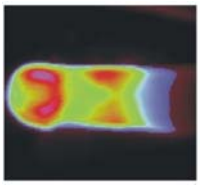
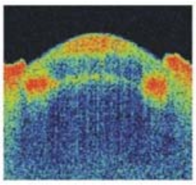
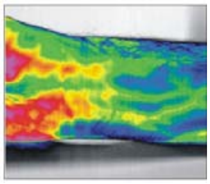
Applied Optoelectronics in Medicine

Aplikovaná optoelektronika v lékařství

Interdisciplinary course at the CTU Prague (P317APL-E, W, 4 credits)

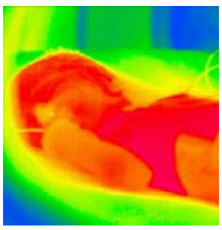


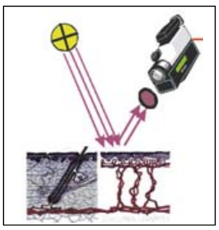



9. Optical imaging methods in medical diagnostics – part I
9. Optické zobrazovaci metody v lekařské diagnostice – část I

Learning aims of the ninth AOM lecture

1) Basic requirements on imaging strategies in medicine
2) Optical biometrics, NIR photography, NIR diaphanoscopy
3) IR thermography imaging (IRTI)
4) Laser Doppler perfusion imaging (LDPI)
5) Photoplethysmography Imaging (PPGI) – part 1: masururing setup



Requirements on imaging strategies in medicine

1: Functional aspects with new reasonable insights

One problematic example:

The FAA recently announced that a new in-flight optical CCD sensor system will be installed in the cockpit of all airlines that will take a picture every 15 seconds. This will be done as a measure to help determine what crews are doing prior to crash.

Requirements on imaging strategies in medicine

2: Possibilities for pattern recognition and diagnostic relevance

Next problematic example:

“Virtual aging” -
fascination or frightening?

Requirements on imaging strategies in medicine

3: Ability as early as possible disease detection

Some milestones in the historical development

1895: Discovery of hitherto unrecognized "X-rays"

1913: development of the vacuum tube with thermionic cathode by Coolidge

1936: Introduction of the screen method by de Abreu

1957: development of computed tomography by Cormack

1967: introduction of CT Hounsfield by

1974: introduction of magnetic resonance imaging

1980: Development of high-frequency ultrasound imaging

1990: Development of optical coherence tomography

∘
∘
∘

2000: Molecular Imaging

From the first X-ray image of modern X-ray diagnostic ... However ... caution. And not at any price!

Newspaper article in “Schweiz am Sonntag”, 02.11.2013:
Needless many people die from cancer because they get too high medical radiation dose. Studies indicate that 20 to 30 percent of the X-ray examinations are unnecessary.

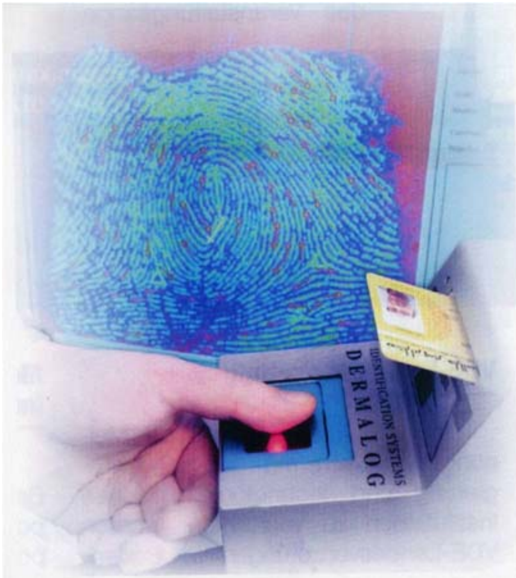
http://www.schweizamsonntag.ch/ressort/nachrichten/schweizer_aerzte_roentgen_zu_viel/

Optical biometrics (OBM)

The human being as ID card

Advantage of optoelectronic
Sensor concepts:

can contribute to increasing the security control by combining anatomical-topo-graphical features with vital parameters like PPG blood volume pulse.



VDE Dialog, Jan./Febr. 2002

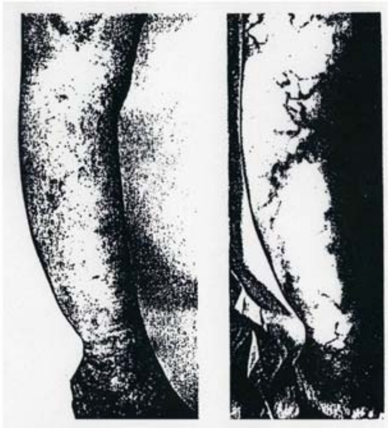
OBM - providing optical solutions for biometric applications

- functional fingerprinting
- hand geometry
- facial recognition
- retinal scanning
- human iris analysis

Near infrared photography - historical recordings

HAXTHAUSEN, H.: Infra-red photography of subcutaneous veins… Brit. J. Dermatol. 45 (1933)

Ordinary (left) and infra-red (right) photography
of the physiological subcutaneous network of the leg

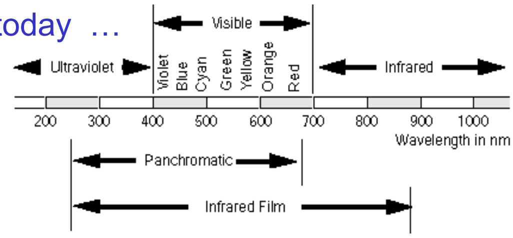


Ordinary (left) and infra-red (right) photography
of the varicose changes of the subcutaneous veins

Near infrared phgotography - look at the Background …

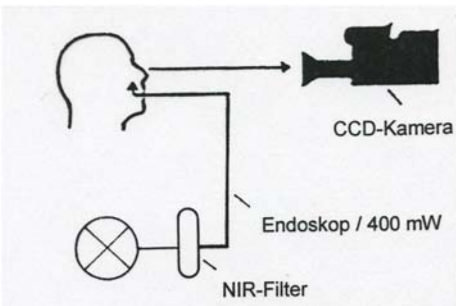
Stephan Lochner: Kölner Dombild (um 1440), Abtei Brauweiler.

Near infrared photography today …



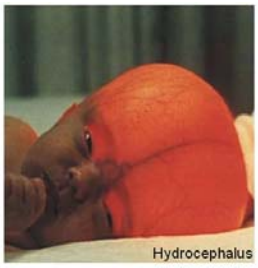
Bilder aus:
Infrared Photography – Biomedical Applications
http://msp.rmit.edu.au

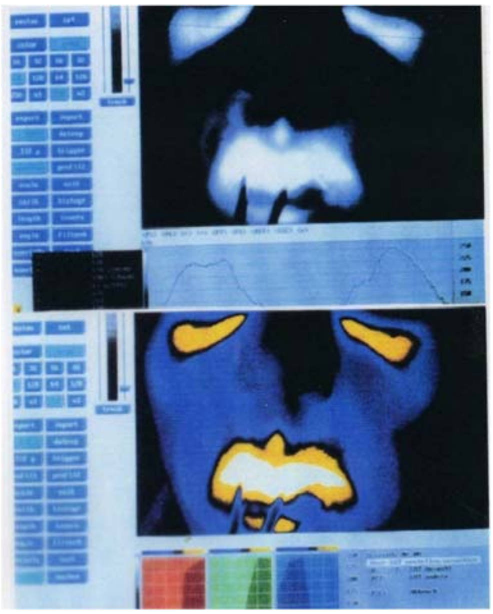
Near infrared diaphanoscopy



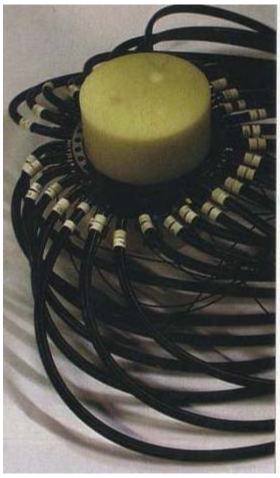
Nach BEUTHAN et. al., 1993

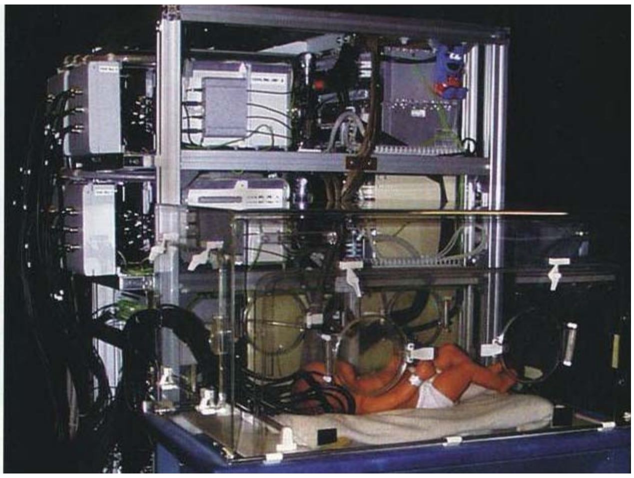
Near infrared diaphanoscopy





Fineroptic Diaphanoscopy



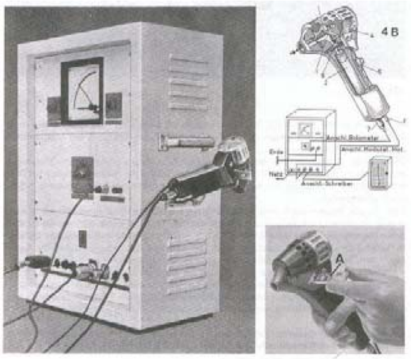


Nach GRAYDON et. al., 1999

Far infrared thermography (thermovision)

Thermography, the art of visualizing and interpreting thermal patterns, is a versatile new tool for science, medicine and technology. It is developing rapidly and spreading into widely diverse fields. Although its origins are more than 130 years old, the first practical applications (in military reconnaissance) were achieved only 15 years ago. Today, clinical thermography offers new hope in the fight against cancer, and has many other uses; it is a completely passive diagnostic method and absolutely safe. In industry, thermography has potential value whenever there are problems in measuring temperature over extended areas, where point contact methods are insufficient, tedious, or impossible (e.g. in inaccessible places). Thermographic microscopes and telescopes offer great possibilities which are only just beginning to be explored. The design of thermographic equipment presents problems which do not arise in most electro-optical systems, including television, and which more nearly resemble the design problems of radio telescopes.

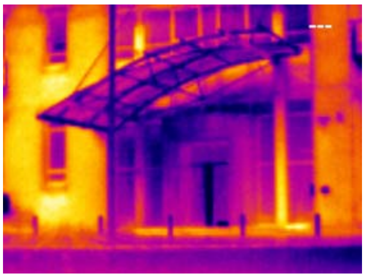
The medical use of infrared thermography started 1952 in Germany. The physician SCHWAMM together with the physicist REEH developed a single detector infrared bolometer for sequential thermal measurement of defined regions of the human body surface for diagnostic purposes [3]. Their method was patented in several countries including the USA. They founded the first medical association of thermography 1954

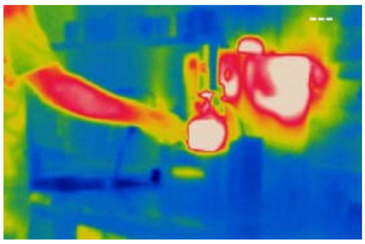


Ultrarot-Strahlungsmesser für Diagnostik und Therapiekontrolle nach Dr. Schwamm-Reeh.

http://www.ndt.net/article/dgzfp-irt-2007/Inhalt/v04.pdf

Far infrared thermography: warum eigentlich?



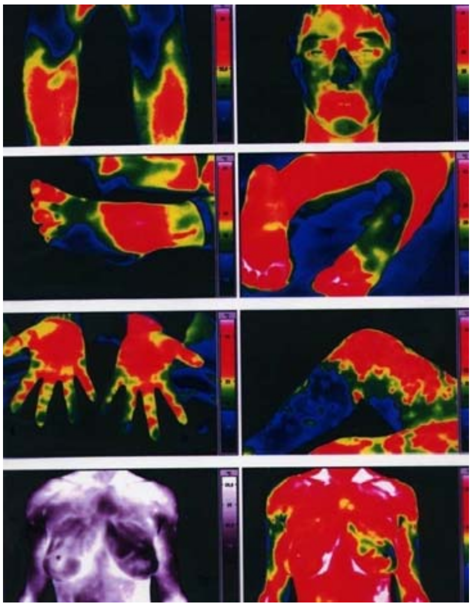


Infrarot-Thermografie

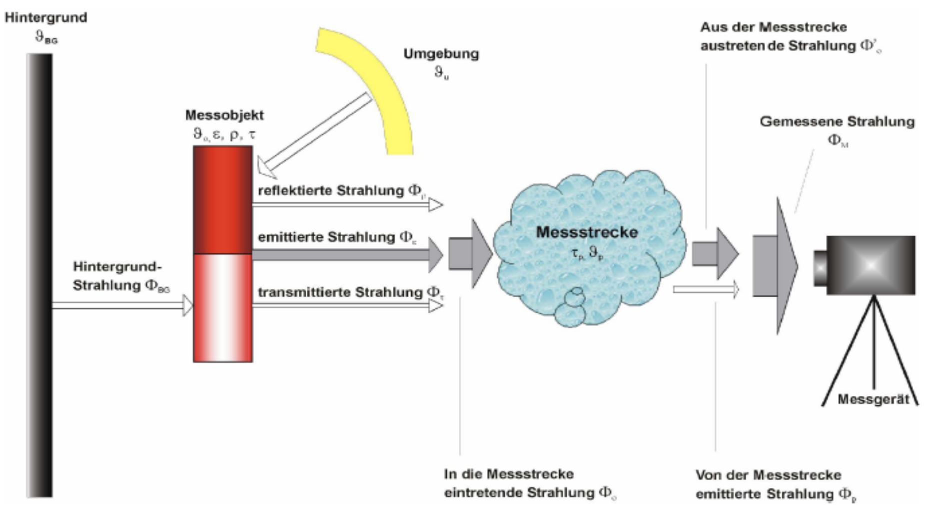
Das (passive) optoelektronische Sensorkonzept (begründet und erstmals durch SCHWAMM und REEH 1953 publiziert) visualisiert die natürliche Wärmeabstrahlung des menschlichen Körpers durch Verwendung von wärmeempfindlichen Kameras.

Typische Auflösungsparameter:
- bis zu 60.000 Pixel/Bild
- 0,1 °C
- 0,8 fps

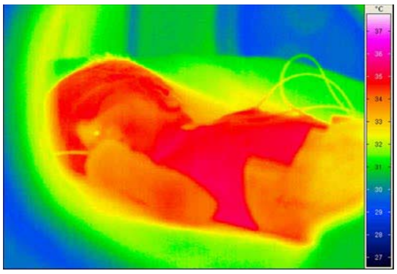
www.InfraTec.de

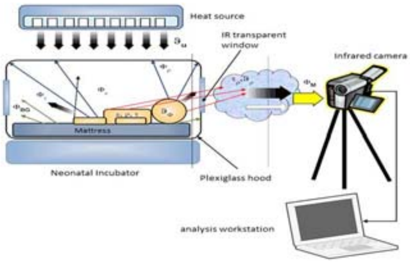


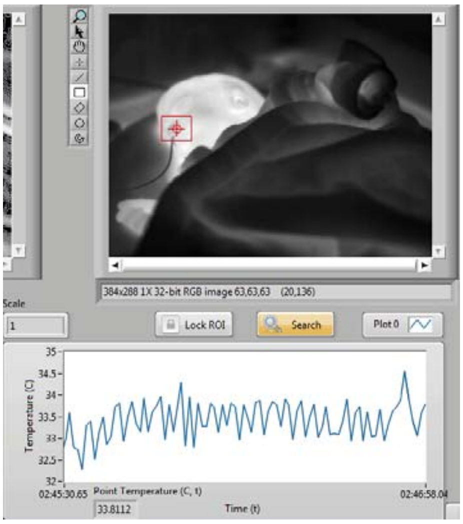
Radiation components of the thermographic measurement setup



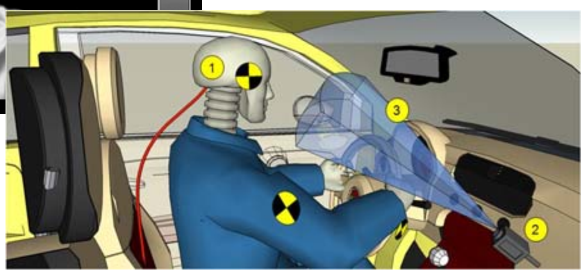
Functional IR therography imaging - aplication example 1







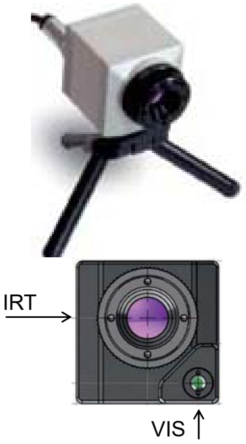
Functional IR therography imaging - aplication example 2

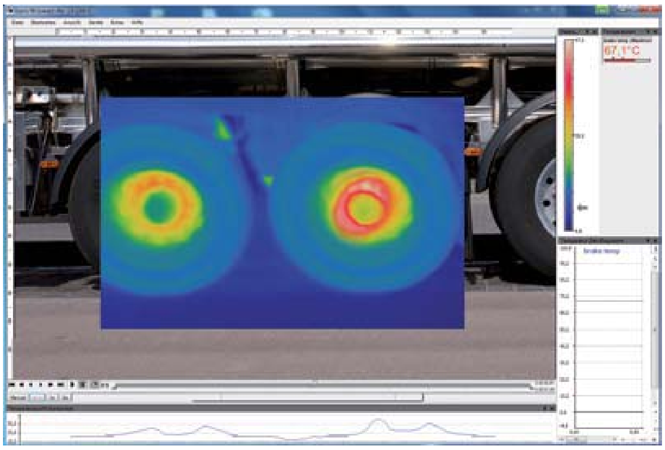


System setting of the automotive car driver thermography

Hybrid remote imaging - VIS und IRT combination

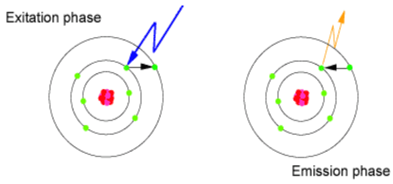
Example: Hybrid camera model PI 160 (OPTRIS company, 2013)
Transition of the VIS image (right, background) with an IRT image at temperatures higher than 35 ° C





Source: Optris-Broschüre 2013

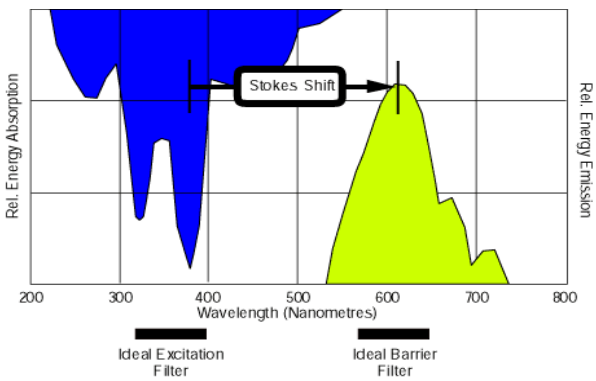
Fluorescence imaging



When Sir George Gabriel Stokes first described the phenomenon of fluorescence in 1852 it is doubtful many people ever considered its potential as a tool for biologists. As often happens with new discoveries, however, scientists figured out a way to exploit this physical process and began to use fluorescent molecules as biological labels.

Many biological samples exhibit fluorescence phenomenon: as a result of (energy) UV illumination and of the characteristic absorption properties of the sample atoms are first raised to higher atomic energy levels in the so-called excitation phase electrons.

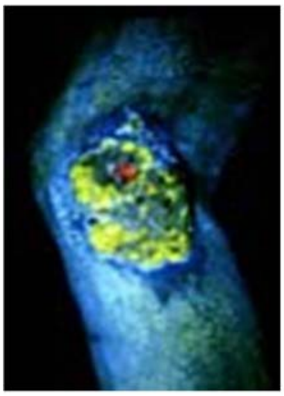
In the following emission phase a visible light is then radiated (with maximum around 610 nm) and by a Photo camera using special filters selectively detected.



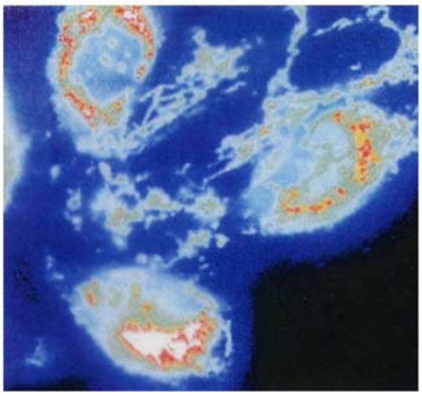
Fluorescence imaging

First fluorescence photograph of the human skin (under UV light) was carried out by WOOD in 1919, first medical publication on observation of different fluorescence effects comes from MARGOT & DEVEZE (1925).

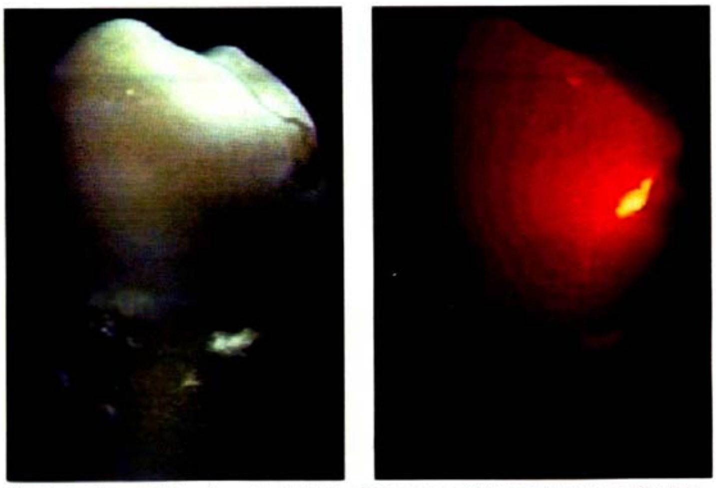
Fluorescence imaging of a wound on the leg



Fuorescence imaging at cellular level



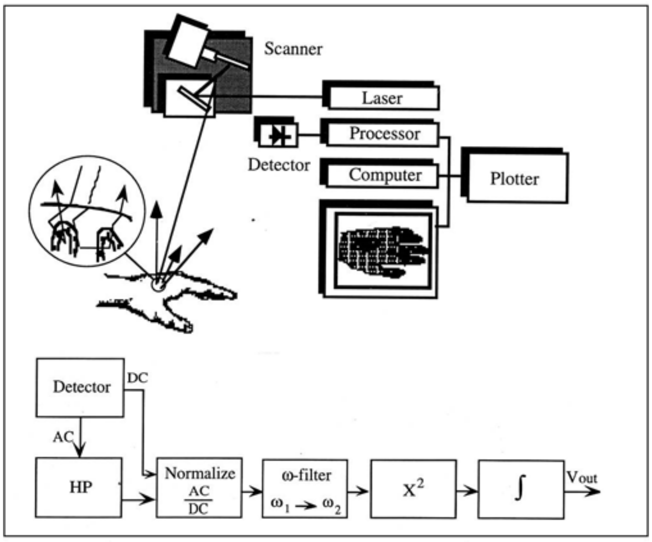
Fluorescence imaging in dentistry



Glowing teeth: an initial cavity on the right side of this tooth is difficult to visualize in white light (left) but shows up clearly as enhanced fluorescence when viewed using the endoscope (right).

Laser Doppler perfusion imaging (LDPI) – measuring setup

Illuminating the tissue with coherent light, utilization of the Doppler effect, punctual detection of backscattered photons, 2D visualization of tissue perfusion by scanning.

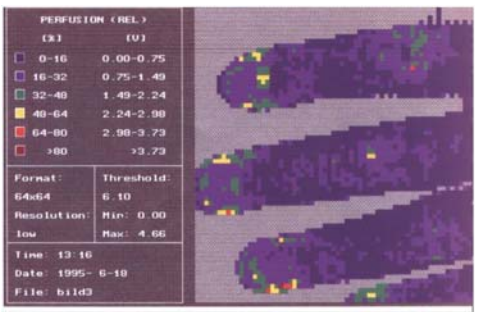


After NILSSON, Linköping

Laser Doppler perfusion imaging (LDPI)

Example: - skin region 10 x 10 cm
- resolution 256 x 256
(pixel size 0.4 mm)

Image acquisition time: ca. 4min

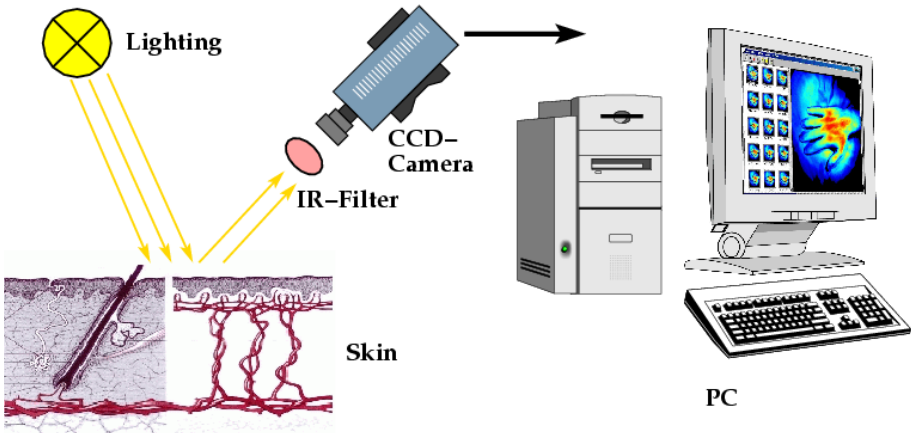


(Source: PERIMED)

Signal processor calculates the product of blood cell velocity and concentration in relative perfusion units:

$$PU = \int_{20\,Hz}^{15\,kHz} f \cdot |S(f)|^2 \cdot df$$

Photoplethysmography imaging (PPGI) – basic facts



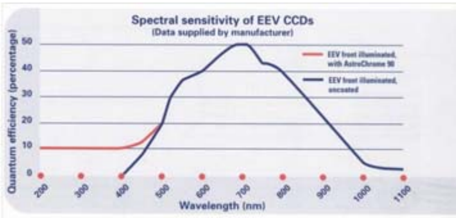
- contactless — measurements in wounds / transplanted skin possible
- spatially resolved — measurement of local variations in skin perfusion, localisation of disorders

PPGI - first generation measuring sytem

“PPGI heart“ - highly sensitive and fast CCD camera

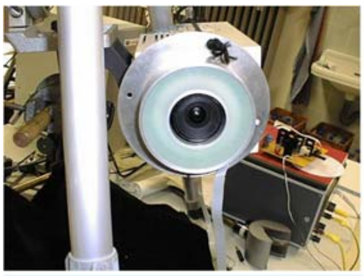
Camera system: UltraPix FE 250

- CCD chip: EEV 37 Frame Transfer
- Resolution: 512 x 512 pixel, pixel size 15 x 15 µm
- Sensitive chip area: 7,7 x 7,7 mm, fill coefficient: >0.95
- Binning: 1x1 to 255x255, subarray-readout
- Readout rate: up to 5.5 MHz (8 fps at full resolution)
- Dynamic range: 14 bit / 84 dB / 16384 grey values
- Working temperature: -40 °C (Peltier cooling)
- Spectral range: 400 - 1100 nm
- Quantum efficiency at 800 nm: QE = 40%



- Light sensitivity: $3x10^{-6}$ Lux
- Full-well capacity (e^-) per pixel (saturation level): 150.000
- Readout noise (e^-) at 500 kHz - readout speed: 9
- Dark current noise (e^-/pixel/s): 15

PPGI illumination unit

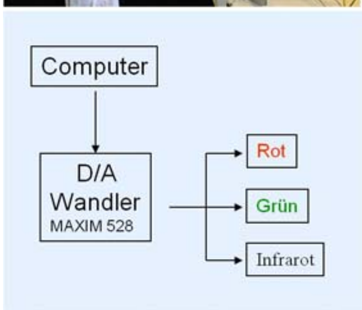


1) Infrared LED ring

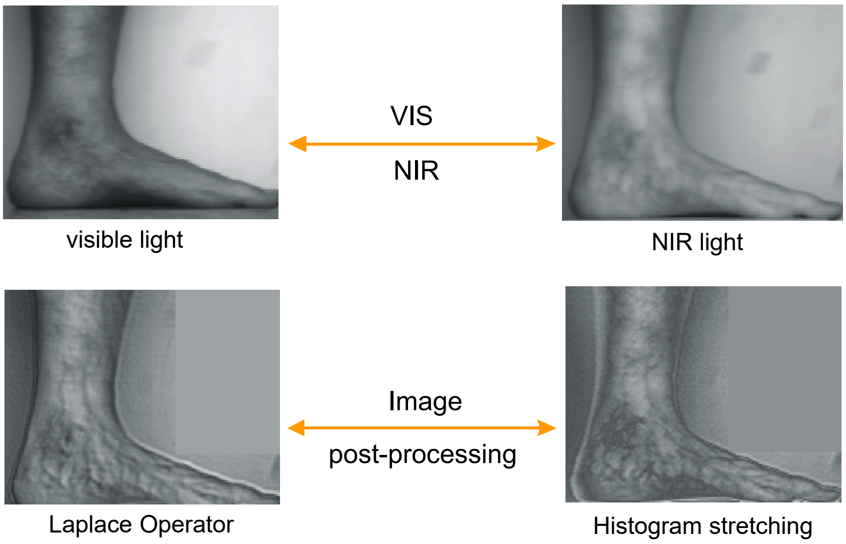
- 46 LEDs with a peak wavelength of 875 nm
- holiness automatically adjustable
- diffuse illumination through diffuser material

2) Multi wavelength LED array

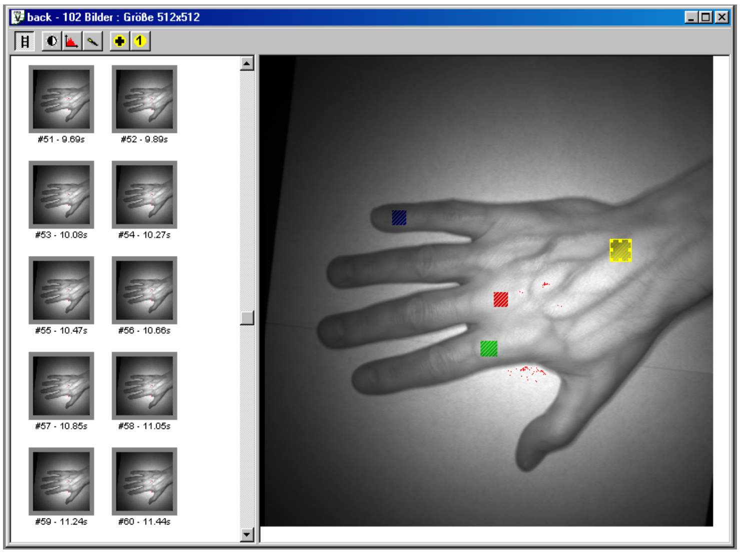
- 3 wavelengths: red, green, infrared (36 each)
- controlled voltage by D / A converter
- holiness adjustable with 256 levels (8 bits)
- Illimination controlled by computer
- without influence each other wavelength



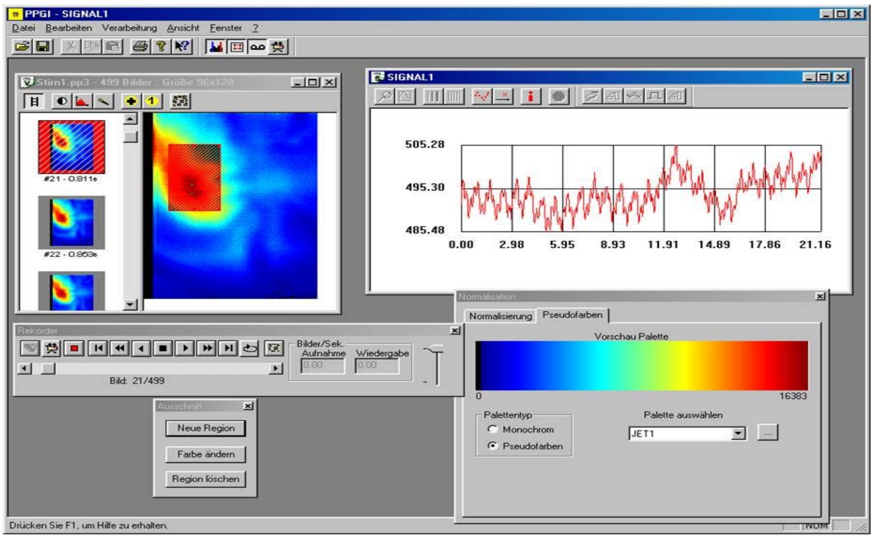
PPGI - visualization of dermal vascular anatomy



PPGI - visualization of dermal vascular anatomy



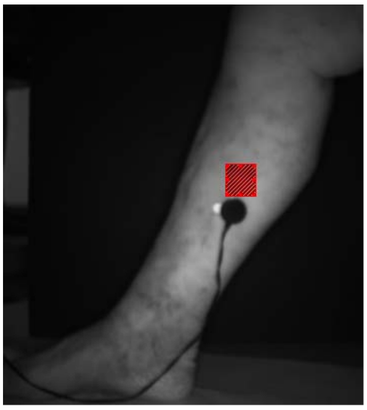
PPGI – first contactless feasibility study



Measurement problem by remote PPGI: movement artifacts in raw video data

Solution:

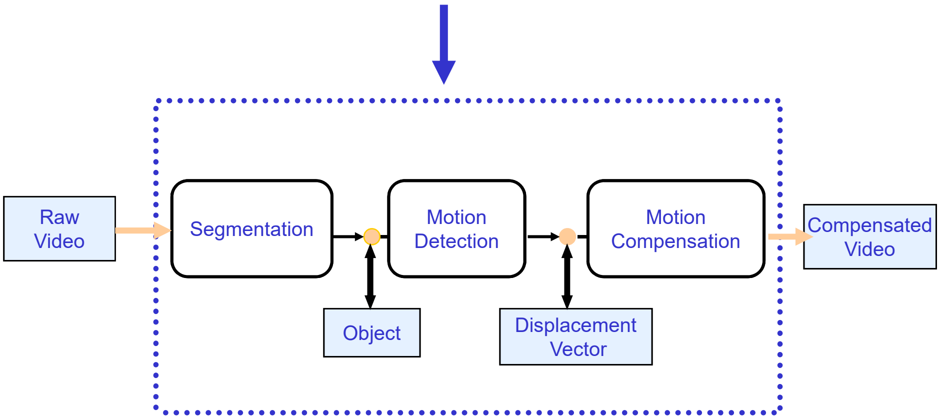
Miscellaneous software strategies for movement arifact reduction icluding object recognition



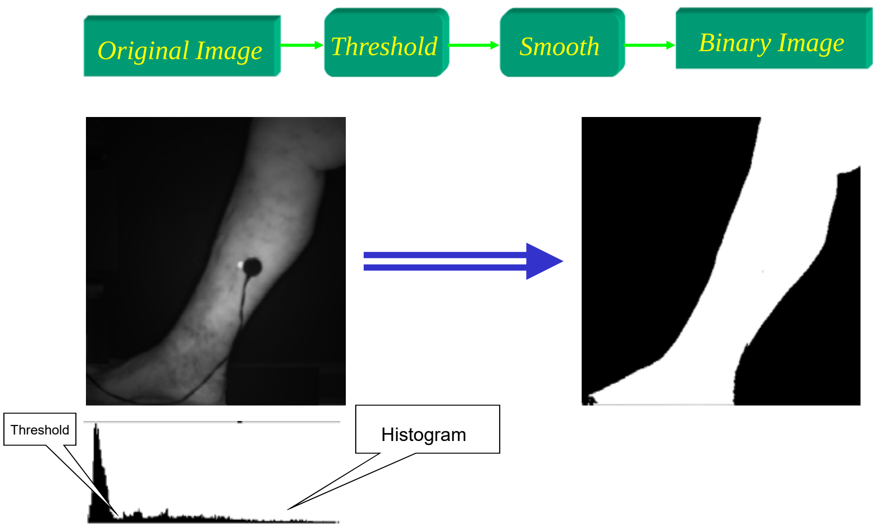
VIDEO

Measurement problem by remote PPGI: movement artifacts

Strategy for movement artifact reduction

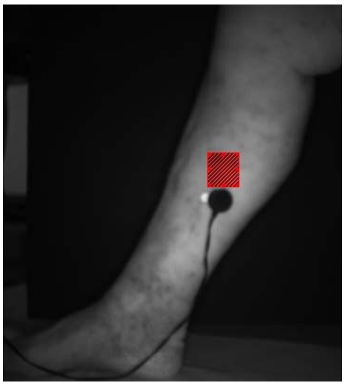


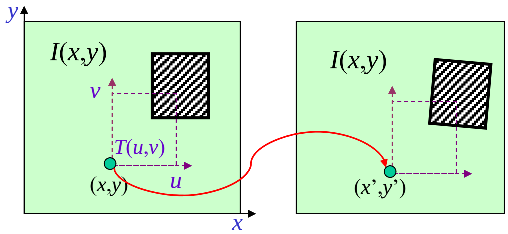
Segmentation (Binarization)



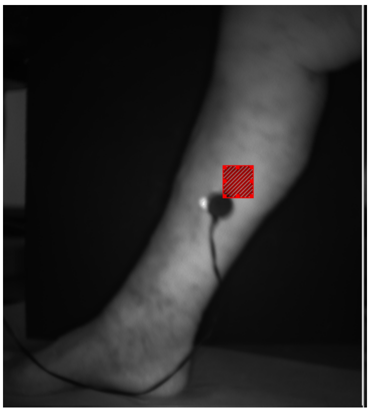
Motion detection

Regions of Interest → Template Matching → Displacement Vector

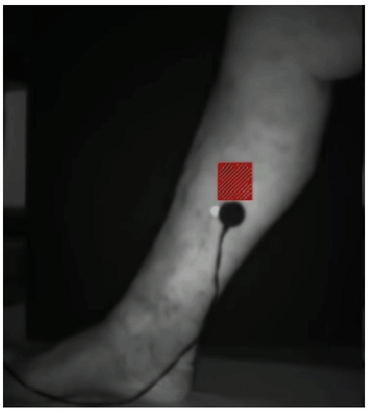




Cross Subtract Function: (minimal)

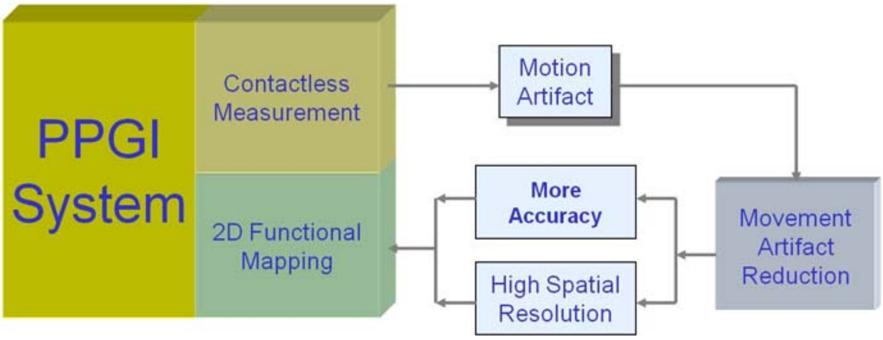


Raw video



Compensated video

PPGI: On the way towards more accuracy and higher spatial resolution



Citát pro devátou přednášku / Quotation of the lecture 9:

"The bodies would not be so nice if they not moving"

Johannes KEPLER (1571 - 1630)
Astronomer at the court of Rudolf II in Prague
and an adviser to General Wallenstein