mediT

Medical Information Technology

Faculty of Electrical Engineering and Information Technology

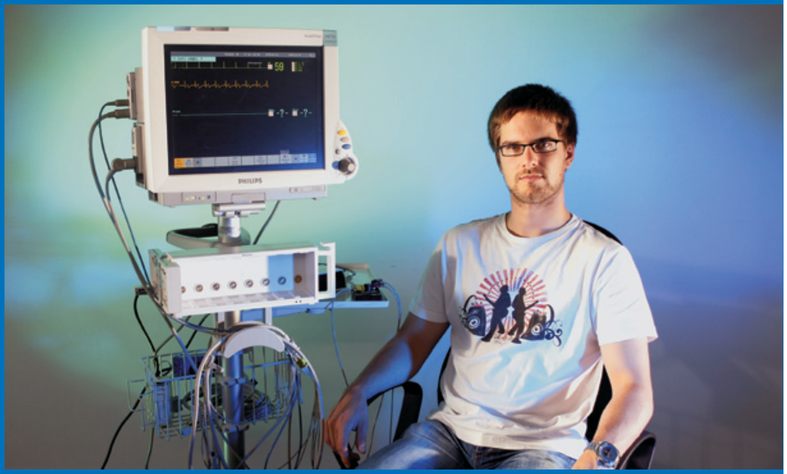
Electronic Solutions for Advanced Healthcare

Director

Univ.-Prof. Dr.–Ing. Dr. med.
Steffen Leonhardt, M.S.

Philips Chair for Medical Information Technology
Helmholtz-Institute for Biomedical Engineering
Pauwelsstrasse 20
52074 Aachen

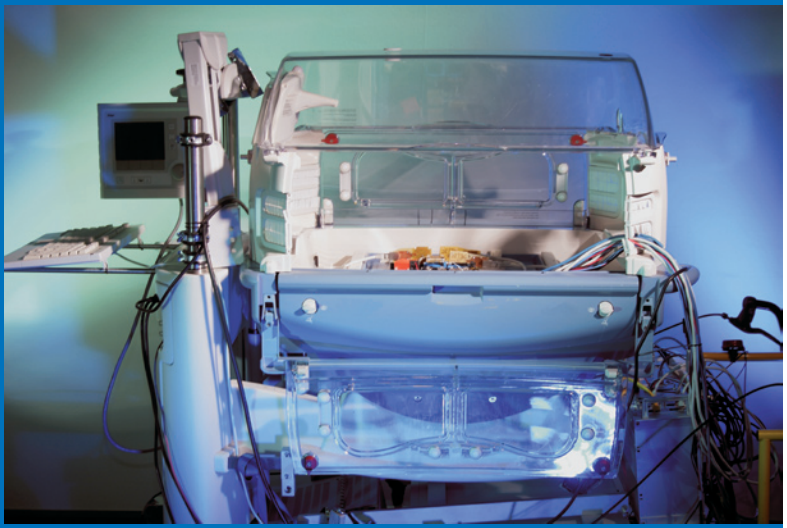
Phone: +49 (0)241 80-23211 (office)
Fax: +49 (0)241 80-82442
Web: http://www.medit.hia.rwth-aachen.de



Staff (Full time equivalents)

Walter, Marian, Dr.-Ing., Senior Scientist
Balzer-Sy, Heidi, Administrative Assistant
Wrobel, Walter, Dipl.-Ing., Laboratory Engineer

Abbas, Abbas, M.Sc.
Beckmann, Lisa, Dipl.-Ing.
Chen, Dan, M.Sc.
Cordes, Axel, Dipl.-Ing.
Eilebrecht, Benjamin, Dipl.-Ing.
Foussier, Jérôme, Dipl.-Ing.
Heinke, Stefanie, Dipl.-Wirtsch.-Ing.
Ismail, Abdul Hamid, M.Sc.
Jetzki, Stefanie, Dipl.-Ing.
Kim, Saim, Dipl.-Ing.
Krause, Inga, Dipl.-Ing. (FH)
Lunze, Katrin, Dipl.-Ing.
Medrano, Guillermo, M.Sc.
Pikkemaat, Robert, Dipl.-Ing.
Vahlsing, Thorsten, Dipl.-Ing.
Vogel, Stefan, Dipl.-Ing.
Wartzek, Tobias, Dipl.-Ing.
Wolfram, Frank, Dipl.- Ing.



RWTH AACHEN UNIVERSITY

Introduction

The Chair for Medical Information Technology is especially concerned with research problems in the field of "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), certain related basic research areas (e.g. signal processing and motion artefact 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 modelling and implementation of feedback controlled therapy techniques. Research topics include tools and methods for the modelling of disrupted physiological systems, sensor supported artificial respiration, active brain pressure regulation, and dialysis regulation and optimization.

We also develop sensors and measurement electronics, for example, in the areas of non-contact sensing techniques (e.g. capacitive bio-potentials and magnetic bioimpedance), bioimpedance spectroscopy and inductive plethysmography. We are also active in biomechatronics, (e.g. robotics and exoskeleton) ultrasound diagnostics, and electrochemical impedance spectroscopy measurement.

Ongoing Research Projects

Non-Contact Monitoring of Heart and Lung Activity

Nowadays, monitoring and evaluation of vital functions, especially pulse and breathing rates, are part of the clinical routine. State-of-the-art monitoring

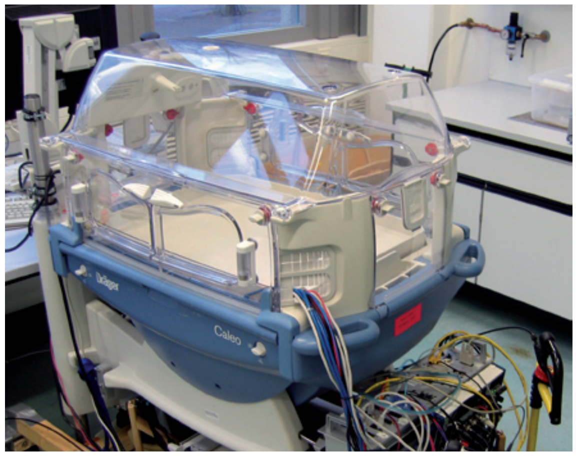


Fig. 2: Application of magnetic impedance measurement in the incubator

requires the use of electrodes which are needed for electrocardiograms (ECG), Impedance Cardiography (ICG), pulse oximetry, or other diagnostic tools. This may cause various difficulties for patients under 24h monitoring or in Intensive Care Units (ICU), as skin irritation, difficult application or additional cabling.

<u>Funded by:</u> (in parts) German Research Foundation (DFG)

SmartLifeSupport – HeartControl & SmartECLA

Many patients in hospitals, especially those located in an intensive care unit, survive with the aid of life-supporting systems. Such systems are technically complex and require specialized and highly trained personnel. In times of increasing complexity of medical procedures and reduced financial options, individualization of therapy can only be achieved with technical aids.
The objective of HeartControl is to realize an adaptive control algorithm for the Ventricular Assist Devices (VAD) and Total Artificial Hearts (TAH). As it is not possible to continuously measure the blood pressure in human body, other values have to be considered to get information on patient actual demand. Therefore, other control mechanisms, e.g. the respiratory or the thermoregulatory system of the human body, are used. For those systems, modelling and sensor development take place. Within the SmartECLA project, optimization of oxygenators, physiological feedback and control as well as safety concept are in focus.

<u>Funded by:</u> German Research Foundation (DFG)

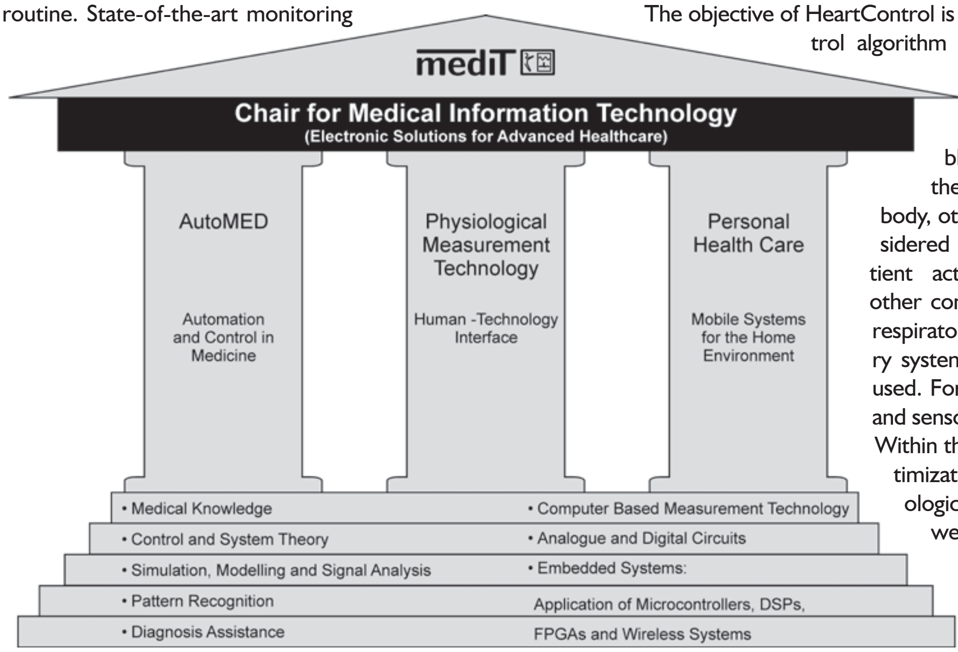


Fig. 1: Research profile of MedIT

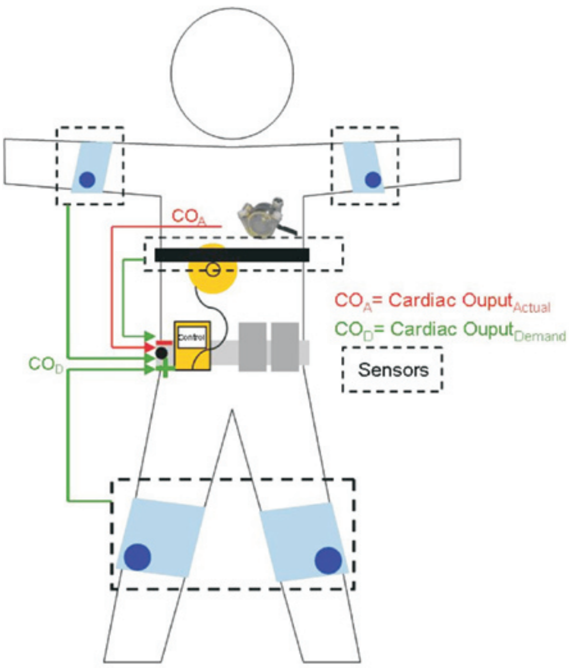


Fig. 3: SmartLifeSupport concept, HeartControl system

Bioimpedance Spectroscopy and Intelligent Textiles

The natural ageing process, sport activities or ill health, often lead to dehydration/overhydration with partly severe consequences. For the attending doctors, it is quite difficult to diagnose such dehydration/overhydration since the symptoms are not very clear. A reduction of weight because of protein malnutrition is also a known problem, from which many old people, cancer patients after chemotherapy, or people with eating disorder usually suffer. To avoid such serious effects and to improve the quality of life for all persons concerned, it is important to control the nutritional status and water balance of the body. In

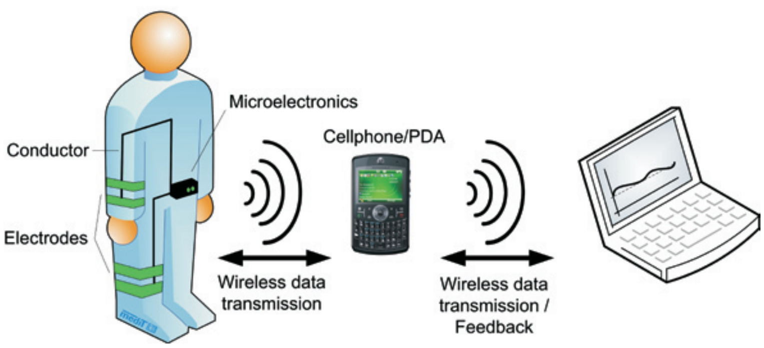


Fig. 4: Concept for a wearable bio-impedance spectroscopy system

this research project, a mobile system will be developed using smart textiles to monitor the nutritional and water balance of human bodies. The Nutriwear system is the first to enable 24/7 continuous mobile measurement of nutritional parameters. The advantages offered by textiles facilitate their integration into working routines and everyday life.

Funded by: German Ministry of Education and Research (BMBF)

IN-ear MONIToring System for Preventive Supervision of Risk Patients (IN-MONIT)

Cardiovascular diseases are among the most common cause of death in western industrial nations. Therefore, it is within the interest of both physician and patient to early determine the cardiovascular risk factors in order to take preventive measures. Since the early 1980s, pulse oximetry has emerged as a de facto standard for non-invasive monitoring of arterial oxygen saturation and heart activity. Although different miniaturized commercial pulse oximetry systems are available, measurement is usually carried out at the extremities of the body (i.e. finger, toe or ear lobe), where frequent movement artefacts are introduced

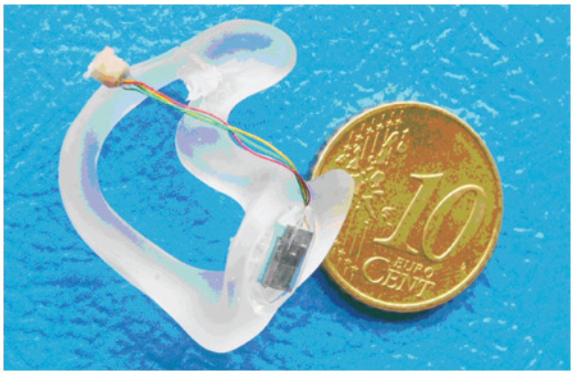


Fig. 5: Micro-Optic Sensor for In-Ear application

(especially in long term monitoring). Another disadvantage is the poor signal quality in occurrence of centralization when the patient is suffering from shock, sepsis, coldness, or cardio-pulmonary abnormalities. However, some of these indications are the main application scenarios of portable oxygen saturation monitors.

To assist in recognizing the irregularities of a subject's cardiovascular system, an optic 24/7 in-ear monitoring system (IN-MONIT) has been developed. Its main component is a micro-optic remission / reflection sensor (MORES®) (see Fig. 5) which is placed inside the auditory canal. From the pulsation of blood within the capillaries, oxygen saturation (SpO2), and heart and respiratory rates can be derived. These raw data are processed locally using a microcontroller and then wirelessly transferred to a Personal Digital Assistant (PDA) or a PC for further analysis.

Funded by: German Ministry of Education and Research (BMBF)

Determination of calcification risk factor in blood

Worldwide, over a 500 million people suffer from a chronic renal disease and depend on dialysis treatment. Due to lack of mineral products regulation, they often have an over saturation of the extra-cellular fluids with calcium and phosphate ions. This, in addition to the lack of calcification inhibitors (e.g. Fetuin A), leads to the development of cardio-vascular calcification associated with an increase in morbidity and mortality risk.

An optimum treatment of the patient is still difficult to achieve, since so far, there is no simple test to accurately estimate the calcification formation process and calcification-inhibitor concentration in the blood. Currently, a laboratory test is available based on the quantification of radioactive ^{45}Ca. The numerous preparation steps and the 90 minutes required incubation period make the test un-appropriate for daily clinical practices. Therefore, a new test needs to be developed based on in-situ measurements of mineral formation kinetics.

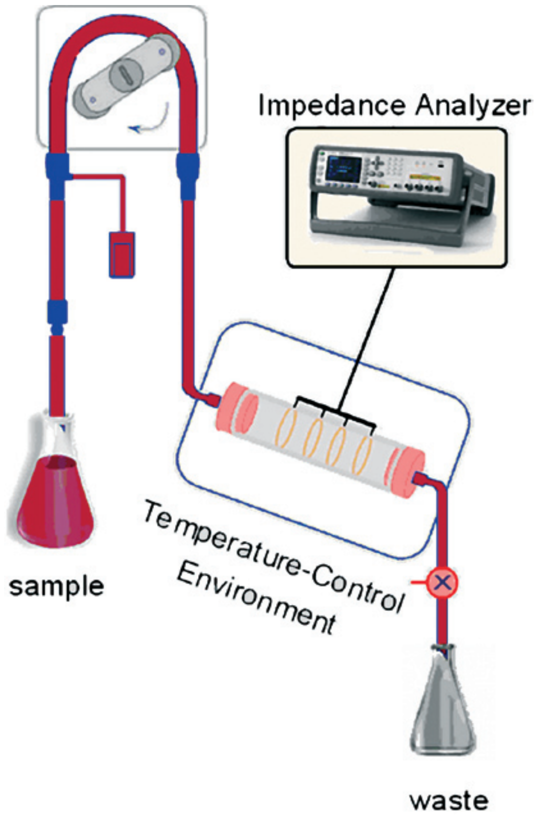


Fig.6: Basic system setup for calcification measurement using EIS

By an interdisciplinary collaboration of engineers and biologists such a test shall be developed based on Electrochemical Impedance Spectroscopy (EIS). The method offers a non-destructive mean for examining and characterizing a number of chemical and physical processes which occur in solution as well as in solids. Using an impedance trace of the mineralization formation process, the calcification inhibition capacity in serum samples will be determined.

Funded by: START Program of the University Hospital Aachen

Automated Protective Ventilation using Electrical Impedance Tomography

Patients with Acute Lung Injury (ALI) or Acute Respiratory Distress Syndrome (ARDS) experience a partial lung collapse leading to an impaired gas exchange. The patient's oxygen supply is reduced and the removal of carbon dioxide becomes more difficult. The standard therapy involves artificial ventilation of the patient with an increased fraction of inspired oxygen and monitoring of physiological parameters, such as blood pressure, pulse and oxygen saturation.

For this purpose, the thoracic Electrical Impedance Tomography (EIT), a technique that is capable of displaying changes of the conductivity distribution along a horizontal body cross section, will be used to monitor the regional ventilation changes of lung. With use of EIT, we work on development of an automated ventilation system that can perform complex ventilation strategies through closed-loop control based on medical expertise.

Funded by: German Research Foundation (DFG)

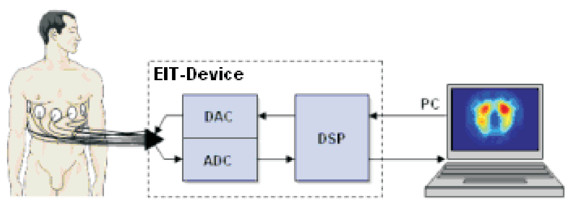


Fig. 7: Electrical Impedance Tomography (EIT), DAC=Digital-To-Analog-Converter, ADC=Analog-To-Digital-Converter, DSP=Digital-Signal-Processor

Control of Intracranial Pressure – towards a "Smart Shunt"

Patients suffering from Hydrocephalus and high intracranial pressure are treated using a shunt. The shunt, a catheter with a mechanical valve connecting the liquor in the brain with another compartment in the body, reduces the Intracranial Pressure (ICP) whenever it is too high.

Every year, more than 18000 patients in Germany get a shunt; however, the complication rate of 50% is quite high. One of the biggest problems is the mismanagement in the drainage. Although too high ICP for a long period can be fatal, a too high drainage is not healthy either.

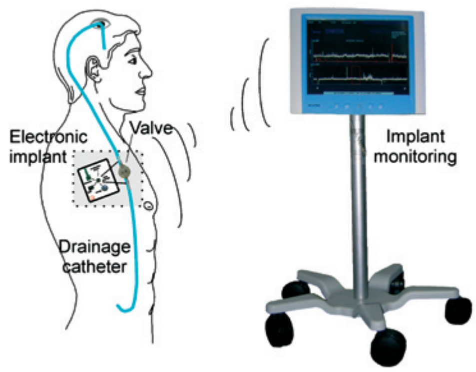


Fig. 8: Smart Shunt application

To prevent a too high drainage due to artefacts in ICP which can occur for example while coughing and moving, give the doctor information about the success of the therapy, and alert him for example when the shunt is blocked, an intelligent shunt has to be developed. A prototype of an implant has been developed which measures ICP and acceleration, and sends the information wirelessly to the doctor monitor. In vivo experiments with pigs have been started to induce a hydrocephalus and implement the prototype. Shunts have been tested in vitro under various conditions in the revised test stand. In future, a mechatronic valve needs to be developed and controlled intelligently by the implant.

Funded by: German Ministry of Education and Research (BMBF), START, Holste Foundation.

Biosignals Monitoring using Infrared Technologies

Infrared-spectroscopic observations permit, as needed, time-resolved analysis of the chemical and biological composition of blood with its protein and cell deposits, e.g. for a continuous, fast-responding and long-term stable glucose sensor.

With a transmission microcell, a two hour semi-continuous measurement of glucose in blood samples was achieved. Simultaneously, the experiments allowed studying the growth of protein and cell deposit inside the device. Current research aims at improving the microcell to take longer measurements, utilising the results about deposit composition from preceding tests. Such a device would allow blood glucose determination and control for patients in intensive care units, where excursus in glucose levels is suspected to impair treatment results. Patients with diabetes mellitus could benefit from an implantable version of the sensor.

Fig. 9: Infrared transmission microcell for blood analysis

Wireless sensing and control of neonatal core temperature

Accurate neonatal surface temperature mapping will assist in pre-diagnosis and prediction of varieties of neonate's hyper-/hypothermia states. Especially, non-invasive methods for mapping neonate skin temperature will be used as temperature measurement standard in the future incubator units. Neonatal Infrared Thermography (NIRT) is considered a novel and prospective method for real-time monitoring of a neonate's body surface temperature. Therefore, a virtual temperature sensing module needs to be integrated into the neonatal incubator control loop.

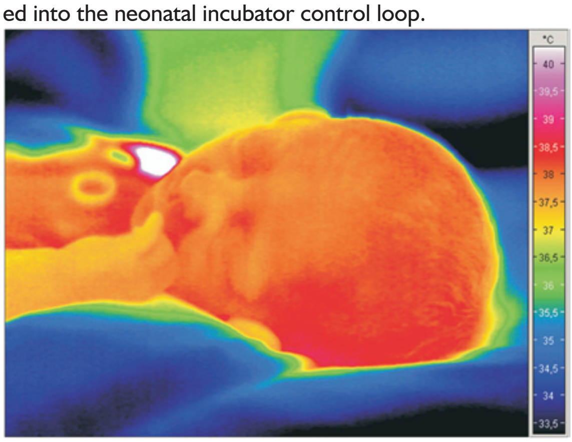


Fig. 10: Thermographic image of neonate

The project goal is to design and implement an intelligent real-time infrared thermogram processing module for classifying neonate's dynamic temperature patterns. Additionally, the module will be integrated into the control loop of the neonatal incubator system.

Selected References 2008

[1] H. Luepschen, D. van Riesen, L. Beckmann, K. Hameyer and S. Leonhardt, "Modeling of Fluid Shifts in the Human Thorax for Electrical Impedance Tomography", IEEE Transactions on Magnetics, Vol. 44, No. 6, 2008, pp. 1450-1453.
[2] M. Steffen, K. Heimann, N. Bernstein and S. Leonhardt, "Multichannel simultaneous magnetic induction measurement system (MUSIMITOS)", Physiological Measurement, Vol. 29, 2008, pp. 291–306.
[3] J. M. Deibele, H. Luepschen and S. Leonhardt, "Dynamic separation of pulmonary and cardiac changes in electrical impedance tomography", Physiological Measurement, Vol. 29, 2008, pp. 1 – 14.
[4] M. Steffen and S. Leonhardt, "Non-Contact Monitoring of Heart and Lung Activity by Magnetic Induction Measurement", Acta Polytechnica, Vol. 48, Nr. 3, 2008, pp. 71-78.
[5] L. Beckmann, S. Kim, H. Dückers, R. Luckhardt, N. Zimmermann, T. Gries and S. Leonhardt, "Characterization of textile Electrodes for Bioimpedance Spectroscopy", Int. Scientific Conference on Smart Textiles – Technology and Design (Ambience08), June 2nd - 3rd, 2008, Boras, Schweden.
[6] S. Leonhardt and A. Aleksandrowicz, "Non-Contact ECG Monitoring for Automotive Application", 5th International Workshop on Wearable and Implantable Body Sensor Networks (BSN08),

the Chinese University of Hong Kong, Hong Kong, China, June 1-3, 2008.

[7] N. Zimmermann, T. Gries, L. Beckmann, S. Kim, G. Medrano and S. Leonhardt, "Monitoring of Body Functions using Textile Electrodes", World Textile Conference (AUTEX 2008), Città Studi – Biella, Italy, June 24-26, 2008.

[8] S. Vogel, M. Hülsbusch, D. Starke and S. Leonhardt, "A System for Assessing Motion Artifacts in the Signal of a Micro-Optic In-Ear Vital Signs Sensor", 30th Annual International IEEE EMBS Conference, Vancouver, British Columbia, Canada, August 20-24, 2008.

[9] S. Jetzki and S. Leonhardt, "An Electric Implant for Hydrocephalus Therapy Assistance", 30th Annual International IEEE EMBS Conference, Vancouver, British Columbia, Canada, August 20-24, 2008.

[10] C. Preis, H. Luepschen, S. Leonhardt and D. Gommers, "Experimental case-report: the development of a pneumothorax monitored by electrical impedance tomography", 21st ESICM Annual Congress, Lisbon, Portugal, Sep. 21 – 24, 2008.

[11] T. Vahlsing, S. Leonhardt, H. M. Heise and V. R. Kondepati, „IR-spectroscopic in-vivo transmission measurement of biological samples using blood glucose determination as example", 6th Conference on Optical Analysis Technology, 25.-26. September 2008, Leverkusen, Germany.

[12] A. K. Abbas and S. Leonhardt, "System Identification of Neonatal Incubator based on Adaptive ARMAX Technique", 4th European Conference of the International Federation for Medical and Biological Engineering (EMBEC 2008 - ESEM 2008), November 23 – 28, 2008, Antwerp, Belgium.

[13] A. H. Ismail, M. Fries, R. Rossaint and S. Leonhardt, "Validating the Reliability of Five Ventricular Fibrillation Detecting Algorithms", 4th European Conference of the International Federation for Medical and Biological Engineering (EMBEC 2008 - ESEM 2008), November 23 – 28, 2008, Antwerp, Belgium.

[14] S. Leonhardt, „Methoden zur kontaktfreien Überwachung von Vitalsignalen", 1. Deutscher Kongress Ambient Assisted Living (AAL 2008), Berlin, 29. 01. – 1.02. 2008.

[15] J. Bickenbach, S. Leonhardt und R. Rossaint, „Protektive Beamtungskonzepte", 2. Dresdner Medizintechnik-Symposium, Dresden, 1.-3. Dez. 2008.

Cooperations

Chair of Informatics 11, RWTH Aachen University
Clinic for Heart, Thorax and Vascular Surgery, University Hospital Aachen
Clinic of Operative Intensive Care, University Hospital Aachen
Department of Control Engineering, RWTH Aachen University
Department of Anesthesiology, University Hospital Aachen
Department of Applied Medical Engineering, University Hospital Aachen
Department of Anesthesiology, University Medical Centre Schleswig-Holstein, Campus Lübeck
Department of Languages and Communications Sciences, RWTH Aachen University
Department of Medical Clinic II – Nephrology and Immunology, University Hospital Aachen
Department of Neurosurgery, Saarland University Hospital
Department of Neurosurgery, University of Heidelberg
Department of Neurosurgery, Unfallkrankenhaus Berlin
Department of Internal Medicine, Gießen University
Institute and Out-patient Clinic for Occupational Medicine, University Hospital Aachen
Institute for High Frequency Technology, RWTH Aachen University
Institute for Textile Technology, RWTH Aachen University
Institute for Spectroscopy and Spectrochemistry (ISAS), Dortmund.
Neonatal Clinic, University Hospital Aachen
and several industrial partners

Team