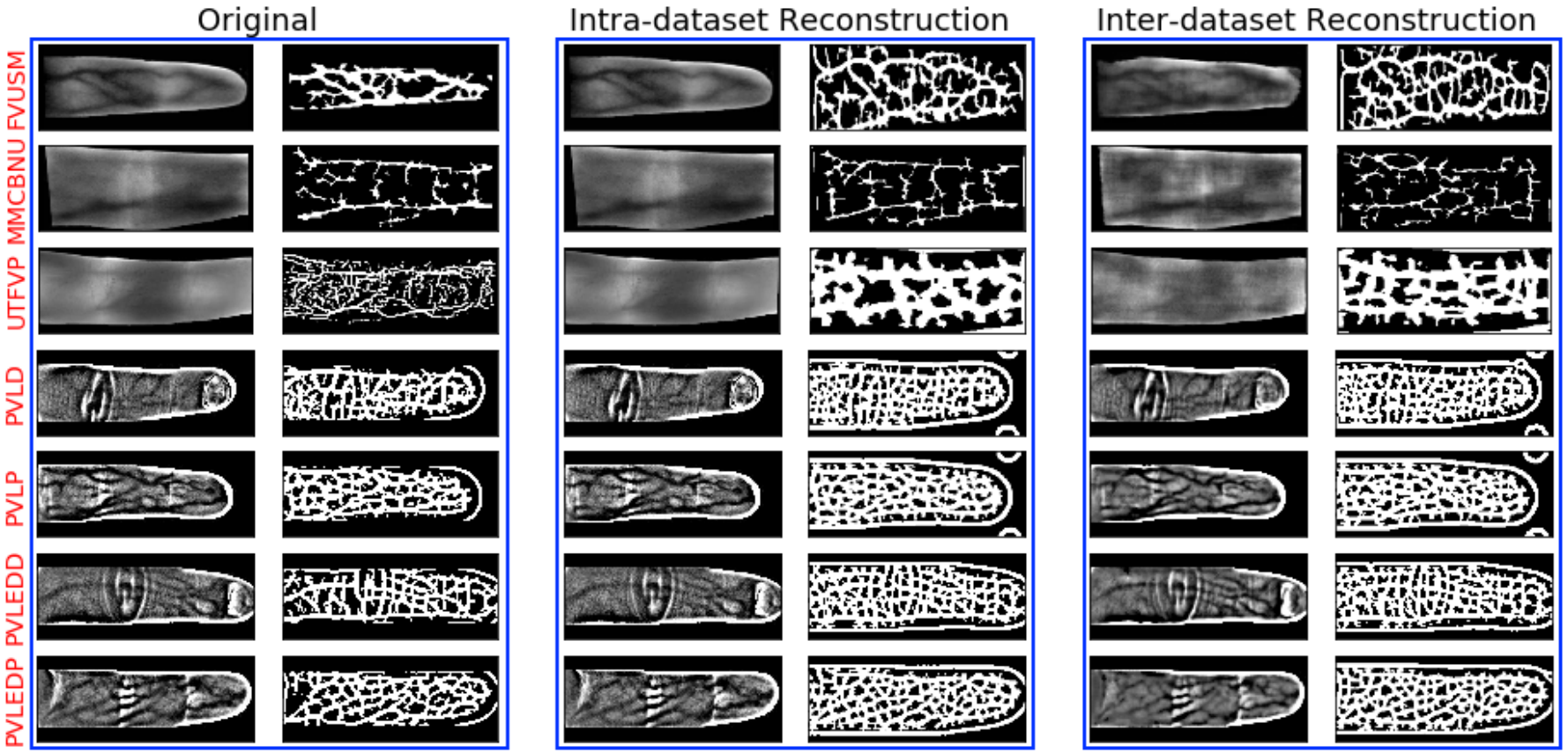


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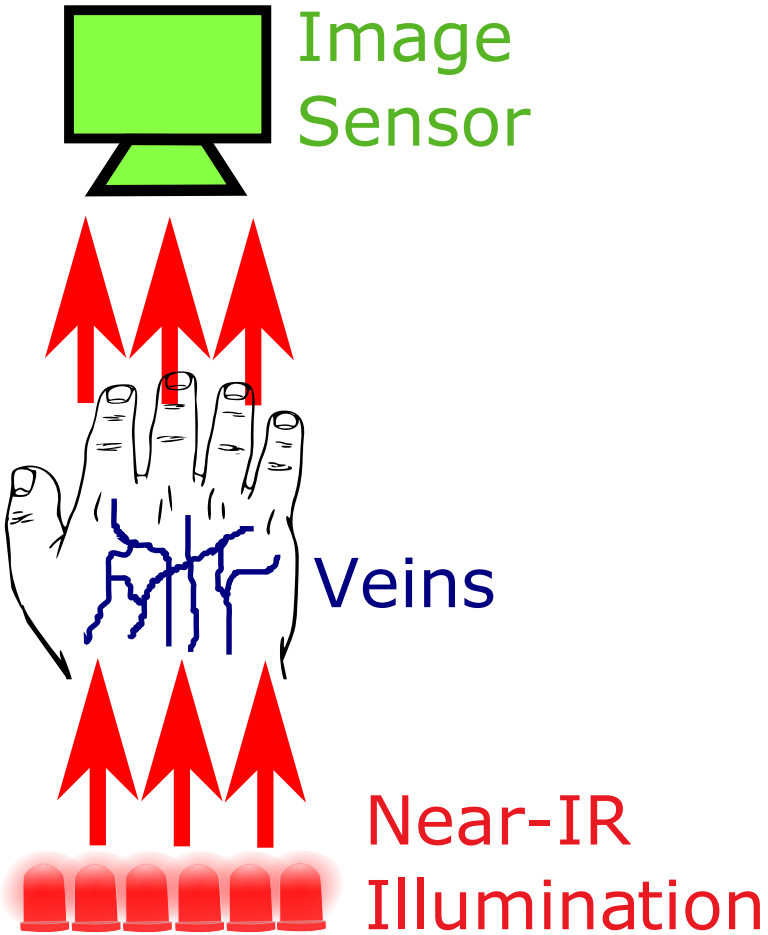
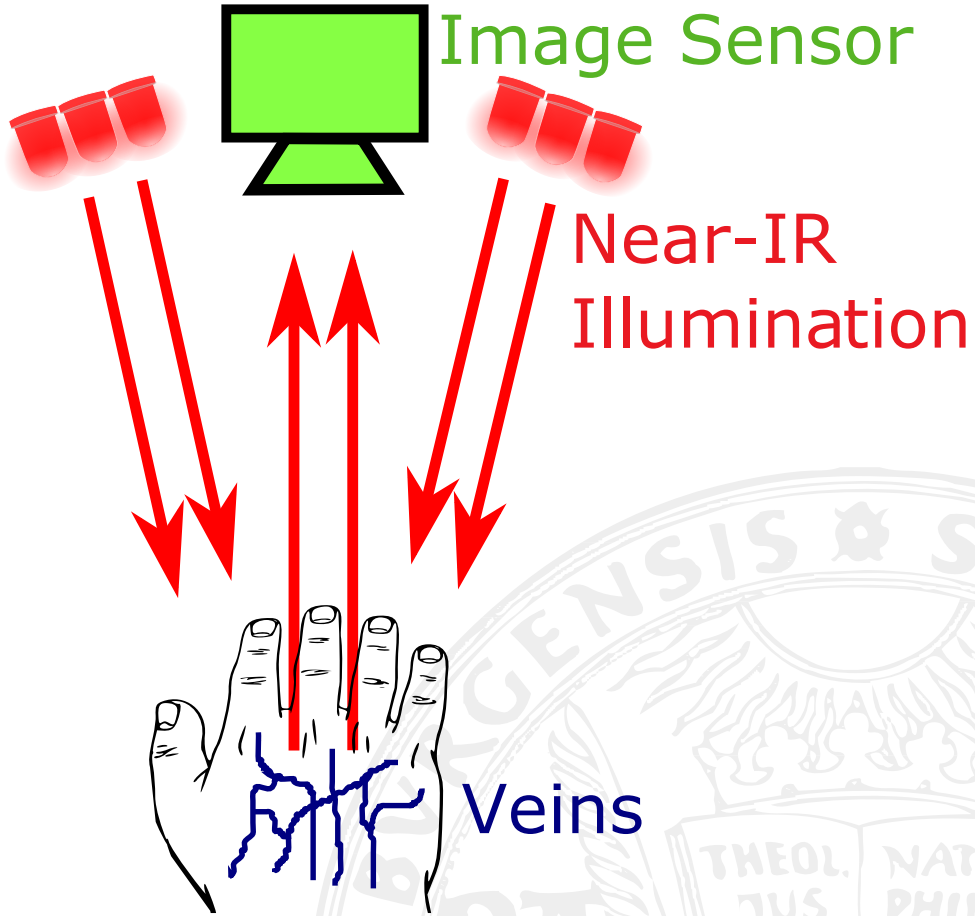
Image Acquisition

- Consisting of a NIR light source (illuminator) and a NIR sensitive camera
- Wavelengths between 730 and 950 nm
- Two types of NIR illumination:
  - Reflected light
  - Transillumination
- Commercial scanners
  - PalmVein (Fujitsu, Sensometrix) all use reflected light
  - FingerVein (Hitachi, Mofiria, XPO Tech/Yannan Tech) all use transillumination
- Publicly available data sets
  - Hand/PalmVein: Use reflected light (except ours [1])
  - FingerVein: Use transillumination

[1] C. Kauba, A. Uhl. Shedding Light on the Veins - Reflected Light or Transillumination in Hand-Vein Recognition. 2018 International IAPR/IEEE Conference on Biometrics (ICB'18).

Transillumination vs. Reflected Light (1)





Transillumination vs. Reflected Light (2)

Reflected Light

- Light source and camera on the same side of the hand
- Light gets reflected at the hand's surface and tissue
- More sensitive to ambient light and dirt/sun lotion on the skin
- Scanners can be built as small as fingerprint ones
- Lower light intensity - reduced power consumption

Transillumination

- Light source and camera on opposite sides of the hand
- Light penetrates the skin and tissue of the hand
- Needs a higher light intensity - higher power consumption
- Scanner devices are bigger due to opposite positioning
- Less sensitive to ambient light and hand surface conditions

Shedding Light on the Veins [1]

- Differences between the two illumination types
- Establishing two dual-illumination hand-vein data sets
  - **VeinPLUS**: reflected light and transillumination
  - **PROTECTVein**: reflected light 850 nm, ref. light 950 nm and transillum.
- Evaluating recognition performance of the single illumination types
- Cross-illumination and cross-spectrum matching

[1] C. Kauba, A. Uhl. Shedding Light on the Veins - Reflected Light or Transillumination in Hand-Vein Recognition. 2018 International IAPR/IEEE Conference on Biometrics (ICB'18).

VeinPLUS

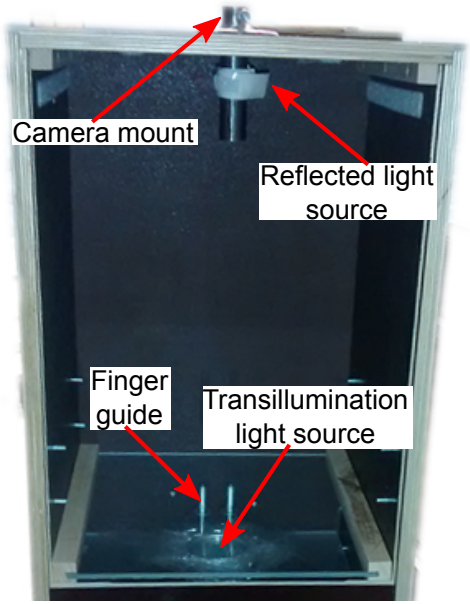
Scanner

- Canon EOS 5D DLSR with IR-blocking filter removed and additional 830 nm IR pass-through filter
- Wooden box to block ambient light
- NIR surveillance lamp consisting of 50 940 nm LEDs for transillumination
- 6 950 nm LEDs mounted on top of the box for reflected light

Data Set

- 107 subjects, 1 session, 2 hands per subject, 3 images per hand
- 2 illumination settings $\rightarrow$ 1213 images in total
- 2784 $\times$ 1856 pixels, RGB colour, jpg images
- ROI images with 500 $\times$ 500 pixels
- Will not be made publicly available due to legal issues with the consent form

VeinPLUS Scanner and Example Images



PROTECTVein

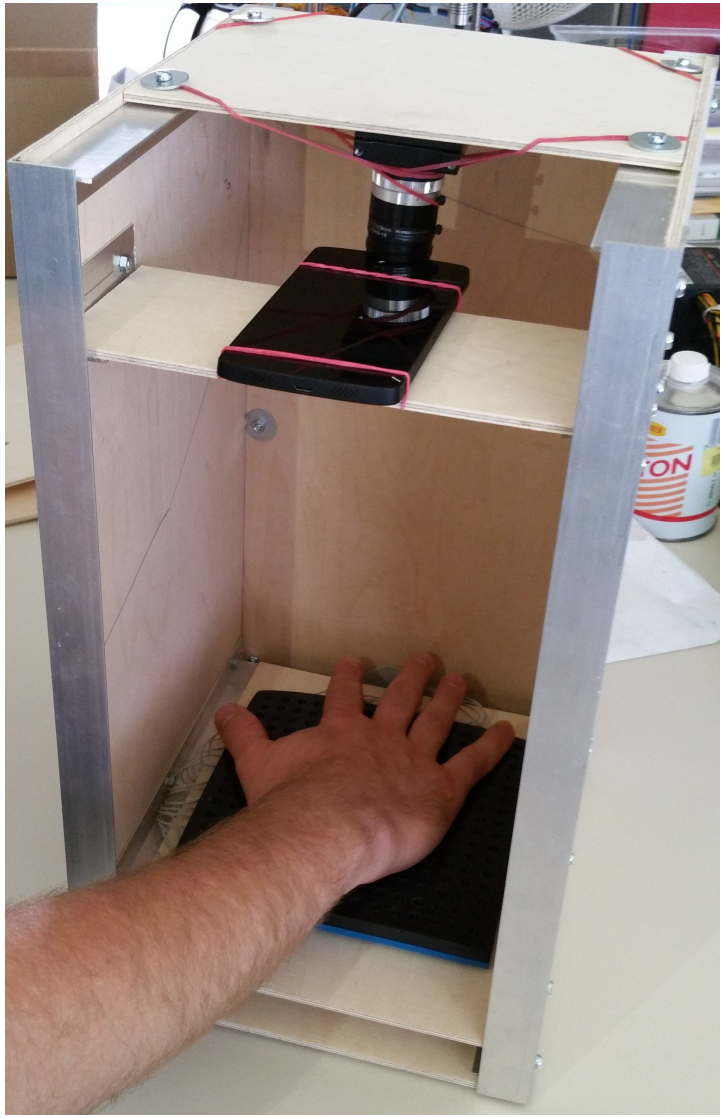
Scanner

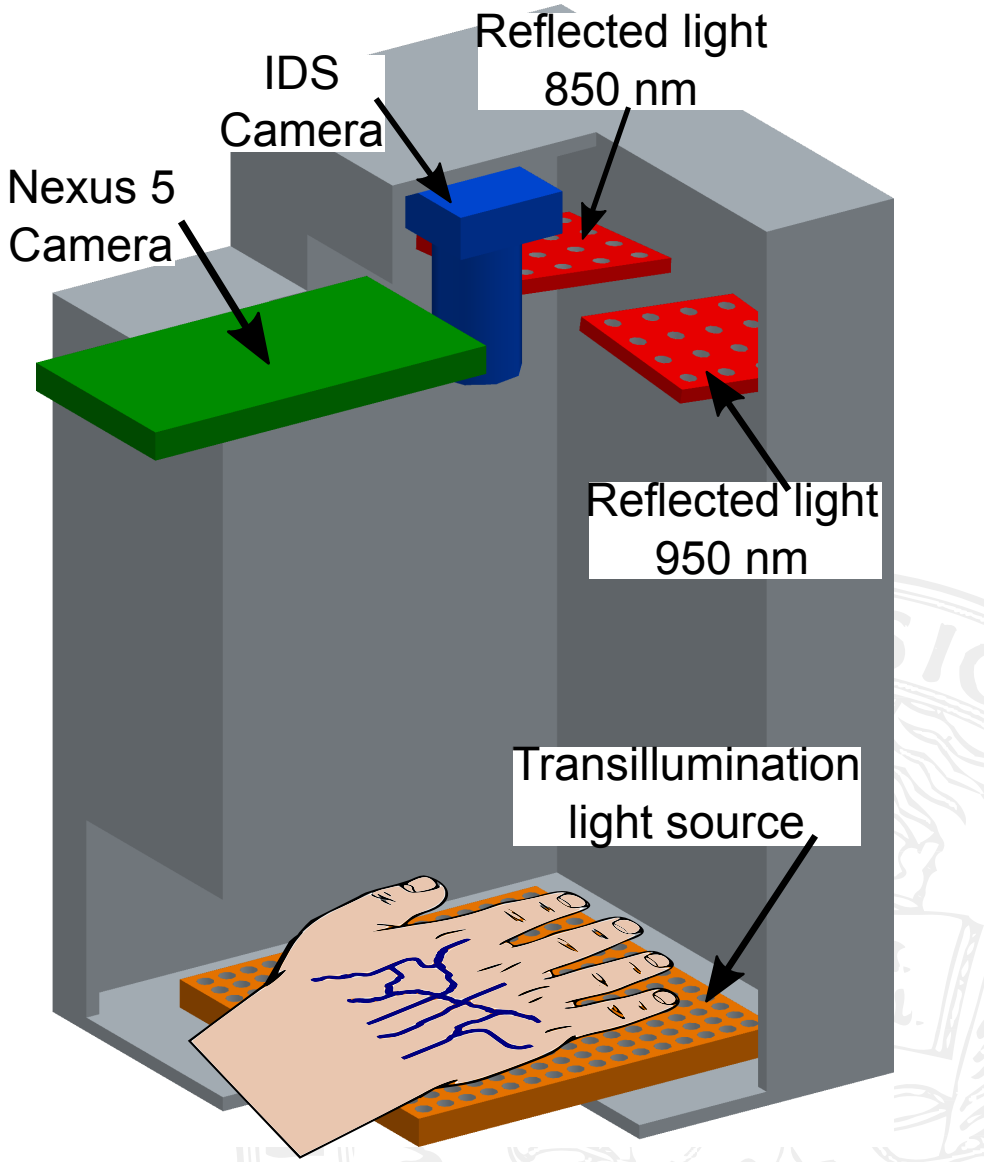
- IDS Imaging UI-1240ML-NIR, industrial NIR enhanced camera
- Modified Nexus 5 smartphone (EigenImaging), IR blocking filter removed
- 16×16 LED board (850 nm LEDs) for transillumination
- 4×4 LED boards (850 nm and 950 nm) for reflected light
- Wooden box for stability and to reduce ambient light

Data Set

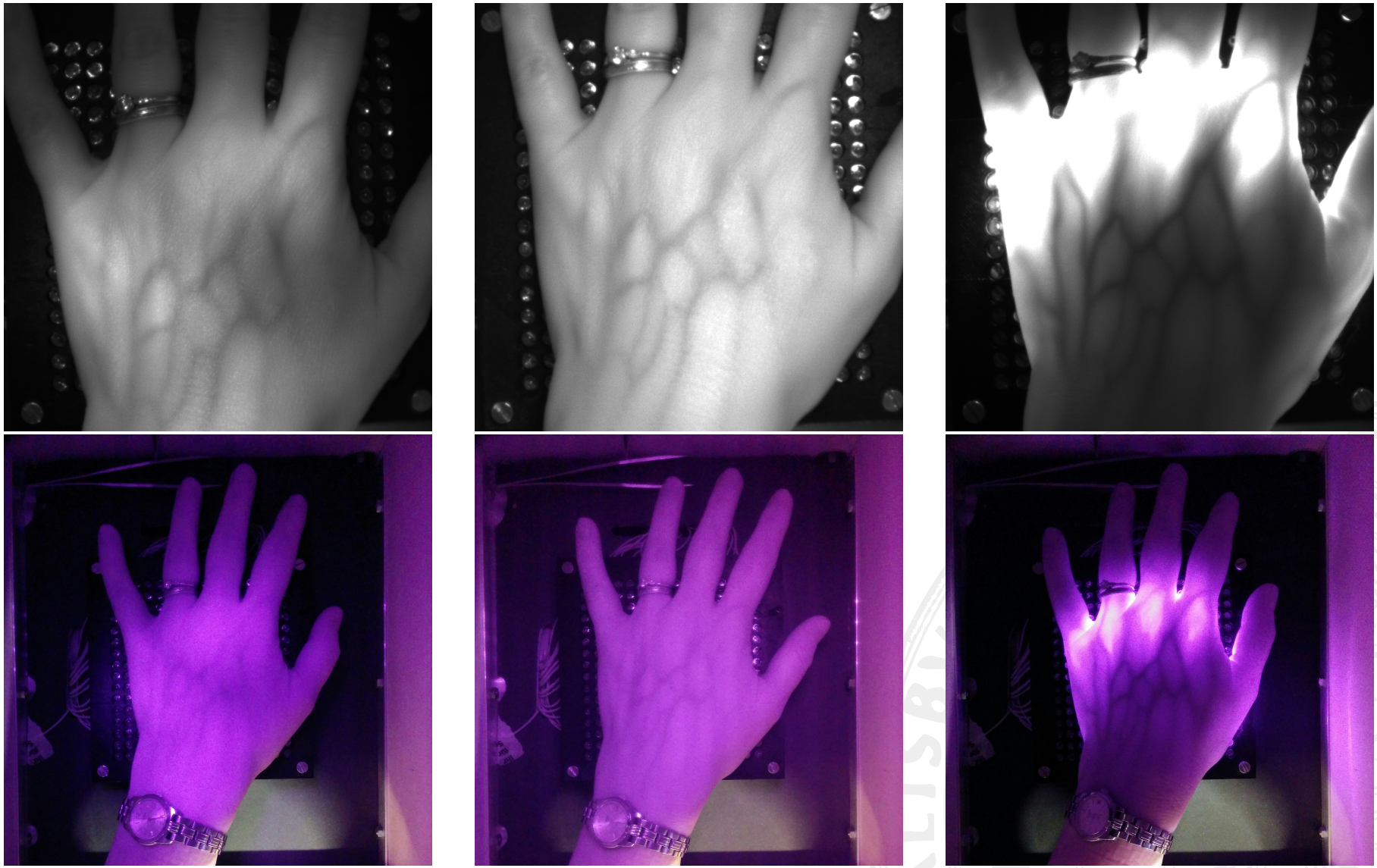
- 40 subjects, 1 session, 2 hands per subject, 5 images per hand
- 3 illumination settings, 2 cameras $\rightarrow$ 2400 images in total
- IDS:720×720 pixels, greyscale, png images
- Nexus 5: 3264×2448 pixels, RGB colour, jpg images
- Is already publicly available

PROTECTVein Scanner





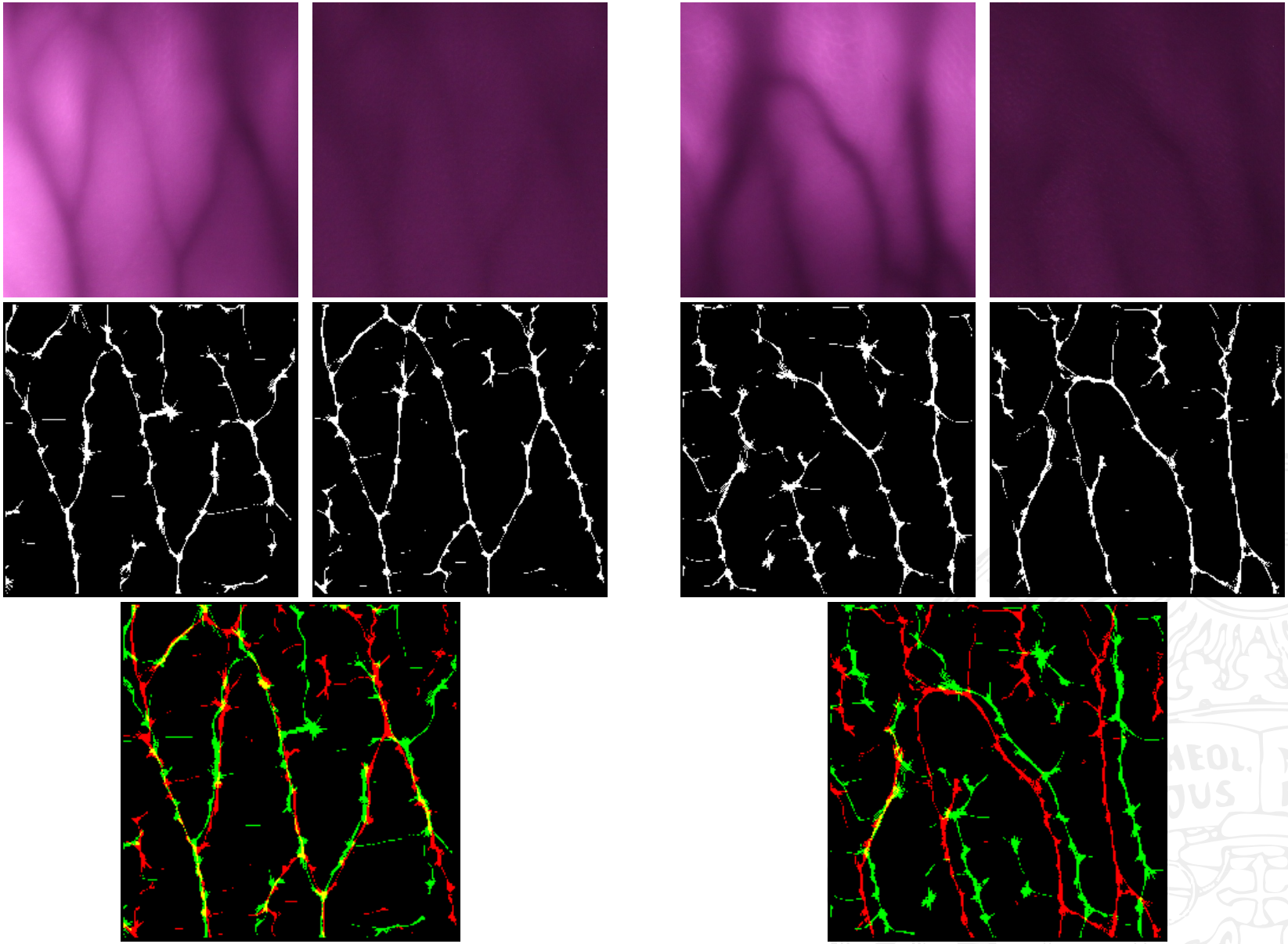
PROTECTVein Example Images



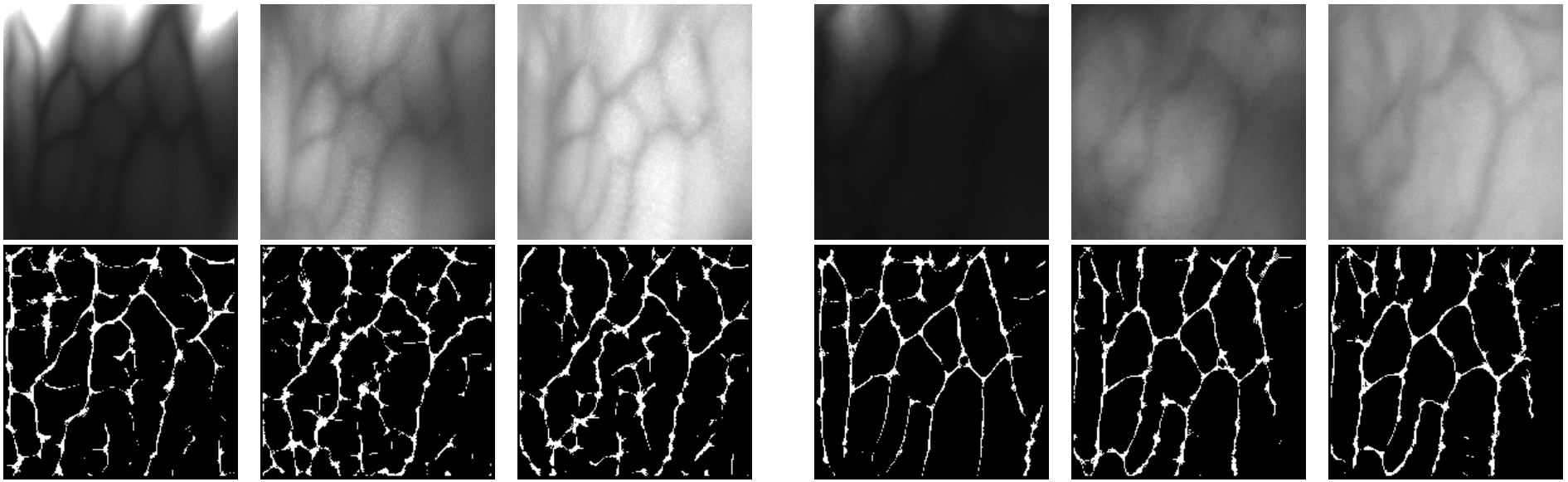
Cross-Illumination / Cross-Spectrum Matching

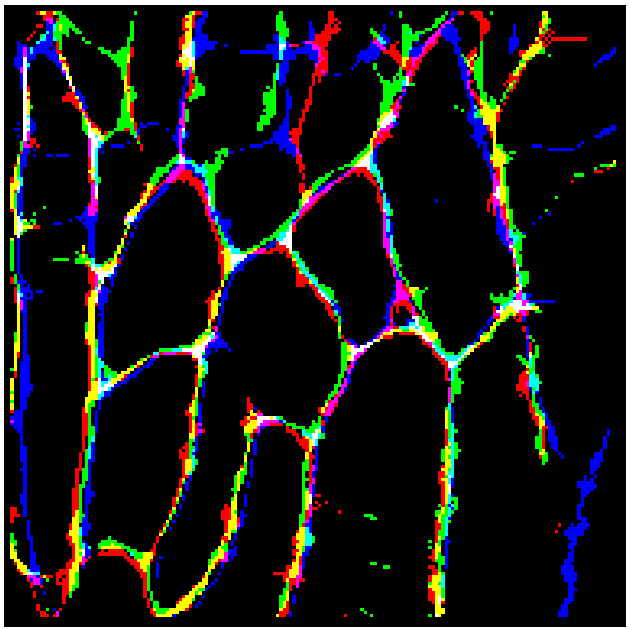
- Vein patterns look similar for the different illumination settings
- Cross matching performance clearly inferior to single illumination/spectrum ones
  - Visible vein patterns differ in some way
  - Same veins are visible (except for smaller ones)
  - Not located at the exact same positions
- May be introduced due to hand movement for VeinPLUS (can be ruled out for PROTECTVein)
- Displacements are different for different subjects
- Non-linear displacements caused by different refraction and light scattering coefficients of the human tissue
- Depending on the vertical positions of the veins inside the hand
- Cannot be corrected by translation/rotation (done at matching step)
- Cross-illumination matching is not possible straight forward

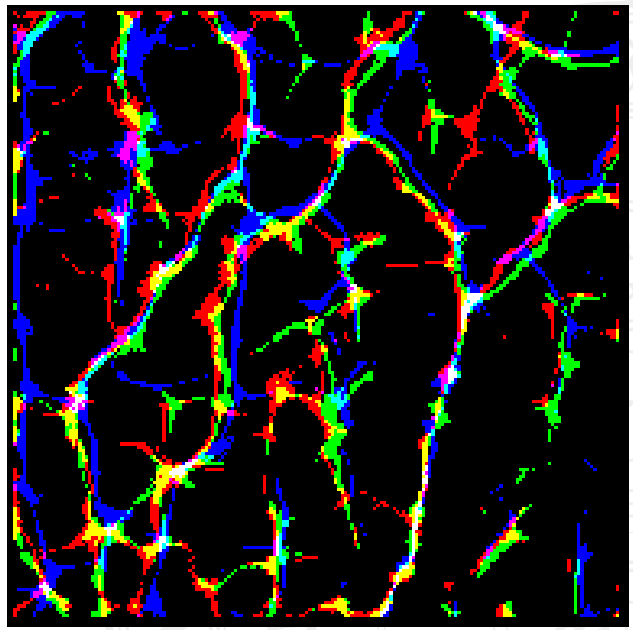
Reflected Light - Transillum. VeinPLUS



Different Illuminations PROTECTVein (1) and (2)







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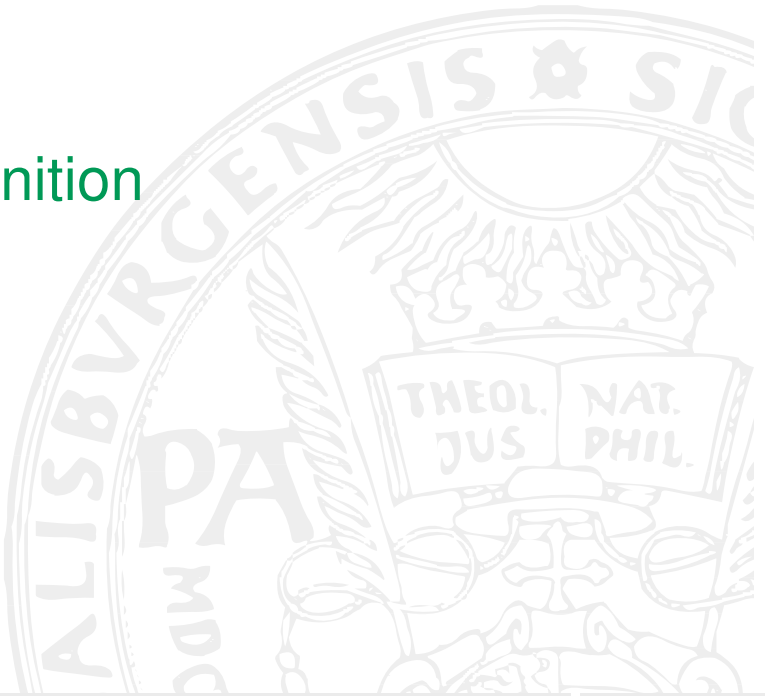
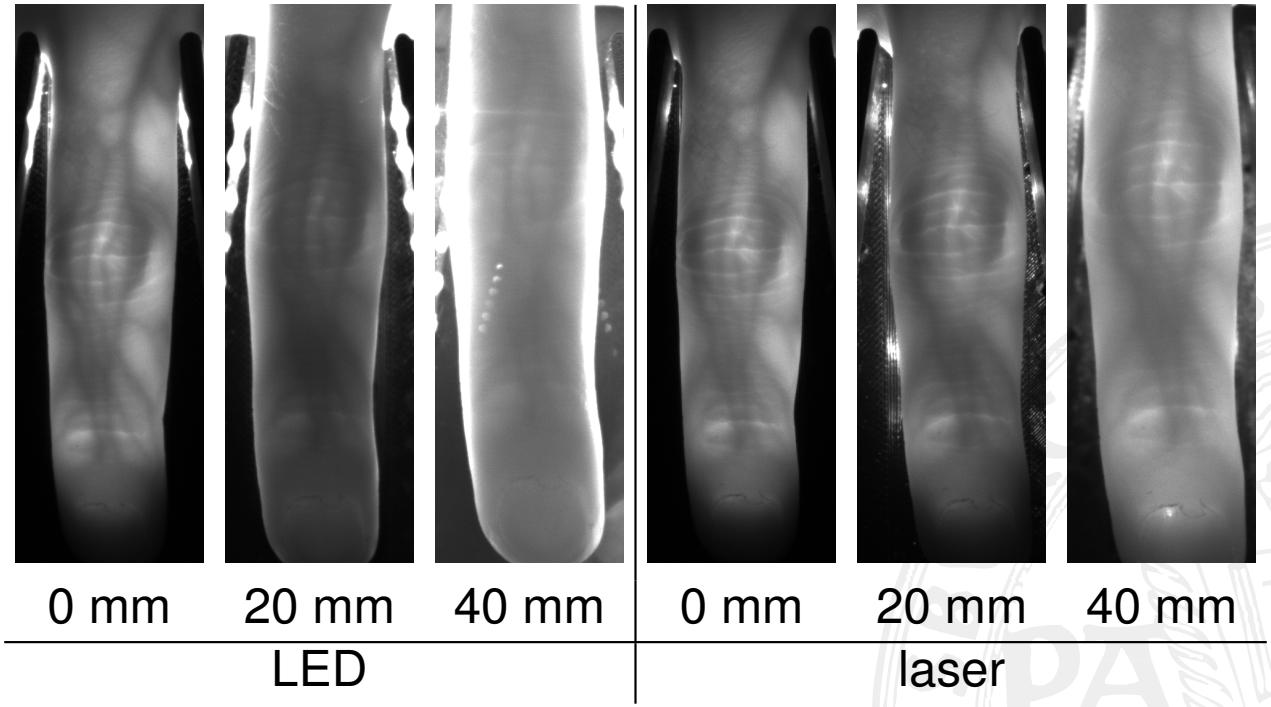


Advantages of Laser Modules over LEDs [1]

- Less bright areas along the finger outlines (scattering reduced)
- Contrast remains high even if the distance between the illuminator and the finger is increased
- Advantages in contactless operation



[1] B. Prommegger, C. Kauba, A. Uhl. Focussing the Beam - A New Laser Illumination Based Data Set Providing Insights to Finger-Vein Recognition. IEEE 9th International Conference on Biometrics Theory, Applications and Systems (BTAS), 2018.

Multi-Perspective Finger Vein Scanner

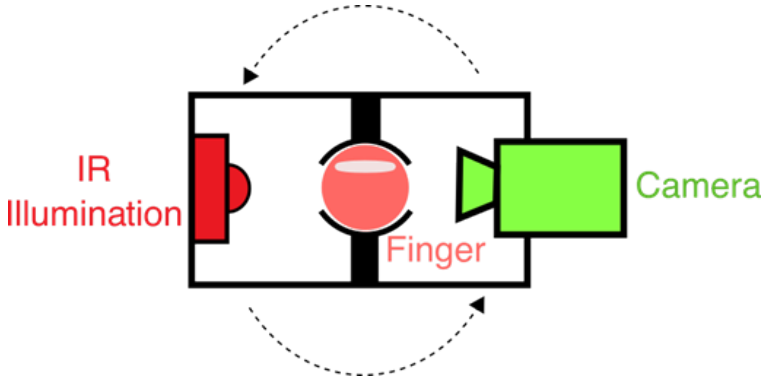


Figure: Basic principle of our rotating finger vein scanner

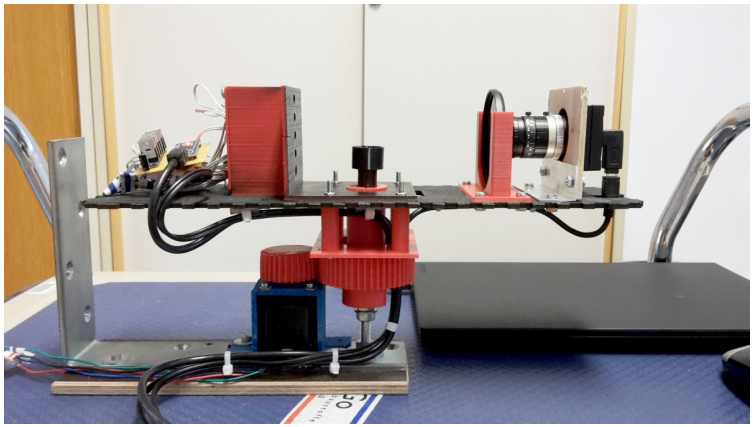


Figure: Custom build multi-perspective finger-vein scanner

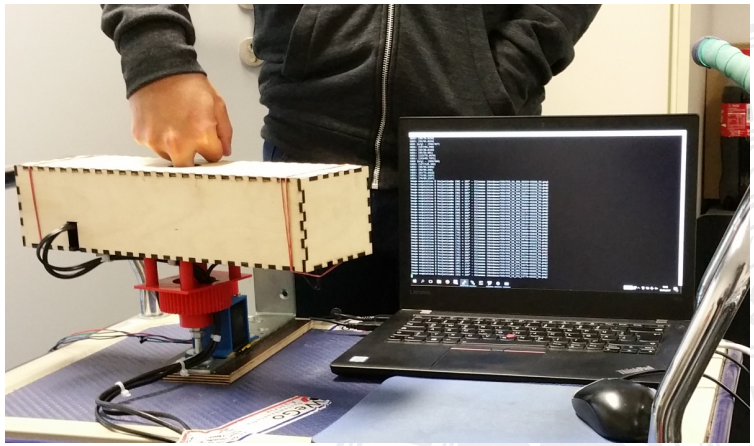


Figure: Data capturing with Scanner V1.0

Purpose of Multi-Perspective Vein Imaging

- Improved recognition performance by fusion of several perspectives
- Improved recognition performance by 3D reconstruction of the vessel structure
- Significantly improved spoofing resistance as current spoofing artefacts are an outprint on paper
- Better understanding of what we are actually imaging (veins ? arteries ? at which depth ?)
- Facilitation of advanced spoofing artefacts by 3D-printing of vessel structures

Multiperspective Finger-Vein Biometrics [1]

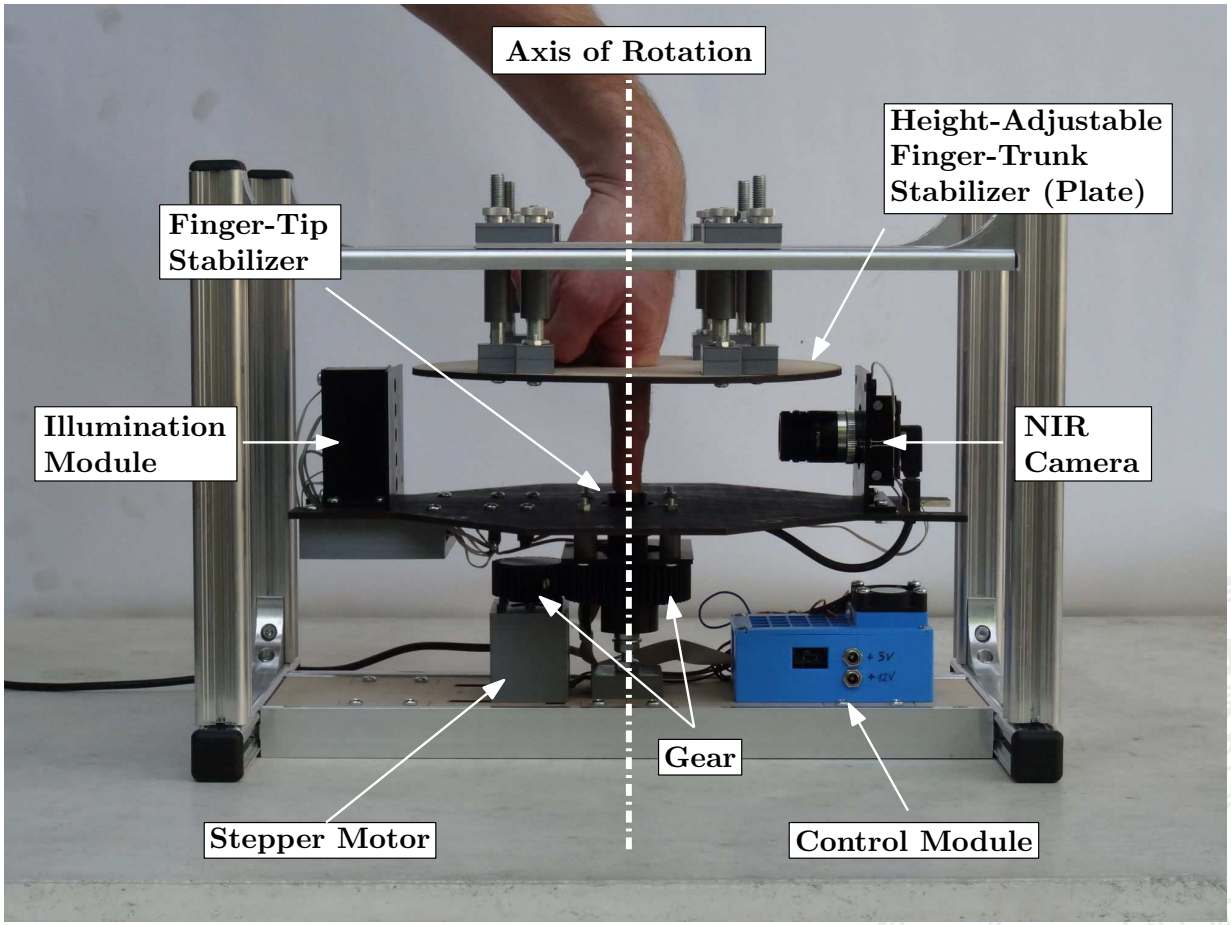
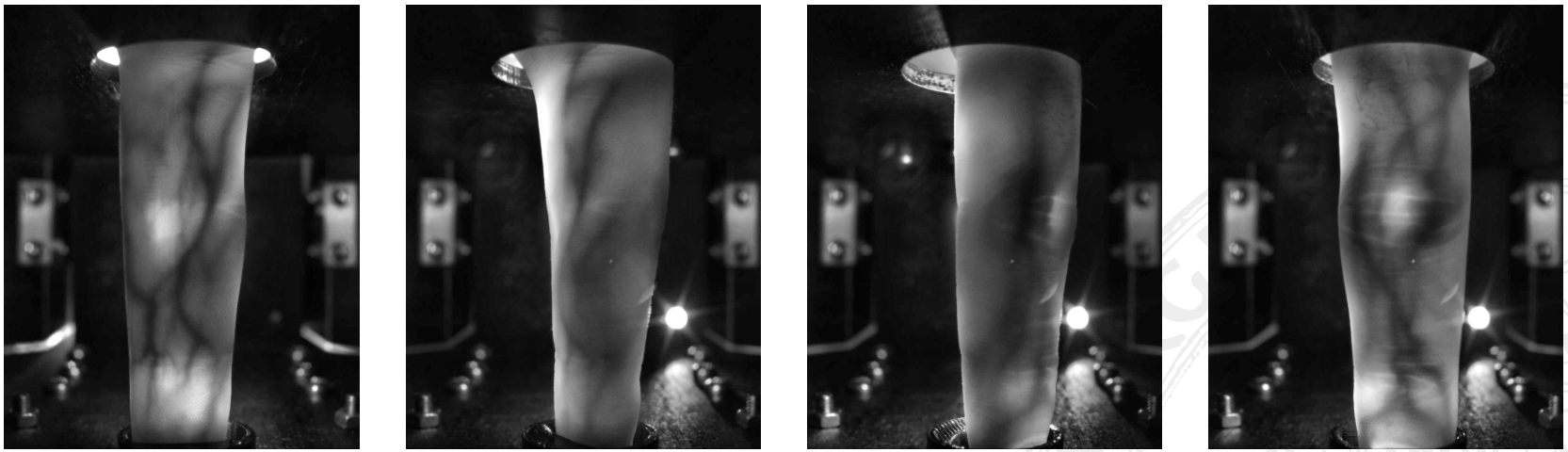


Figure: Multi-perspective finger vein scanner V2.0

[1] B. Prommegger, C. Kauba, A. Uhl. Multi-Perspective Finger-Vein Biometrics. IEEE 9th International Conference on Biometrics Theory, Applications and Systems (BTAS), 2018.

PLUSVein-Finger Rotation Data Set I

- Up to now only palmar (and one dorsal) data sets
- No evaluation of other perspectives possible
- New finger-vein data set providing images all around the finger (360°-view)
- Acquired using our custom build sensor



0° 60° 120° 180°

Figure: Example images of the data set acquired from 0° to 180° in 60° steps

PLUSVein-Finger Rotation Data Set II

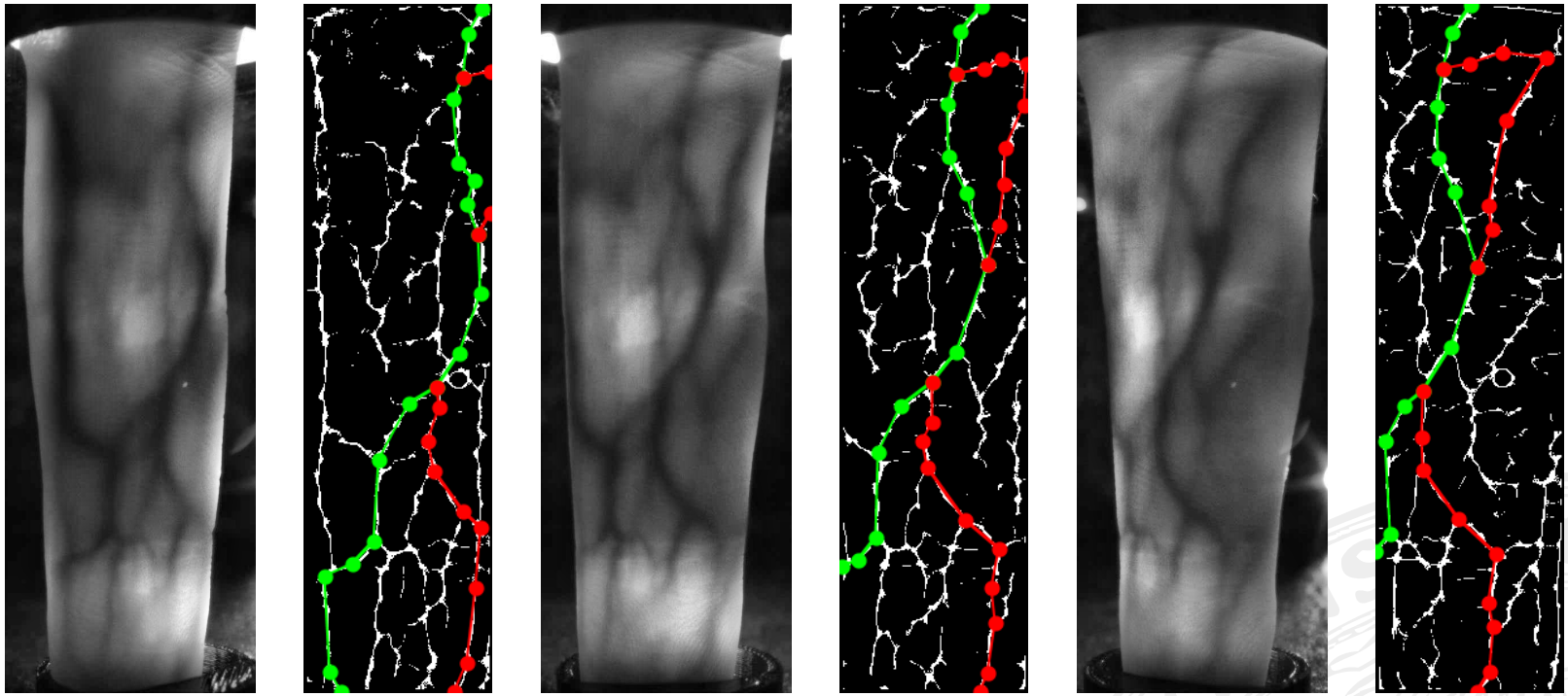


Figure: Examples of finger vein images and extracted MC features acquired at different longitudinal rotation angles. Left: -30°, middle: 0° (palmar view), right: 30°

Experiments

Performance evaluation of different perspectives all around the finger

- Step-size 5°

Fusion of selected perspectives

- Multiple perspectives (2-72)
- One against all other

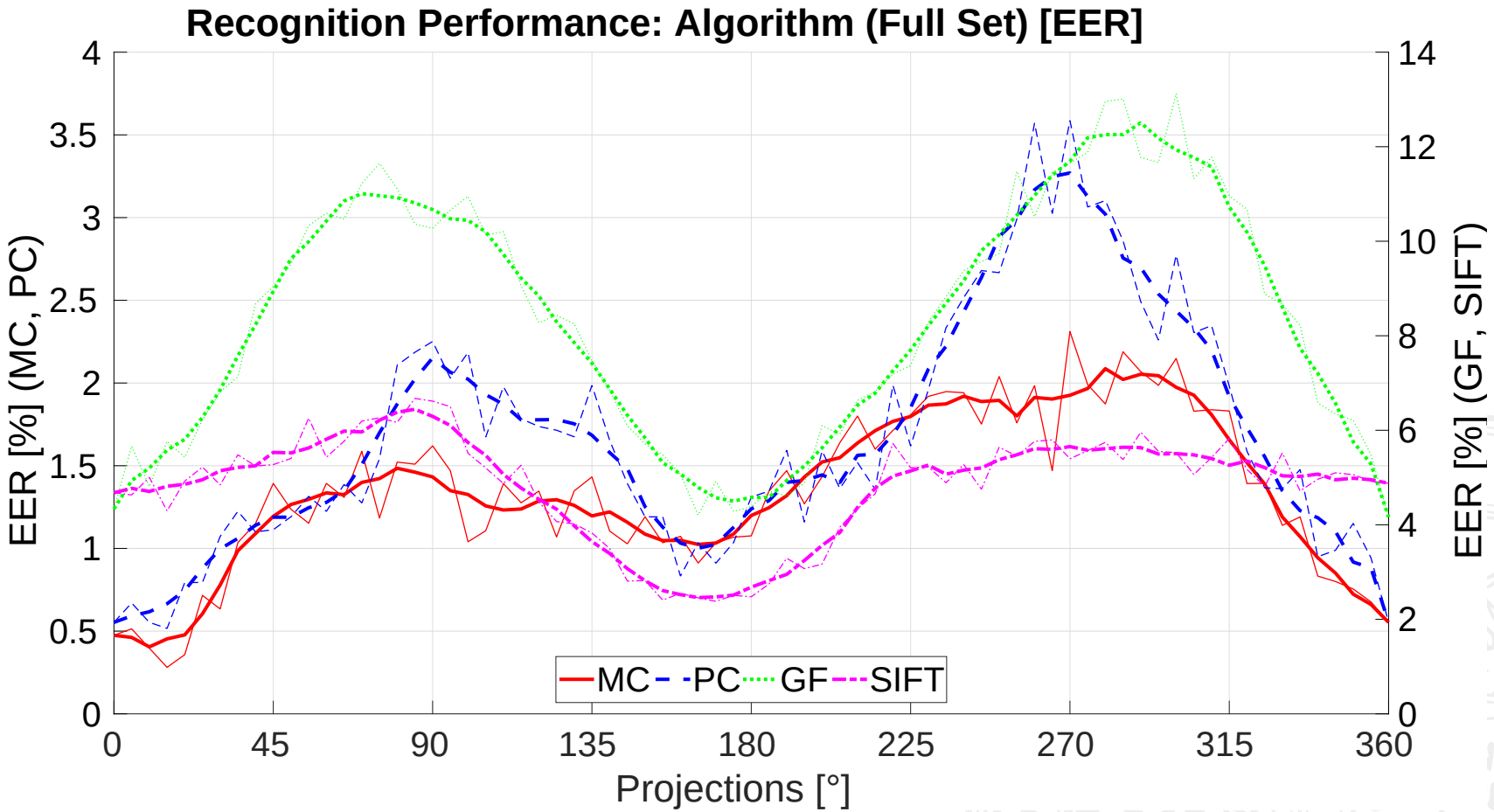
Used recognition schemes

- Vein pattern based methods (binarization)
  - Maximum Curvature (MC)
  - Principal Curvature (PC)
  - Gabor Filter (GF)
- Key-point based methods
  - SIFT

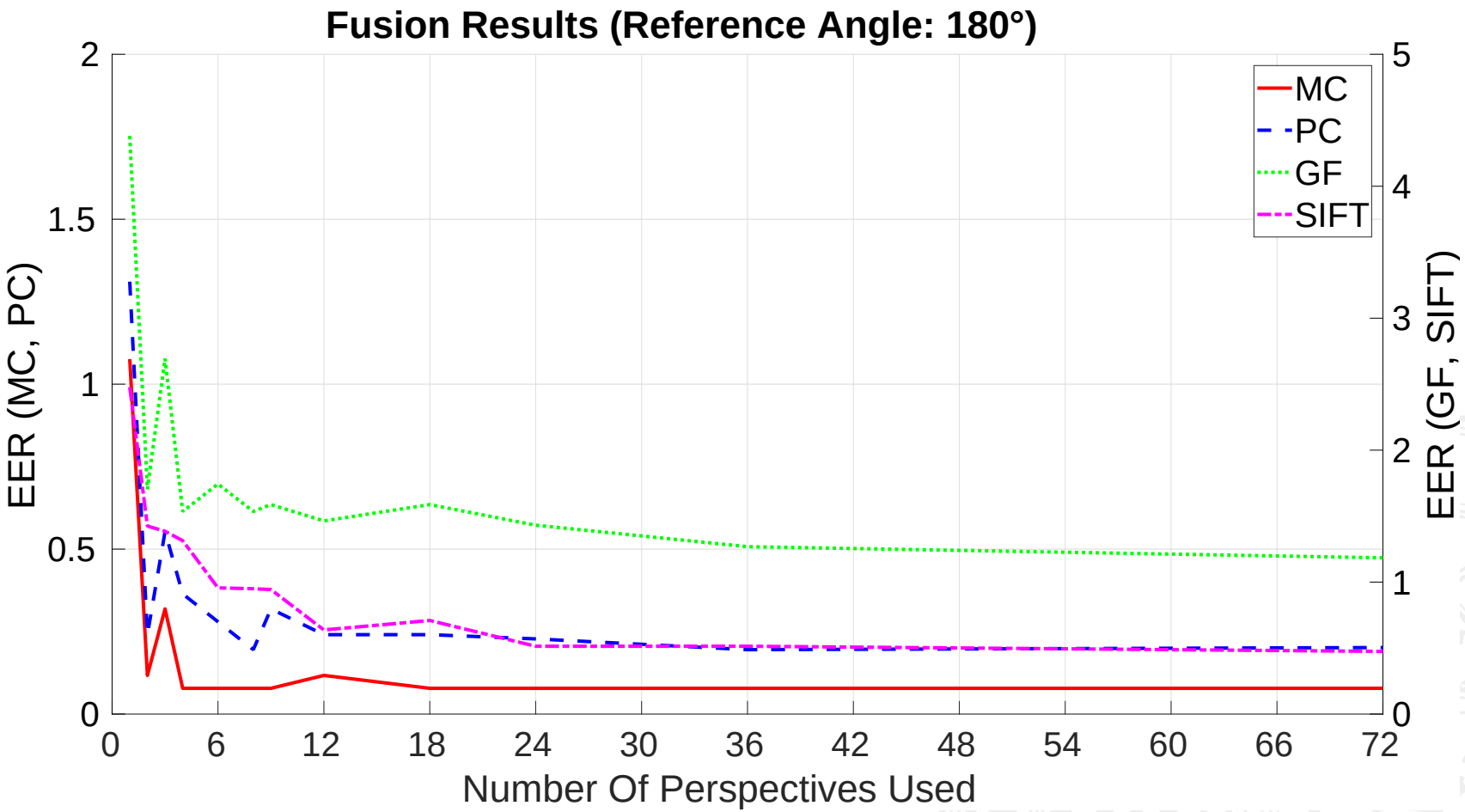
Used performance indicators

- EER
- FMR100
- FMR1000
- ZeroFMR

Results: Recognition for different Projections



Results: Multi-Perspective Fusion



Longitudinal Finger Rotation

What is longitudinal finger rotation?

- misplacement of the finger during acquisition

The problem of longitudinal finger rotation:

- causes a deformation of the vein pattern
- negatively effects recognition performance

The vision:

- make finger vein recognition robust to rotation

The idea [1]:

- enrol multiple perspectives
- compare single perspective against enrolled data

[1] B. Prommegger, A. Uhl. Rotation Invariant Finger Vein Recognition. IEEE 10th International Conference on Biometrics Theory, Applications and Systems (BTAS), 2019.

The Problem of Longitudinal Finger Rotation

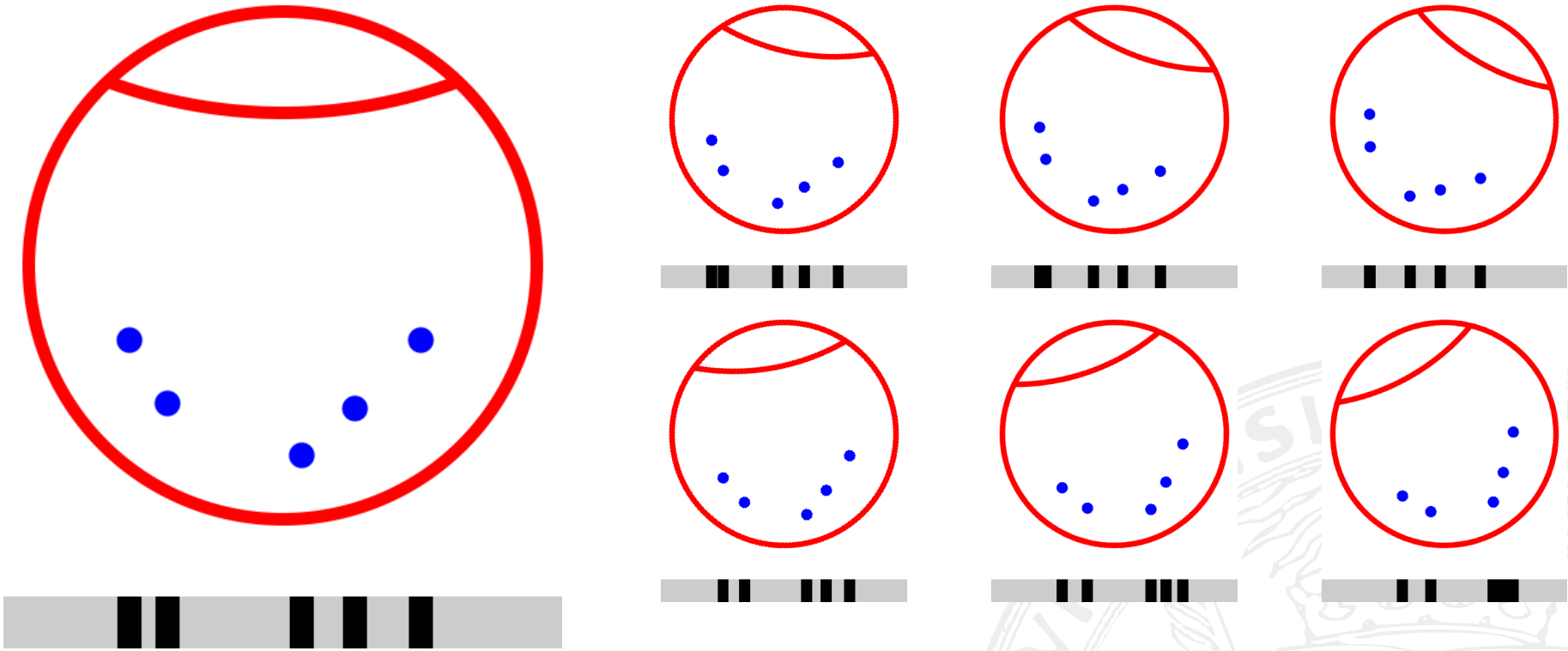


Figure: Longitudinal finger rotation principle: a schematic finger cross section showing five veins (blue dots) rotated from -10° to -30° (top row) and 10° to 30° (bottom row) in 10° steps. The projection of the vein pattern is different according to the rotation angle following a non-linear transformation.

Rotation Detection and Correction [1]

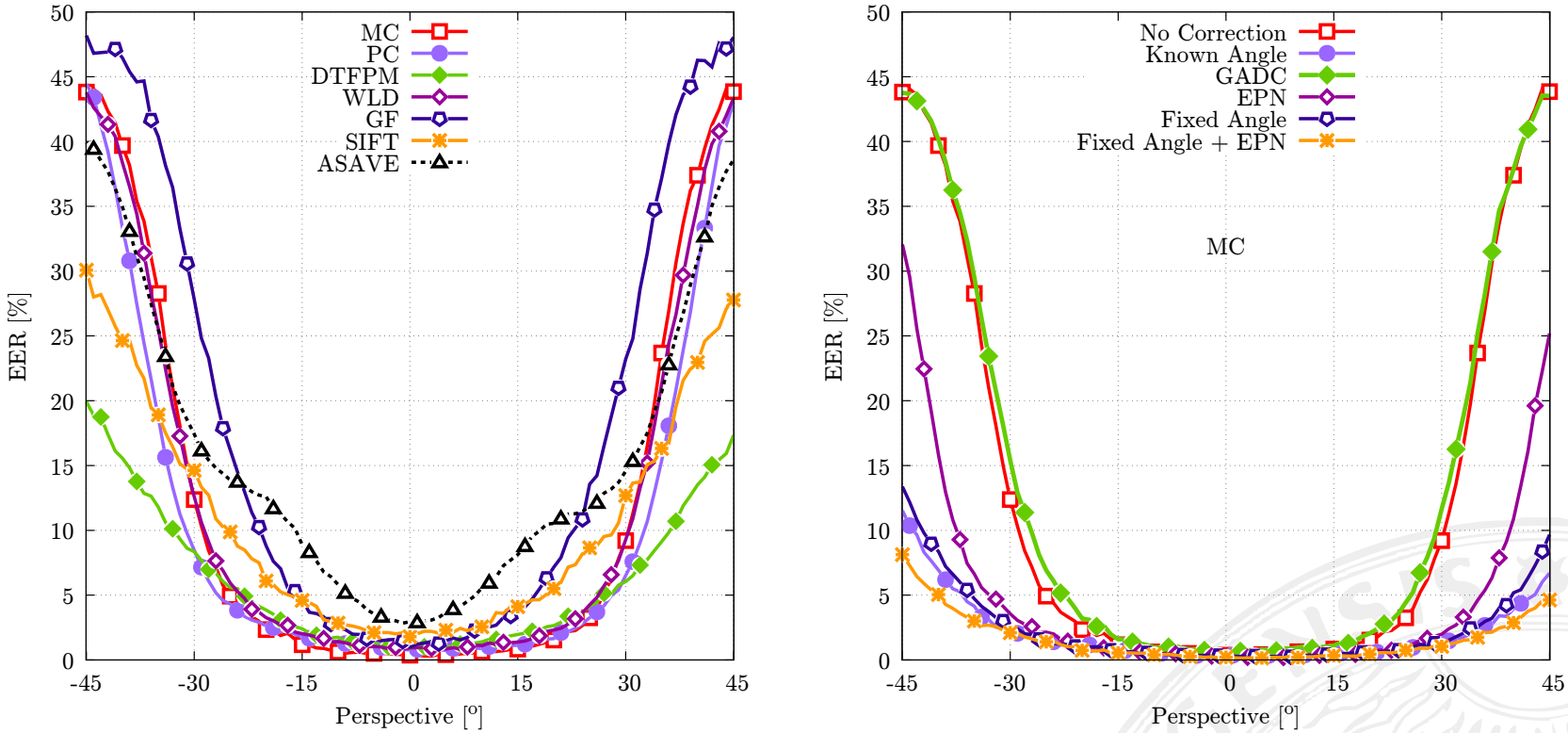


Figure: Trend of the EER across different rotation angles. Left: Performance of different finger vein recognition schemes, right: different rotation compensation approaches for the same scheme (Maximum Curvature)

[1] B. Prommegger, C. Kauba, M. Linortner, A. Uhl. Longitudinal Finger Rotation - Deformation Detection and Correction. IEEE Transactions on Biometrics, Behavior, and Identity Science 1:2, pp. 123-138, 2019.

Multi Perspective Enrolment (MPE)

Idea

- Enrol subject using multiple perspectives (sophisticated sensor)
- Verification: single perspective (simple sensor) vs all enrolled perspectives
- Max score level fusion
- Invariant to rotation in case enrolment covers complete (rotational) range of interest

Assumptions

- Circular finger form
- Enrolment perspectives are linearly spaced

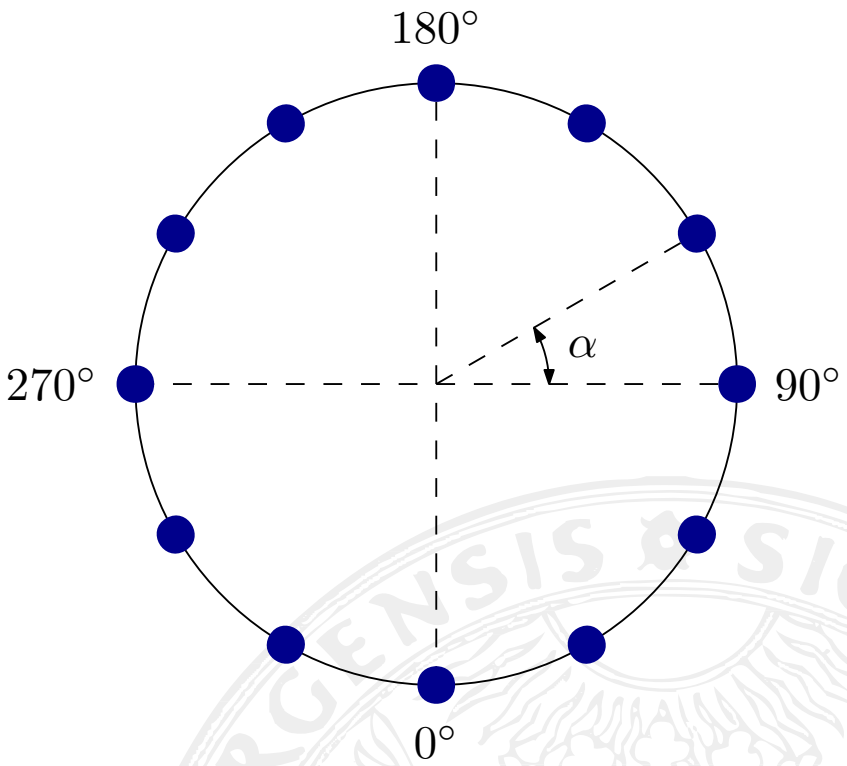
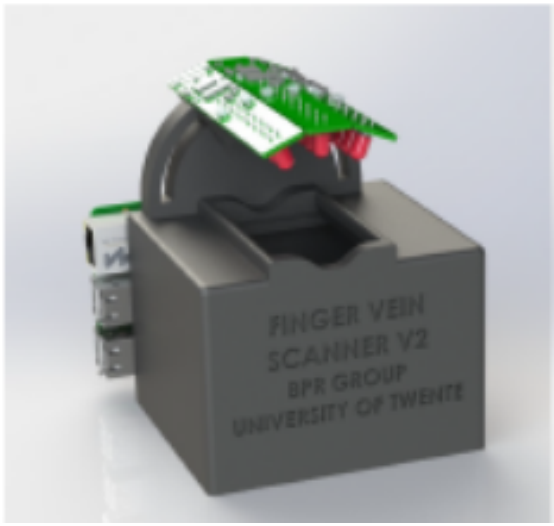
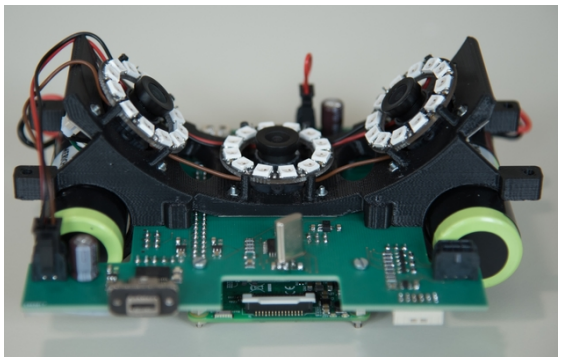


Figure: Camera positioning for MPE for a rotational distance of $\alpha = 30°$ between the enrolment perspectives.

First Multi Perspective Scanners



University of Twente
3 Perspectives Scanner



HESSO/IDIAP/GlobalID
3 Perspectives Scanner

Outline

1 Introduction & Motivation

2 Security of Vascular Hand Biometrics

3 Scanners for Vascular Hand Biometrics

4 Towards unconstraint Finger Vein Recognition

5 Conclusion

Conclusion

Lessons learnt

- Eye-based vascular biometrics: many disadvantages, no commerial products
- Hand-based vascular biometrics: Highly innovative and promising biometric modality with many advantages
- Commercial products available, recognition accuracy mainly based on claims
- Certain drawbacks:
  - Recognition performance in large user groups not well understood (template entropy not yet known)
  - Robustness wrt. environmental and physiological conditions not investigated
  - Spoofing resistence has to be improved
  - Current sensors do not allow to store and process acquired imagery, only templates are obtained

Thank you for your attention!

Questions?