An open source healthcare sensor platform
for electrical engineering education and deployment

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INTRODUCTION

At the department of electrical and electronic engineering of Fontys University of Applied Sciences we are defining a real-life learning context for our students, where the crossover with regional healthcare companies and institutes is maximized. Our innovative educational step is based on openly sharing electronic designs for health related measurement modalities as developed by our students. Because we develop relevant reference designs, the cross fertilization with society is large and so the learning cycle is short.

The philosophy behind openly sharing designs is based on context-rich short cycle learning. Teaching from engineering theory books has a slow adaptation towards societal trends. More fresh knowledge can be gained from the Internet and scientific papers, but real self-directed learning can only be initiated by doing projects having a societal relevance. In our open platform, we share results in order to challenge external parties to feed projects with real contexts.

The question is whether our engineering students can be involved in real world design opportunities by developing robust electronic modules. While the current educational curriculum for the students can be characterized by designing micro electronics for Internet of Things and Cyber Physical Systems [1] like products, the link to the regional businesses presented in this paper can be seen as the research line connecting the activities in the regular educational curriculum. Our method to find the answer to this question is to start the design of medical sensor modules pro-actively, and offer them openly on a public Wiki webpage. As a result, we have already seen the first follow-up projects with external institutes on applying the proposed sensor modules to real-life needs.

1 THE ELECTRICAL ENGINEERING OPPORTUNITY IN HEALTHCARE

Education fulfils a crucial role in today's hi-tech society, and is therefore subject to actual trends. Fundamental changes can be seen in how students deal with education. At our department for Electrical Engineering we are in a process of introducing application themes in our education as an answer to this trend. One of the themes is healthcare, which is an application area that is in a clear paradigm shift. As a consequence, our educational methods and our education content must change.

Some of the trends in healthcare affect the supply chain of care-related knowledge and technology. Healthcare is no longer a curative action of doctors in a hospital. The diagnosis and cure of diseases is coming out of the professional environment to our homes and neighbourhoods. For cost-down and early detection of more complex conditions, it is no longer feasible to involve a professional for every single pain indication, health question, or diagnosis for each patient. In addition, the conditions to detect diseases have become more complex. Historically the process of diagnosis was up to a certain level deterministic. For example, we could measure fever with a thermometer, heart abnormalities with an ECG recording, and urinary tract infections with a urinalysis to find bacteria and white blood cells. Nowadays, diseases having a major impact on society are sometimes the result of specific societal conditions. Think of obesity, stress [2], addiction, learning and development disorders [3] and cardiovascular diseases. These are referred to as epidemic diseases and public health problems. With these diseases where both physiology and behaviour is involved, we have to screen in natural environments to find patterns in lifestyle and behaviour. As a result, modalities for measuring physiological phenomena are now applied in ambulant care settings without direct supervision of professionals [4]. The technological shift that is needed is conform the Data-Information-Knowledge-Wisdom (DIKW) triangle [5] expressing how raw data can be combined into a higher value resource of information. We need multiple sensor sources (polygraphy) to enable estimation of behaviour, which could never be measured with a single sensor in ambulant situations.

As an extension to the need for ambulant care, explorative research and design projects are aiming at the measurement of physiological parameters in everyday life. For example, a development team may think of an advanced sports support tool that monitors calories burnt in the human body [6]. Another example can be a smart textile project [7] in which soft wearables are made interactive by stress estimation from heart-rate variability. Such projects and the associated research groups normally focus on the application development, the envisioned function or the materials. The electronics for monitoring the physiological parameter is normally a means of the project and not a goal. The academic challenge of implementing such electronics is not seen as a core challenge of the project, because the common methods are described in literature. However, when the electronic circuit is finally needed in the project, it appears that it is not simply available as an open platform. Therefore, it has to be developed by concept designers with only basic electronic skills, and as a result, the implementation is prone to poor quality and common basic electronic mistakes are likely to be made.

2 THE ENGINEERING DEPARTMENT

The Fontys University of Applied Sciences, shortly referred to as "Fontys", is a knowledge and educational institute with over 4100 employees and about 42.000 students [8]. Within Fontys, there are 29 institutes that offer 85 bachelor programmes and 26 master programmes. Fontys courses are offered at 22 locations within the Netherlands, with a high concentration of institutes in the southern part of the country. One of the major campuses is located in Eindhoven, which is home for the Engineering institute comprising the Electrical Engineering, Mechanical Engineering, Mechatronics and Automotive tracks. The engineering programmes are offered in Dutch and English in order to create an international environment for learning.

The city of Eindhoven is strategically beneficial where it hosts research departments of many multinational companies. It has established a position as a major design centre and is a breeding place for new enterprises. Eindhoven forms a triangle with Leuven in Belgium and Aachen in Germany which is seen as an innovation high-tech area. This geographic location is also very suitable for the specific field of healthcare. Companies like Philips and Imec are doing their health related research and development in the region. Eindhoven has two hospitals with prominent centres of expertise for cardiovascular and perinatology respectively. Within the triangle as mentioned before, there is the academic hospital in Maastricht with a research department of Medtronic next to it.

The educational curriculum of the Electrical Engineering programme of Fontys is created to deliver engineers as designers of electronic solutions. With that denominator, the courses are very suitable for collaboration with external stakeholders. From the second year on, students work in quarterly projects with 6 to 8 students. These projects are referred to as “Engineering eXPerience Organization (EXPO)” projects, and are an appropriate means to bring students into contact with external parties for solving problems of low complexity [9]. In the third year, there is an internship at a company where the students do a design project. Finally, there is the “Integrated Product Development (IPD)” group project in the forth year, which prepares the students for the individual graduation project. These projects where students have to solve real-life problems under the supervision of teachers, are our lever to do research by connecting students with professionals.

So the geographic and demographic location of Fontys, together with the applied practical orientation, makes it a very suitable competence centre for developing electronic modules for healthcare applications.

3 TRENDS IN ENGINEERING EDUCATION

Cooperative learning of student teams is common practice, and proven to be successful by longitudinal studies [10] and supported by methods to get the most out of it [11]. It falls back to fundamental learning methods as referred to as Social Constructivism by Vygotsky [12]. In addition, it is known that students learn from co-creation with industry [13]. Successful study programmes have been formed around a combination of learning from teamwork, and involving industry in defining projects as a learning context [9]. Our approach is to go a step further: we are not just feeding our University project teams with design questions from industry but we share knowledge and results publicly in order to speed up cross-fertilization with many external parties.

4 PROPOSAL: THE EDUCATIONAL PLATFORM

As a solution to the paradigm shifts in education and the application field of healthcare, and using the demographic advantage of the city of Eindhoven as a design and technology area, we started the development of an educational platform that goes beyond the project-based educational program. The core of the platform is an online open Wiki page [14]

In our educational platform, we openly share healthcare related sensing modalities. The method used is the development by students and for students. For example, with Electrical Engineering students we develop modules for measuring bodily functions. These are documented in such a way that someone who is less experienced with electronics can replicate it. Subsequently, a design student can work on an electrode integrated in textile. With these ingredients, a psychology or sports technology student is facilitated in doing field experiments for monitoring the influence of human behaviour on heart rate.

The stakeholders in need for electronic modules to monitor bodily functions are identified as companies, educational institutes and research institutes. They are in the application field of healthcare (from diagnosis to care and cure), professional sports and leisure sports, and interactive art installations. We have started to develop reference designs for the most common methods for measuring bodily functions. In the projects, the basic reference designs are made and documented, either on demand or on our own initiative.

Besides developing the prototypes in projects, and subsequent publishing the circuit and reference board layout, the built-up knowledge is educated in courses. A course "Sensor Technology" is given in the fourth year to our own Electrical Engineering students, and a broader "Measurements on the Human Body" course is given to the Fontys Centre for Healthcare and Technology [15].

In this way, we make the knowledge available for our own students who follow Fontys courses, but also for explorative research in other disciplines and for external institutes. The only condition we ask for borrowing electronic designs from Fontys is that the experience comes back to improve the reference designs. In the next section, some reference designs and one successive application project are given as an example.

5 TECHNOLOGY: EXAMPLES

The practical work so far, is focused on two approaches. The first approach is to estimate physiological states of people. Modules for measuring heart rate, breathing rate, core body temperature and fall detection are at a satisfying level. Modalities in this first approach are normally worn on the human body for unobtrusive measurements. The second approach is to install modalities in the living area of the person under test in order to estimate behaviour. The first steps have been made by two projects. In one project a person's body weight is measured in an office worker's chair. In a second project, the stress levels of mentally disabled youngsters in special houses are monitored in order to predict aggression attacks. Some of these examples are described below.

5.1 Heart rate by photoplethysmography

A non-invasive method for monitoring heart-rate is based on photoplethysmography (PPG): the optical method of measuring the pulsation of blood in for example the ear lobe [16]. We have developed a reference design using the infrared HRM-2511B ear clip from Kyto Electronic Co. in China [17]. An example of a realization of the reference design on an experimentation board is shown in *Fig. 2*.

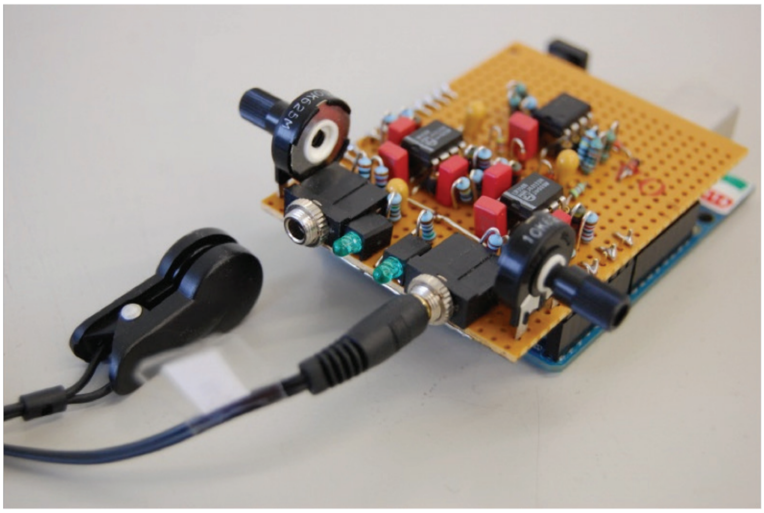

Fig. 2. A prototype for monitoring heart rate by means of the optical method of Photyplethysmography

The PPG reference design has not only proven a high didactic value because of the electronic filter implementation, but has especially found a wide field of applications for monitoring sports and stress. It was used by the University of Tilburg (The Netherlands) for measuring stress based on Heart Rate Variability at their psychology department.

5.2 Accelerometry for fall detection

There are many accelerometer modules commercially available that are optimized for wearable applications. However, in all cases, they come as a closed product. There is neither direct access to the data, nor an option to implement custom algorithms. In the vision of our open source platform, we are currently developing both hardware and algorithms for the 3D detection of motion, with the carrier application of fall detection. In *Fig. 2* and *Fig. 3* there is an impression of fall tests with our students and the recorded accelerometer signals measured on the wrist.

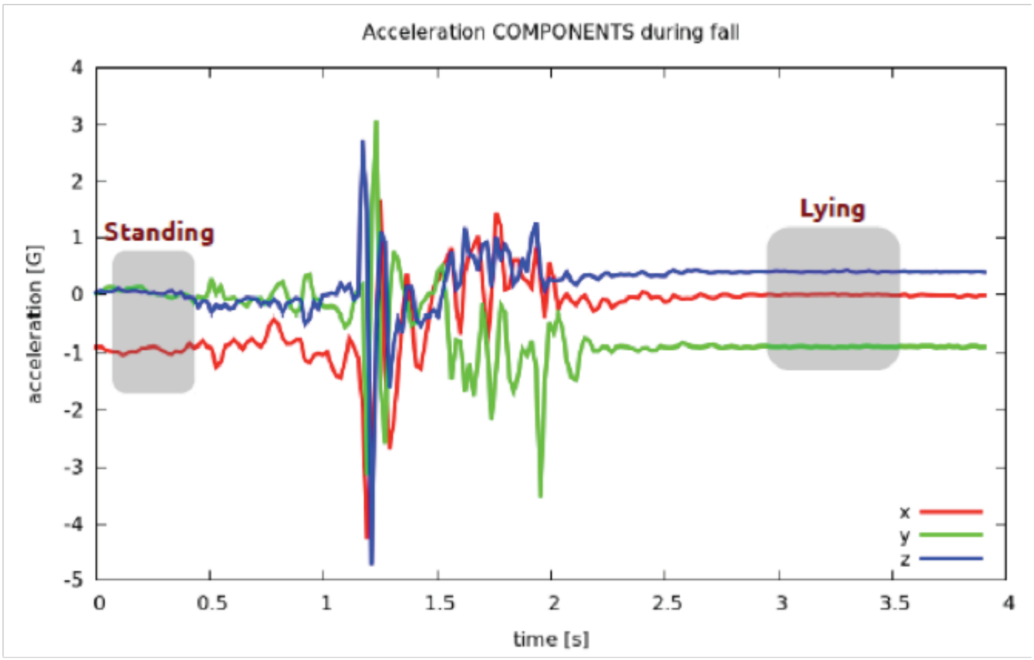

Fig. 2. In the project for fall detection, students made a microcontroller module that is able to detect indicators of falling for the use with elderly people

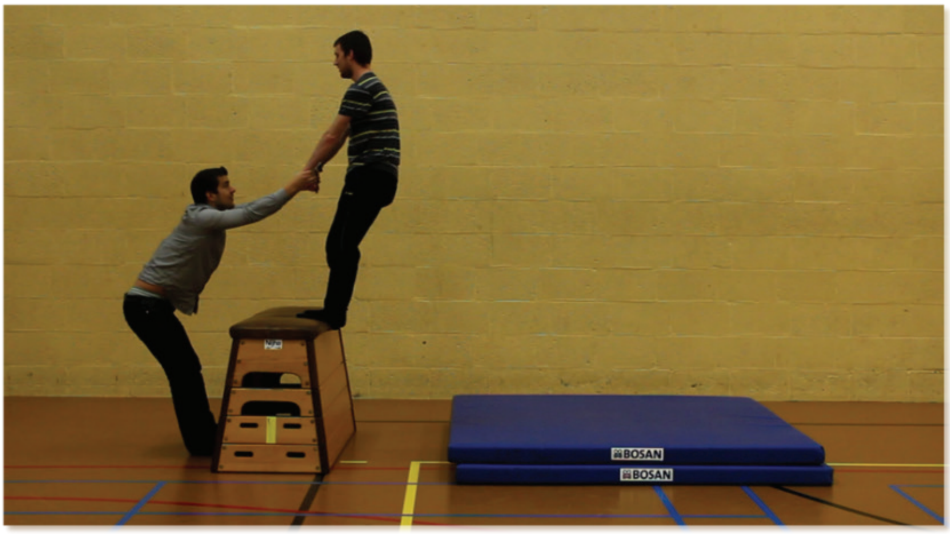

Fig. 3. Impression of creative fall experiments

6 THE ROSA PROJECT

Severinus is a care organization located in Veldhoven, the Netherlands It provides inclusive care to persons with mental disabilities. These people are vulnerable and often unable to express and regulate their mental state or discomfort like pain, stress, and anxiety. Assessment of excessive stress by the care givers is done by signalling plans on score lists using observations of behaviour. The project ROSA [18] aims to develop and implement an objective stress warning system, based on the polygraphic recording of behavioural and physiological patterns. The ROSE team found the Fontys Wiki page, and asked for participation by implementing sensor modalities.

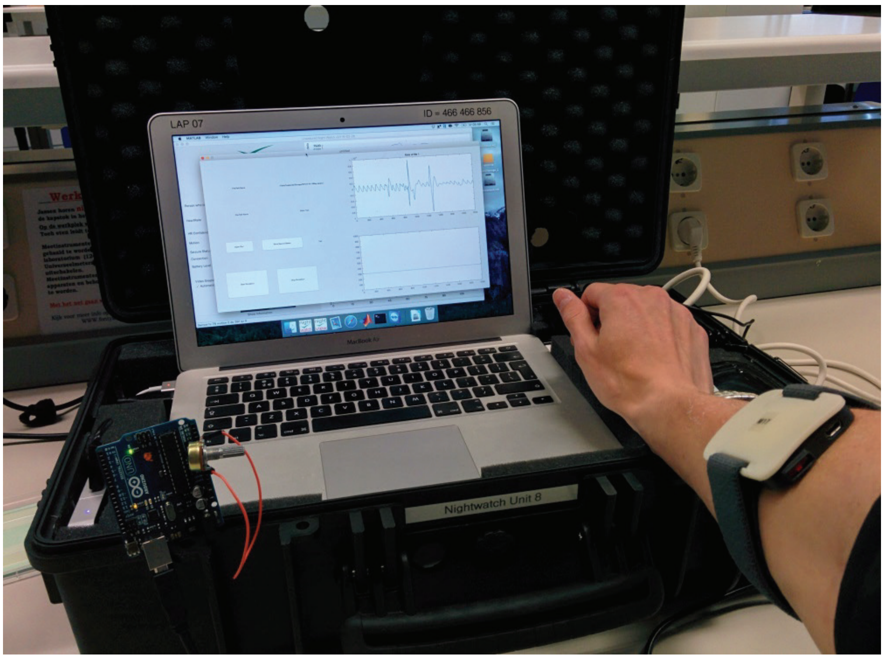

Fig. 4. The base station as the core of the ROSA project technical implementation

Our engineering students are assisting the project by addressing specific topics. A group of fourth year students has adopted a base station for centralized recording of physiological parameters as shown in *Fig. 4*. In addition, they have added new

sensing modalities like galvanic skin response as a measure for stress. After adding more physiological and also movement measurements, we can offer the care giver involved a system to investigate specific datasets. Based on this we can discover how excessive stress manifests in the signals, and automate the estimation process.
From an educational perspective, this project is interesting because basic courses like programming, sensor systems and signal processing are placed in a real life context. Secondly, the project is a longer initiative on which we can base a continuous line of student teams.

7 FUTURE WORK

With respect to the question whether students can be involved in real-life, we have made a proposal for the most promising technology modules (measurement modalities) that fit in our educational curriculum. What has to be developed further are the structural partnerships. These will guarantee continuity and they will create evidence that there can be a fluid crossover between our students' work and the need in society. The first sensing modules were based on our own common sense of what is needed in the world: the partners will bring in new application areas. What we do expect is that reference designs for networks of sensors have to be added as well, because of the added diagnostic value [19].

8 CONCLUSION

To summarize, the open source platform development gives our students real-life contexts for learning innovative techniques and applications while our institute appears on the radar of the local professional development community with state of the art technology and knowledge. We realize we are on the onset of a learning curve. Some technical successes are needed to become an expertise centre for providing technology to measure people's behaviour. Our long term goal is to create opportunities for students to start their own businesses with the technology developed during their study. At this moment, we have already experienced that the students involved do see the direct application value of some of the basic courses, especially signal processing, analogue electronics, sensor technology and embedded software. We also observed that the students of our applied university are probably not the right candidates when it is about inventing completely new physical sensor principles. However, they can have a serious value for companies in the region by implementing sensor systems based on the integration of proven technology.

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