Healthcare Needs, Company Innovations, and Research - Enabling Solutions Within Embedded Sensor Systems for Health

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Abstract. This paper presents a research, innovation, and collaboration initiative at Mälardalen University in Sweden, within embedded sensor systems for health (ESS-H). ESS-H uses the needs of patients and caregivers as a starting point for identification of problems, and from this the development of new sensor systems to monitor elderly and/or multi-morbid people in their home is performed. The development of these systems is performed together with industry in order to enable innovations to reach the market in a near future. The initiative has during its first three years resulted in about 100 scientific publications. There are several research prototypes on their way to become commercial prototypes, and both the industry and healthcare are happy to continue the collaboration. The concept seems promising as a model to be used when aiming at developing new technologies for the healthcare sector.

Keywords: Embedded sensor systems for health · Health technology · Home monitoring

1 Introduction

The healthcare system in the western world is under change, challenged by demographic changes and people not only with one disease, but multi-morbid. The point-of-care is moving from hospitals to homes, a trend that is foreseen to increase in the future. This will empower the individual, in that he/she gets a larger influence over his/her health. Distributed health monitoring systems, comprising embedded sensor systems, will thus have a large potential market, nationally in Sweden as well as worldwide, and has the potential to be used both in the prevention of disease and in the monitoring and control of physiological states.

The costs and volumes of healthcare are increasing, mainly related to an aging population, and to the proliferation of multi-factorial diseases such as diabetes, stroke, chronic respiratory diseases, and heart disease. Intelligent and adaptive systems for the sensing and evaluation of health status for prevention, monitoring and rehabilitation are

Healthcare challenges addressed by researchers and industry in close collaboration.

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amongst the most important elements in resource-efficient and individualized healthcare. Hence, the world market for products in the area of embedded sensor systems for health will grow tremendously in the decades to come.

The area of embedded sensor systems for health applications is rapidly developing, and there is a strong market pull for advanced intelligent sensor systems that strengthen or sustain the health of humans. Because of the rapid development and the market pull, research and product development is performed in parallel, and research results will be rapidly deployed in commercial products. The motivation from both a commercial and a scientific perspective is to be able to develop more capable and more dependable systems. From a commercial point of view, this means a competitive advantage. From a scientific point of view, this means contributing to an important area where the aims are to improve human health and minimize human suffering.

Embedded sensor systems for health is an important development and research area. The rapid development in physiological sensor and embedded systems technology gives possibilities for a broad deployment of sensor systems. This is an enabler for more intelligent and cognitive sensor systems; better informed systems as well as safer and more dependable systems, deployable in safety-critical applications (e.g. healthcare monitoring). To enable this, more efficient and predictable sensor nodes and communication techniques must be developed to match the development of the sensors themselves. This was one of the main challenges recognized by the EU ICT work program, FP7, and is also highlighted in Horizon 2020 [1]. For systems used in safety-critical applications, it is of uttermost importance that the behavior of the system and the dependability of the system can be tested and verified. Proper testing and verification of systems and system components will also enhance product quality and lower maintenance costs.

User friendliness, including intuitive use of the sensor systems, is essential in this application area, both with respect to safety and due to the fact that not all users (e.g. elderly and care staff) are familiar with this kind of technology. The involvement of users and focusing using their needs as a starting point in the development of new methods and systems is of large importance [2–8].

The aim of the present paper is to present a research, innovation, and collaboration initiative at Mälardalen University in Sweden, within embedded sensor systems for health (ESS-H). ESS-H uses the needs of the patients and caregivers as a starting-point for identification of problems, and from this, the development of new sensor systems to monitor elderly and/or multi-morbid people in their home is performed. The development of these systems is performed together with industry in order to enable innovations to reach the market in a near future.

2 Motivation

Changes in lifestyle, and increased expectations of a sustained high quality of life, also at higher ages, put new demands on our healthcare systems. To enable people to remain active, care providers need to provide wearable and distributed health monitoring systems, allowing people to continue their normal activities independent of location; at home, at work or in hospital. Monitoring of changes and trends in health status can

facilitate early intervention and prevent severe conditions to develop. Hence, this can prevent suffering for patients and it also means large savings for society. Moving the point-of-care from hospitals to homes is a trend that will increase in the future. Distributed health monitoring systems will thus have a large potential market, nationally as well as worldwide.

Chronic diseases, such as heart diseases, stroke, cancer, chronic respiratory diseases and diabetes, were accounted for over 60% of all deaths in 2005 [9]. Further, 80% of premature heart disease, stroke and diabetes can be prevented with life-style changes [9]. The high prevalence of multi-morbidity makes the situation even more complicated, especially in older patients (a prevalence up to 98% has been observed) [10]. Monitoring health conditions related to multi-morbidity generates huge amounts of data, and methods to handle this information are called for. Further, a holistic approach must be considered. The situation is complex, since multiple diseases often interact with each other, and so can the medication. It is important to focus on the patient and to consider all diseases and interactions to give the best possible care for the patient.

Innovative development in medical technology and new medicines are predicted to have a large influence on future development of the health industry. It is predicted that 30% of the economical resources in the US will go to the health industry in the year 2050. Also the Swedish healthcare's share of the national budget, today 9% of the GNP, is predicted to increase due to an increasing demand on services that promote health-related quality of life [11].

The above needs and future market possibilities have drawn the attention of several of our industrial collaboration partners, as well as healthcare providers, e.g. Västmanland's county council and the municipality of Västerås. As a result of this, a cluster of health technology companies is identified.

3 Working Methods

The present research, innovation, and collaboration initiative within embedded sensor systems for health has several pillars that support the model. The collaboration with caregivers and presumptive end-users of the systems is crucial in order to identify the real needs. Research competence that can solve real problems and develop embedded sensor systems is just as important. Finally, the adoption of industrial partners in the project group is aimed at overcoming the common gap between research prototypes/solutions tested in project form and the final introduction into the market.

3.1 Identification of Needs and Challenges in Healthcare

Traditionally, development of new technology often has been technology driven, i.e. new technology has been introduced mostly because it is available. This is to a certain extend also true for the healthcare sector, and thus many systems have been introduced, which have not been based on actual request from the healthcare. Many of these technologies have anyhow meant a lot to healthcare, but still the spread might have

been larger and even more successful if the starting point had been an actual need and request from the healthcare.

By including care staff, patients, relatives or workers, depending on the situations, throughout the whole development chain, the technology will be welcomed when ready to introduce in the care. Thus the researchers and also industrial partners need to collaborate closely with the healthcare by letting them take part in:

- the identification and formulation of the research problem
- finding possible solutions
- defining how the solution is working through test during the development and in its intended environment
- how the solution can be improved.

In the presented work, the healthcare staff has been involved during the continuous work. Further, the interest of new technology and solutions by the caregivers has facilitated the work. For example, in addition to our work, both the regional municipality Västerås stad and the county council Landstinget Västmanland have established their testbeds, inviting innovators and companies to meet their presumptive customers [12, 13].

The work has been performed by arranging focus groups, continuous discussions with presumptive users, and testing of prototypes together with the presumptive users.

3.2 Research Challenges

Dealing with human health and safety, it is extremely important that all parts of a sensor system for health fulfills both the aim for more capable systems as well as the aim for more dependable systems. Within ESS-H, research therefore is conducted with the aim of producing more capable systems, by advances in the core competence areas as will be explained below. The starting point is a real identified need from the caregivers, as explained above. Research is conducted with the aim to increase and verify dependability of new sensor systems.

ESS-H's core competence areas are:

- Biomedical Sensor Systems
- Biomedical Signal Processing
- Intelligent Decision Support
- Reliable Data communication.

Tasks that can be performed by an embedded sensor system for health includes acquisition of physiological parameters, different levels of signal processing of these parameters, data aggregation and data analysis, decision support, and feedback to both the patient an caregiver, adapted to the receiver.

Scientific challenges includes:

- Reliable acquisition of physiological data
- Personal biofeedback
- Reliable distribution of decision support
- Safe and secure communication (also considering personal integrity aspects).

3.3 Industrial Collaboration

Industrial partners have been included in the project as full members from the start of the initiative. Thus, they have been able to contribute to the solutions, and this also guarantees that the novel systems are possible to produce when they reach this phase. Some of the partner companies have also enrolled an employee as an industrial PhD student, which mean that this person actually can contribute to solve the research challenges together with the university staff. From the company perspective, this is a way to gain competence for their employees.

4 Result and Discussion

The interest from the healthcare sector to work together with the ESS-H researchers and industrial partners has been large. As starting point, identification of real problems that need to be addressed by the research team has been performed. When the research prototypes and industrial prototypes are developed (or before), there are two available testbeds which can identify further improvements of the systems from a user perspective This will hopefully also mean that the next step in the future, to introduce a system to the market, will be less cumbersome.

Bringing together academic and industrial researchers from several disciplines has shown to create a double cross-fertilization as a result of co-production. The cross-fertilization between academic and industrial researchers has been proven to increase the understanding of the problems at hand for all involved parties. Co-production will therefore lead to better results with better industrial value as well as higher academic importance. The cross-fertilization between disciplines is very important in systems-oriented research. Understanding of the whole system is important for obtaining the best solution for a particular subsystem. Without this system understanding, the risk of sub-optimization is apparent, if each discipline solves its sub-system problems without concerns about the overall system. Within the ESS-H projects, both types of cross-fertilization are present.

Presently, the initiative has been ongoing for three years, resulting in about 100 scientific publications. There are several research prototypes on their way to become commercial prototypes, and the industry is happy to continue and intensify the collaboration. Also the healthcare sector is happy to continue the collaboration in the present project and in new projects.

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