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Centre for Integrated Electronic Systems and Biomedical Engineering – CEBE

The Centre for Integrated Electronic Systems and Biomedical Engineering (CEBE) has been established in 2008 (www.cebe.ttu.ee) by the Faculty of Information Technology at Tallinn University of Technology. It is one of the seven Estonian centres of research excellence, which are supported by EU structural funds. It consists of research teams of the Department of Computer Engineering, Department of Electronics and Technomedicum.

CEBE is a natural extension of long-term cooperation between the research teams. A new modern Embedded Systems and Components research environment was recently jointly established in frames of the project SARS, EU23626. It consists of three baselabs: Communicative Electronics (SIE), Micro- and Nanoelectronic Components (MINAKO), and Synthesis and Analysis of Embedded Systems (ASSA) as the ground for research activities in CEBE. The partners of CEBE are also the founding members in the Competence Centre in Electronics, Info- and Communication Technologies (ELIKO, EU22640), which was established with the goal to develop innovative technologies, based on intelligent embedded systems, through strategic cooperation between the science and industry sectors.

The mission of CEBE is to carry out fundamental and strategic interdisciplinary R&D in the fields of electronic components and systems, and computer and biomedical engineering by a collaborating consortium with applications in medicine, semiconductor and information technologies. New methods and tools are developed for design, verfication, test and debugging of mission-critical and dependable embedded systems, based on nanoelectronics and sensor networks. The cooperation network of CEBE with highlighted main research topics is depicted in Fig. 1.

One of the most important application targets for CEBE is to contribute to biomedical engineering. A new paradigm – patient-centric health care – is emerg-

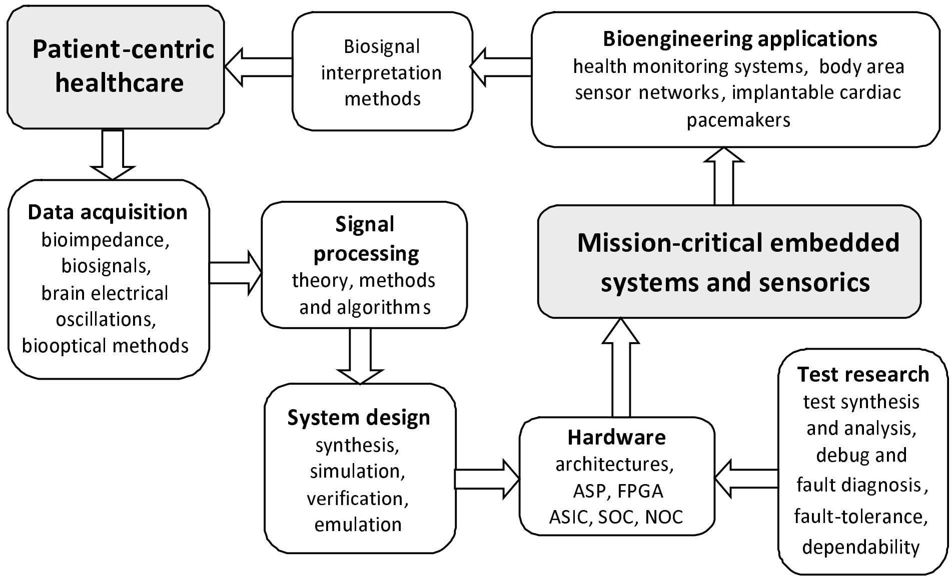

Fig. 1. Cooperation network in CEBE.

ing today to provide each citizen with accurate and up-to-date information regarding diseases and conditions, diet and exercise, and other health-related issues. This new paradigm cannot have a real effect without technological support. Big and heavy systems in the medical diagnostic centres must be replaced by small and flexible instruments, following the patient. Mobile and wearable equipment, lab-on-a-chip type analysing microdevices for on-site medicine for treatment at the place (home, workplace, street, accident or recreation area, also hospital ward) are the basis of the new paradigm, targeting diagnosis and care, point-of-care treatment by implantable devices as cardiac and brain pacemakers, automatic syringes of insulin and other medical devices. Lab-on-chips are considered to be the devices of the 21st century. They are complicated on-chip systems containing computers, sensors and actuators, electrical, mechanical and microfluidic components and also communication links for body area and personal area networks, which are connected into local and wide area networks. A new generation of medical devices is under development, which includes specific mission-critical communicative embedded systems with highest grade of dependability. This is the field where CEBE is currently contributing.

In a close cooperation between partners, new signal processing methods and new architectures for dependable signal processing are being developed in CEBE to be applied for analysing different biosignals in order to improve existing and develop new non-invasive methods for medical technology. The main research topics in biomedical engineering are: brain research, diagnostics of cardiovascular diseases, sudden cardiac death prediction, and bio-optical monitoring.

This research is coupled with applications in health monitoring systems, body area sensor networks and implantable cardiac pacemakers. An active scientific work is directed to understand and affect the processes in the brain, to monitor blood pressure and cardiovascular diseases, to study potentially dangerous myocardial arrhythmogenic behaviour, and to monitor end-stage renal disease patient treatment quality. Analysis of brain bioactivity signals (EEG/ERP/EP), also linear (spectral, correlation) and non-linear (entropy, length distribution of low variability periods) independent component analysis (ICA) of biosignals are utilized.

The described research and applications in bio- and medical technology are closely tied with research in electronics technology and computer hardware design, where new methods for signal and data acquisition, signal processing algorithms, reconfigurable processor architectures, and applications of impedance spectroscopy are being developed. New complexity-reduced processing of sensor signals using non-uniform synchronous sampling in time and space domains allow to minimize computational power, energy consumption and electronic circuitry. The research is focused on mixed signal (analogue/digital) specific processors which will make a revolution in development of implantable and wearable biomedical technology where the energy supply problems have to be solved effectively, e.g. using human body heat and other energy harvesting methods. Another research objective is BioMEMS, the next generation of biomedical devices requiring novel, function-specific, and ultra low power signal processing methods and means with reduced complexity. Impedance spectroscopy will become an effective sensoric tool for getting the biological and physiological information from living matter. Reducing of digital complexity will depend mainly on the processing algorithms, whereas the methods and algorithms for joint time–frequency analysis will determine greatly the success of embedded signal processing. The research objectives are also metal–semiconductor and metal–biomaterial interfaces for the developing of structures for semiconductor devices and electrodes for lab-on-chip devices.

Reliability of biotechnology is crucial, because the biomedical devices must operate without human supervision and control (indoor and outdoor environments, on the skin and under the skin) during several years without interrupting. On the other hand, the scalability of electronics technology, approaching to physical limits, causes serious dependability problems. Ultra-thin wires and insulation layers exhibit a reduced level of long-term stability. As a result, the design methodology of complex microelectronics-based systems has to deal with reduced reliability of underlying hardware. Dependable systems have to be created from unreliable hardware and software components. Technology forecasts expect higher rates of permanent and transient faults, which make fault-tolerant design, built-in self test, embedded fault diagnosis, and self-repair capabilities a necessity. Such techniques are suited to facilitate long-term dependable circuits by self repair in the field of application. The roadmap of semiconductor industries sees a requirement of such technology by about 2012.

The main objectives of the research in design and test of embedded digital systems include modelling and synthesis, verification and debug, test generation and fault simulation, self-test, diagnosis, and fault tolerance. The primary objective is to find suitable integrated methodologies to cope with the complexity in developing reliable applications out of non-reliable circuits, to reduce time-to-market and to ensure high quality and reliability of embedded systems by developing new methods for design and test. It includes design methods of heterogeneous electronic systems, improved efficiency of simulation and verification, diagnostic modelling and test generation, based on recent results in the decision diagrams theory, hierarchical functional test generation, defect analysis methods, and fault tolerance methods for new emerging systems architectures. Prototype tools will be created to prove the correctness of concepts and hypotheses and to evaluate new solutions.

CEBE includes around 80 researchers, about 40 of whom are senior staff members and the rest are PhD students. CEBE has an international advisory board consisting of 10 world famous scientists in the CEBE fields from Germany, France, UK, Finland and Hungary. During the last 5 years, scientists of CEBE have been involved in 14 projects within EU FP5-FP7 and other international programs, which has led to a widespread cooperation with leading research teams of EU and worldwide. More than 120 joint papers with researchers from 15 countries have been co-authored. CEBE researchers are behind 2 high-tech start-ups and are holding 25 patents. CEBE is cooperating in Estonia with ELIKO, Artec Group, Smartimplant, Cybernetica AS, Elcoteq, National Semiconductor Eesti, Clifton AS, JR Medical, AS LDI, LDIAMON AS, Tensiotrace OÜ, Girf OÜ, AB Medical Service AS, also with 2 clinics and 4 Estonian hospitals. Internationally CEBE cooperates with several world leading industrial companies like St. Jude Medical, National Semiconductor, TDI Inc., Göpel Electronic, STMicroelectronics, AerieLogic, TransEda and some others.

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