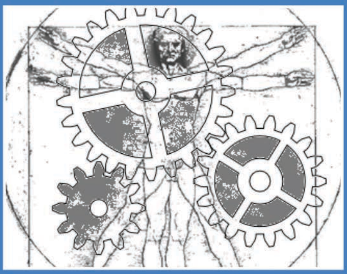
Prof. Pierre-André Farine, EPFL

BodyPoweredSenSE

WEARABLE ICT FOR ZERO POWER MEDICAL APPLICATIONS

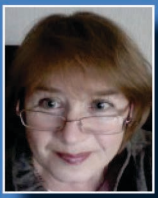


Prof. David Atienza, EPFL

Dr. Danick Briand, EPFL

Prof. Thomas Gross ETHZ

Prof. Christofer Hierold, ETHZ



Dr. Maria Knyazeva, CHUV

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What it's about…

Developing smart, energy aware, user friendly wearable sensors and associated medical algorithms for the early diagnosis of Alzheimer's disease and childhood epilepsy, where the sensors derive power from the user's body energy (heat and motion) as well as from ambient light.

Context and project goals

Increasingly the analysis of a patient's physiological state requires long-term monitoring, during day to day activities, in order to precise a diagnosis or to evaluate the efficacy of an on-going treatment. Although wearable sensors can significantly benefit mankind in this long-term monitoring process, today's solutions invade the user's normal life as sensing platforms require removal, replacement and reconfiguration for battery recharging. Moreover, they are often too large, user-unfriendly and difficult to interpret their results.

Zero power medical devices can revolutionise human sensing, as new software and hardware architectures will lead to drastically lower power demands. Energy will then be harvested from natural sources (body heat, body motion, solar) such that recharging is no longer a prime necessity. Hence, users will experience a plug and play, near unperceivable, "forever on" usage pattern thereby enabling very long data capture periods not feasible today.

This project will support this zero power technology paradigm and apply them in realistic, demanding and extremely relevant use cases: the early prediction of Alzheimer's Disease (AD) in the elderly and the diagnosis of epilepsy (EP) in young children.

The research follows a layered approach starting with the design, development and fabrication of the natural energy harvesting sources. Then, in this project we will integrate them into a wearable platform, called ZPSense, in which the energy will be optimised in a global process to minimize the wastage of energy conversion and storage. The ZPSense platform will leverage very low power microprocessor and sensing circuitry optimised for bio-signals and fabricated to fit into highly ergonomic devices. A new approach to energy aware software design and multi sensor integration will ensure the ZPSense platform to operate at maximum quality of service for a given energy profile.

The ZPSense system will include a 24-channel EEG, a three-channel ECG and a novel patient environment monitor. It will interoperate on a body area network performing a multi-parametric analysis and fusion resulting in a more complex medical analysis than using three sensors separately. Using state of the art algorithms, the system will allow health care workers to more effectively diagnose AD and EP. The ZPSesnse system will be tested with real patients and will be thoroughly evaluated to determine their clinical and user satisfaction. Since care at home is the primary medical motivation, the industrial partners BodyPoweredSenSE will ensure a generic approach to health care at home, captured in a flexible friendly Home software application, as well as a user-centered design approach putting the user's needs at the centre of the ZPSense's ergonomic design.

How it differentiates from similar projects in the field

The fields of energy harvesting, energy aware computing, bio-medical wearable sensing, and medical diagnostic computational algorithm are all deeply researched topics at this time. This project is different in that it sums the needs and benefits of each of these fields into a synergistic whole. Every research aspect incorporates an understanding of the other and aims to deliver an overall superior solution technologically, medically and for the human benefit.

Quick summary of the project status

The energy harvesting work by SAMLAB and MNS has resulted in several prototypes being tested in the laboratory. TEGs have been integrated into headwear and the stretching piezo composite materials are being evaluated both on machines and to some extent on laboratory volunteers. The energy conversion to storage research of ESPLAB continues well with some silicon having been designed and a tape out due soon. The energy aware run time of NSG has been designed and design of the embedded clinical applications for ECG and EEG have begun as well as the design of a test hardware platform so that real time energy consumption during SMART sensing can be evaluated.

At the clinical level, NSG is working with KS to finalize the set of epilepsy detection algorithms and CHUV has begun testing EEG algorithms to detect localization patterns that could be used to detect degradation in neural pathways using low density EEG. ESL has begun work on system level networks and potential means to save energy through collaborative system behaviors.

Success stories

Presence in the media:

L'Express, Mercredi 17 juillet 2013, *Le corps producteur d'électricité.*

Main publications

Milad Ataei, Christian Robert, Alexis Boegli, and Pierre-André Farine, Design of an Integrated Thermoelectric Generator Power Converter for Ultra-Low Power and Low Voltage Body Energy Harvesters aimed at EEG/ECG Active Electrodes, In Journal of Physics: Conference Series, vol. 557, no. 1, p. 012017. IOP Publishing, 2014.

Ruben Braojos, Ivan Beretta, Giovanni Ansaloni and David Atienza, Early Classification of Pathological Heartbeats on Wireless Body Sensor Nodes, Sensors, vol. 14, num. 12, p. 22532-22551, 2014.

Ruben Braojos, Hossein Mamaghanian, Francisco Rincon, Alair Dias Junior, Giovanni Ansaloni and David Atienza, Ultra-Low Power Design of Wearable Cardiac Monitoring Systems, IEEE/ACM 2014 Design Automation Conference (DAC), San Francisco, CA, USA, 2014.

Ruben Braojos, Ahmed Dogan, Ivan Beretta, Giovanni Ansaloni and David Atienza, Hardware/Software Approach for Code Synchronization in Low-Power Multi-Core Sensor Nodes, IEEE/ACM 2014 Design Automation and Test in Europe (DATE) Conference, Dresden, Germany, 2014..

Hossein Mamaghanian, Giovanni Ansaloni, Mohamed M. Sabry, David Atienza and Pierre Vandergheynst, Hardware-Software Inexactness in Noise-aware Design of Low-Power Body Sensor Nodes, Designing with Uncertainty - Opportunities & Challenges, York, United Kingdom, 2014.

Ruben Braojos, Ivan Beretta, Jeremy Constantin, Andreas Burg and David Atienza, A Wireless Body Sensor Network For Activity Monitoring With Low Transmission Overhead, The 12th IEEE International Conference on Embedded and Ubiquitous Computing, Milan, 2014.

Elham Barzegaran, Cristian Carmeli, Andrea O Rossetti, Richard S Frackowiak, Maria G Knyazeva , Weakened functional connectivity in patients with psychogenic non-epileptic seizures (PNES) converges on basal ganglia, Journal of Neurology, Neurosurgery and Psychiatry.

"Keep your friends close, but keep your medical sensors closer…"