Sensor fusion for long term monitoring of vital signs

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- Vital signs: Sensors - Evaluation - Diagnosis
- Sensor fusion
- Long term monitoring in GAL-project

Scenario of COPD-Rehabilitation

Chronic obstructive pulmonary disease:

- Continous decrease of oxygen uptake capacity in lungs
- Especially dangerous for smokers
- > 4 Mio. patients in Germany

Rehabilitation of COPD patients:
Supervised training on ergometer
with recording of vital signs:

oxygen saturation in blood, p_{O2}, p_{CO2},
ECG, breath frequency,
blood pressure

Stationary in clinics
or mobile at home?

Stationary rehabilitation

advantages

- stable instruments
- less motion artefacts
- sophisticated software
- medical assistance
- high compliance

disadvantages

- patient has to visit clinics
- access only by appointment, not on weekend
- only small groups at same time
- high cost

-> mobile rehabilitation with automated mobile supervision

Mobile recording of vital signs

Already well established mobile diagnostics:
24h ECG and 24h blood pressure

But for long term mobile vital sign diagnostics in training:

- Energy requirements - costs - compliance:
  long term/continous recording,
  wireless communication, battery exchange

- Error signal reduction:
  Disadvantage: More motion artefacts
  Reduction of data rate
  avoiding false alarms
  -> Time synchronous recording, **sensor/data fusion**

Vital signs

- ECG
- Blood pressure
- Body temperature
- Blood oxygen saturation
- Skin resistance

Derived:

- Heart rate variability
- Breath frequency

Main error sources:

- Motion artefacts
- Electromagnetic interference

How to distinguish from vital sign signals?

Sensor fusion

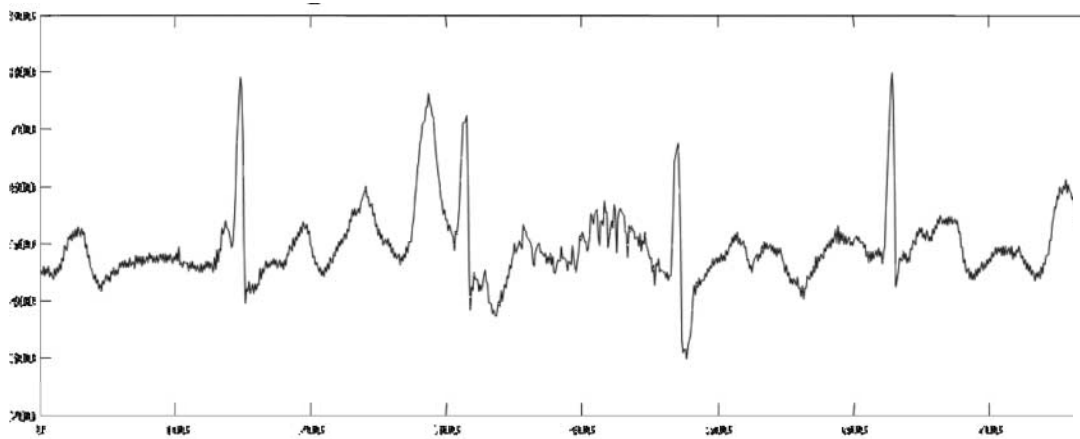
Basic idea:
Distinguish signal from error by independent measurements of multiple sensors

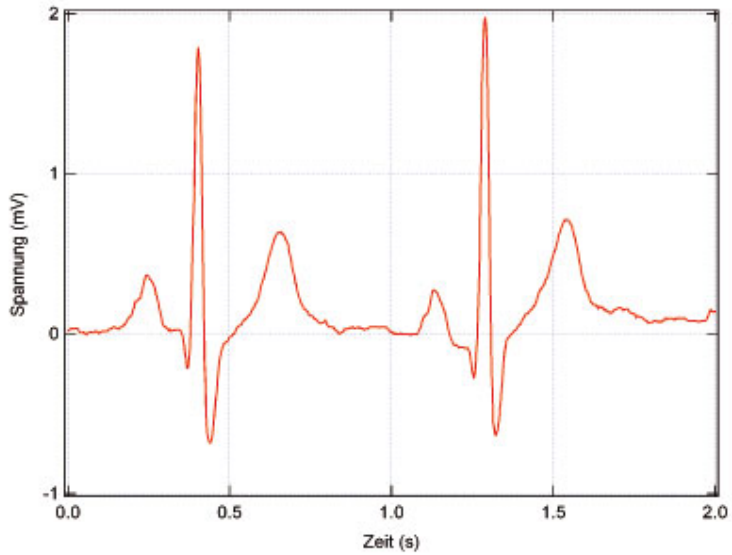
Errors occur by side effects and superposition of disturbances

- Omit signals containing errors
- Detect/remove errors: Redundancy / Complementarity
- Correlation/pattern recognition to separate signal&noise
- Gradients can distinguish signal and error

By same methods:
separate vital signals from each other

Example: ECG

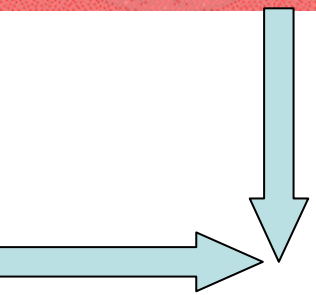




By fusion with other sensors:

- Electrical heart activity -> heart rate variability
- motion artefacts -> remove by acceleration sensor
- breath frequency -> correlate with oxygen saturation
- time delay between heart rate and pulse wave:
  blood pressure
- and reduction of data rate, higher quality of data

Sensor fusion



ecg

blood pressure

oxygen saturation

skin resistance

Accel-eration, time sync.

Fusion

Fusion

Fusion

Fusion

(Remove Motion Artefacts)

ecg

Fusion

breath frequency

blood pressure

Fusion

heart rate, energy variability

oxygen saturation

Fusion

blood pressure

temperature, heat flow

Fusion

energy

Long term monitoring in GAL project

- Integration of ECG, blood pressure, temperature, blood oxygen saturation, skin resistance and breath frequency, heart rate variability
- accelaration, time
- integration as „**vital sign watch**“ in body area network
- personal data access for **assisted personal health decisions**

Conclusions

Vital parameter recording for supervision of rehabilitation

- Mobility for cost reduction and higher compliance
- Sensor fusion reduces errors and thus allows more reliable diagnosis
- Sensor fusion to determine higher order information

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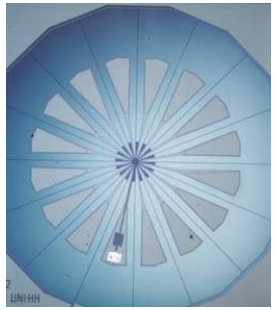
Technology

Sensors



Bio-
Medical

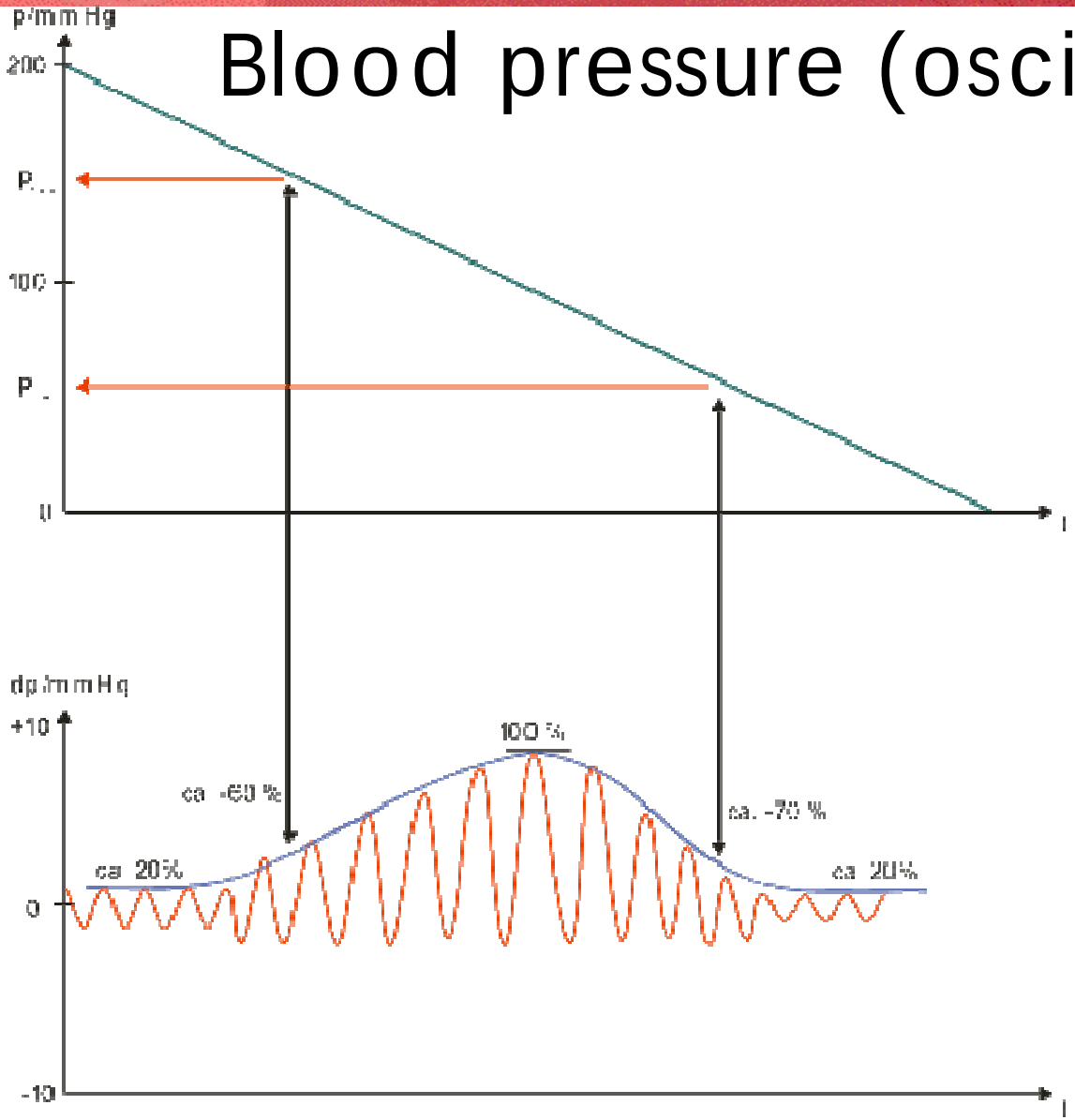
Systems

THz

Magnetics

http://www.emg.ing.tu-bs.de/

Blood pressure (oscillometric)



Quelle: Dissertation A. Wack, Nichtinvasive Blutdruckmessung unter Ergometriebedingungen, 16.06.2006