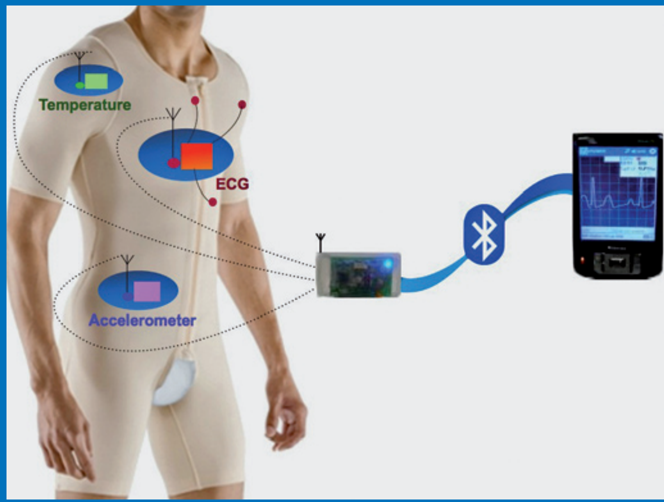
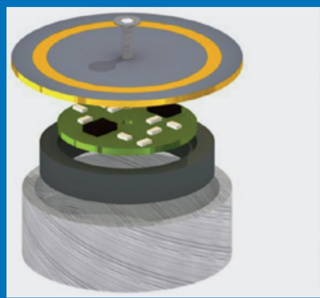
mediT

Medical Information Technology

Faculty of Electrical Engineering and Information Technology

Smart Solutions for Advanced Healthcare





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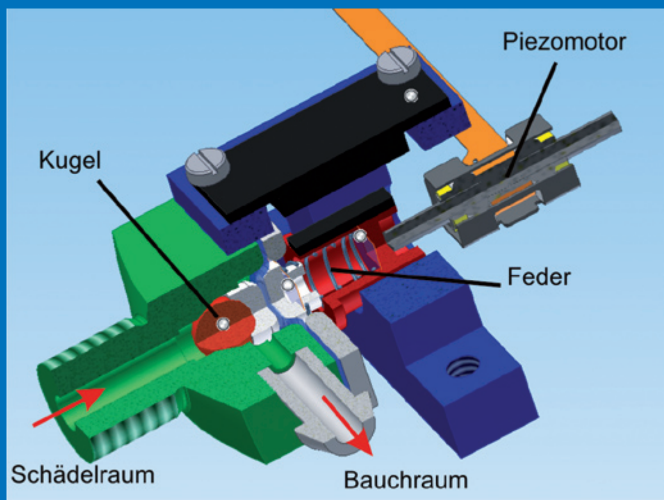

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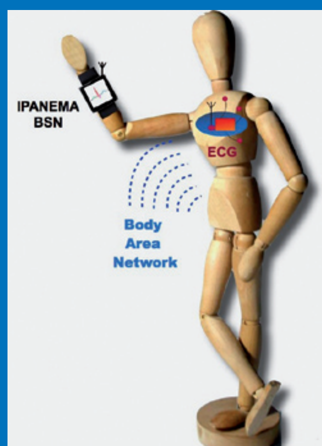

RWTH AACHEN UNIVERSITY

Introduction

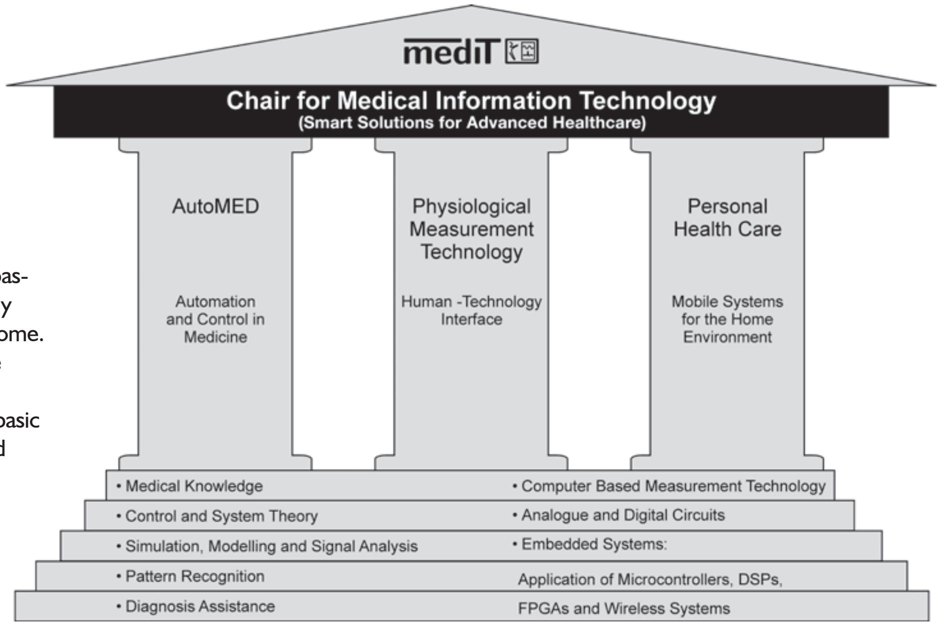

Fig. 1: Research profile of MedIT.

The Chair for Medical Information Technology is especially concerned with research problems in the field of "Unobtrusive Measurement Technologies", "Personal Health Care", and "Automation and Control in Medicine".
The topic Personal Health Care encompasses wearable medical devices, particularly diagnostic devices, designed for use at home. Current technological developments are in the fields of "Intelligent Textiles" and "Body Area Networks" (BAN), related basic research areas (e.g. signal processing and motion artifact rejection), and sensor fusion. Due to demographic trends, especially in developed nations, the laboratory also focuses on the needs of the elderly (e.g. enabling greater autonomy at home).
Automation and Control in Medicine is involved with the modeling of medical and physiological systems and the implementation of feedback controlled therapy techniques. Research topics include tools and methods for the modeling of disturbed physiological systems, sensor supported artificial respiration, active brain pressure regulation, and dialysis regulation and optimization.

Where necessary and sensible, sensors and measurement electronics are developed, for example, in the areas of non-contact sensing techniques (e.g. magnetic bioimpedance), bioimpedance spectroscopy and inductive plethysmography. Active research is furthermore conducted in biomechatronics.

Selected Ongoing Research Projects

LAVIMO-long term monitoring of vital parameter signs by ear sensors

Cardiovascular diseases are among the most common causes of death in western industrial nations. Therefore, early determination of the cardiovascular risk factor is necessary in order to take preventive measure. The LAVIMO (Long Term Monitoring of Vital Signs by In-Ear Sensor) project aims to assess the cardiovascular functionality using photoplethysmographic (PPG) signals acquired from an in-ear sensor. By long-term monitoring of vital signs such as heart rate or arterial oxygen saturation, it is possible to provide a comprehensive personal health care system which can also meet the daily patient's requirements of mobility, usability and robustness.
Pulse oximetry is a reliable, non-invasive method for monitoring of vital signs. In comparison to conventional systems, which are applied to peripheral parts of the body, LAVIMO is based on an alternative solution, namely a "reflective PPG sensor", which can be placed in the auditory canal. This allows a 24/7 measurement with particularly high wearing comfort. Since in-ear measurement would bring some essential advantages, new areas of application will be developed (i.e. personal health care and sports). As a major advantage, stable conditions concerning perfusion and temperature are expected, since the nearby brain perfusion is sustained in all situations. Therefore, compared to conventional finger-clip sensors, even in case of shock-induced centralization, a valid measurement can be ensured.
The central component of the system is is a micro-optic reflective sensor, which is sealed within a biocompatible ear mold. An electrical measurement equipment as a sensor interface performs direct high resolution data conversion for long-term data recording by a personal computer. Preclinical trials in humans indicated that pulse and breathing rate as well as arterial oxygen saturation can be measured with high accuracy.
In the near future, we believe that such optoelectronic sensing strategies will be found in a wide range of applications, like ambient assisted living and telemedicine.
Funded by: German Ministry of Education and Research (BMBF)

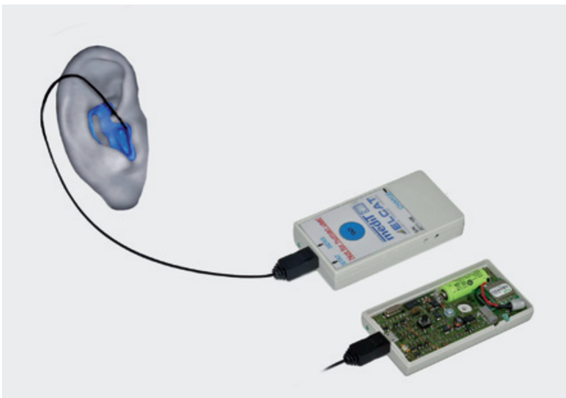

Fig. 2: LAVIMO In-ear sensor and measurement equipment.

IBED – Intelligent Bed: innovative, informative, and intelligent

The demographic change in the German society is an often cited problem, which is poised to cause dramatic problems for patient care in hospitals. While the number of admissions in German hospitals increased by 22% in the past 20 years, the number of hospital staff was decreased by -1.4% during this time. This situation will get even worse considering that: (a) by 2060, 40% of the German population will be older than 60 years, and (b) number of hospital admissions is highly correlated with patients' age. It will therefore be a challenge for hospitals to ensure adequate patient care in light of a decreasing staff / patient quotient. Furthermore, multiple clinical studies have shown an improved patient outcome if a patient's risk-condition was detected early so that an appropriate therapy could be administered quickly. Examples include the so called early warning scores and sepsis diagnosis and treatment. The survivability of sepsis patients increases by 10% for each hour by which the treatment is initiated earlier. In this context, the main question is how the required continuous monitoring on intermediate and normal care stations can be realized without leading to an explosion of costs.

The presented iBED offers the opportunity to defuse the previously mentioned set of problems as it allows an unsupervised automated and unobtrusive monitoring of patients. The integrated sensors allow to measure, despite possible clothes, ECG, pulse-rate, respiratory frequency and temperature. This combination of sensors and a dedicated signal processing provide the possibility for a reliable detection of artifacts to exclude these intervals from the subsequently following expert system. This expert system calculates a continuous index of the patient status and hence can trigger an early alarm and prompt further examinations. This enables especially on the intermediate care ward, continuous monitoring of patients without the need of cables connect to them. A further possible application is the home-healthcare (especially for the elderly) and consumer market. Vital signs of chronic ill patients can be monitored for long time periods (weeks, months or years) at home. Trends which indicate a decreasing patient health status can be transmitted automatically to the family doctor. Due to early intervention, elaborate and expensive following treatments can be avoided.

Funded by: Ziel 2.NRW

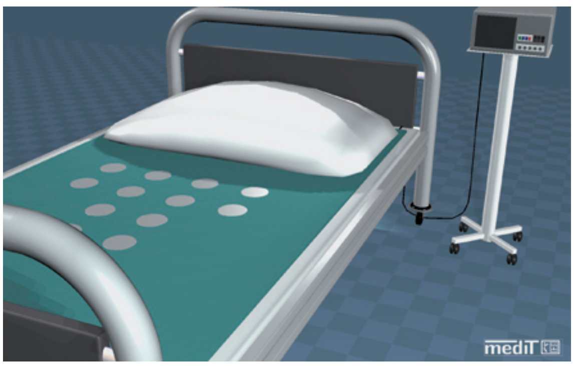

Fig. 3: iBED with integrated sensors for automatic and unsupervised contact-less monitoring.

Capacitive ECG for Mobile Applications

In a cooperation project with the Ford Research Center Aachen, MedIT addressed the issue of medical engineering in vehicles. Future aim of the cooperation is to come up with enhanced safety features, which consider the driver's health status. Thus, as a first step the capacitive ECG was tested as one modality for monitoring the driver's heart activity. Therefore, an ECG device was developed and six capacitive electrodes were integrated into the backrest of the driver's seat. The whole system was installed in a series-production car and tested for its applicability and reliability on the Ford proving ground in Lommel, Belgium. Different driving scenarios were taken into account to draw conclusions about the functionality in everyday life applications, examine the operability, and define limitations of the system. According to that, tests were conducted on highway, city- and country roads and even different clothing of the drivers were considered. Taking into account that motion artifacts could render the ECG signal useless, the results exceeded the expectations with heart rate detection rates of up to 95 % on the highway. Even if different types of clothing were found to negatively affect the signal reliability, with drivers wearing single or double layers of cotton, appropriate signal quality for sensible heart rate detection was reached. However, working out the reasons for corrupted signals will be subject to future research of MedIT.

Fig. 4: Multichannel capacitive ECG system integrated into a driver seat.

As an increased workload or even an overload is one of the most critical situations supposedly leading to a higher amount of car accidents, the ECG was tested for its indicative value of an increased workload. Since the heart rate variability (HRV) is known to be correlated with stressors, different HRV parameters were target measures of a stress study, which was carried out in a laboratory setup and a real world driving scenario. In this study, several test subjects were exposed to a certain stress level and the response of their heart in terms of changes in HRV parameters was measured. The results showed that some HRV parameters are very promising for workload detection. However, as easily imaginable by the heart rate as one measure, the parameters are also affected by other influencing factors, so that combining different sensors and vital signs will result in a more precise and reliable measure of the workload of a driver. The system was presented at several press events in Aachen, Lommel and Denver and finally got major attention on the IFA trade fair 2011 in Berlin. Even that only capacitive electrodes were tested in a vehicle so far, additional contactless sensors may allow for registration of more vital signs, such as breathing, blood pressure and other parameters, which are useful for enhanced safety features in vehicles. Thus, MedIT is anxious to push further cooperation projects with the automobile industry.

Funded by: FORD Research Europe, Aachen

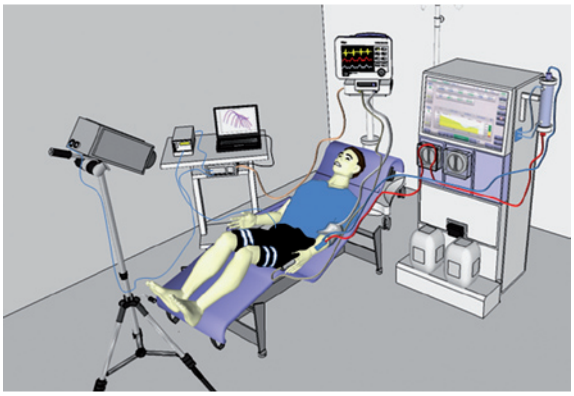

Fig. 5: Concept of the multimodal monitoring system.

SmartDialysis – Multimodal Monitoring System for Optimization of Intradialytic Hydration Status

Hemodialysis (HD) is the most common treatment for patients with end-stage renal disease (ERSD) results in removal of fluid excess and solute-waste products. Despite continuous improvement in dialysis technologies, clinical tolerance to hemodialysis is still a problem, reducing patient's life expectancy. The main intradialytic complications include long-term hyper- and hypotension episodes, and the disequilibrium syndrome. The etiology of these phenomena is assumed to be based on non-physiological changes in body fluid composition and volume during treatment. Once the dynamics of fluid and solutes distribution and exchange mechanisms between body compartments is known, the above mentioned complications could be avoided. The project aims to establish a multimodal system for continuous monitoring of patient's hemodynamic behavior based on bioimpedance spectroscopy (BIS), electrocardiogram (ECG), infrared thermography, physiological modeling, and other external sensors. To maximize patient's comfort, textile and capacitive electrodes integrated into clothing (e.g. shorts) and clinical bed will be applied. The system offers immediate registration of several physiological parameters as well as the incidence of hypotensive episodes. Post (statistical and regression) analysis will reveal possible relationships between suggested parameters and observed complications. Fluid and solute transport kinetics will be parameterized based on a tetra-compartmental physiological model describing the main underlying activities at cellular and tissue level. An end-point of the project would be a real-time closed-loop control of dialysate fluid composition (especially sodium and potassium concentration, and acid-base balance), ultrafiltration-rate pattern, and blood temperature to match dialysis therapy to the individual needs of the patient.
Recently, trials were conducted on 90 ESRD patients undergoing regular dialysis treatments at the dialysis clinic of the RWTH Aachen University Hospital, see Fig. 5. Results showed promising indicative / predictive power of BIS and ECG related parameters (e.g. extracellular resistance, QT-wave period) for intradialytic complications.

Funded by: ERS Boost Fund Project, RWTH Aachen University

Magnetic Induction Monitoring

Continuous monitoring of respiratory and cardiac activities is especially important for patients in intensive care unit and newborn infants in an incubator. As the application of conventional methods is associated with side-effects (e.g. skin irritation, contact problems or large energy requirements), the magnetic induction method offers a promising alternative. The method is based on the fact that both respiratory and heart activity result in displacement of air (poor-conducting) and blood (well-conducting) across the thorax. This will cause a measurable change in the body's electrical impedance distribution. By magnetic induction measurements, which use inductive eddy currents, a contactless determination of those changes is possible. The main technological challenge is to handle very small signals in a noisy environment. Therefore, special importance was given to the use of a highly precise and fast circuit design inside the radio frequency measurement parts, and to maintain low power consumption as the application is intended for mobile monitoring scenarios.
A magnetic induction monitoring system including 3 channels was developed at MedIT and attached to a chair. This gives the possibility to monitor the vital parameters during daily routines, e.g. office work, car driving or during watching TV. A possible set-up is presented in Fig. 6.

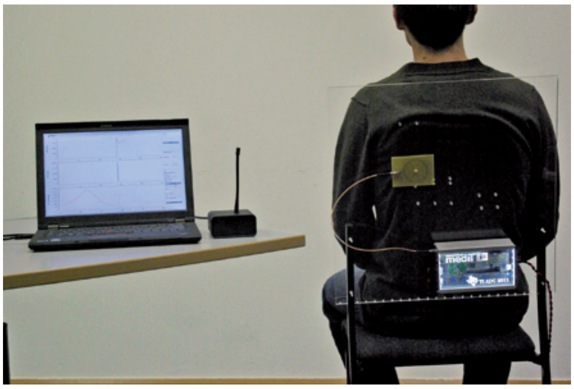

Fig. 6: Realization of a magnetic induction method integrated in an office chair.

The magnetic field is sent out and measured by a coil placed on the chair's back-rest. The back-rest is made of acrylic glass in order to have a direct view of the coil position with respect to the body. The acquired data is preprocessed by

a microcontroller and transmitted by link wireless to a PC, where it is stored and visualized. In order to improve the system design, analytic as well as simulative analyses have been carried out beforehand. In a first proof of concept, good functionality of the system was verified by measurements on human volunteers.
Funded by: European Union, Project Heart Cycle

Impedance Controlled Surgical Instrumentation (ICOS)

The hip joint replacement has played a major role in the endoprosthesis with over 150.000 primary implantations only in Germany within 2008. Because of the demographic change and the increasing survival expectation for the upcoming years, an increase in the implementation number is expected in the future. As the average life time of hip joints endoprosthesis is between 12 and 15 years, the number of revisions for the artificial hip joints is also most likely to increase (22.500 cases in Germany, 2008). During revision, the old bone cement has to be removed to ensure proper fixation of the new implant. The standard revision procedures are ruffian to the patient and the risk of femurs cracking or puncture of vasculature is not excludable. The aim of the project is to achieve a high patient safety by developing an online measurement system for impedance-controlled bone cement removal during the milling process. As presented in Fig. 7, the system includes a bioimpedance spectroscopy (BIS) measuring setup that is integrated in the surgical milling device. The BIS measurement current is conducted to the milling shaft with a sliding contact and is applied to the patient via the milling head. Measured impedance values reflect the remaining thickness of the residual bone cement in comparison to the tissue.

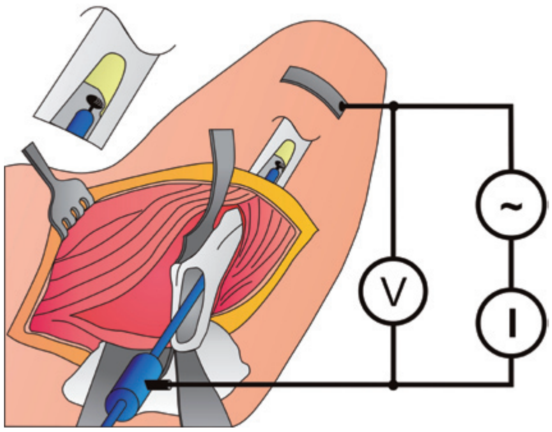

Fig. 7: ICOS Operation Theatre.

During the preparation of experimental trails and for identifying the measuring system, a femoral test bed (Fig. 8) was designed. The inner diameter (15 cm) of the femoral test bed corresponds to the diameter of an adult human leg. The 16 electrodes on the wall are replaceable and enable different measuring setups. In the bottom of the femoral test bed are 2 options for fixing a bone cement dummy (hollow cylinder), one in the middle and the other excentric according to human physiology.
Funded by: German Ministry of Education and Research (BMBF)

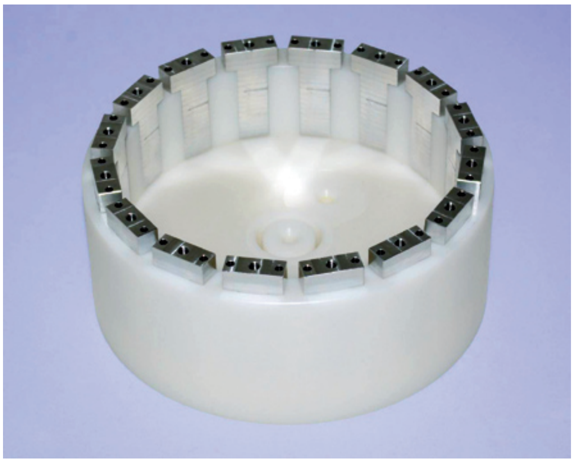

Fig. 8: Femoral test bed.

SmartECLA – Innovative Extracorporeal Lung Assist

Patients suffering from acute lung failure depend on artificial ventilation in order to survive. In severe cases this therapy may not be sufficient anymore and long term extracorporeal membrane oxygenation (ECMO) may be used as a last resort rescue therapy. Adapted from short term cardiopulmonary bypass, these machines now need an increased ability for autonomous and unsupervised operation. The aim of the Smart-ECLA-Project is the development of an advanced extracorporeal lung assist system, which works self-governed. Apart from the material aspects (hemolysis and long term biocompatibility), a prerequisite for safe and reliable operation is the implementation of an adequate automation and safety scheme. Fig. 9 shows a typical clinical setup.
During this project, a model of the patient physiology and a complete technical system were implemented and evaluated with focus on the extracorporeal circuit with the oxygenator, the lung and the tissue capillary bed. Based on the model, a patient orientated control system was also designed. In simulations and in animal experiments, the system achieves the requirements on stability and patient orientated behavior.
Funded by: German Research Foundation (DFG)

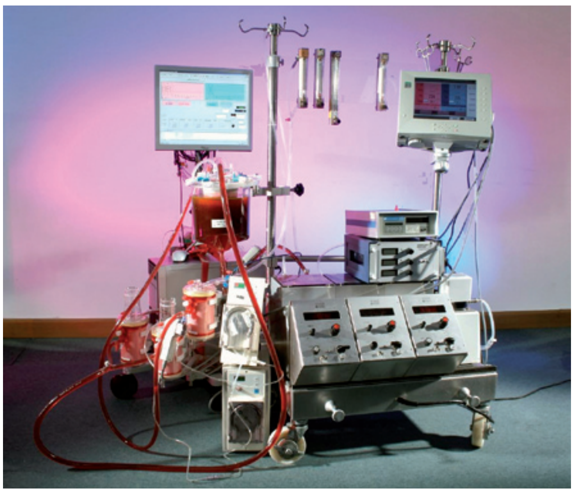

Fig. 9: Typical clinical setup for ECMO system.

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Prizes and Awards

- T. Wartzek: 1st prize at the MEDICA MEDIA R&D Talent Award, MEDICA 2011, Düsseldorf, Germany.
- J. Foussier and D. Teichmann: 1st prize out of 155 in Texas Instruments Analog Design Contest 2011.
- C. Brendle: Viktor und Mirka Pollak-Prize in Medical Engineering 2011, RWTH Aachen.

People at MedIT

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