Biometrics (CSE 40537/60537)

Lecture 5: Use of hand in biometrics

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Lecture 5: Use of hand in biometrics

- Hand-related modalities
- Palm print
- Hand geometry
- Hand vein recognition
- Finger vein recognition
- Hand temperature

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Hand-related modalities

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What properties of the hand we use in biometrics?

What properties of the hand we use in biometrics?

1. Impressions
   - fingers (Lecture 1: fingerprints)
   - inner side of the hand (palm prints)
2. Geometry
   - hand (2D and 3D)
   - fingers (2D and 3D)

What properties of the hand we use in biometrics?

What properties of the hand we use in biometrics?

3. Veins
   - measured on inner or outer side of the hand (palm vein)
   - inside the wrist
   - inside the fingers (finger vein)
4. Temperature
   - measured on inner or outer side of the hand
   - individual features are hidden in temperature distribution, not in the absolute hand temperature
   - often used for segmentation in geometry-based approaches
5. Knuckles

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Palm print

Levels of observation

1. Main lines
   - direction, bifurcations, endings, crossings
   - but NOT 'line of life', 'line of fate', etc.
2. Ridges and valleys
   - minutiae (level 2 features) located on the inner and side part of the hand

Source: State of the Art Biometrics Excellence Roadmap, MITRE Tech. Rep., Vol. 1, 2008

Palm print

Levels of observation

3. Texture (pattern)
   - use of texture-sensitive techniques to transform the image into the feature space: Gabor filtering (different directions, size and position), Local Binary Patterns (LBP)
   - image correlation: simple but not accurate (sensitive to non-individual features and deformations)

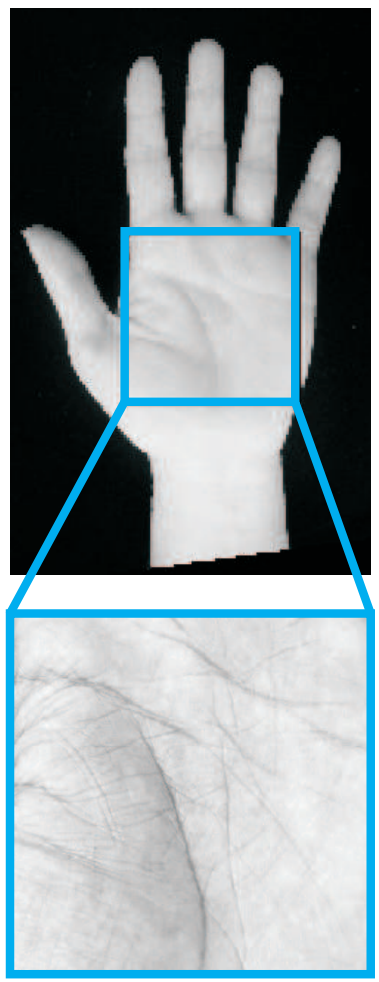
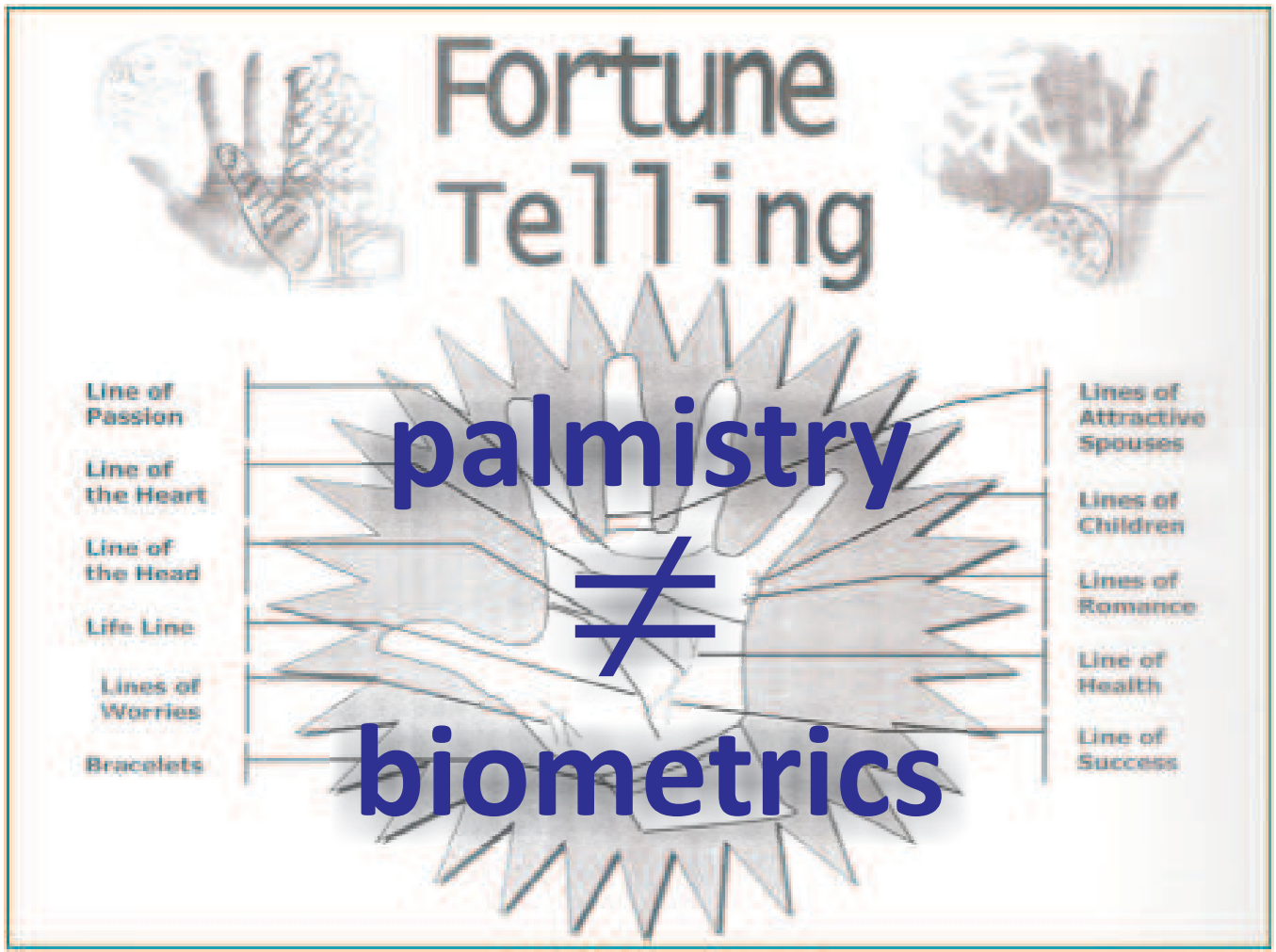


Image on the right based on: A. Kumar, et al., Personal Verification using Palmprint and Hand Geometry Biometric, AVBPA, 2003

Palm print vs. palmistry



Palm print

Example palm print reader: CrossMatch ID 2500

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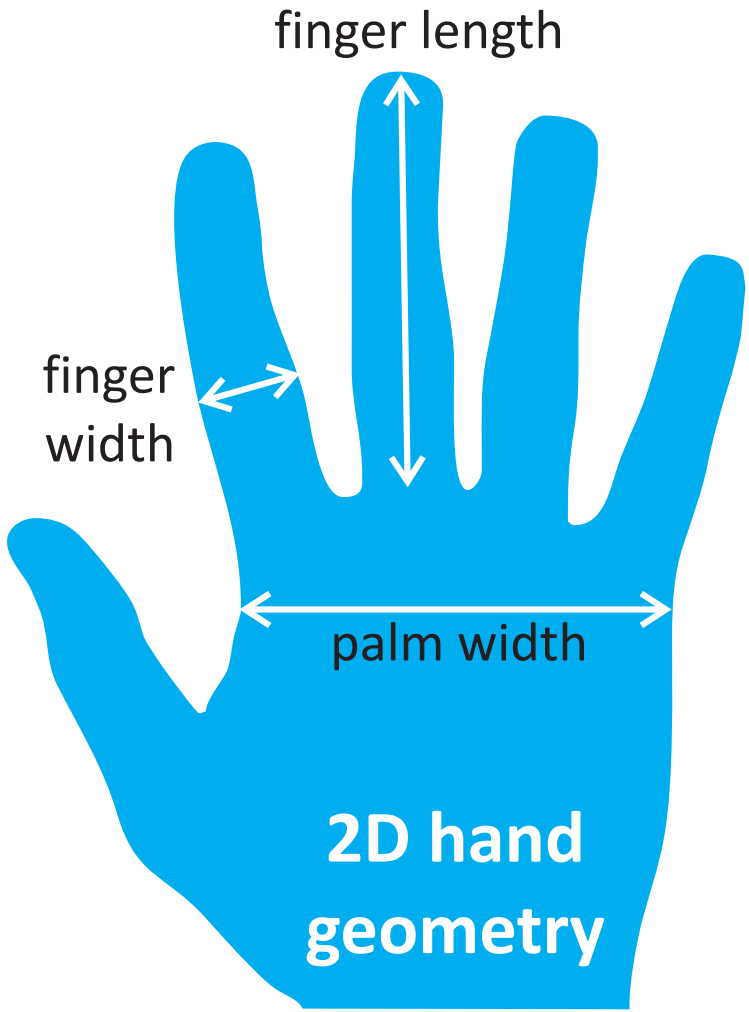
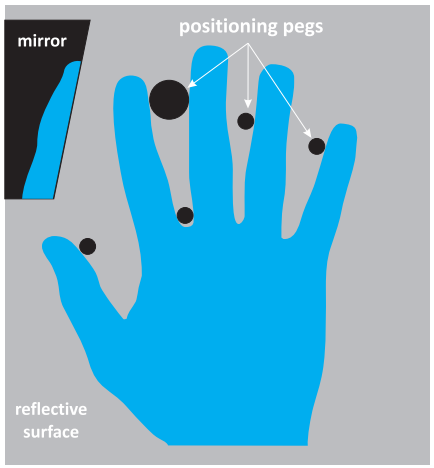
Hand geometry

What and how we measure?

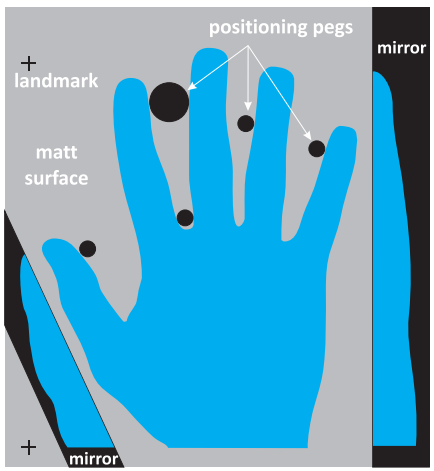
1. 2D properties
   - fingers and palm width
   - fingers length
1. '2.5D' properties
   - 2D + height of palm and thumb
   - implemented by orthographic scanning: 2D scans in two planes at right angles
   - the most popular hand geometry approach
2. 3D properties
   - 3D scanning (like in 3D face)

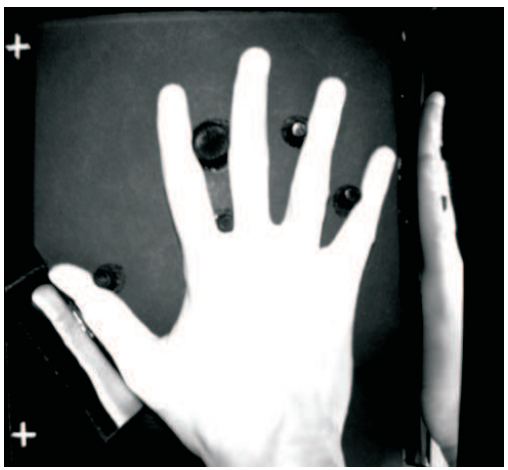


Hand geometry: image capture



HandKey II
(commercial)





Warsaw
University
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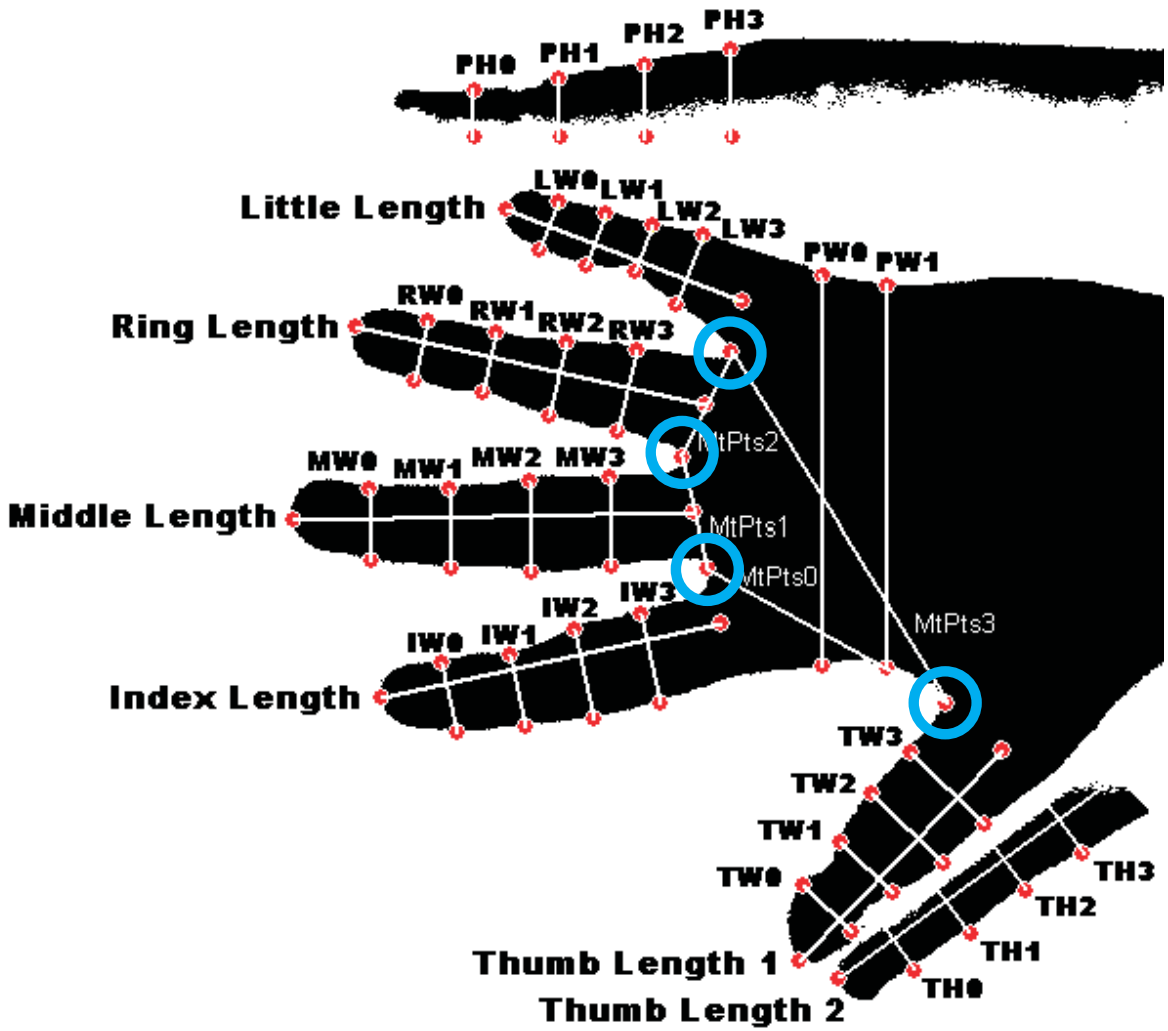
(laboratory)

Hand geometry: image capture

Example commercial system (HandKey II)

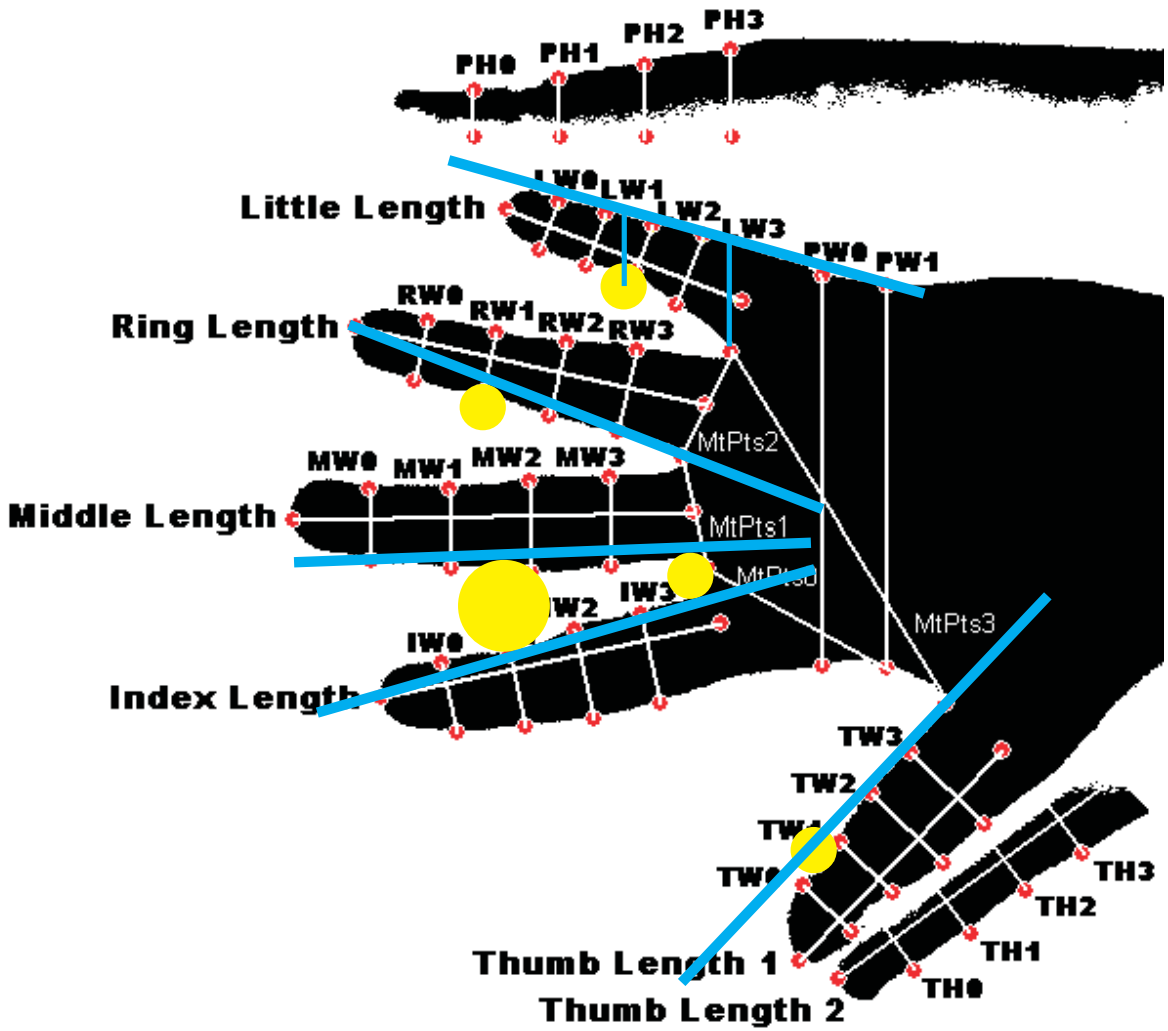
Hand geometry: image capture

1. Finger meet points



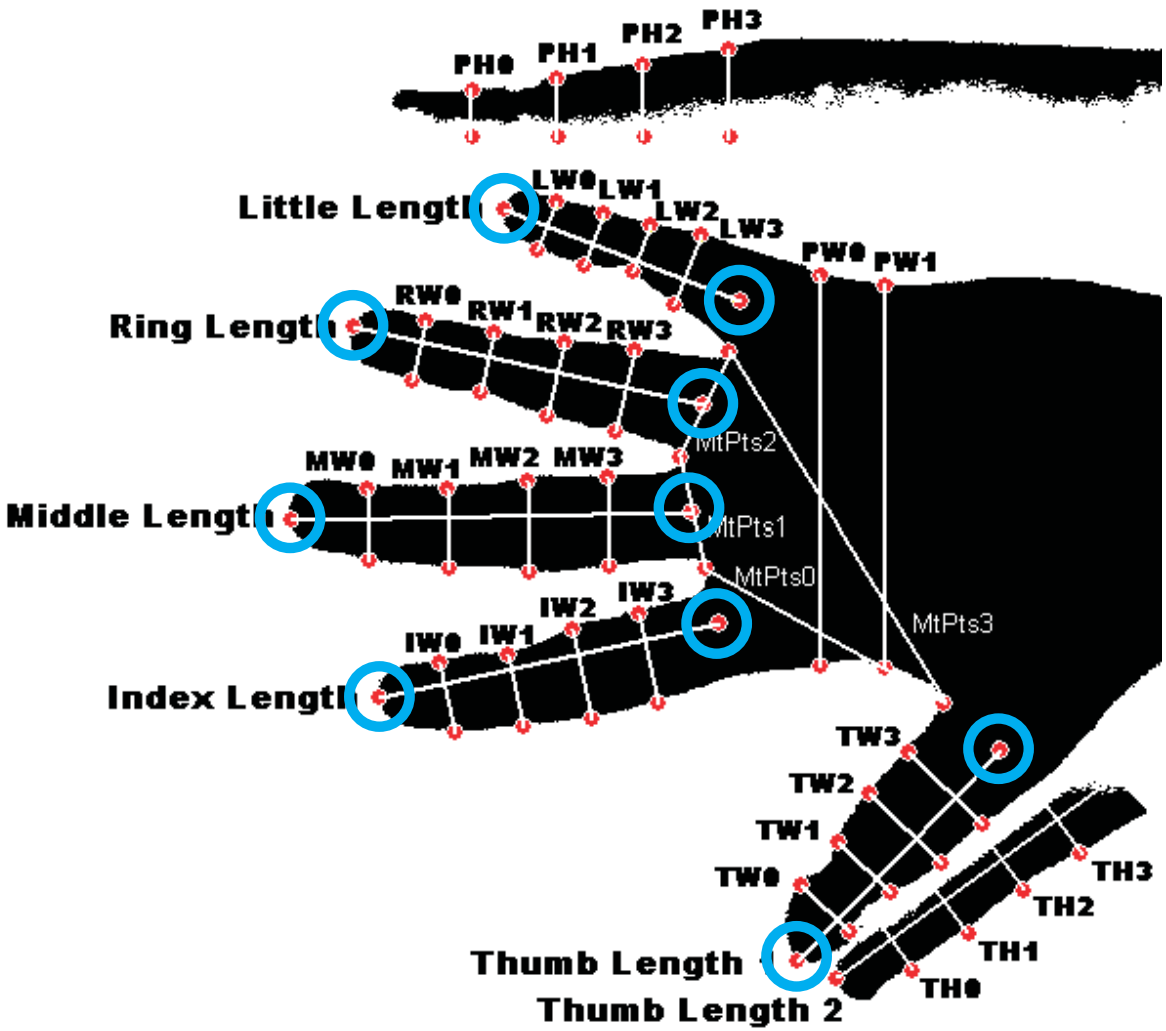
Hand geometry: image capture

2. Finger directions



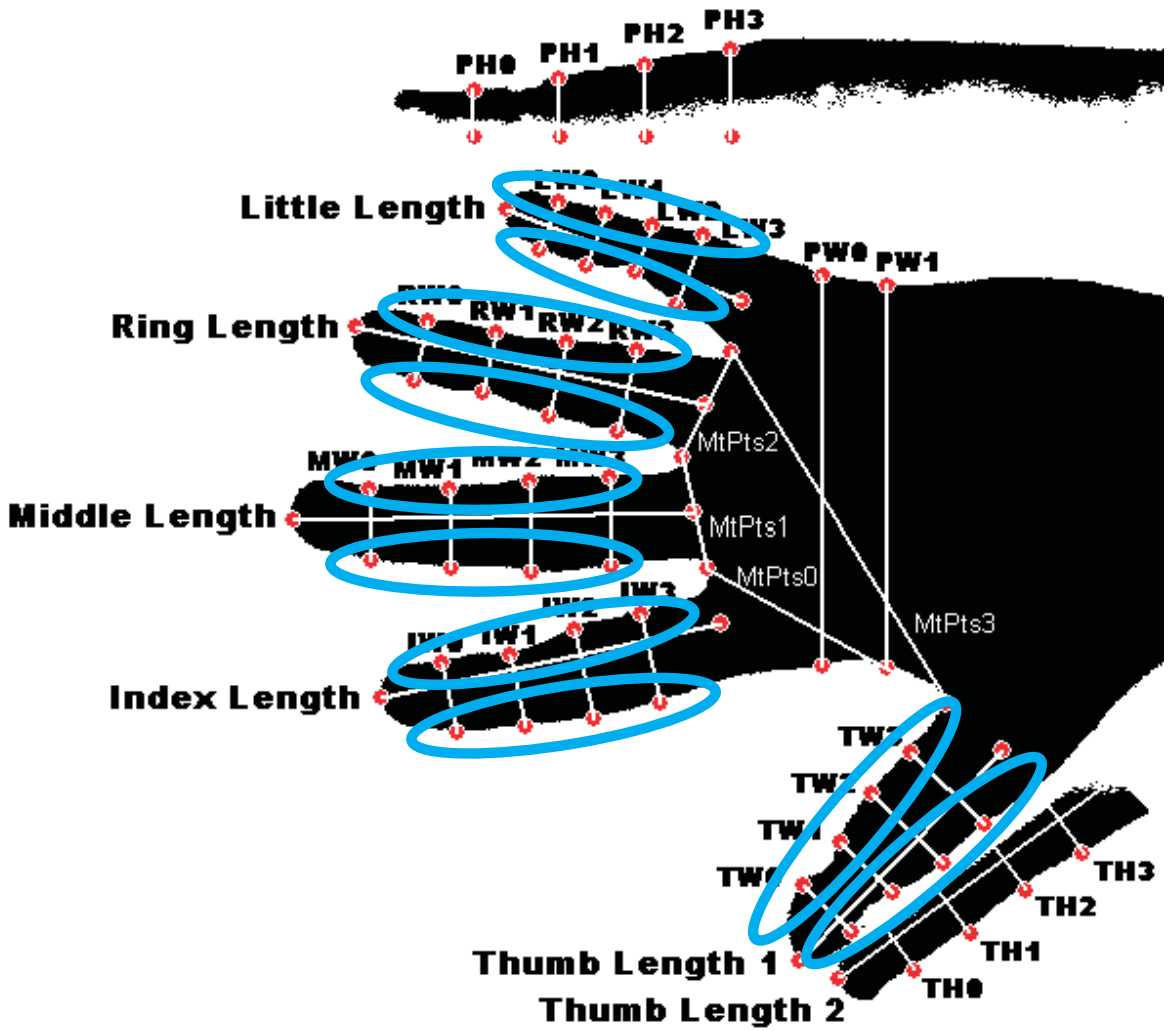
Hand geometry: image capture

3. Finger base points and finger tips



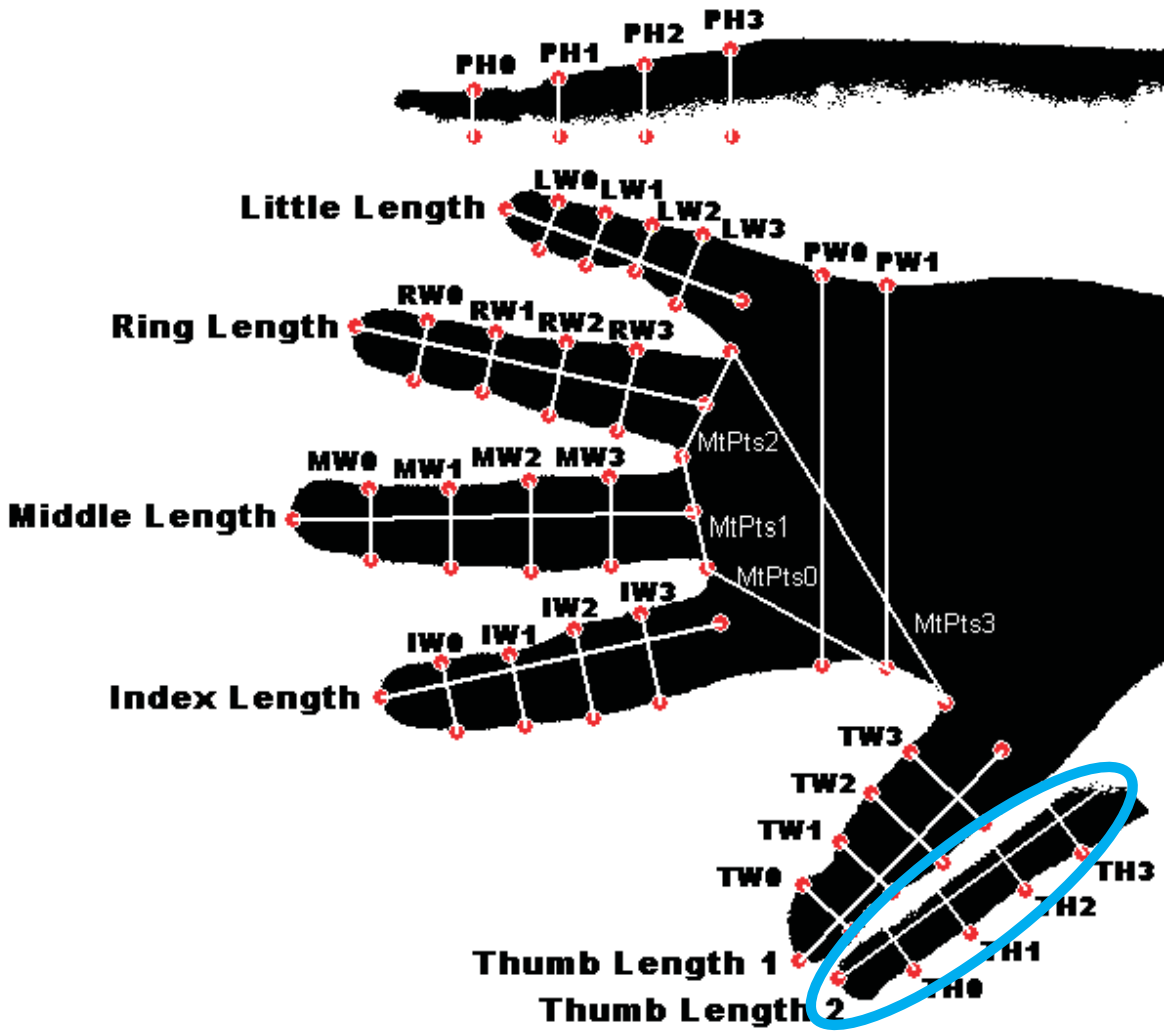
Hand geometry: image capture

4. Finger border points



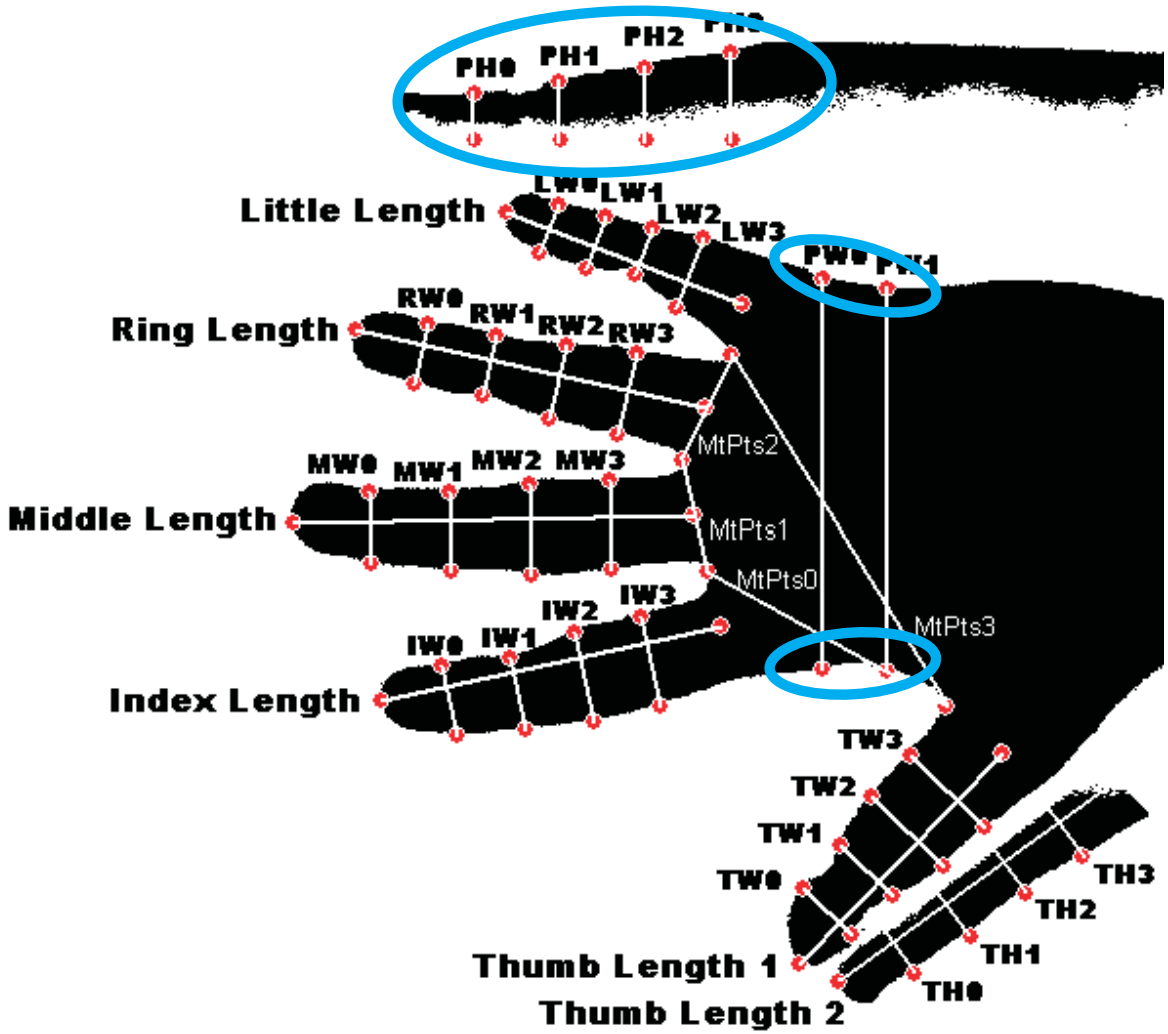
Hand geometry: image capture

5. Thumb mirror points



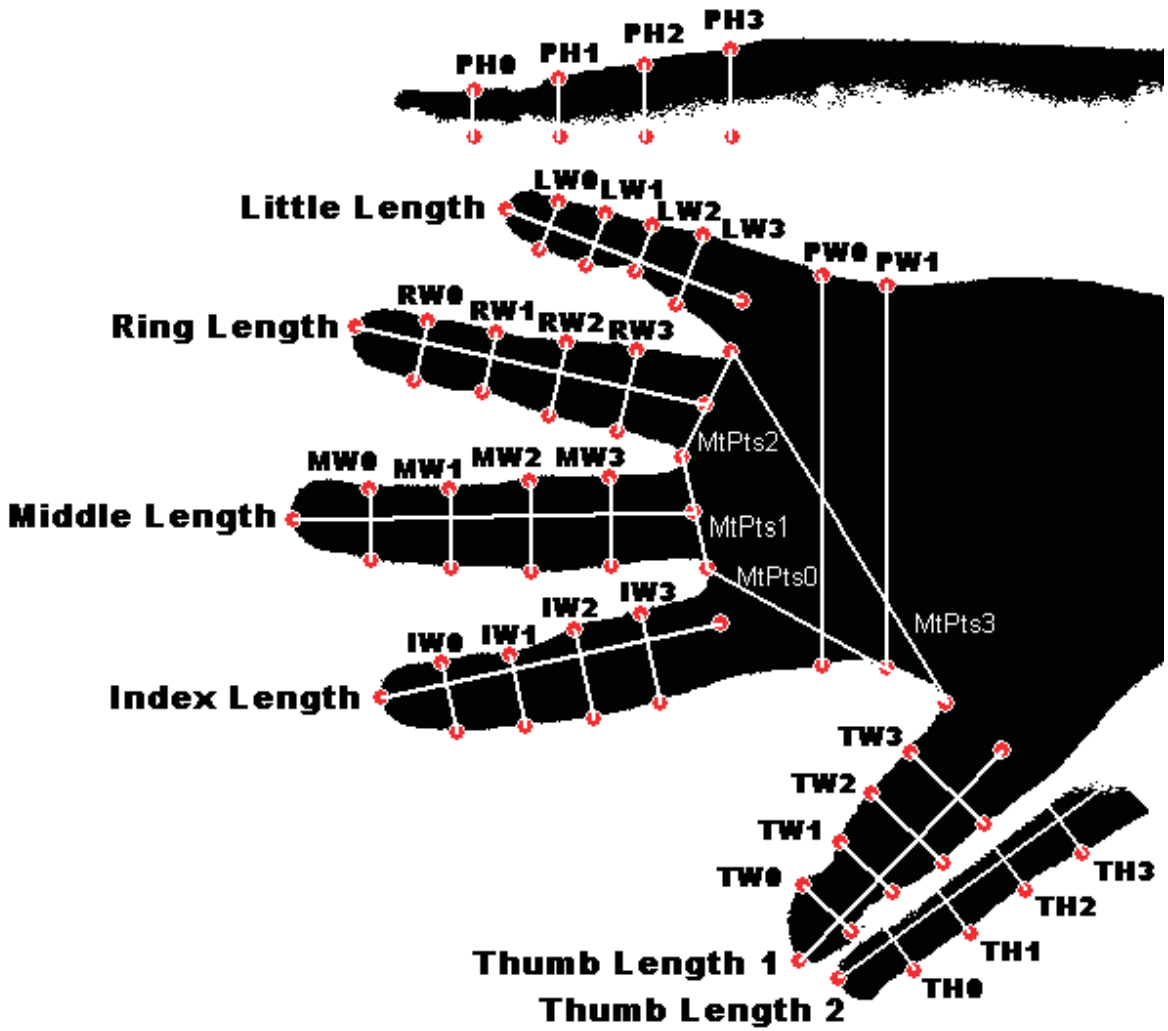
Hand geometry: image capture

6. Hand border points



Hand geometry: image capture

Full set of hand geometry features



Hand geometry

Classification (popular approaches)

1. Linear classification
   - reference template represented by a central element
     - one of the existing templates (e.g. having the smallest distance to all the remaining templates)
     - representing possibly non existing hand: average or median template
   - decision based on the distance between the reference template and the verification template; typically weighted Ln norm is used:

$$\|x - y\|_n = \sqrt[n]{\sum_i \frac{|x_i - y_i|^n}{\sigma_i^n}}$$

     where σ_i is sample standard deviation of the i-th feature
   - EER about 1% (when $L1$ weighted norm is used)

Hand geometry

Classification (popular approaches)

2. Nonlinear classification
   - Neural networks
     - common classifier (network) for all persons
       $\Rightarrow$ classification 1:N, EER $> 10\%$
     - each person has its 'own' classifier (network)
       $\Rightarrow$ classification 1:2, EER about 1.5%
   - Support Vector Machine (SVM)
     - maximizing the gap between samples representing two different classes
     - 'kernel trick' $\Rightarrow$ transformation of non-linear problem into linear problem possible to be solved in a higher dimensional feature space
     - EER below 1% (when Gaussian kernel is used)

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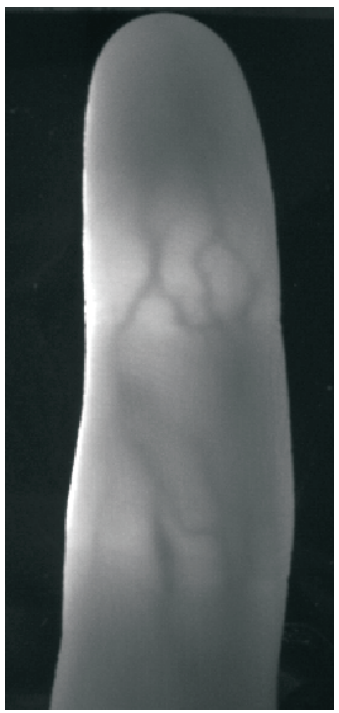
Palm veins and finger veins

Palm veins

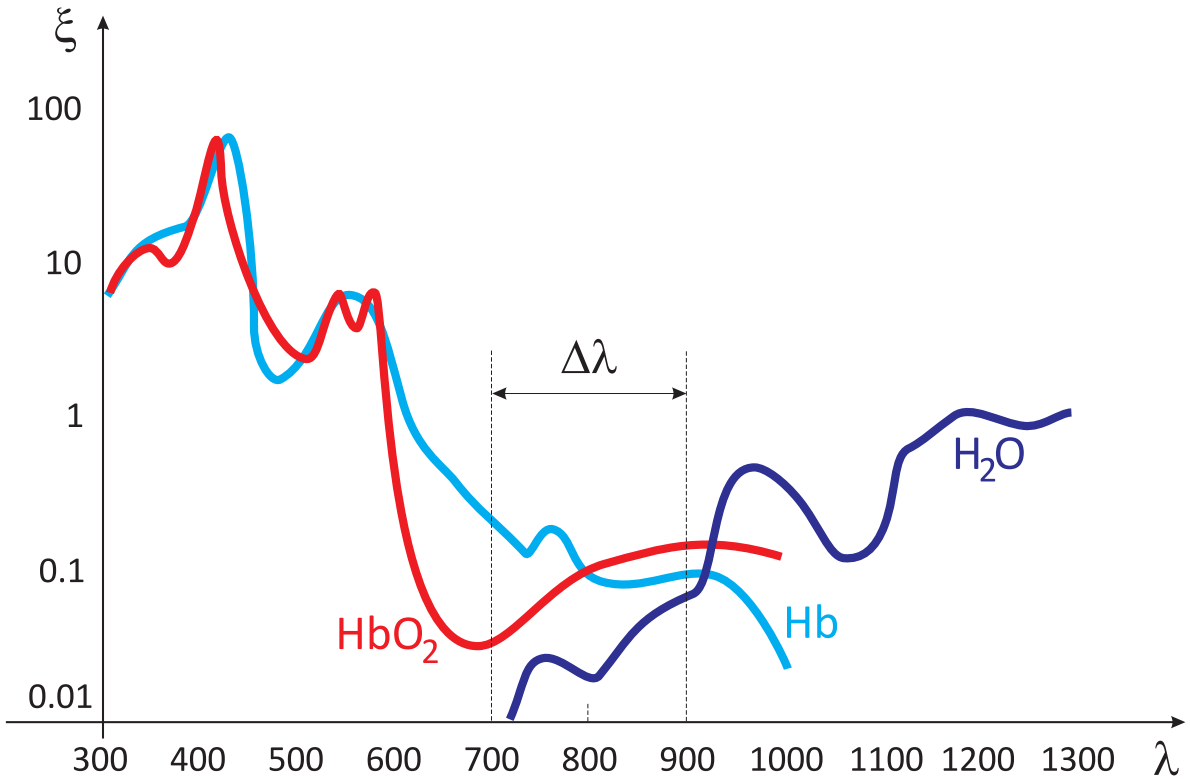
Biometrics and Machine Learning Laboratory Warsaw University of Technology

Finger vein

Hitachi
Finger Vein Authentication White Paper, 2004

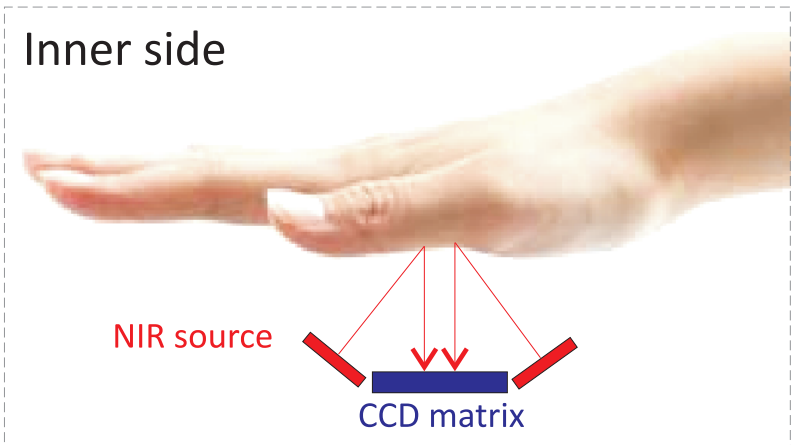


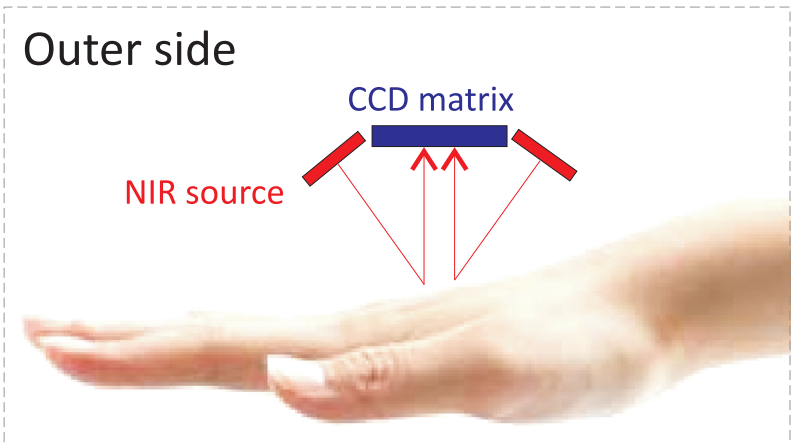
Infrared light absorption

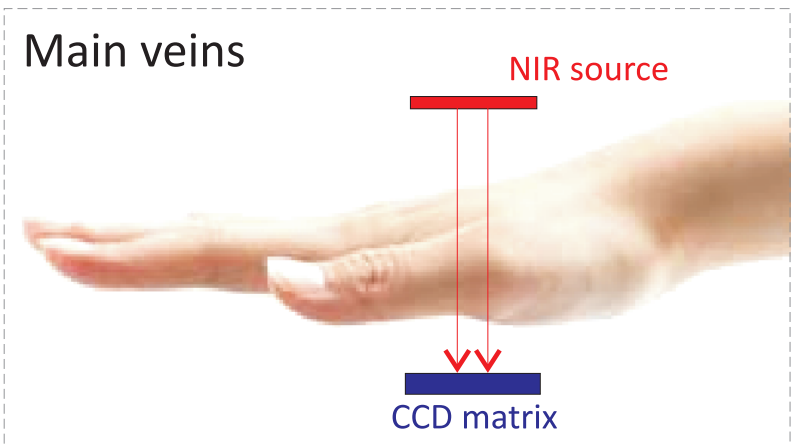


Absorption coefficient ξ of the deoxyhemoglobin (Hb), oxyhemoglobin (HbO_2) ad water (H_2O) as a function of the illuminating light wavelength λ (hemoglobin concentration 50μM). Graph based on A. Sassaroli, *et al.*, "Near-infrared spectroscopy for the study of biological tissue", Tufts University.

Palm veins: image capture







Palm veins: image capture

Commercial examples: imaging inner side of the palm

Fujitsu PalmSecure readers

Raw image

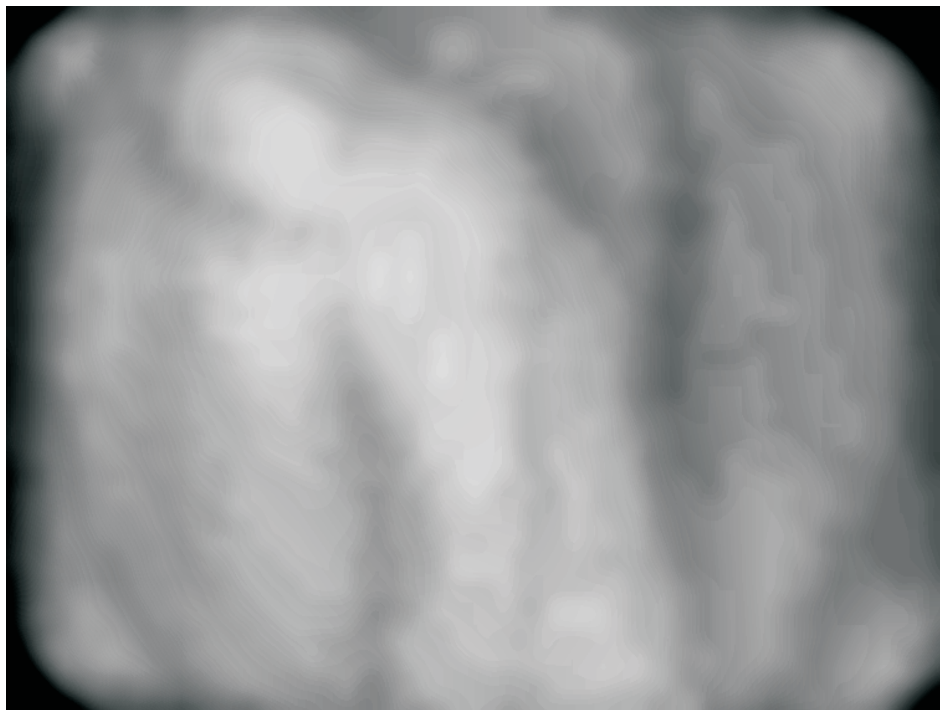
Source: State of the Art Biometrics Excellence Roadmap, MITRE Tech. Rep., Vol. 1, 2008

Palm veins: image capture

Commercial examples: imaging outer side of the palm

VP II reader
Techsphere

Source: State of the Art Biometrics Excellence Roadmap, MITRE Tech. Rep., Vol. 1, 2008



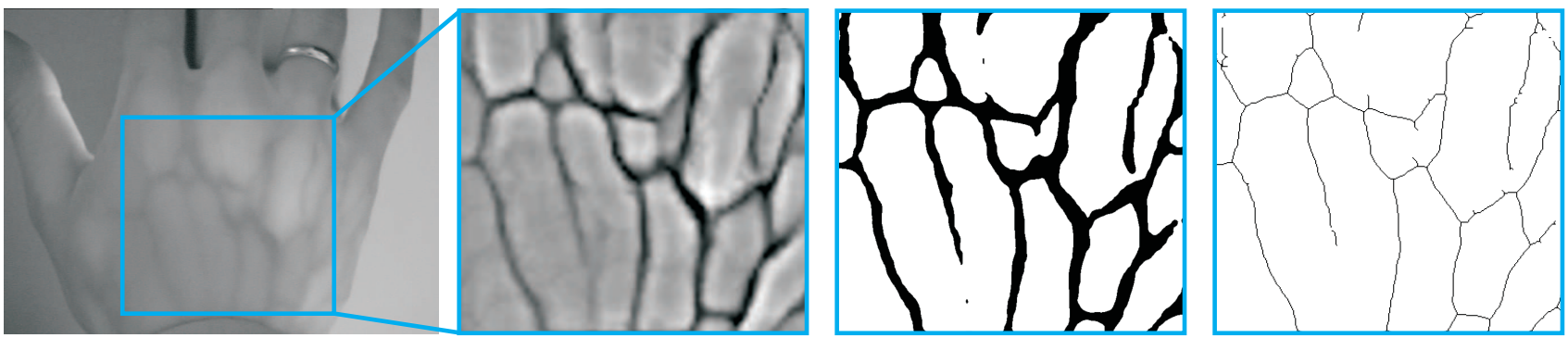
Raw image

Source: S.K. Im, et al., An Biometric Identification System by Extracting Hand Vein Patterns, Journal of the Korean Physical Society, Vol. 38, No. 3, March 2001, pp. 268-272

Palm veins

Image pre-processing and feature extraction

1. Noise reduction and edge detection (mid-pass filtering)
2. Calculation of binary or skeletal image



Raw image | Edge enhancement | Binary image | Skeletal image

Palm veins

Image pre-processing and feature extraction

3. Calculation of the dissimilarity score
   - Hamming distance for binary images
   - Hausdorff distance for skeletal images
4. Performance of the example commercial system (Fujitsu PalmSecure, CBT Round 6 Public Report, IBG, 2006)
   - false rejection rate = 4.23%, false acceptance rate = 0.0118% (enrollment and authentication realized on the same day)
   - false rejection rate increases to 8.52% when enrollment and authentication are on different days

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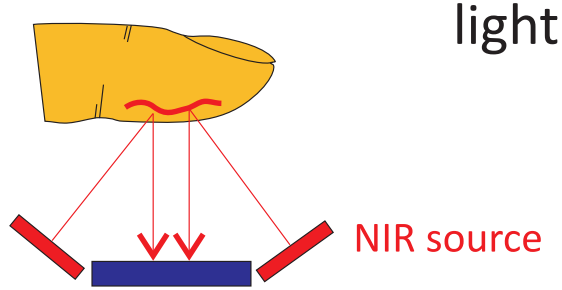
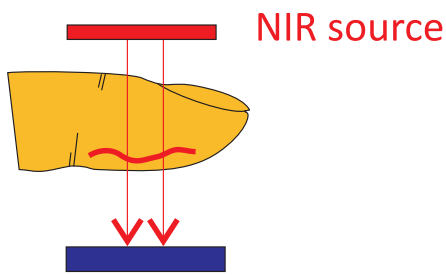
Finger veins: image capture

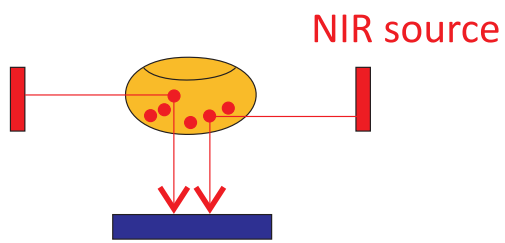
Capture of the reflected light



Top illumination



Side illumination



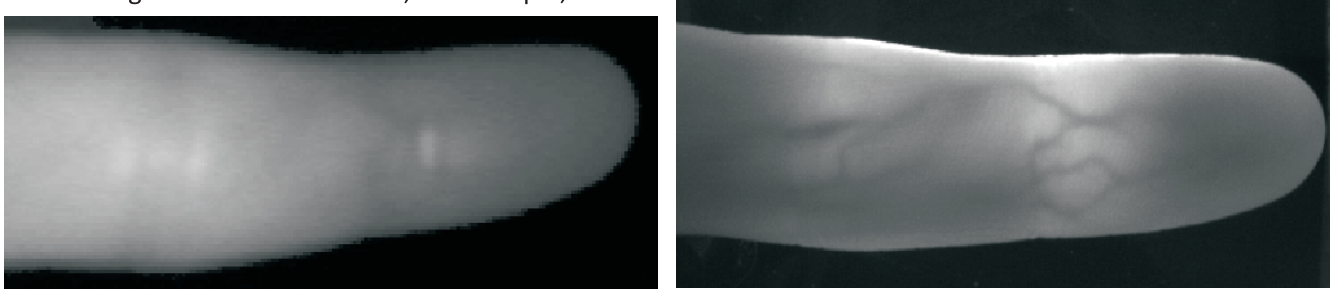
Finger veins: image capture

Example commercial readers

Hitachi readers: VeinID with side illumination (left and right) and H1 with top illumination (middle)

Source: State of the Art Biometrics Excellence Roadmap, MITRE Tech. Rep., Vol. 1, 2008

Source: Finger Vein Authentication, White Paper, 2004



Use of reflected NIR light

Use of top illumination

Finger veins

Example application

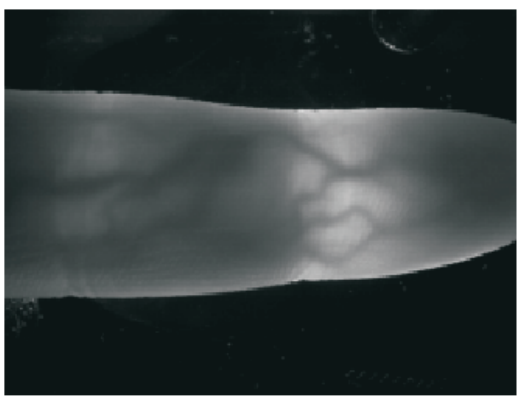
First biometric ATM in Europe (9/11 Płocka Str., Warsaw, Poland)

Source: prnews.pl, May 2010

Finger veins

Feature extraction and matching

1. Vein tracking in raw, gray scale image
   (Q: do you remember ridge tracking in fingerprint recognition?)
2. Image intensity quantization into three quanta:
   {VEIN, UNCERTAIN, BACKGROUND}



Raw image

Finger vein template

Source: N. Miura, *et al.*, Extraction of Finger-Vein Patterns Using Maximum Curvature Points in Image Profiles, *IAPR Conf. on MVA*, May 16-18, 2005 Tsukuba Science City, Japan

Finger veins

Feature extraction and matching

3. Calculation of the dissimilarity score d

$$d = \frac{\text{number of disagreeing elements: VEIN-BACKGROUND}}{\text{entire number of VEIN elements in both images}}$$

4. Performance of the example commercial system (Hitachi UBReader, CBT Round 6 Public Report, IBG, 2006)
   - EER = 0.55% (2.04%), enrollment and verification in the same (different) day

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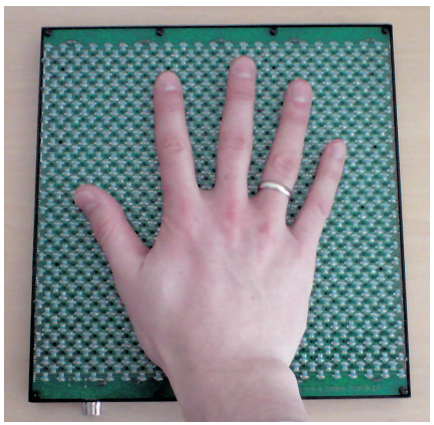
Hand temperature

What we measure?

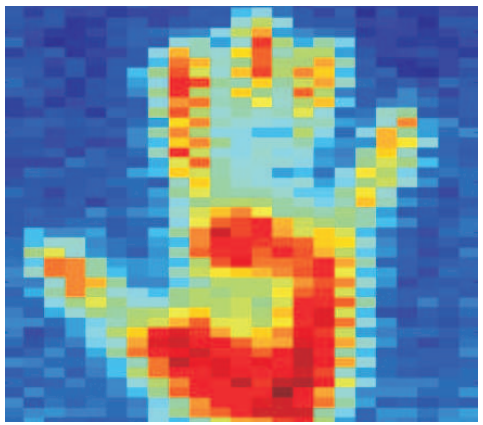
1. Temperature of the hand skin
   - inner or outer part of the hand
   - we are interested in relative temperatures, not global hand temperature
2. Sensitive to ambient conditions
   - repeatable measurements
   - good idea to use as liveness detection, since relative temperatures are difficult to be copied

Hand temperature

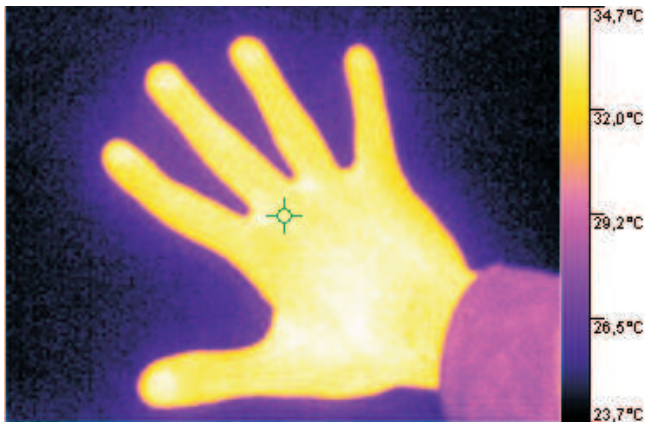
How we measure?



Matrix of thermal sensors



Raw matrix image

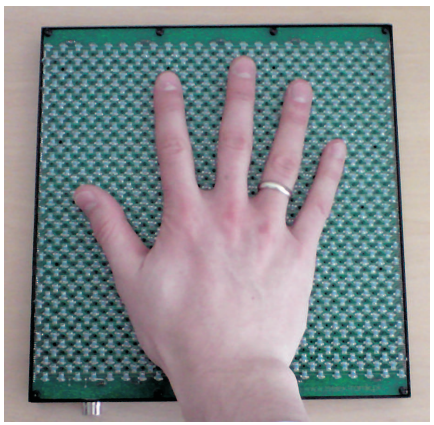


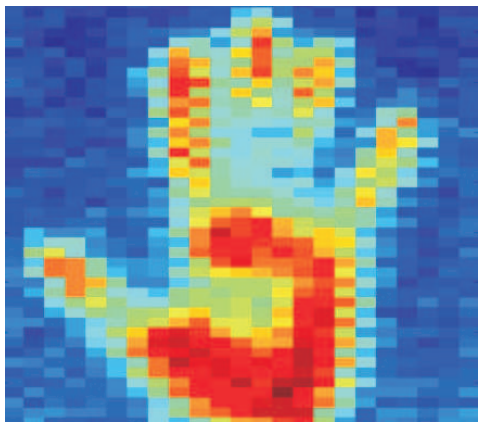
Raw thermal camera image

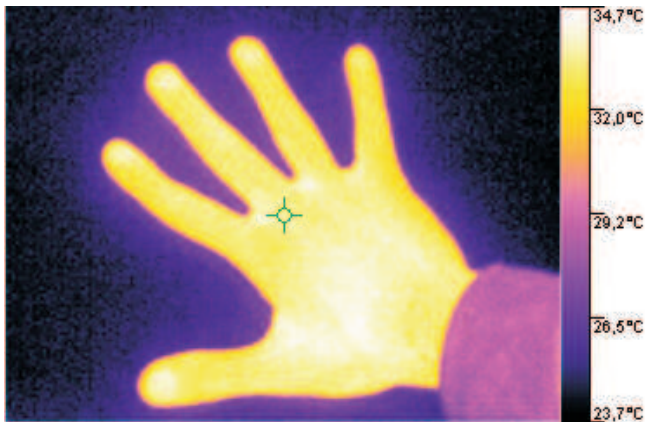
1. Matrix of thermal sensors
   - about 1k sensors (relative precision $\pm 0.18°\text{F}$)
   - scanning time: about 4 seconds
   - hand must have a physical contact with sensors

Hand temperature

How we measure?


Matrix of thermal sensors


Raw matrix image

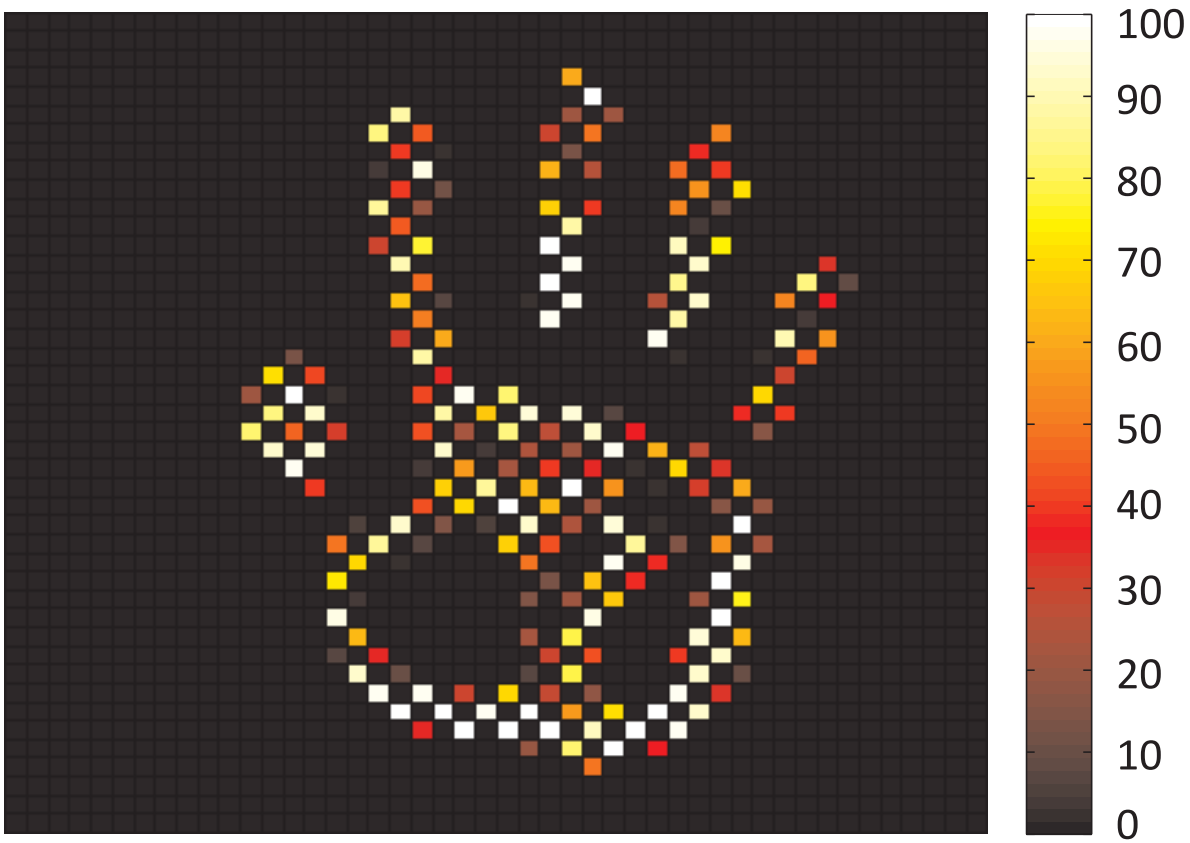


Raw thermal camera image

2. Thermal cameras
   - typical parameters: 320 $\times$ 240 pixels, scanning time below 50 ms (for professional equipment: 1024 $\times$ 1024 pixels, scanning time below 10 ms)
   - contactless, fast and accurate but ... expensive

Hand temperature

Do the entire hand provide good features?



The graph shows how frequently, and which thermal sensors are selected after 255 iterations of the mRMR method, assuming that we look for 120 best features.

Hand temperature

Typical classification problem in multidimensional feature space

1. Non-parametric classification
   - kNN (k nearest neighbors): sample is classified by a majority vote of its neighbors (it is assigned to the class most common among its k nearest neighbors)
   - for example: if k = 1, then the sample is assigned to the class of that single nearest neighbor
   - EER about 6% for PCA+LDA feature selection and kNN binary classification (k=1) [Czajka and Bulwan, ICB 2013]
2. Parametric classification
   - typically Support Vector Machine or neural network is used
   - EER about 14% for mRMR feature selection and SVM binary and linear classifier [Czajka and Bulwan, ICB 2013]

Hand biometrics and art ...