Fingerprint Recognition Technology: Liveness Detection, Image Quality and Skin Diseases

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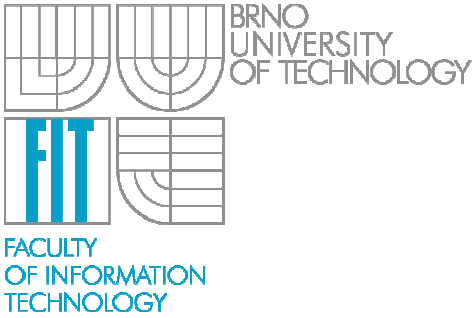
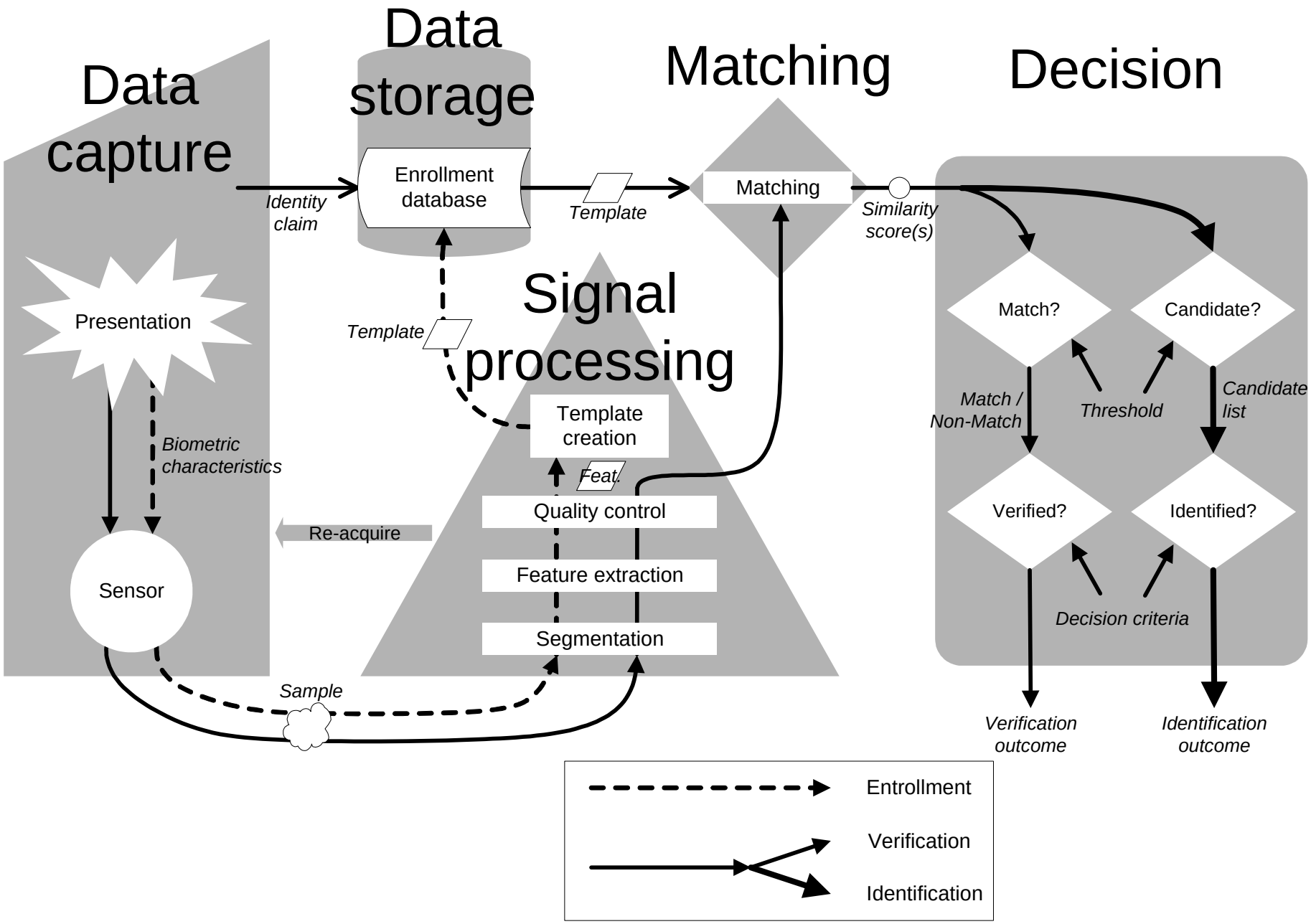


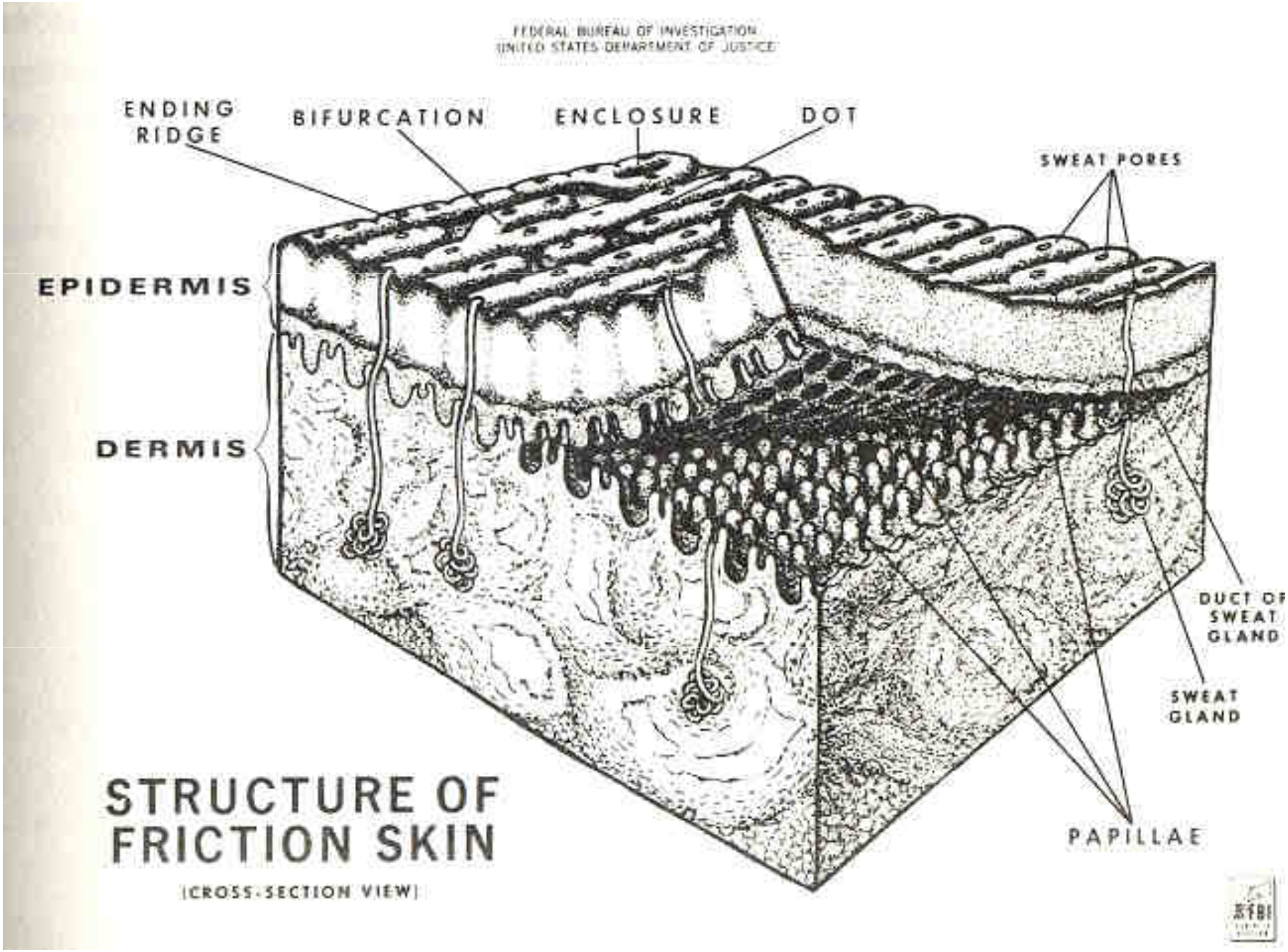
March 28, 2011

Introduction

General biometric system



Skin structure on fingers



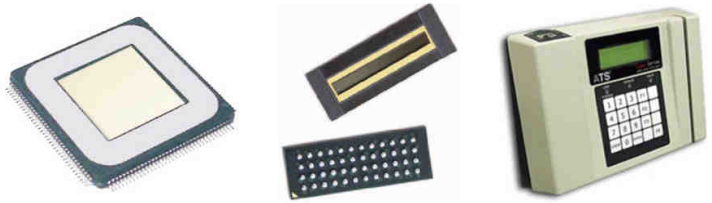
Technologies of fingerprint sensors

Optical Technology

Capacitive Technology

Ultrasound Technology

E-Field Technology

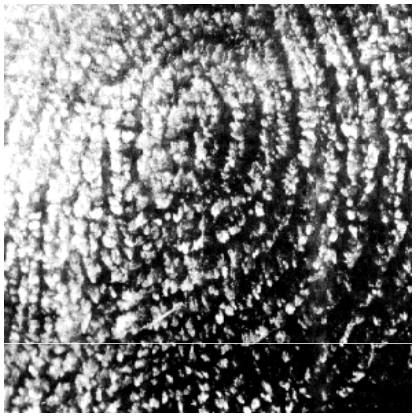


Electrooptical Technology

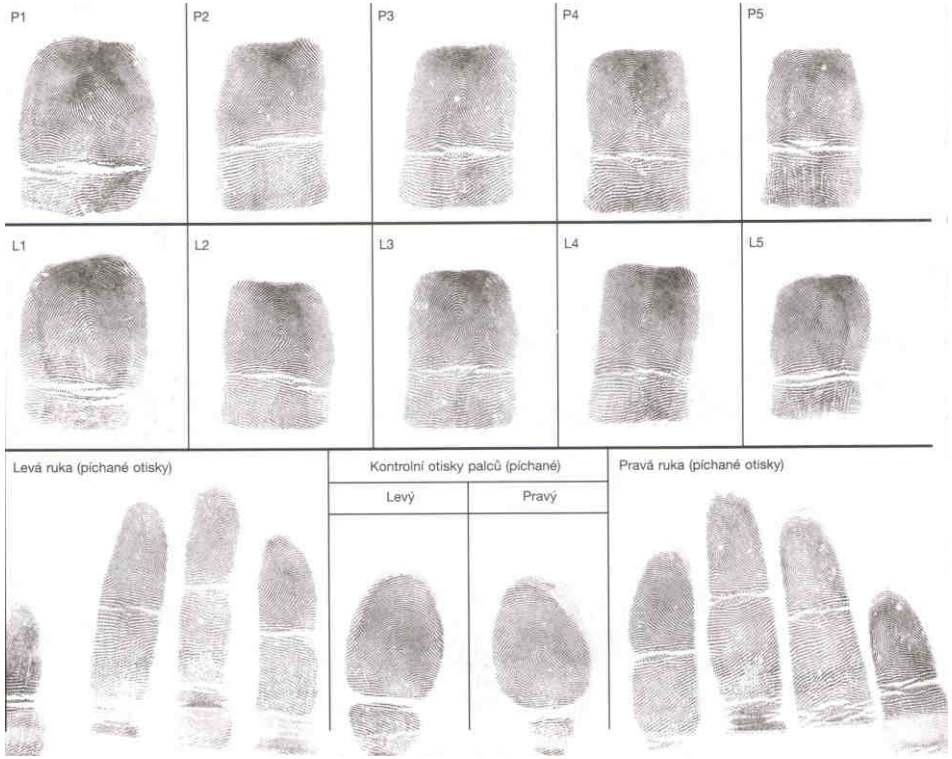
Pressure Sensitive Technology

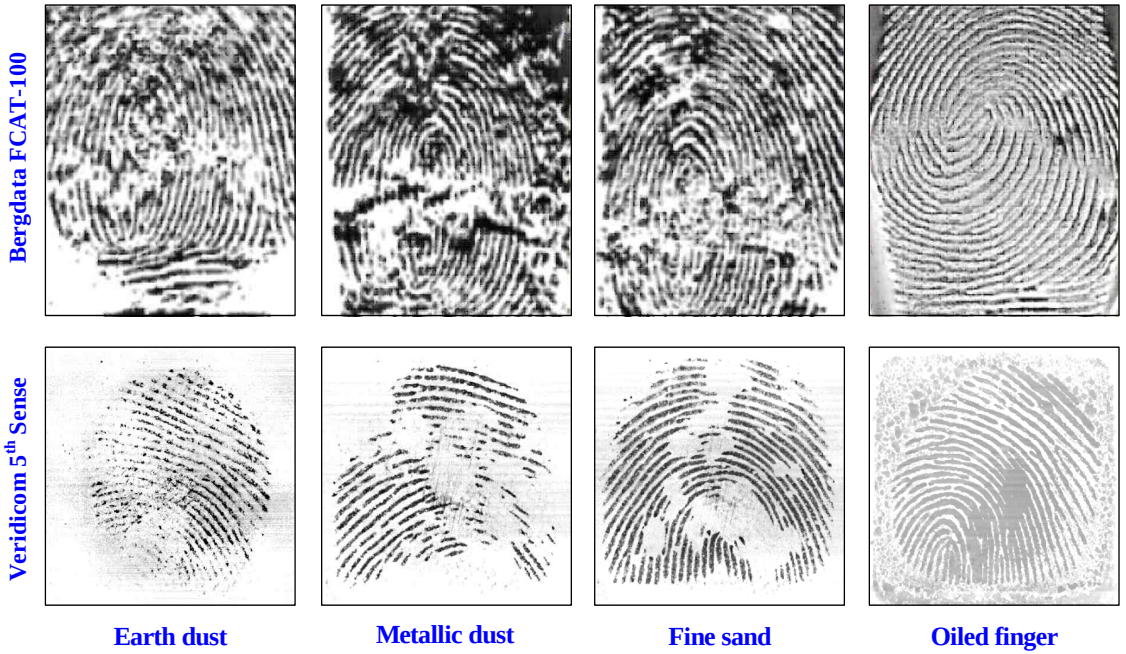
Thermal Technology

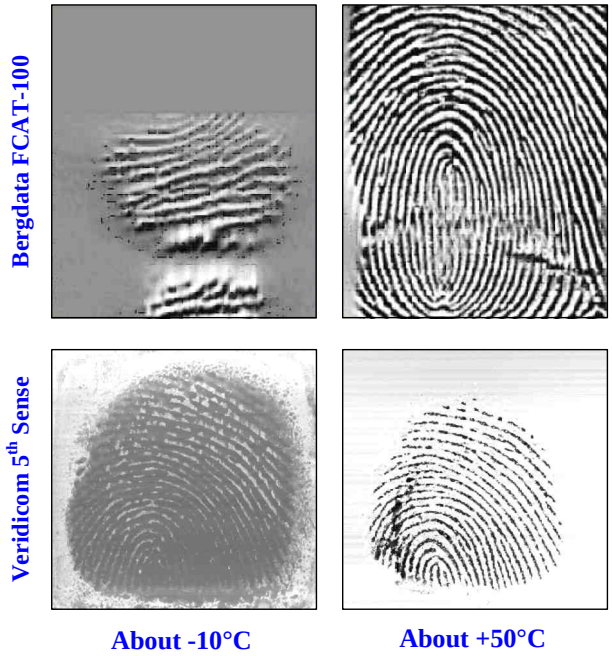
Other problems at sensorics

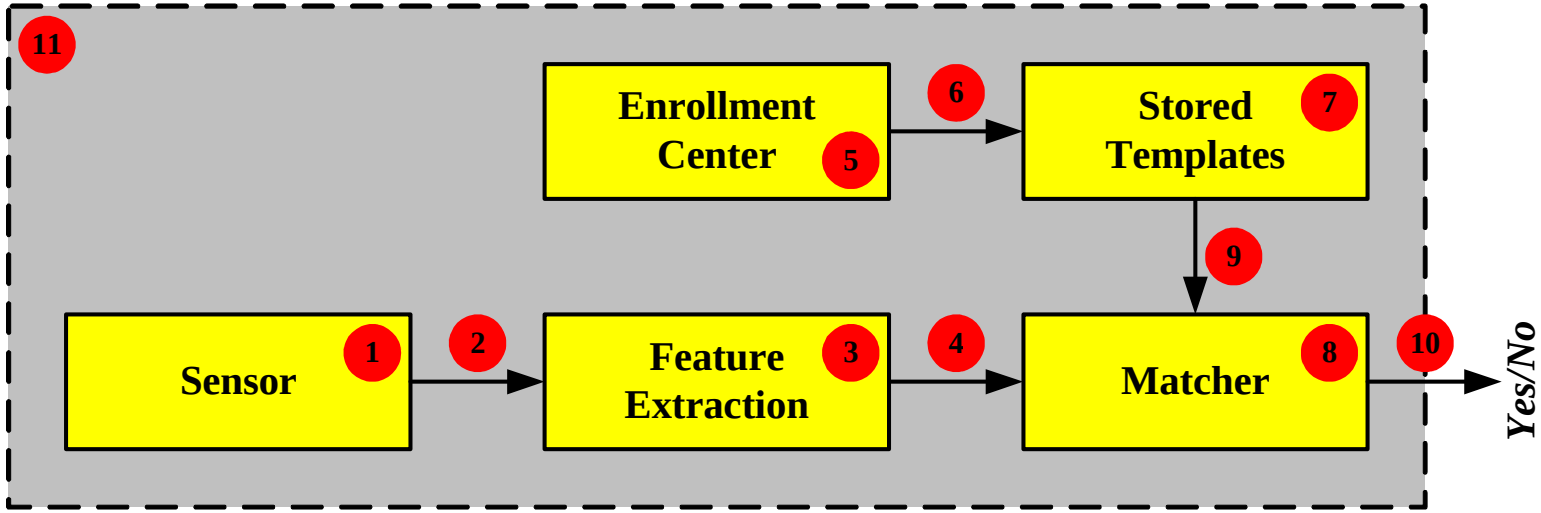


Dactyloscopic card





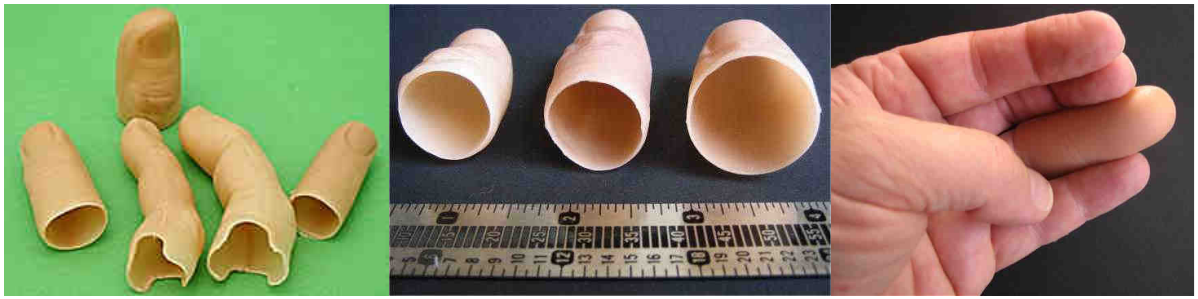



11
Enrollment Center
5
6
Stored Templates
7
9
Sensor
1
2
Feature Extraction
3
4
Matcher
8
10
Yes/No

Finger fakes

Suprema SFM 3020
(fake – rubber stamp)

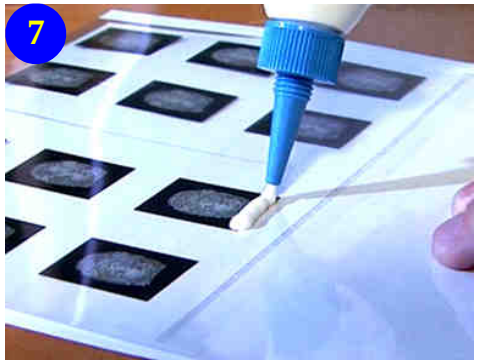
Artificial fingerprints (SFinGe)



Artificial fingers

Fake fingerprints of different materials

How to produce a fake finger(print)?

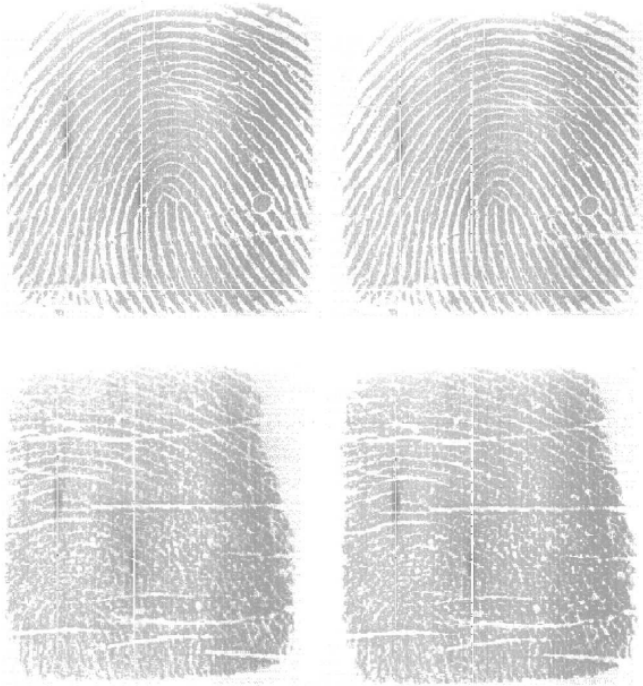


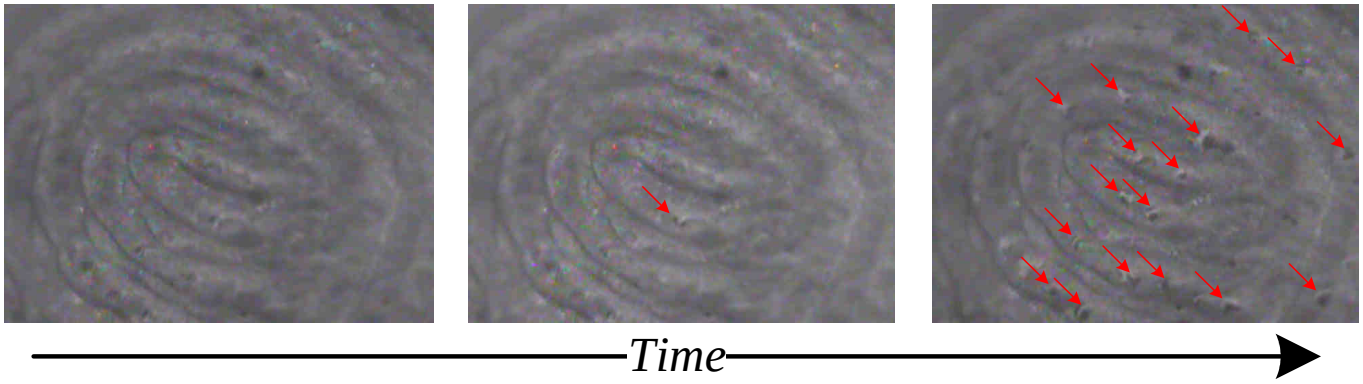
Play video

Liveness detection

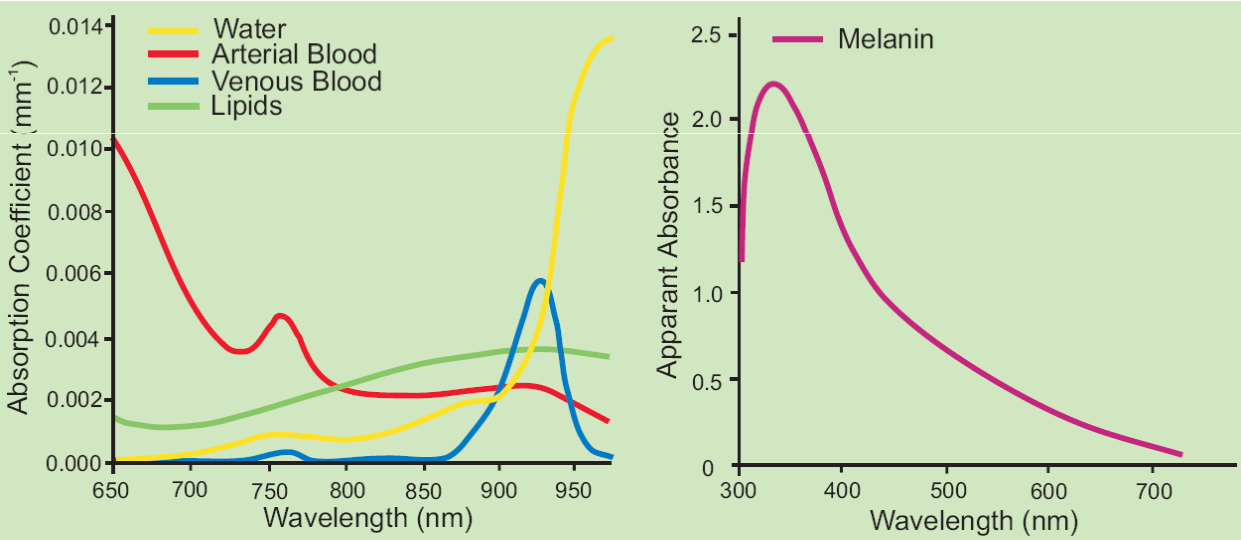
Perspiration

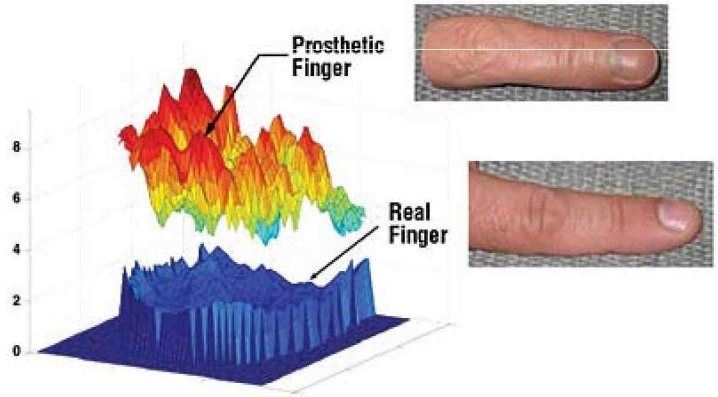
- Clarkson/Virginia universities
- 600 sweat glands in 1 inch^2
- Duration approx. 5 seconds
- High intra-class variability

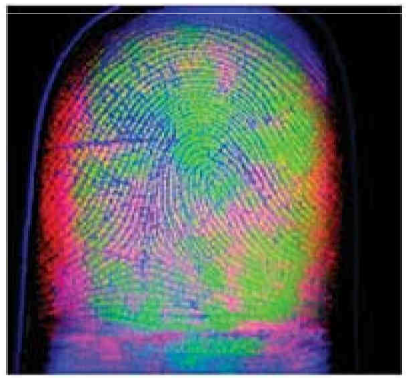


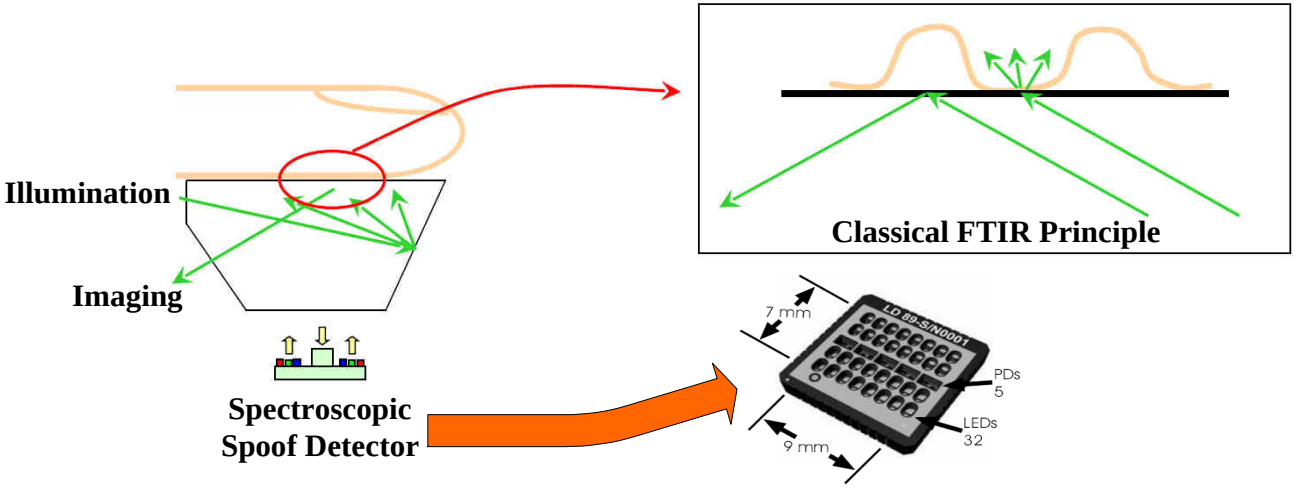


- Lumidigm Ltd.(Albuquerque)
  - Clones: TST Biometrics GmbH, Sagem Morpho etc.

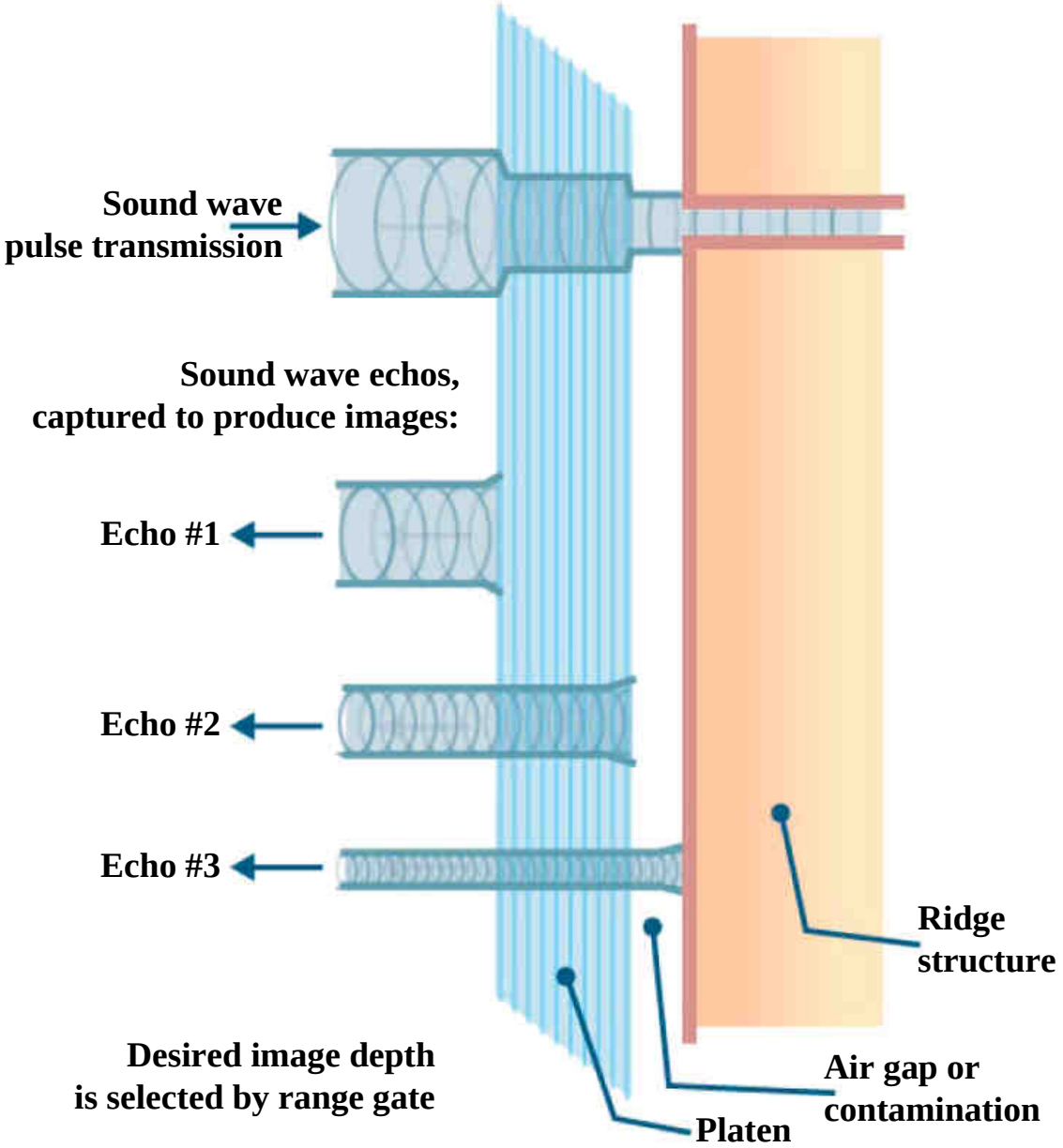






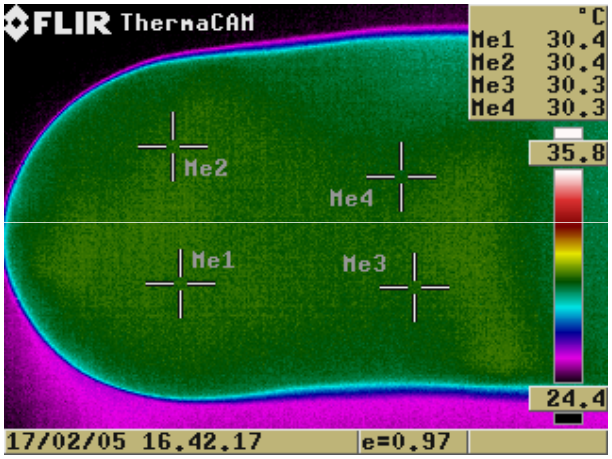


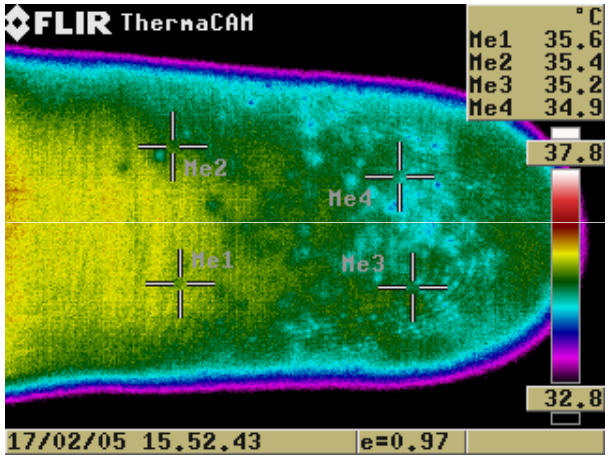
- Ultra-Scan / Optel

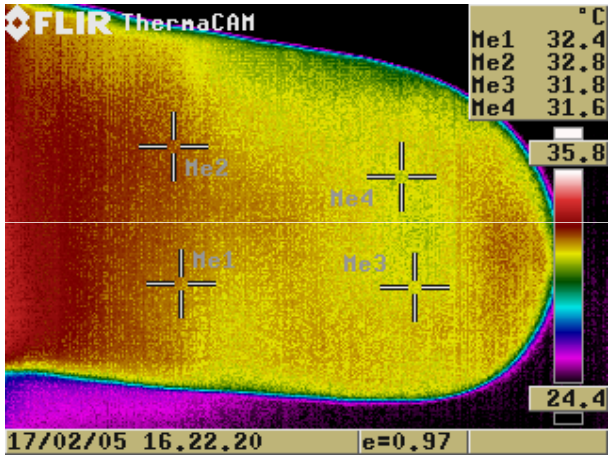


Temperature + Hot & cold stimulus

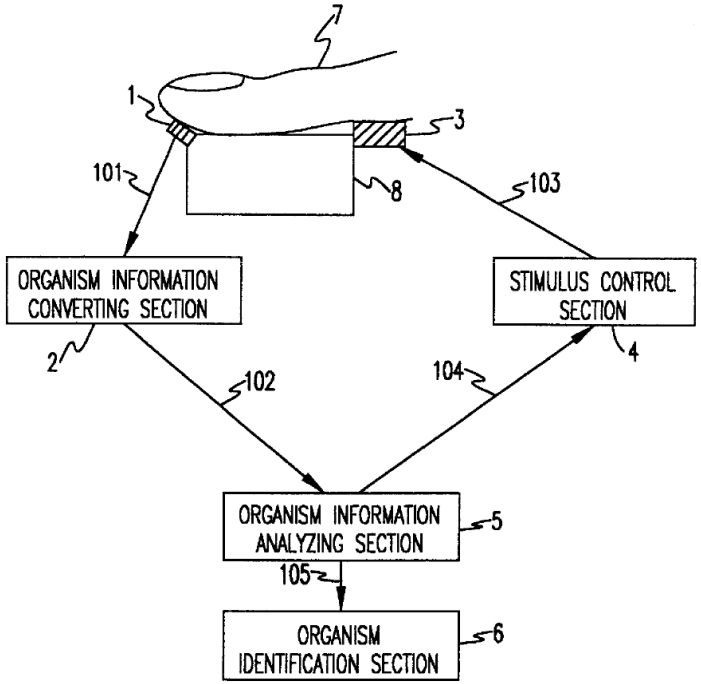
- Temperature





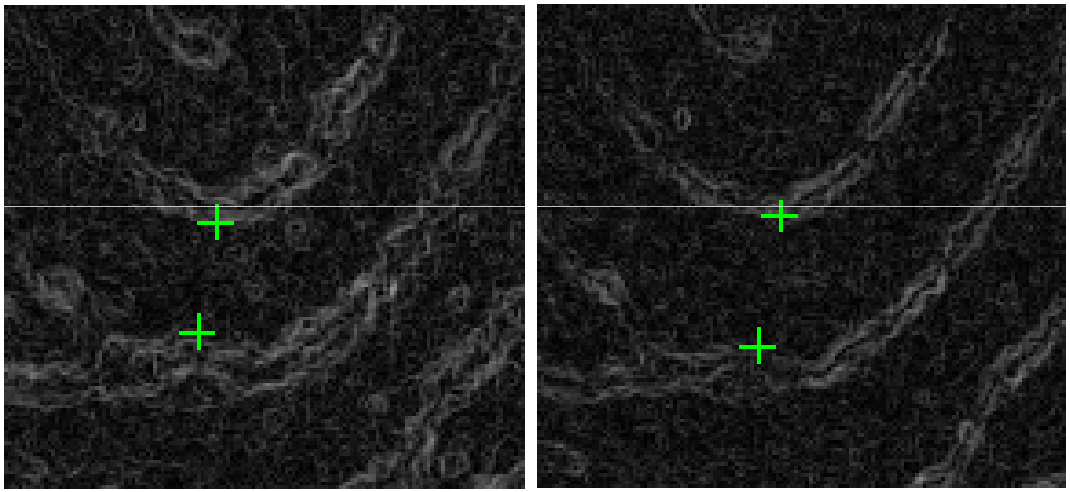


- Hot and cold stimulus



Pressure stimulus

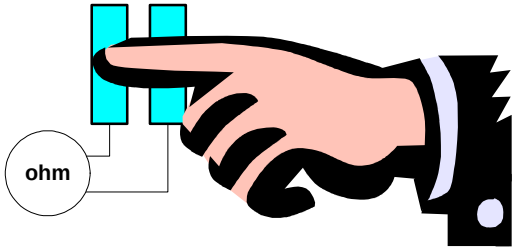
- National utility model ÚPV 19364



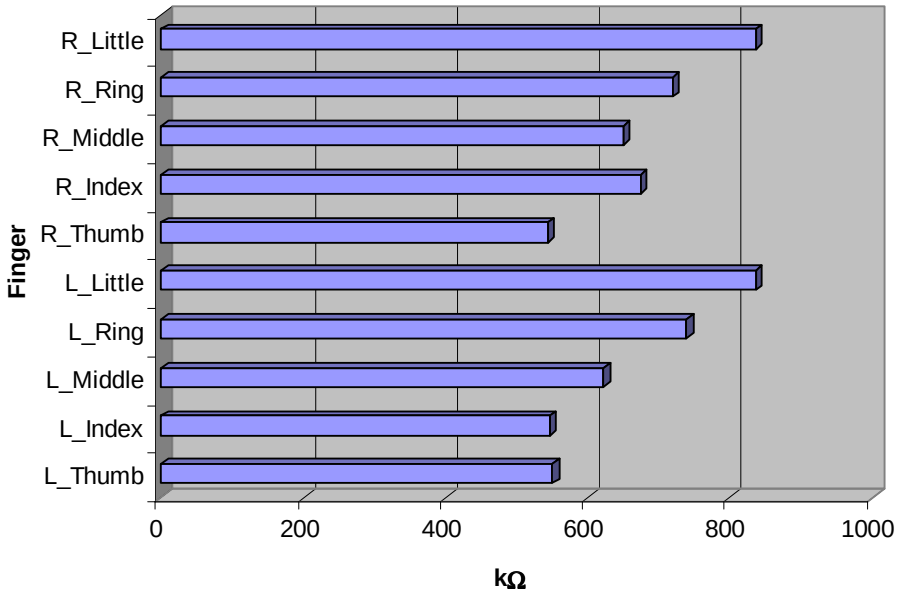
- Ridge elasticity
  - 20%

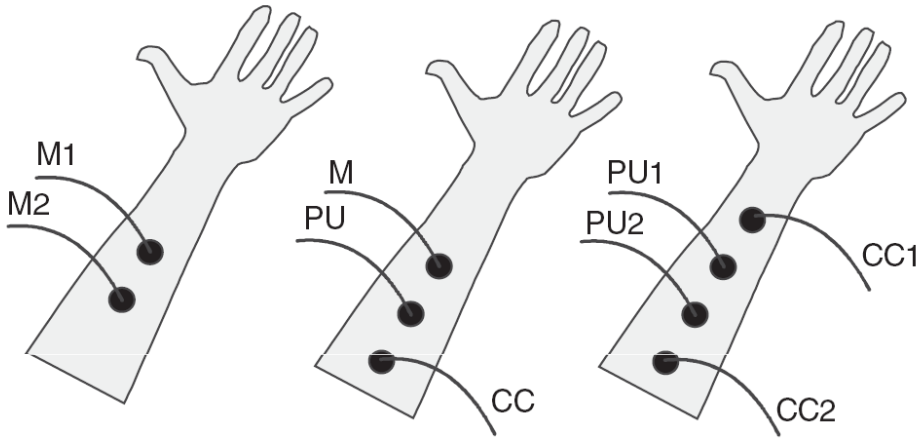
- Change of color (RGB)
  - G ~ 42

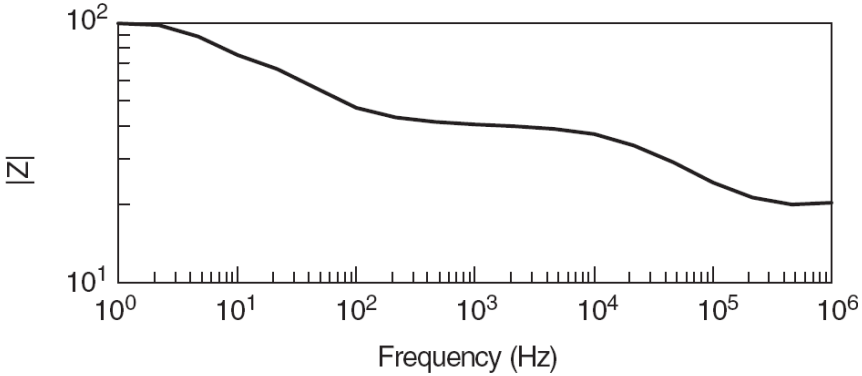
- Bio-impedance →
- Resistance / Conductivity

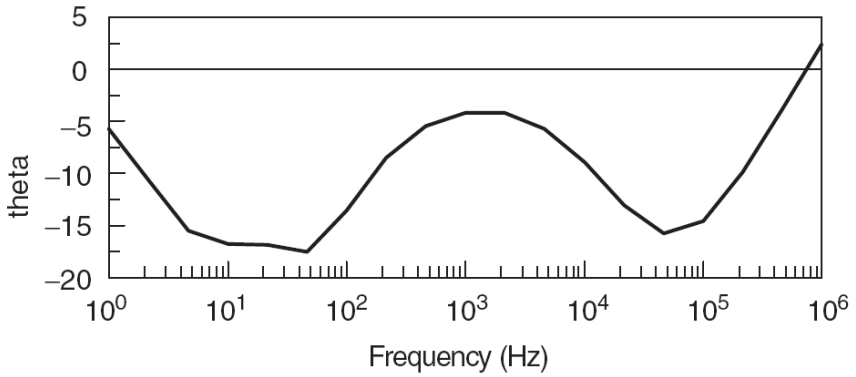


Measurement with DC low voltage

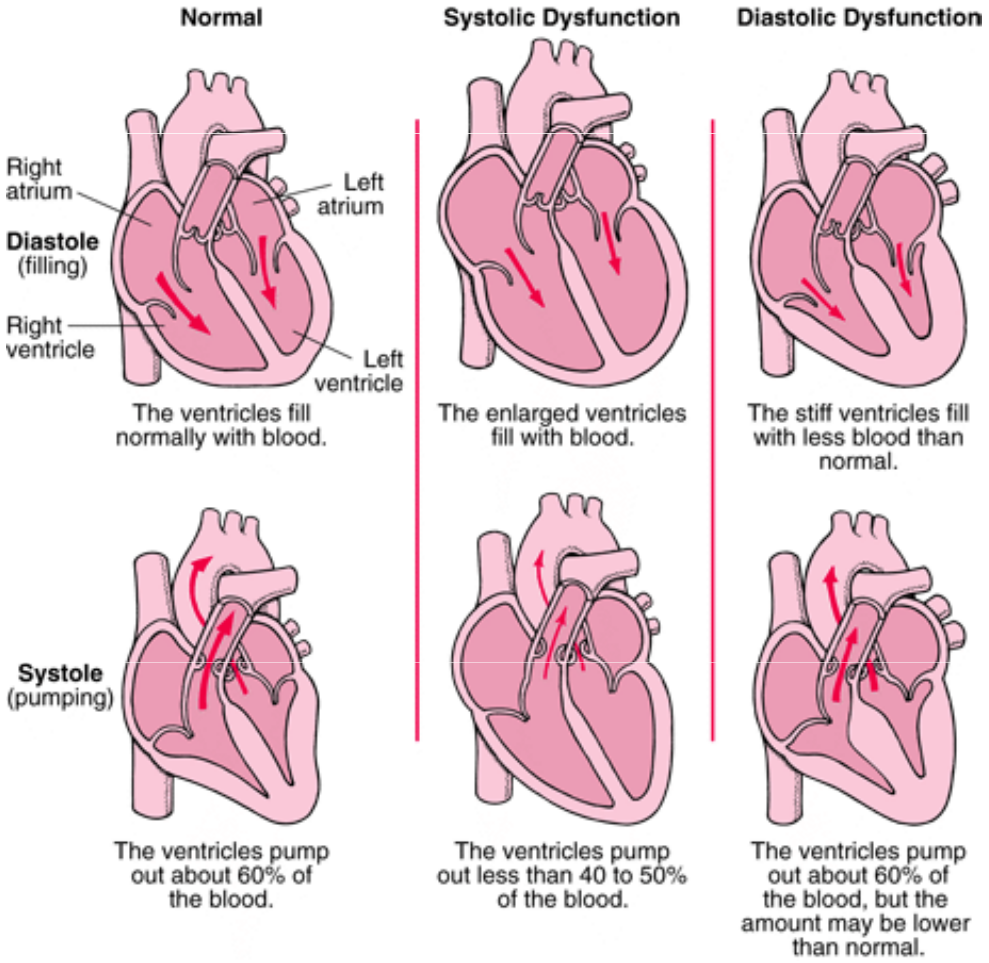


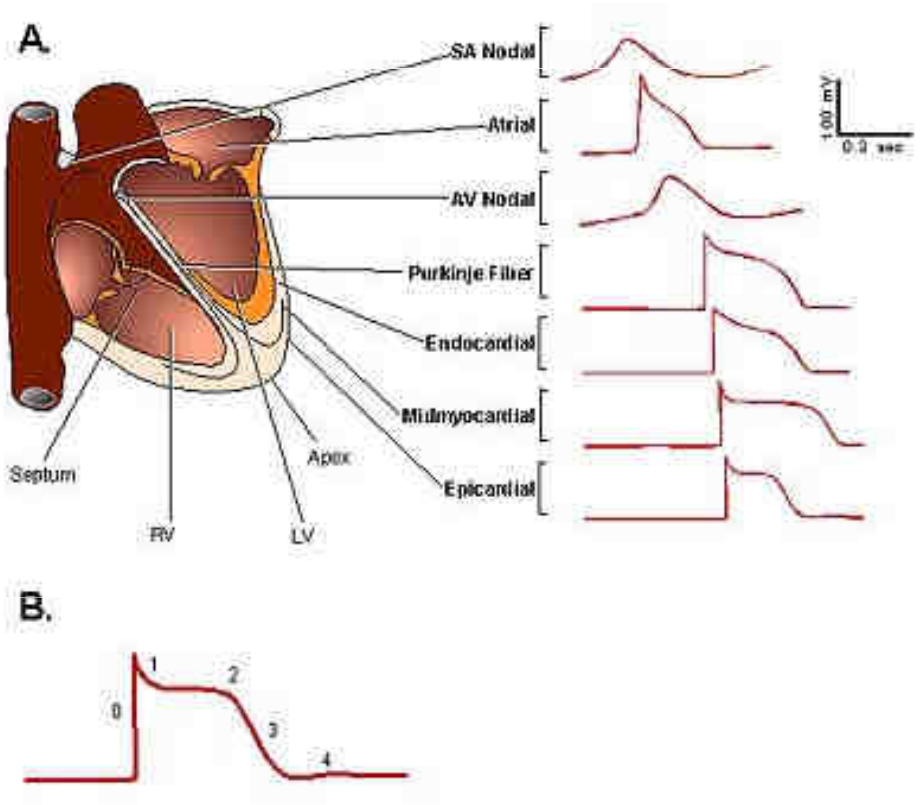




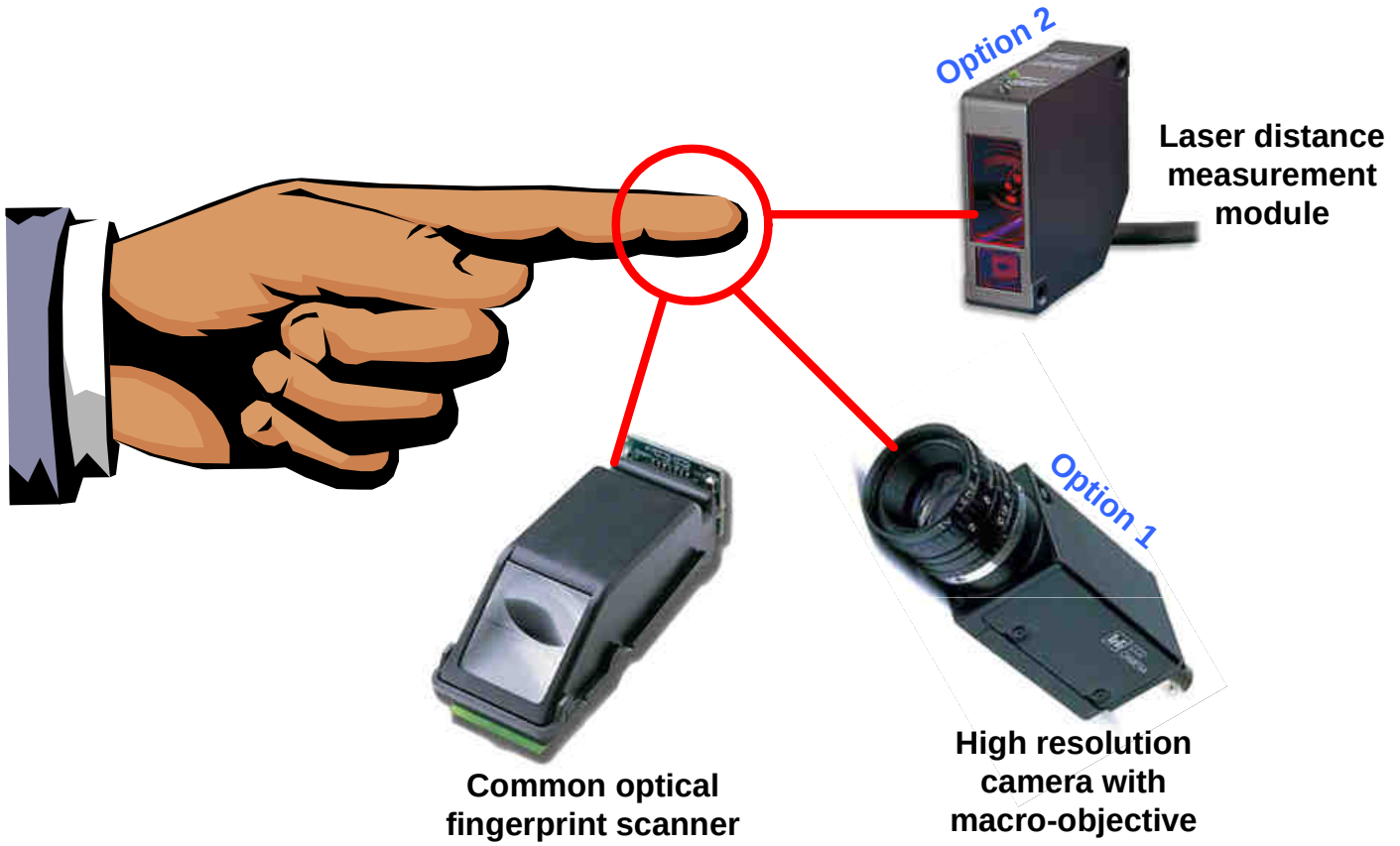


- Heart activity

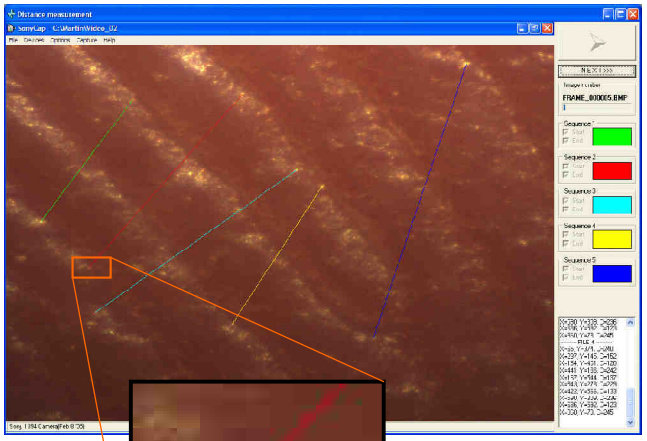


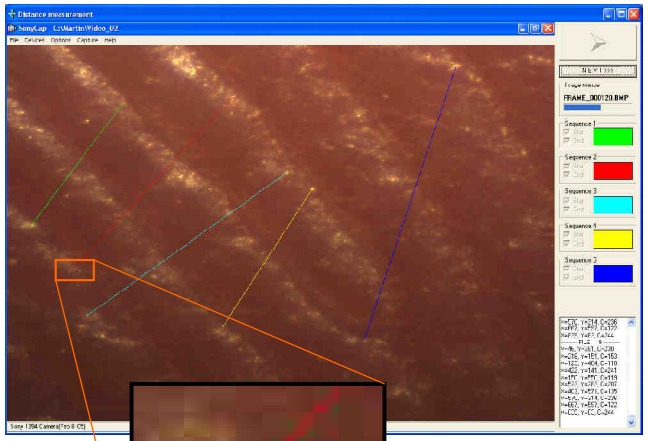


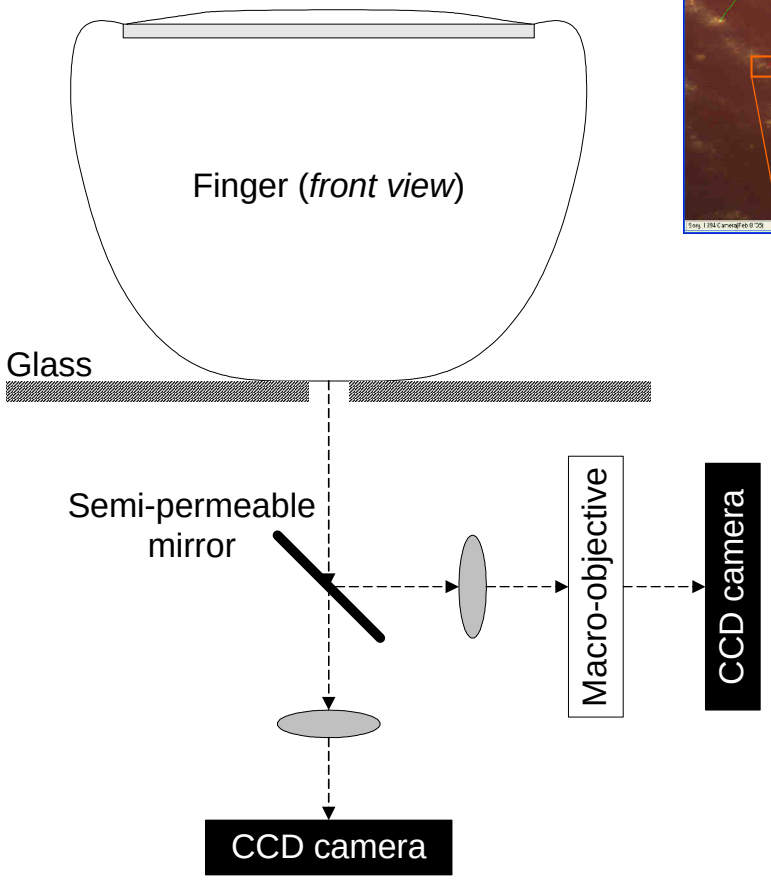
- International patent WO/2007/036370

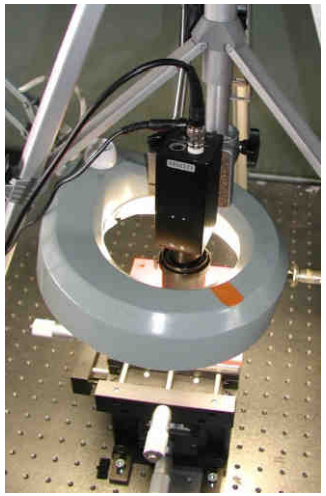


- Macroobjective I.

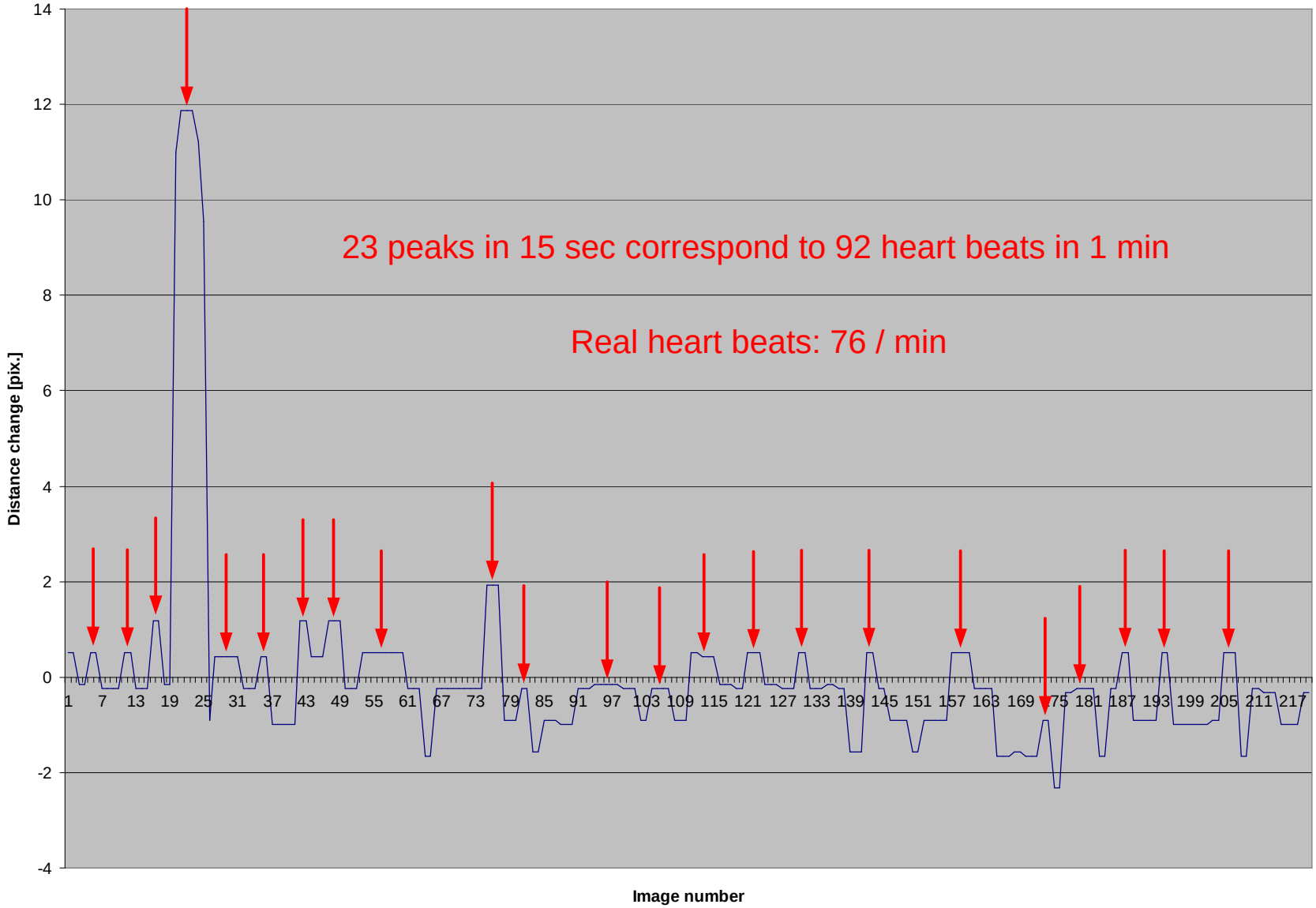




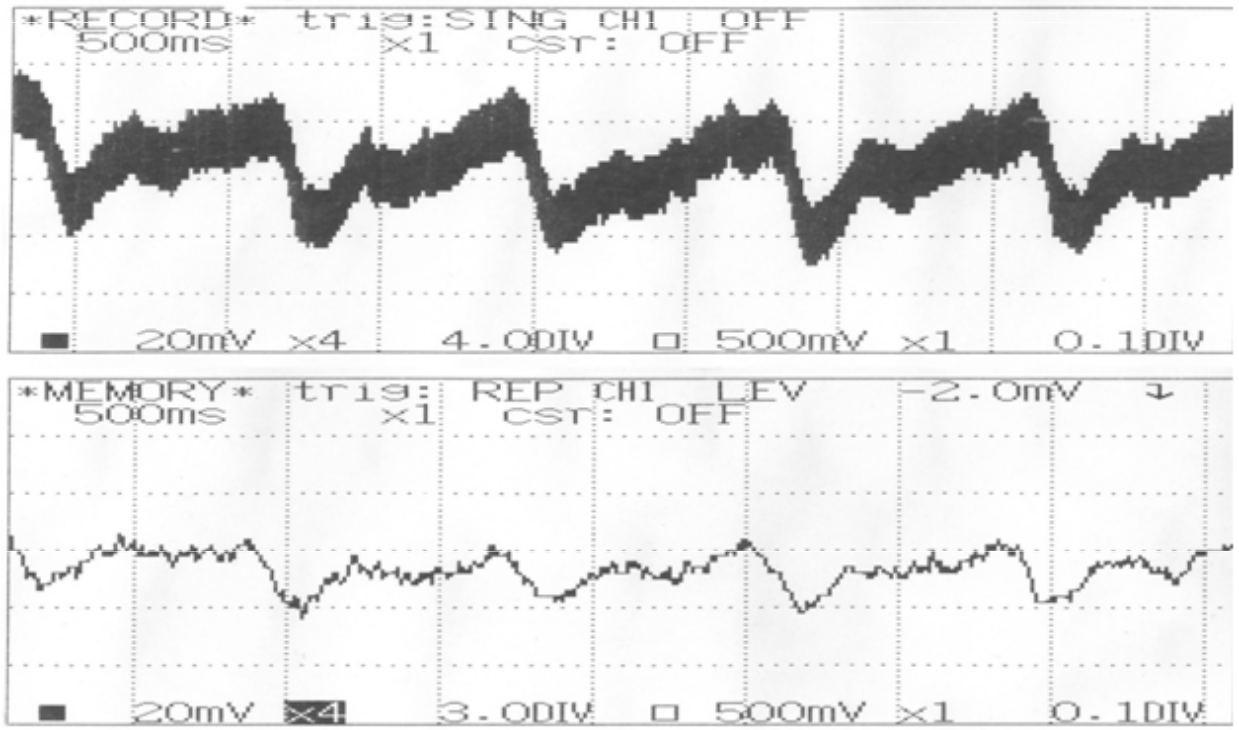


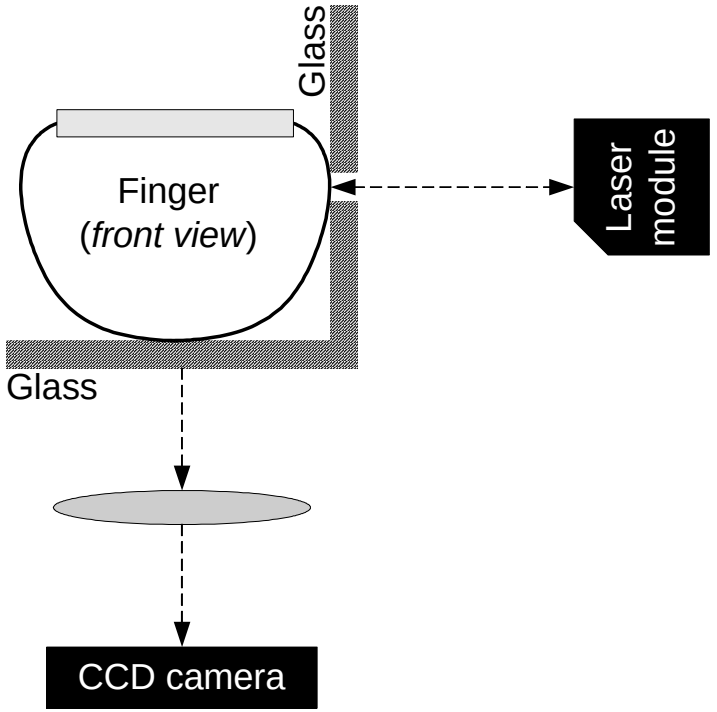


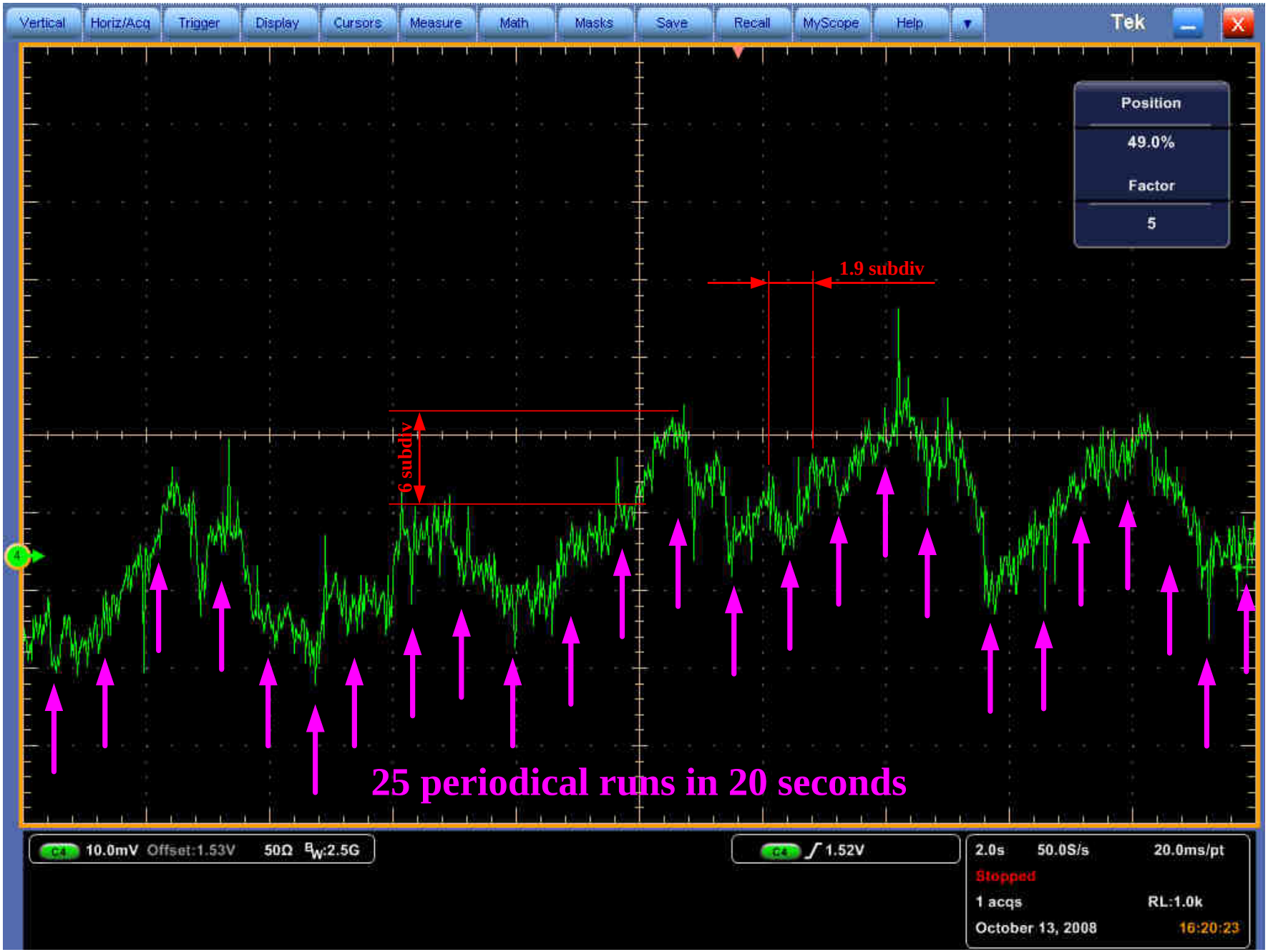
- Macroobjective II.



- Laser I.


RECORD trig:SING CH1 OFF
500ms x1 CSr: OFF
20mV x4 4.0DIV 500mV x1 0.1DIV
MEMORY trig: REP CH1 LEV -2.0mV
500ms x1 CSr: OFF
20mV x4 3.0DIV 500mV x1 0.1DIV


Glass
Finger
(front view)
Laser module
Glass
CCD camera


Vertical
Horiz/Acq
Trigger
Display
Cursors
Measure
Math
Masks
Save
Recall
MyScope
Help
Tek
Position
49.0%
Factor
5
1.9 subdiv
6 subdiv
25 periodical runs in 20 seconds
10.0mV Offset:1.53V
50Ω
BW:2.5G
1.52V
2.0s
50.0S/s
20.0ms/pt
Stopped
1 acqs
RL:1.0k
October 13, 2008
16:20:23

Blood oxygenation

- Infrared illumination (660 nm / 940 nm)
- Reflection vs. transmission

- Finger veins

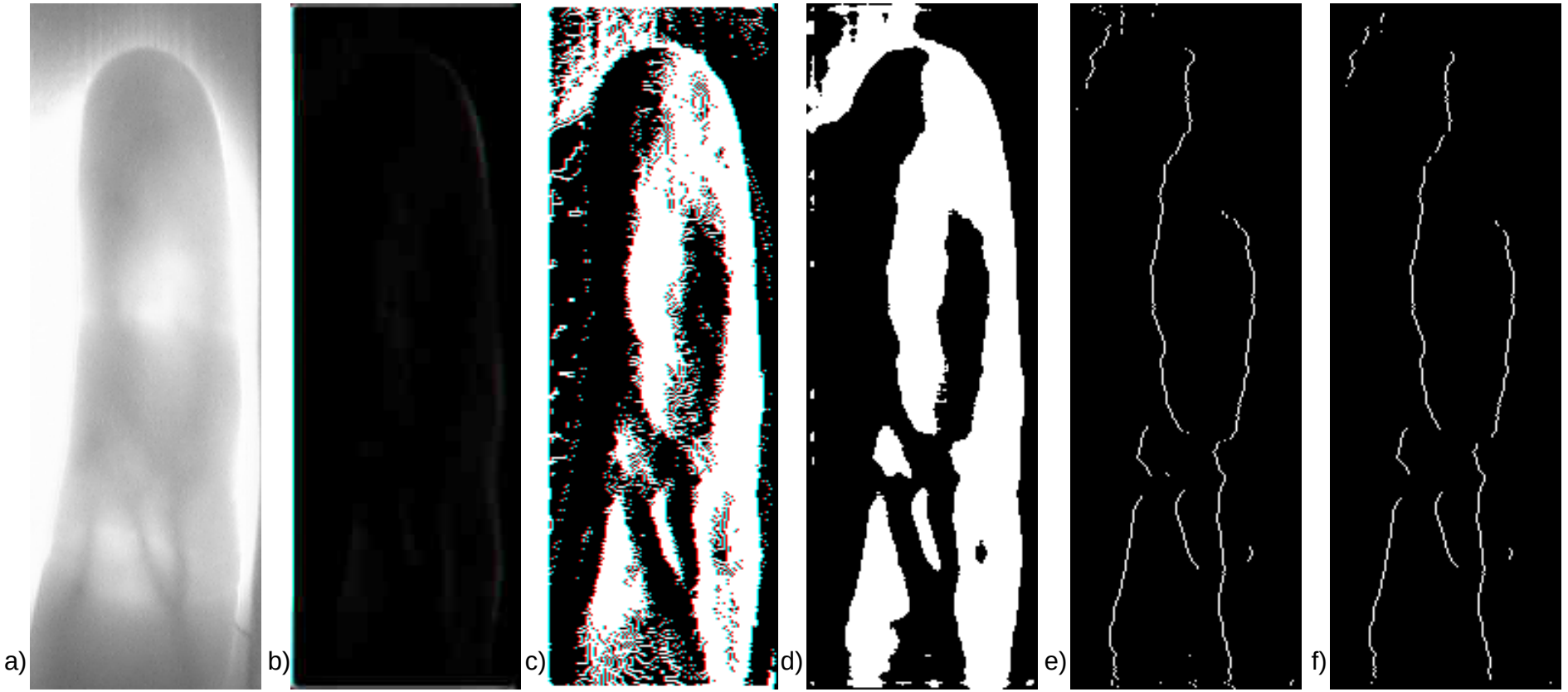
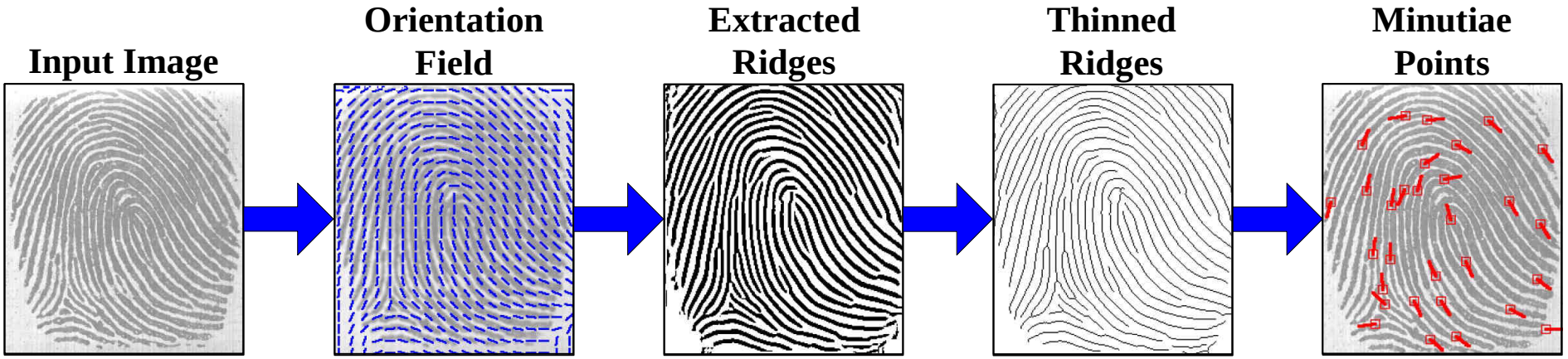


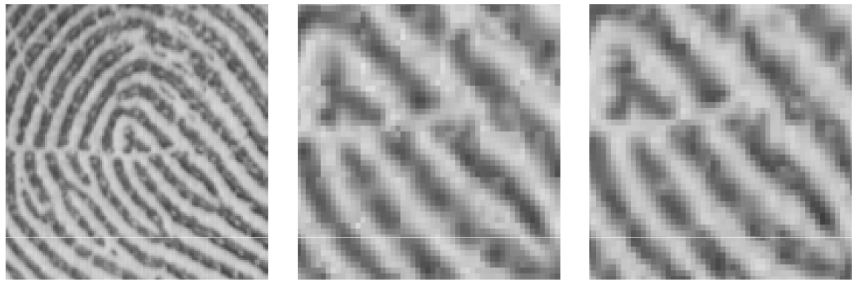
Image quality

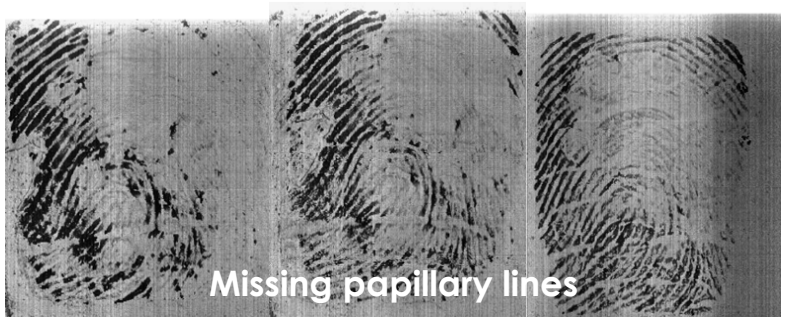
Fingerprint recognition process

- Flowchart results of the minutiae extraction



- Change of image quality



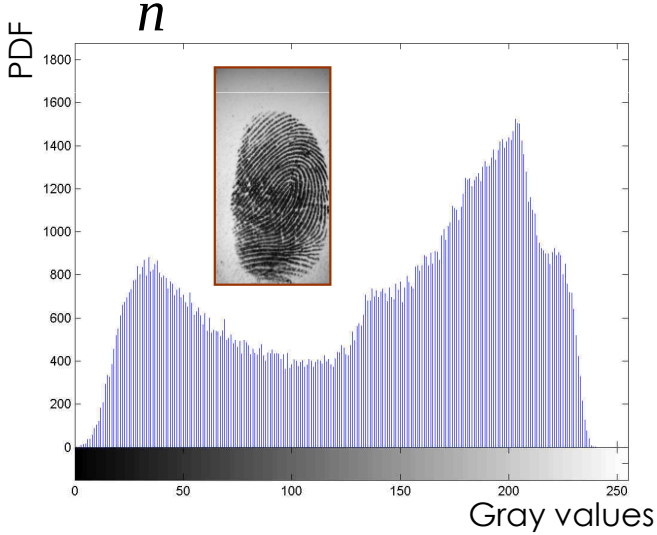


- Suprema Evaluation Development Kit SFM3xxx

Model / Features	**SFM3000**	**SFM3010**	**SFM3020**	**SFM3050**
Sensor	FingerLoc AF-S2 by AuthenTec	FingerChip by Atmel®	not known	TouchChip® TCS2 by UPEK
Technology [Dra25]	e-field	thermal, sweep	optical	capacitive
Power supply	3.3 V (DC)	3.3 V (DC)	3.3 V (DC)	3.3 V (DC)
Take-off current	100 – 300 mA	4.5 mA	not known	not known
Resolution [DPI]	250	500	500	500
Sensor size [mm]	13 × 13	11.6 × 0.4	16 × 19	10.4 × 14.4
Module size [W×D×H] [mm]	55 × 40 × 8	55 × 40 × 8	55 × 40 × 8	55 × 40 × 8
Image size [pix.]	128 × 128	360 × 500	272 × 320	256 × 360

Fingerprint Image Contrast & Histogram

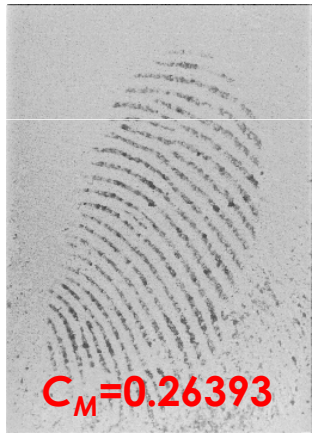
- Michelson contrast $C_{Michelson} = \frac{(L_{\max} - L_{\min})}{(L_{\max} + L_{\min})}$
  - L_{max} – intensity of foreground (papillary line/ridges)
  - L_{min} – intensity of background (valleys)
- Weber contrast $C_{Weber} = \frac{\Delta L}{L}$
  - ΔL – intensity difference between foreground and background; L – intensity of background
- Fingerprint image histogram $Hist(r_k) = \frac{n_k}{n},\ k = 0,1,2,\ldots,L-1$
  - r_k – k^{th} gray grade value
  - n_k – number of pixels in channel r_k
  - L – number of gray grades
  - n – sum of pixels in the image



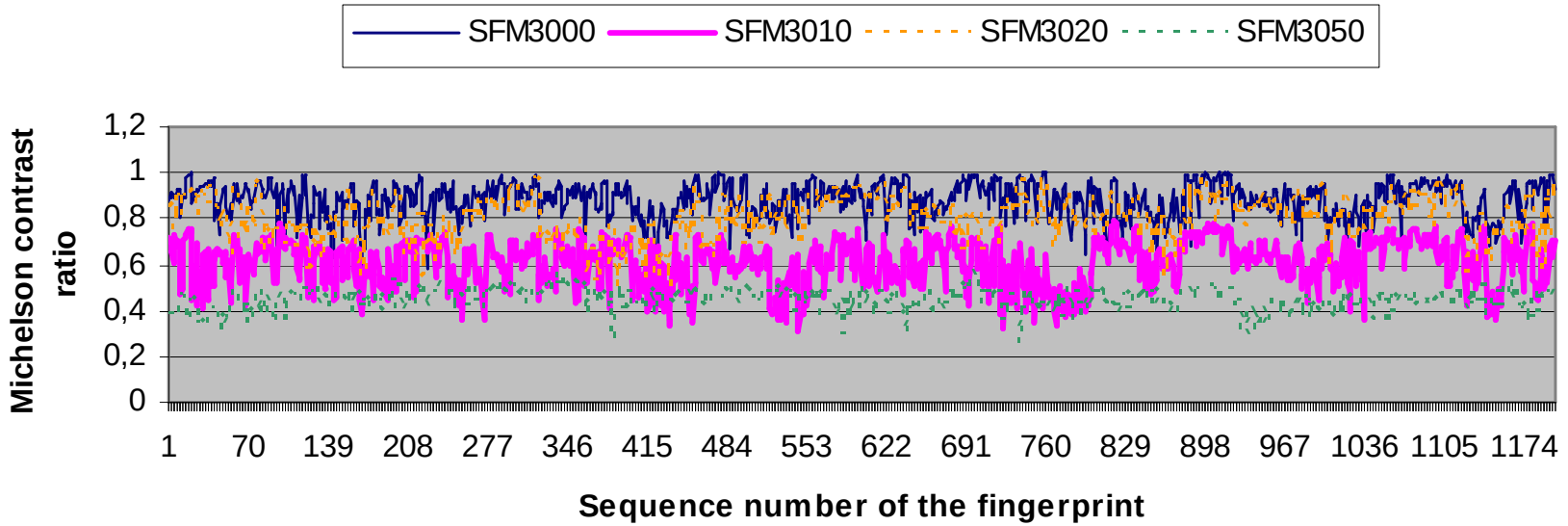
- Used Michelson contrast
  - Higher values (close to 1) are better results (SFM3000)

C_M=0.98441

C_M=0.58689

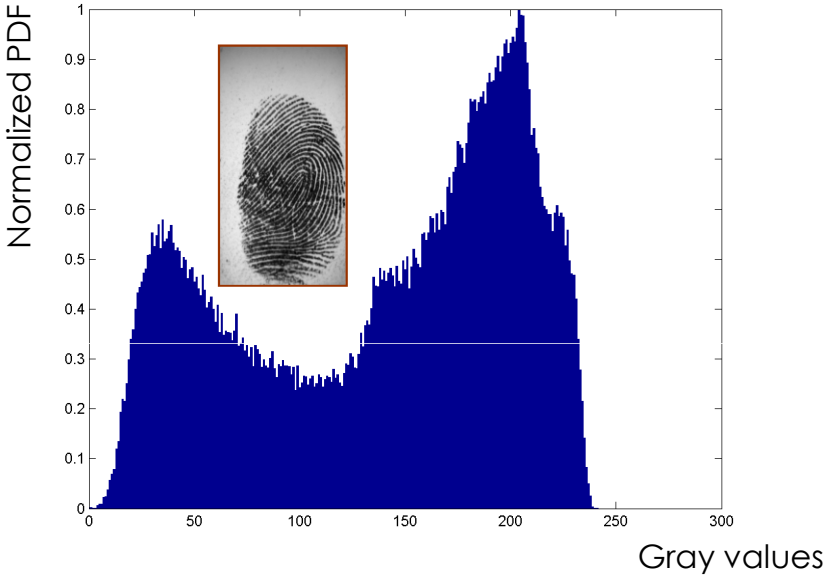


C_M=0.26393

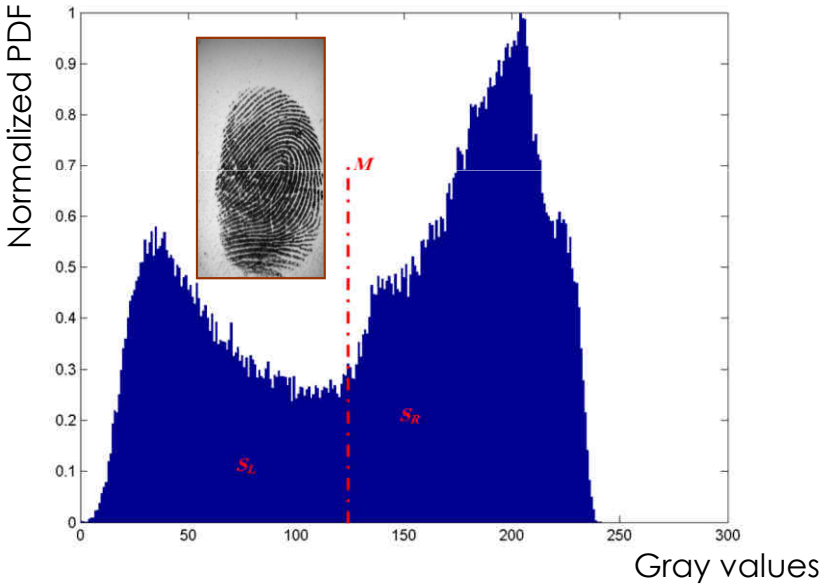


Histogram normalization & Mean value

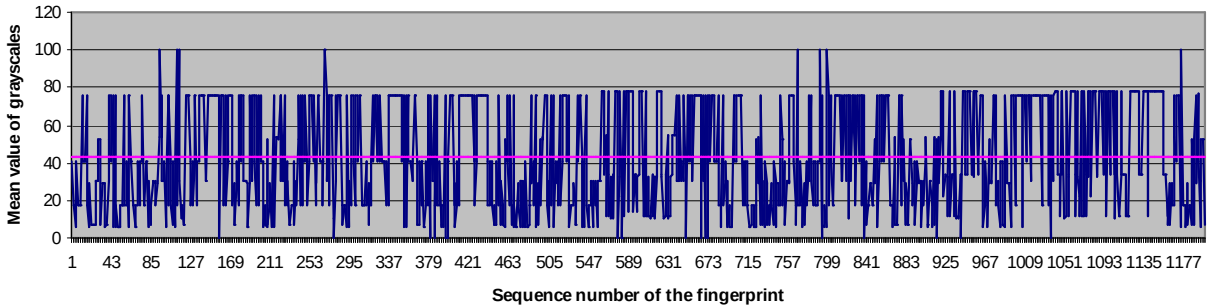
- Histogram normalization
  - Probability distribution function in range <0;1>



- Mean value
  - $S_L = \sum_{i=0}^{M-1} h_n(i) \qquad S_R = \sum_{i=M}^{255} h_n(i)$
  - *M* – mean value
  - Ideal case: $M = 128$ ($S_L \cong S_R$)
  - *Theoretical M*: $M_T = \frac{B_{Dark} + B_{Light}}{2}$
    - B_x – start & end of histogram
  - Deviation *D*: $D = \left| 1 - \frac{M_T}{M} \right| \cdot 100\%$

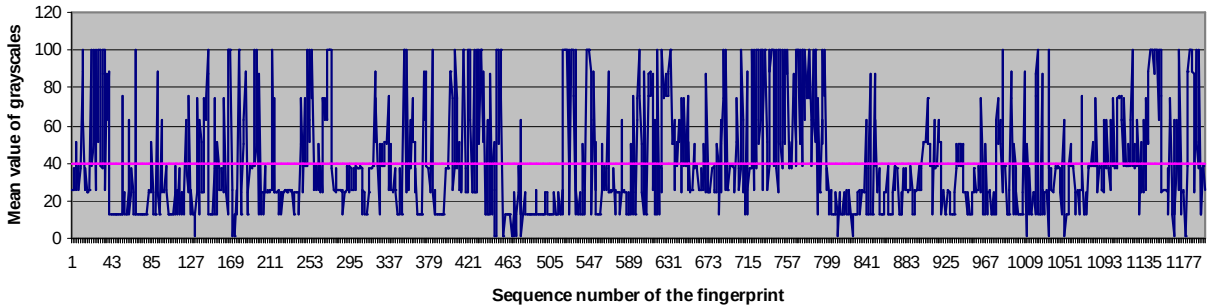


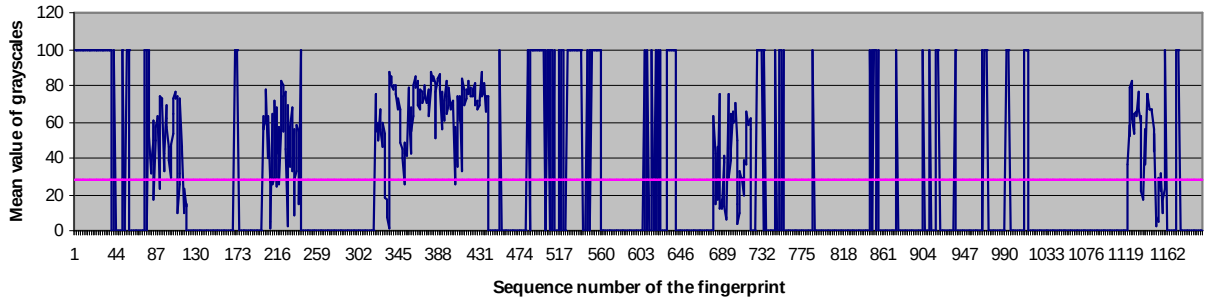
Mean value of grayscale levels – deviation



SFM3000, avg ≅ 43%

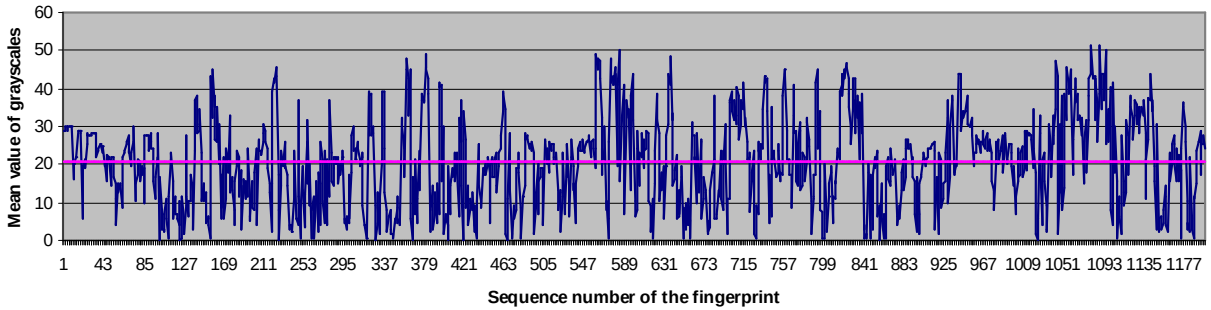
SFM3010, avg ≅ 40%



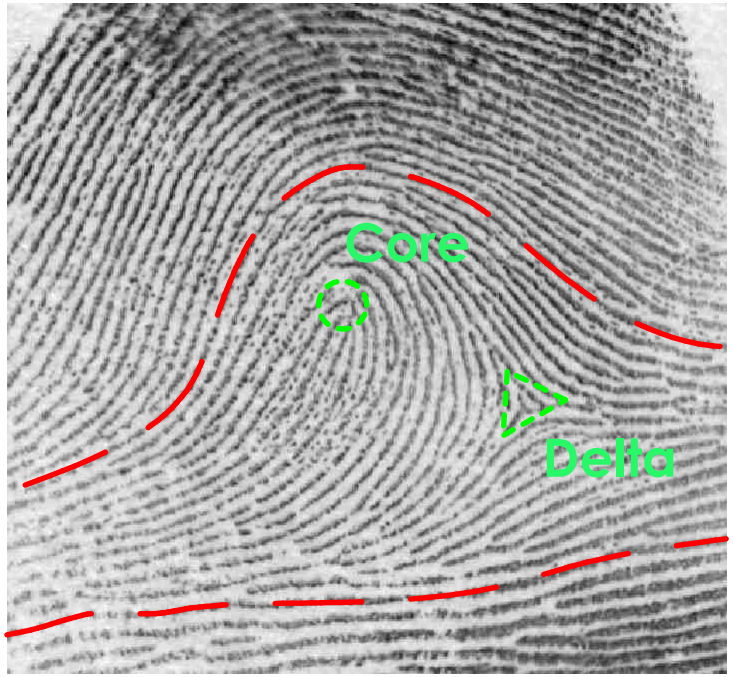


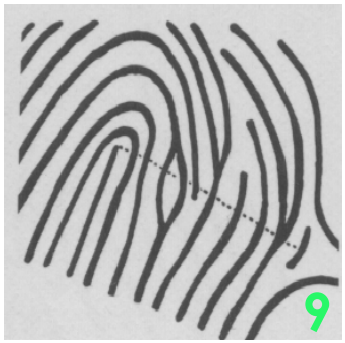
SFM3020, avg ≅ 28%

SFM3050, avg ≅ 21%



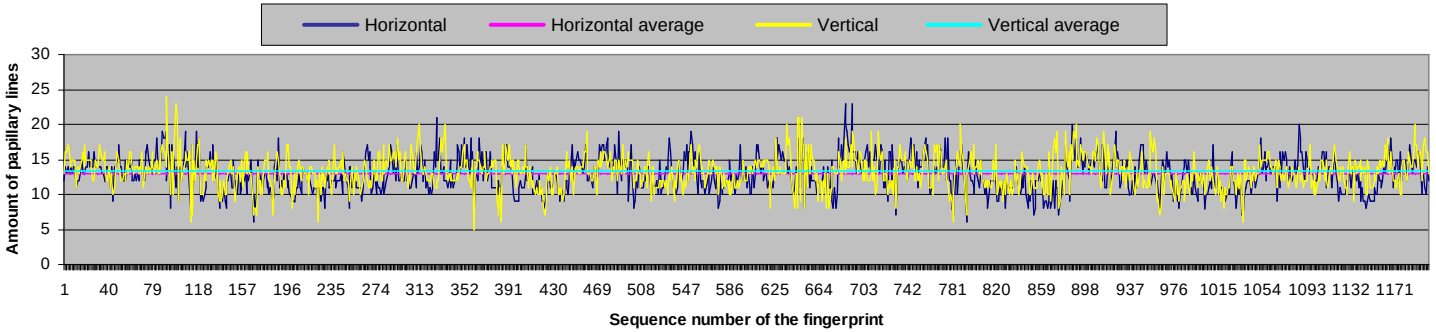
- In dactyloscopic literature defined as number of papillary lines between delta and core
- For estimation of fingerprint's center could be used horizontal and vertical values of papillary lines (comparison with homocentric circles)





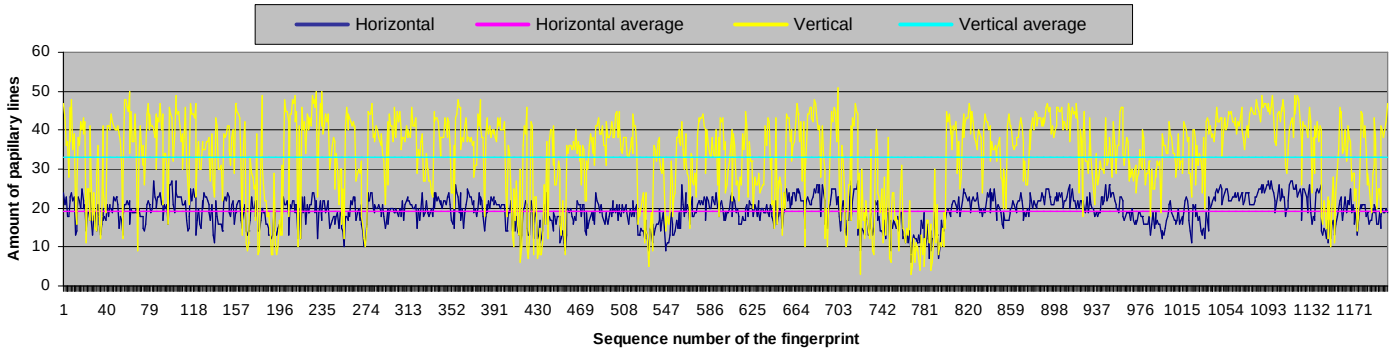
Number of papillary lines

Sensor	SFM3000	SFM3010	SFM3020	SFM3050
Horizontal minimum	6.00	6.00	9.00	10.00
Horizontal average	12.86	19.30	19.93	21.25
Horizontal maximum	23.00	27.00	30.00	31.00
Vertical minimum	5.00	3.00	11.00	11.00
Vertical average	13.26	33.18	22.79	25.67
Vertical maximum	24.00	51.00	31.00	37.00

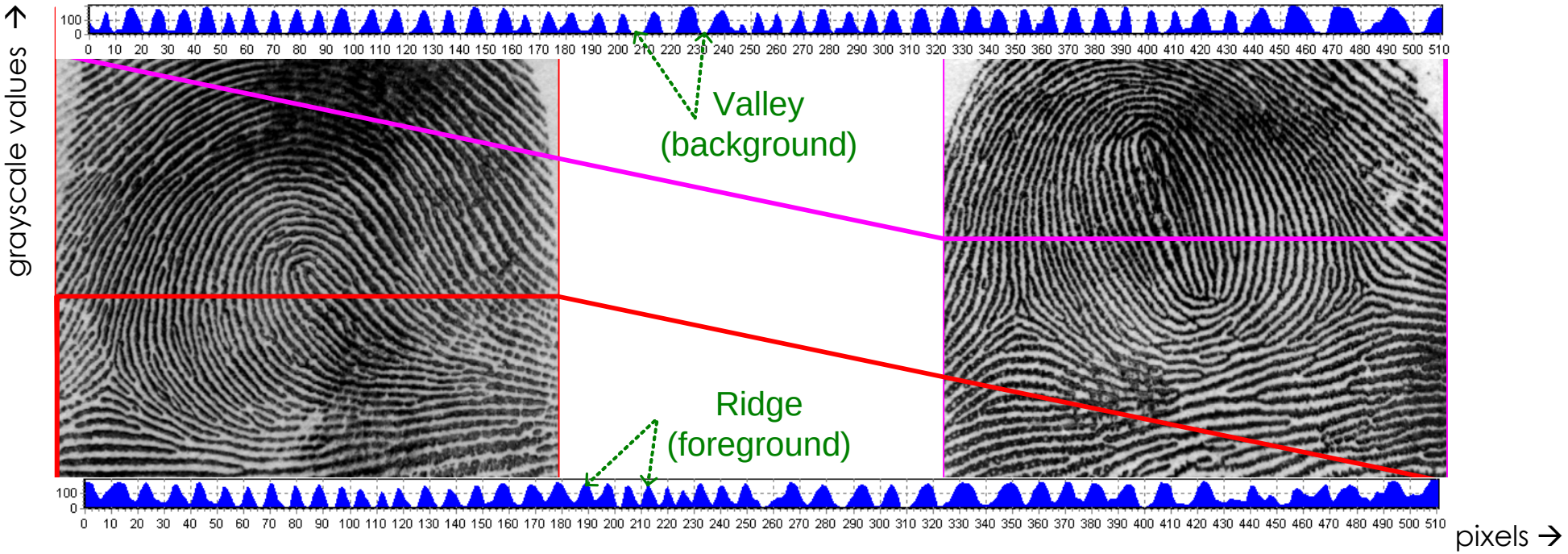


SFM3000, stable

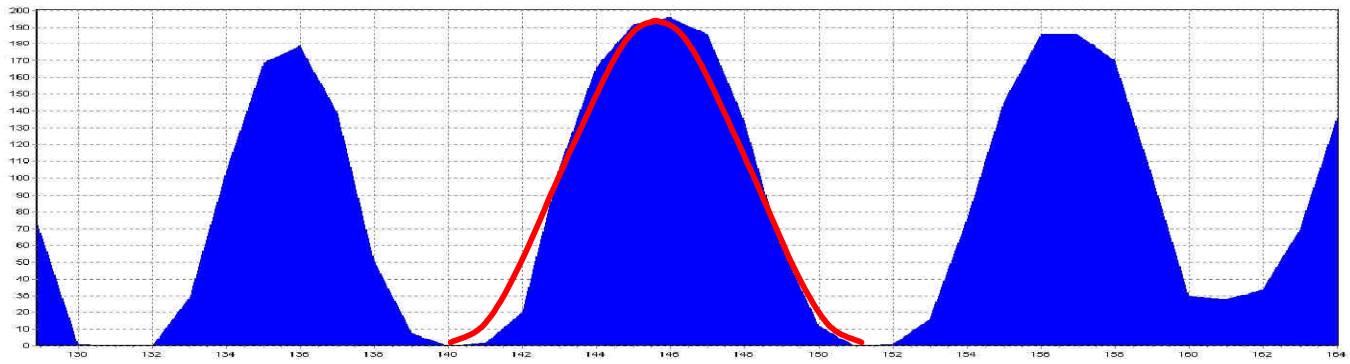
SFM3010, unstable



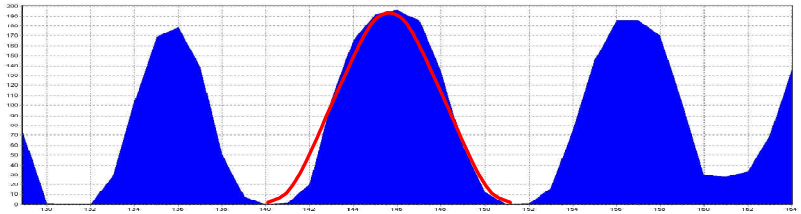
- Crosscut of the fingerprint near the center



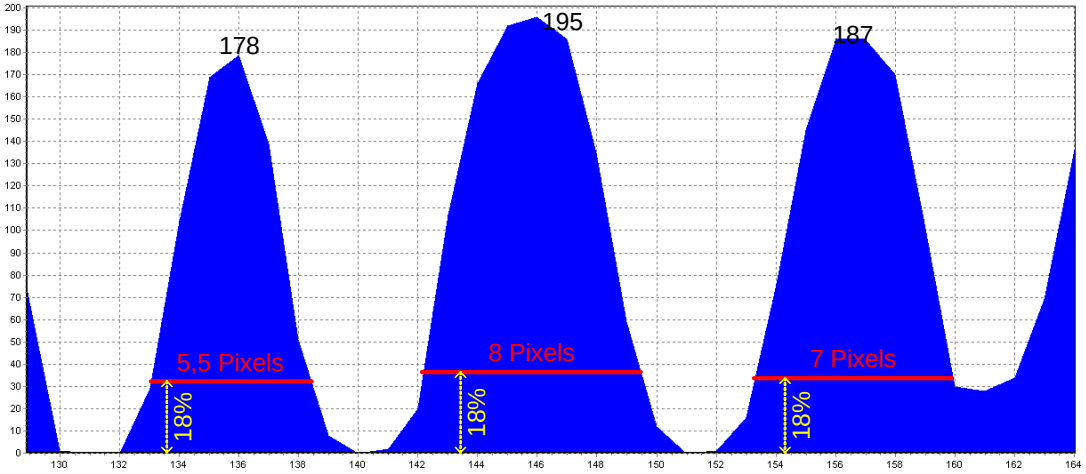
- Application of sine function ti the crosscut



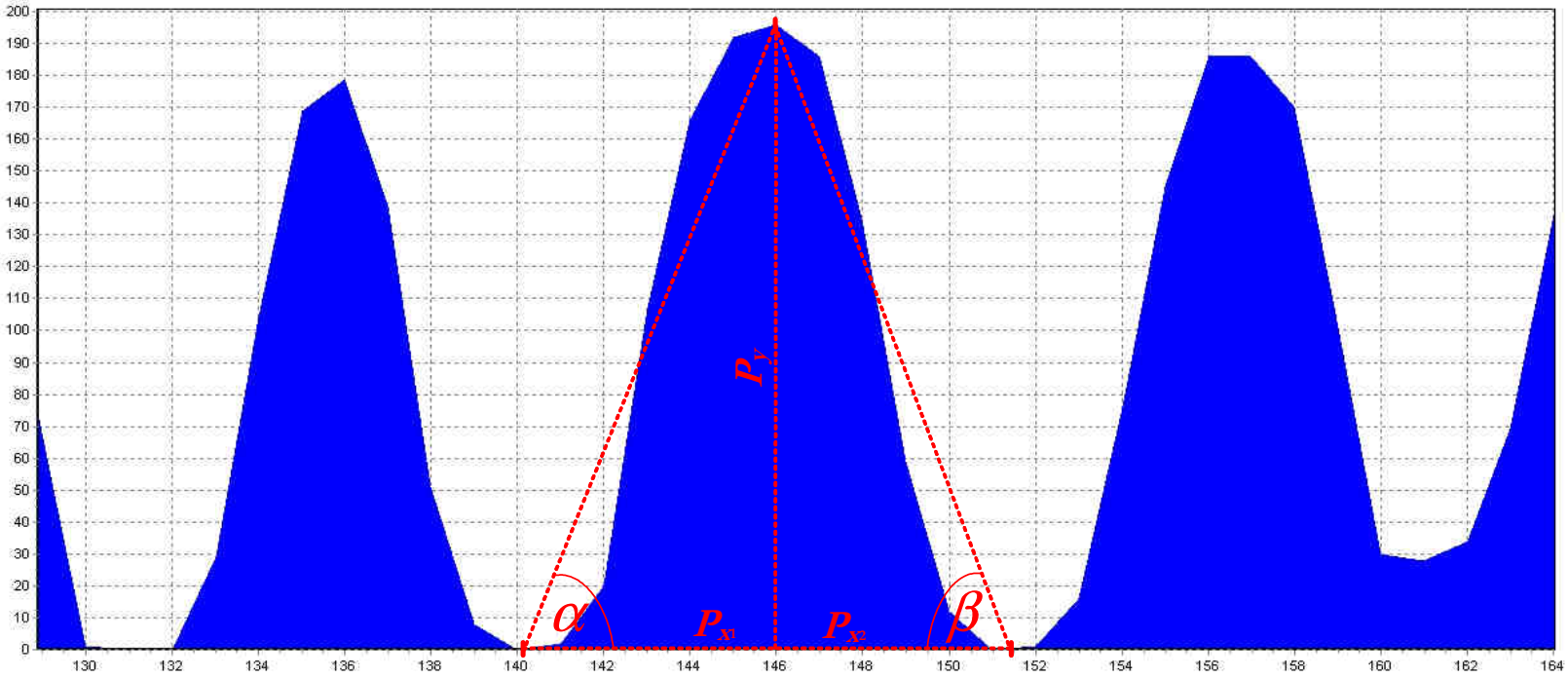
- Deviation of the papillary line curvature from the sine function
  - $D_D = \left(\frac{A_{FP}}{A_{\sin}} - 1 \right) \cdot 100\%$
  - where $A_{FP} = \int_{x_S}^{x_E} f(x)dx$, $A_{\sin} = \int_{x_S}^{x_E} \sin(x)dx$, $x_S = -\pi/2$, $x_E = 3\pi/2$



- Deviation of thickness of papillary line from normalized state
  - $D_{Th} = \left(\frac{Th}{0.033} - 1 \right) \cdot 100\%$
  - where $Th = \frac{2.54}{R_{DPI}} \cdot N_{Pix} \quad [cm]$
  - N_{Pix} – number of pixels
  - R_{DPI} – resolution of the sensor

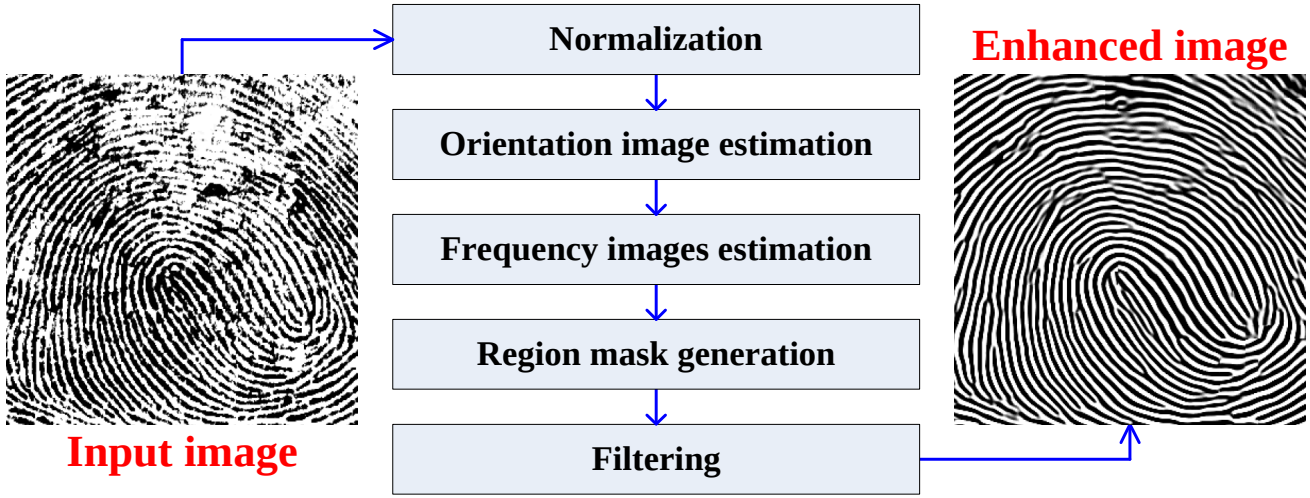


- Deviation of steepness of papillary line from a normalized state
  - Deviation of the upward angle $D_\alpha = \frac{|\alpha - 60°|}{60°} \cdot 100\%$
  - Deviation of the downward angle $D_\beta = \frac{|\beta - 60°|}{60°} \cdot 100\%$
  - where $\alpha = \arcsin\left(\frac{P_{x_1}}{\sqrt{P_{x_1} + P_y}}\right)$ $\beta = \arcsin\left(\frac{P_{x_2}}{\sqrt{P_{x_2} + P_y}}\right)$

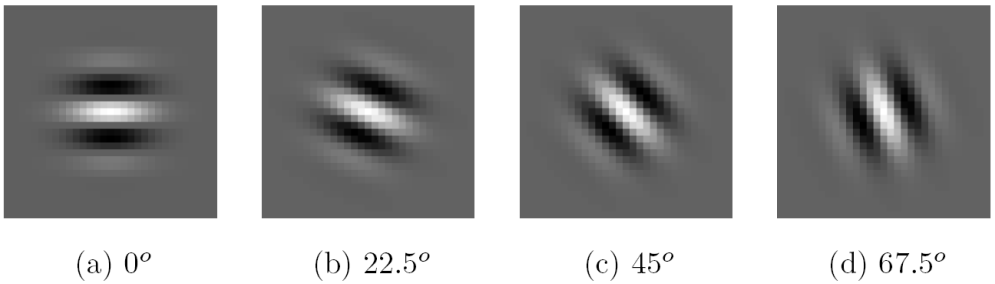


Filtering in spatial domain

- Normalization – reduction of variations in gray-level values along ridges and valleys
- Orientation image estimation – orientation tendency of papillary lines in local neighborhood
- Frequency images estimation - frequency of ridge and valley structures in local neighborh. along orient.
- Region mask generation – differentiation of pixels to unrecoverable (non-ridge) and recoverable (ridge)

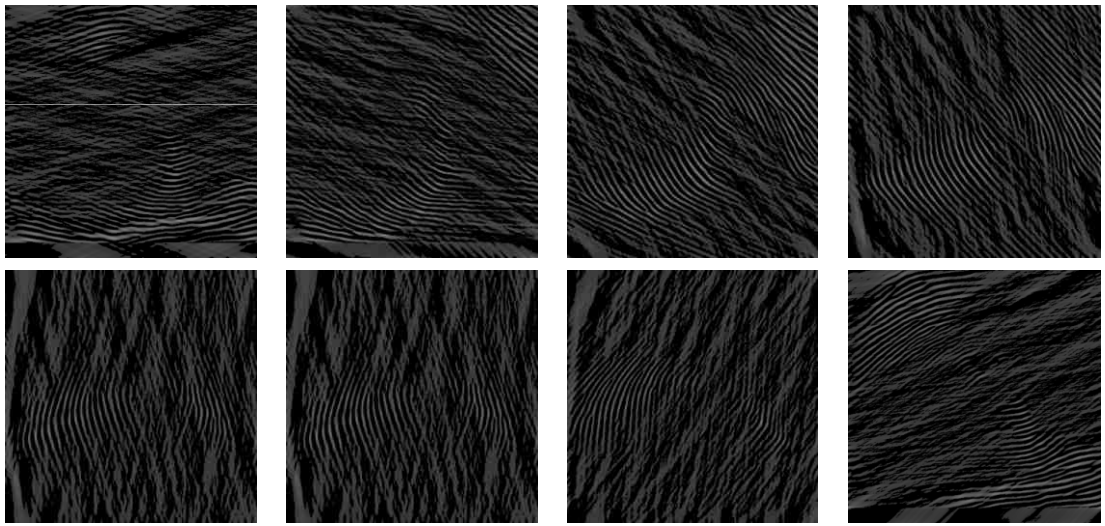


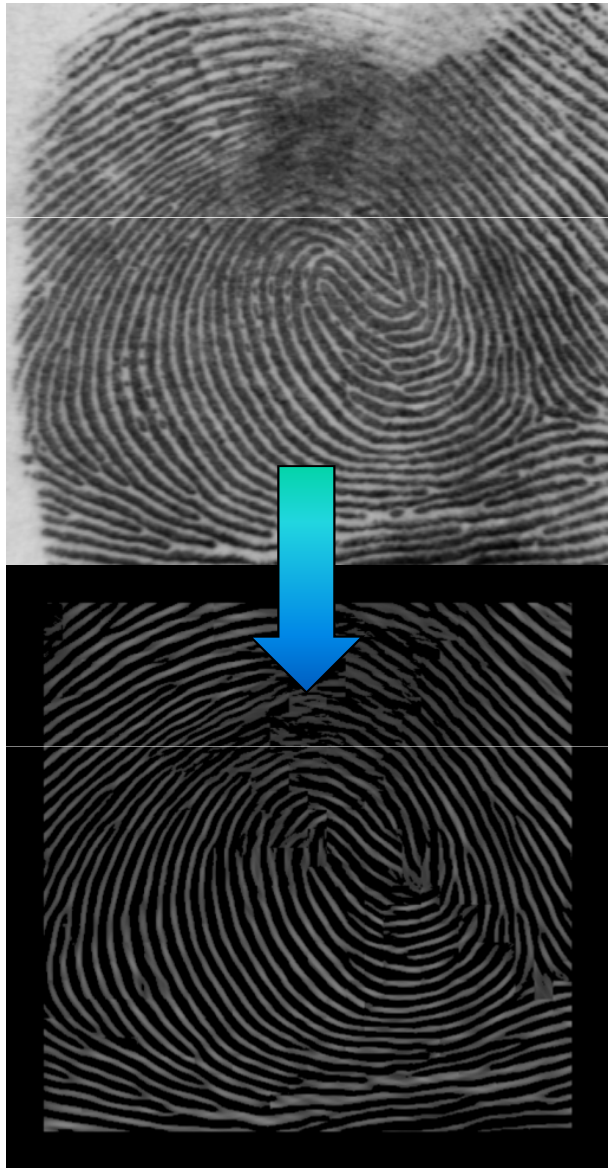
- 2D Gabor function with 8 rotation about 22.5°



(a) 0^o (b) 22.5^o (c) 45^o (d) 67.5^o

(e) 90^o (f) 112.5^o (g) 135^o (h) 157.5^o





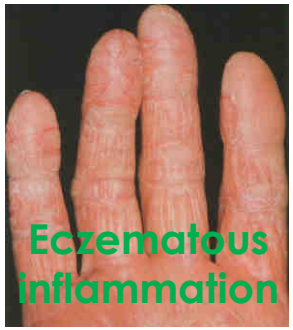
- FFT → Filtering → IFFT
- Used filters for fingerprint enhancement
  - Butterworth filter
    - Maximally flat magnitude filter
  - Ikonomopoulos filter
    - Based on Lin & Hong approach
  - Low-pass filter
    - Classical filtering, however have good results
  - Chebyshev filter
    - Comparable with Butterworth filter, different frequency response

Skin Diseases

- Change of papillary line structure

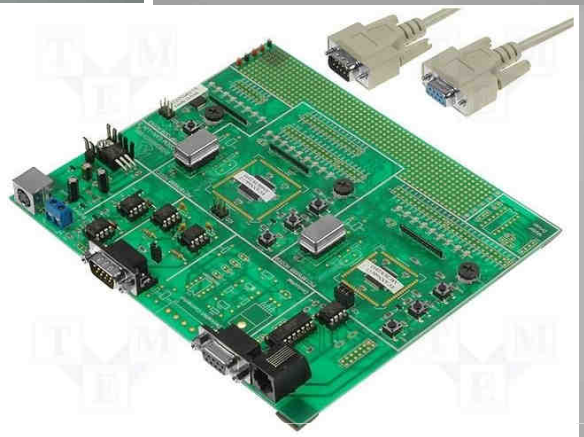
- Change of skin color

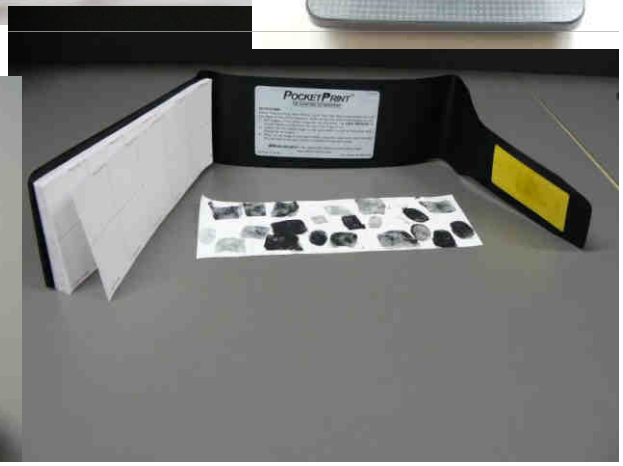
- Change of pap. line structure and skin color



Biometrics – Equipment

- strade.fit.vutbr.cz





Laboratory of biometric systems

Thank you for your attention.