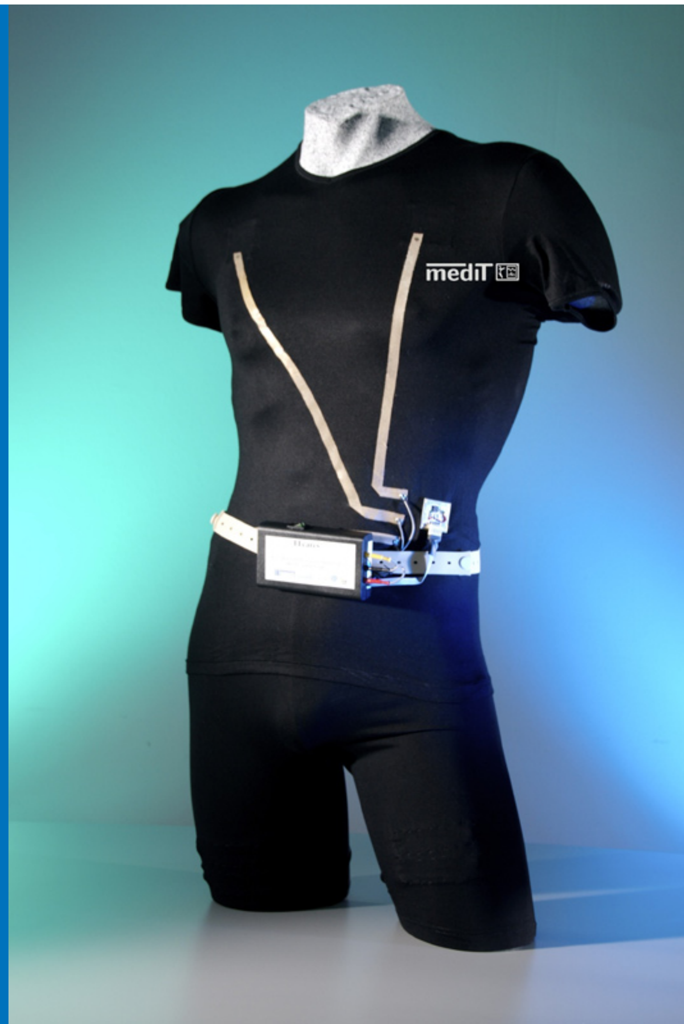
mediT

Medical Information Technology

Faculty of Electrical Engineering and Information Technology

Smart Solutions for Advanced Healthcare



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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), 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 modeling and implementation of feedback controlled therapy techniques. Research topics include tools and methods for the modeling of disrupted physiological systems, sensor supported artificial respiration, active brain pressure regulation, and dialysis regulation and optimization.

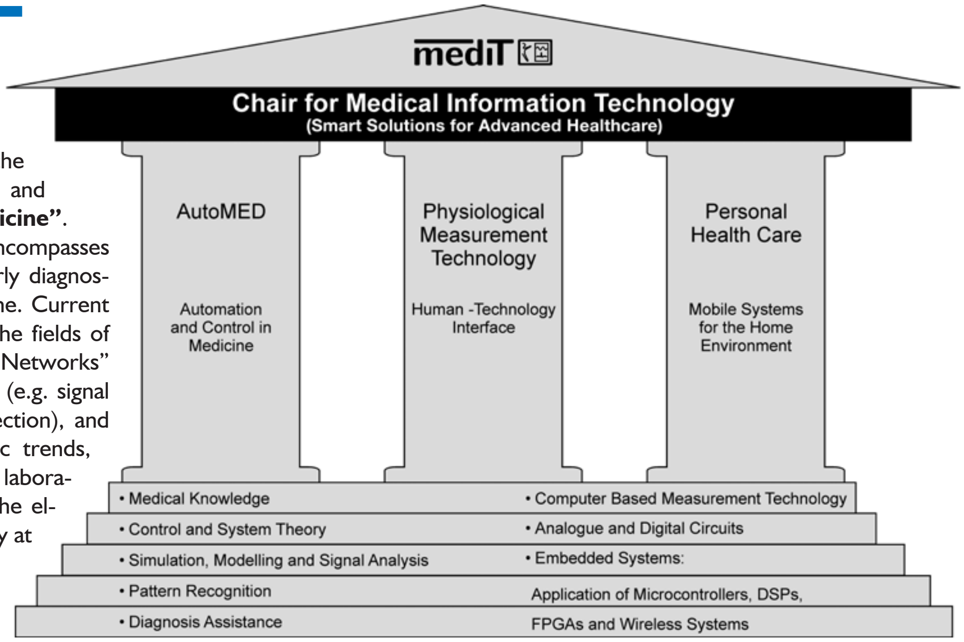

Fig. 1: Research profile of MedIT.

Where necessary and sensible, we also develop sensors and measurement electronics, for example, in the areas of non-contact sensing techniques (e.g. magnetic bioimpedance), bioimpedance spectroscopy and inductive plethysmography. We are also active in biomechatronics.

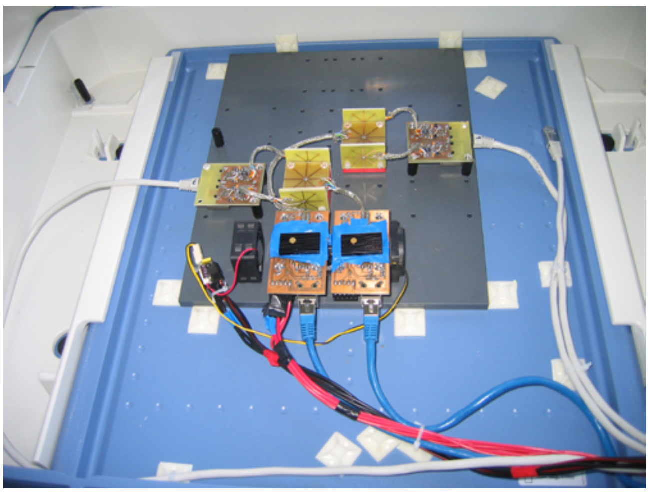
Fig. 2: Coil array sensor head.

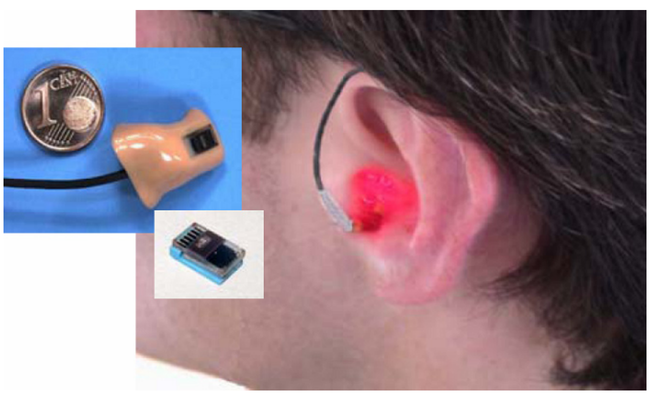
Fig. 3: Miniaturized optoelectronic sensor for in-ear pulse oximetry.

Ongoing Research Projects

Non-Contact Monitoring of Heart and Lung Activity

Heart and lung activity can be monitored through the measurement of electrical impedance fluctuations within the chest. These fluctuations are caused by the mechanical actions of the heart and lungs, which move matter of either high- (air) or low- (blood) electrical impedance throughout the thorax, thereby affecting both the local and average impedance distributions inside the chest. By applying magnetic fields to the body and observing the resulting magnetic induction, we can obtain a non-contact impedance measurement, which is applicable for heart and lung activity monitoring especially for patients under 24h monitoring or in Intensive Care Unit (ICU). The system can also be integrated in an incubator to enable contactless monitoring of the lung activity of newborns.

Funded by: Exploratory Research Space (ERS)

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

Cardiovascular diseases are among the most common causes of death in western industrial nations. Therefore, early determination of the cardiovascular risk factors is necessary in order to take preventive measures. As a part of the project, an optic 24/7 in-ear monitoring system (IN-MONIT) has been developed to assist in recognizing the irregularities of a subject's cardiovascular system. Its main component is a micro-optic remission/reflection sensor (MORES®) 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 wirelessly transferred to a Personal Digital Assistant (PDA) or a PC for further analysis.

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

SmartLifeSupport – HeartControl & SmartECLA

Many patients with severe cardiac insufficiency survive under the aid of Ventricular Assist Devices (VAD) or Total Artificial Hearts (TAH). The HeartControl project aims to realize an adaptive control algorithm for the Aachen VAD (VERSUS) and TAH (MiniACcor). Since it is not possible to continuously measure the blood pressure in the human body, other values have to be taken into account to get information about the patient's actual demand. Therefore, secondary control mechanisms as the respiratory system or the thermoregulation of the human body are used. For those systems, modeling and sensor development are investigated.
Within the project SmartECLA, optimization of oxygenators, physiological feedback, and control as well as safety concepts are in focus.

Funded by: German Research Foundation (DFG)

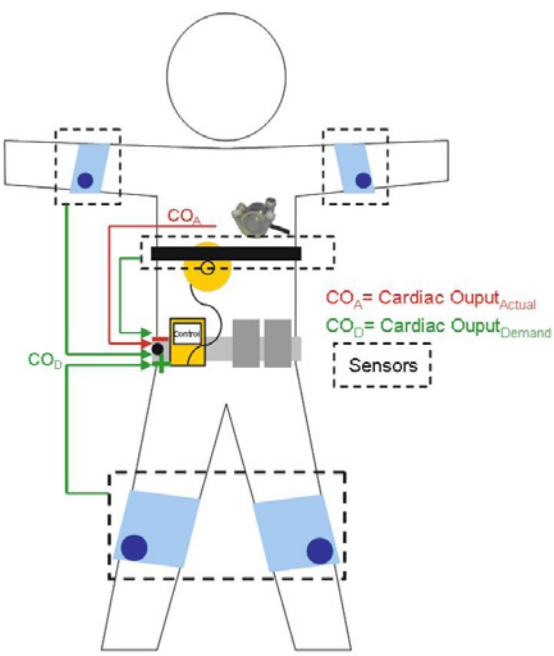

Fig. 4: SmartLifeSupport concept, HeartControl system.

Bioimpedance Spectroscopy and Intelligent Textiles

The natural aging process, sport activities or ill health, often leads to dehydration/overhydration with partly severe consequences. For an attending doctor, it is quite difficult to diagnose such cases since the symptoms are not very clear. 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 in the body. In this project, a mobile system will be developed using smart textiles to monitor the nutritional and water balance of human bodies. Advanced algorithms to detect activity and posture will allow an intelligent adaptation of the Nutriwear system to the daily life of the user. This innovation enables the 24/7 continuous mobile measurement of nutritional parameters. The advantages offered by textiles facilitate their integration into working routines and daily life.

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

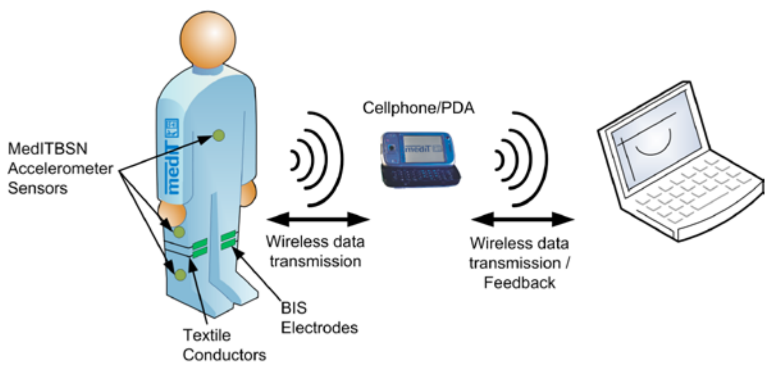

Fig. 5: Concept of a wearable bio-impedance spectroscopy system.

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 as reduction in oxygen supply and difficulties in carbon dioxide removal. The standard therapy involves artificial ventilation of the patient with an increased fraction of inspired oxygen and monitoring of several physiological parameters. 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.

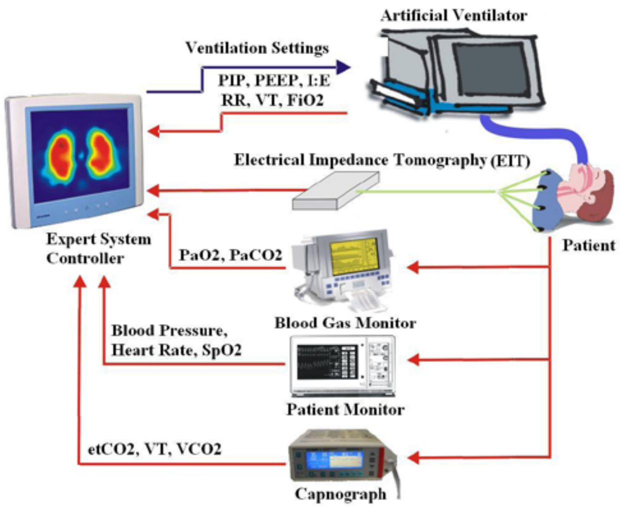

Fig. 6: Closed-loop EIT-based controlled system for individualized protective ventilation.

Control of Intracranial Pressure –towards an "intelligent Shunt"

Patients suffering from Hydrocephalus and high intracranial pressure are treated using a shunt (i.e. drainage catheter) to reduce the Intracranial Pressure (ICP) whenever it is too high. One of the biggest problems of the therapy is the mismanagement in the drainage due to artefacts in ICP, which can occur for example while coughing and moving. Too high ICP for a long time can be fatal; but also over-drainage is not healthy either. To prevent over-drainage, give the doctor information about the success of the therapy, and alert him for example when the shunt is blocked, an intelligent shunt with a mechatronic valve has to be developed. Towards the intelligent shunt, an external drainage has been developed which can adapt the liquor drainage of patients suffering from high ICP under acute care in an ICU. Additionally, analysis of the ICP dynamics and development of algorithms to control the liquor drainage according to the patient's condition are in process.

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

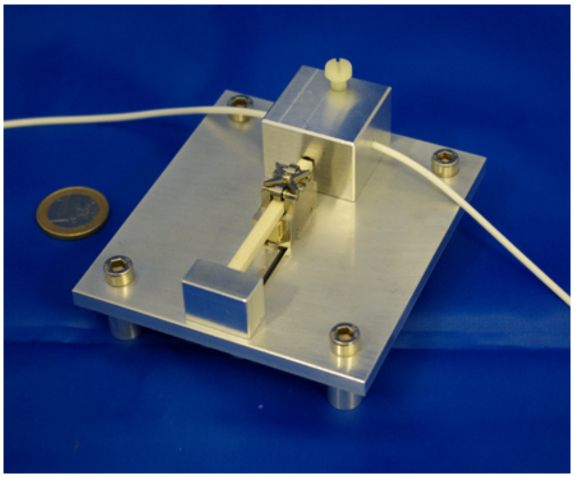

Fig. 7: Control of liquid flow within the external drainage.

Wireless Sensing and Control of Neonatal Core Temperature - Neothermic

Temperature measurement of newborn infants during the incubation period is vital and a major aspect in a regular Neonatal Intensive Care Unit (NICU) procedure. Therefore, developing a non-invasive and optimal temperature monitoring method is important for the neonate's clinical care. The Neothermic project will lead to the development of an incubator that responds to any physiological and pathological disturbance on neonatal status in a robust and stable way. Additionally, we investigate the efficiency of a non-contact thermography system. Accordingly, the project consists of prototyping an optimal and adaptive control system for the infant incubator, real-time infrared thermography imaging, and monitoring of respiratory and ventilation function of neonates.

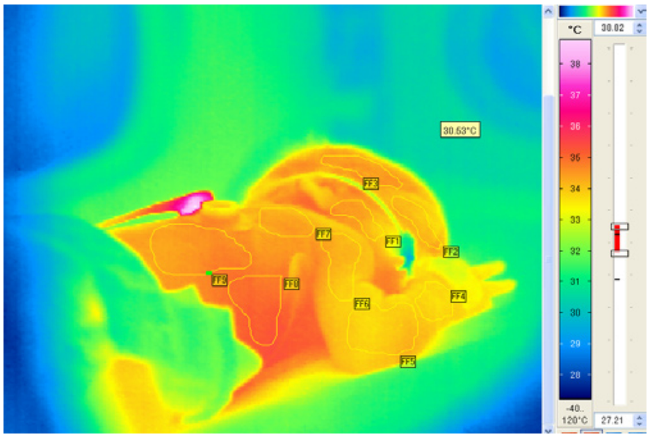

Fig. 8: Thermographic image of a neonate with automatic selection of regions of interest.

Non-Invasive Hemodynamic Monitoring

The assessment of hemodynamic parameters (i.e. cardiac output or stroke volume) is vital for the improvement of Chronic Heart Failure (CHF) therapies. Nowadays, the gold standard method for measuring these parameters is the thermodilution method, which involves using a pulmonary artery catheter. However, the method is usually associated with high risk of infections, sepsis, and arrhythmias, as well as increased morbidity and mortality. To overcome these problems, a textile-integrated bioimpedance measuring system shall be developed, which will allow monitoring of hemodynamic parameters non-invasively at home. Alternative electrodes positions, combination of measurement techniques, computer assisted simulation of the thorax models, along with others will be considered in the project.

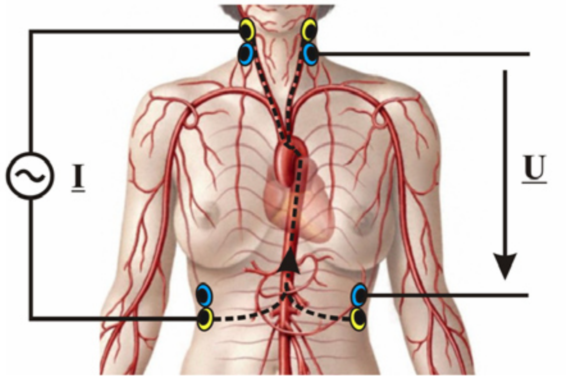

Fig. 9: Measurement Principle of Impedance Cardiography (ICG).

Intelligent Toilet Home Monitoring Appliance

An intelligent toilet system shall be developed for monitoring patient's health status, especially for those with diabetes mellitus type II or chronic heart diseases. Body weight and composition, heart rate, extremity perfusion, and urine-glucose levels will be collected in a fully automated manner while maintaining the simplicity of conventional toilet. Besides of the development of high sensitive measurement electronics, algorithms for extraction of key parameters have to be found. The extracted parameters will be stored in a relational database for automatic long-term trend analysis by an expert system.

Funded by: Federal Ministry of Economics and Technology (BMWi)

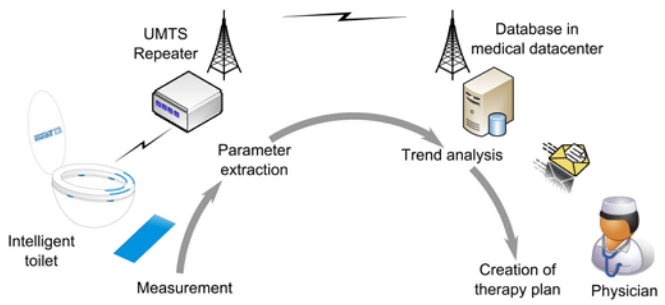

Fig. 10: Concept of Smart Toilet for Home Monitoring Applications.

HeartCycle – Compliance and Effectiveness in HF and CHD Closed-Loop Management

The EU project HeartCycle aims to improve the quality of life and care for patients with coronary heart disease or heart failure by developing a personalized complete care system, which integrates care at home with professional care in the hospital. The system consists of two loops; an inner home-based loop directly interacts with the patient in his daily life, and an outer one, which supports medical professionals with a Decision Support System and maintains individualized plans for optimal therapeutic strategy. Algorithms for deriving conclusions / decision support from parameter analysis shall also be developed.

Funded by: European Union (EU)

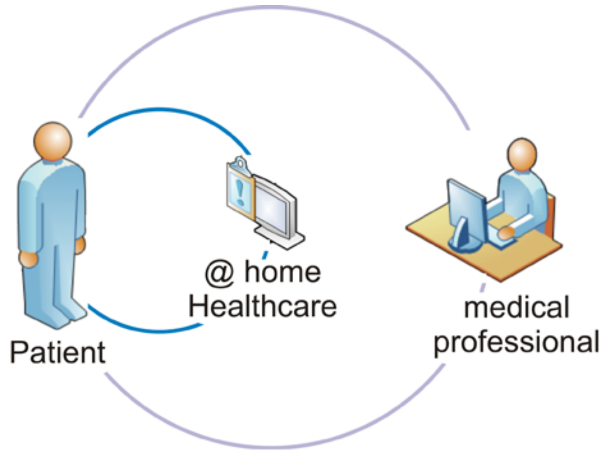

Fig. 11: Home- and Professional-based Loops.

Diagnostic Solutions for Mobility

The demographic changes that many countries are going to face will be accompanied by an increasing number of elderly car drivers, and thus automotive medical support is coming into focus. To monitor vital signs of car passengers, like electrical and mechanical heart activity as well as breathing rate, we investigate and implement non-contact monitoring methods, namely capacitive ECG monitoring (cECG), ballistocardiograms (BCG), and magnetic impedance systems. Incorporated in the driver- and the co-driver seat, we could show the feasibility of unobtrusive cardiac monitoring whilst normal driving. Apart from measurement technology, this scenario poses specific challenges concerning movement artefacts contained in the measurement signals which have to be addressed by advanced signal processing methods and real-time embedded software.

Fig. 12: Test car for automotive medical support solutions, labels added afterwards.

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Prizes and Awards

- T. Wartzek: 1st Prize in the Competition for Young Researchers at the AUTOMED 2009 conference.
- R. Pikkemaat, L. Fieten, K. Radermacher, S. Leonhardt: Innovation Award for Medical Engineering 2009 of the German Federal Ministry of Education and Research (BMBF) for the project "Regelung der chirurgischen Fräskopfführung auf Grundlage richtungsspezifischer elektrischer Impedanzanalyse".
- S. Leonhardt: appointment as adjunct faculty at the Computer Science Department, Virginia Commonwealth University, Richmond, VA, USA

Team

People at MedIT