Medical Healthcare Monitoring with Wearable and Implantable Sensors

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Abstract. The last decade has witnessed a surge of interest in new sensing and monitoring devices for healthcare, with implantable in vivo monitoring and intervention devices being key developments in this area. Permanent implants combined with wearable monitoring devices could provide continuous assessment of critical physiological parameters for identifying precursors of major adverse events. Open research issues in this area are predominantly related to novel sensor interface design, practical and reliable distributed computing environments for multi-sensory data fusion, but the concept itself is deemed to have further impact in many other areas. This position paper describes a scenario from the UbiMon [1] project, which is aimed at investigating healthcare delivery by combining wearable and implantable sensors.

1 Introduction

In recent years, a number of promising clinical prototypes of implantable and wearable monitoring devices have started to emerge. Whilst the problems such as long-term stability and biocompatibility are being actively pursued, their potential clinical value, particularly for the management of chronic diseases, is increasingly being recognized. For acute diabetes, the blood glucose level can be monitored continuously in vivo. For epilepsy and other debilitating neurological disorders, there are already on the market implantable, multi-programmable brain stimulators which save the patient from surgical operations. Similar applications have also been identified in cardiology for the identification and prediction of life threatening episodes.

The key motivation of this research is due to the fact that local provision of specialist services is often difficult, considering the relative infrequency with which a particular disease may be encountered by a typical general practitioner.

2 Patient Monitoring

Shorter hospital stay and better community care are expected to be the future trend of national health services. To this end, mobile and distributed monitoring of patients before and after surgical treatment becomes indispensable. The UbiMon project is concerned with monitoring patients under natural physiological state for the detection and prevention of transient but possibly life threatening abnormalities. Implantable biosensors are particularly suitable for post-surgical care as the sensors can provide more accurate and directly measured data regarding the patient's condition. These sensors can generally be placed inside the body during the operation with minimal additional cost.

One of the major challenges of continuous in vivo sensing is the determination of the context with which the physiological signals are sampled. This includes different patient activities, as well as environment factors that trigger the physiological response. Combining the sampled clinical data with the associated context could provide further insight to the natural cause and progression of the disease. For instance, with arrhythmic heart disease monitoring, the underlying cause of the altered ECG signals can be attributed to the intrinsic cardiac condition as well as a number of other factors including the physical and mental stress of the patient. This illustrates the type of architecture that the UbiMon project envisages by integrating ancillary sensory readings with the primary ECG information to provide a more complete picture of the physiological status of the patient.

3 The UbiMon Body Sensor Network Architecture

Part of the research in UbiMon is network-oriented: The body sensor network system, illustrated in Figure 1, has been designed by using six main components: the sensors, the remote sensing units, the local processing units, the central server, the patient database, and the workstations. These components are interconnected by using both ad hoc body-area and general wireless communication technologies.

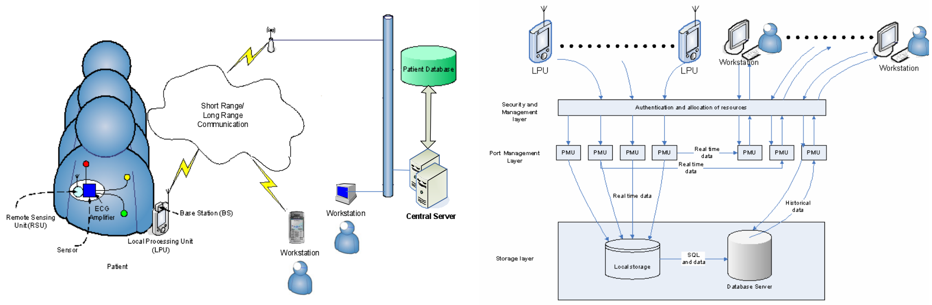

Figure 1. Overview of the UbiMon Body Sensor Network architecture

With the UbiMon architecture, the remote sensing units consist of physiological sensors which are placed on the subject, and are capable of delivering real-time data to an local processing unit via wireless RF link. The local processing unit then processes the incoming data streams in preparation for sending over the wireless networks. The central server receives the real-time multi-sensory data and stores it to the database, with which long-term trend analysis on historical data can be conducted. This allows the prediction and identification of potential life-threatening conditions. The patient database is optimally designed for coping with multiple continuous data streams, as well as queries from client applications. To ensure security, the database is only reachable through the central server after authentication. Workstations are generally used by the clinicians to view and interrogate subject data for detailed examination of significant cardiac events.

4 Body Sensors and Activity Recognition

The detection of the activities and conditions of patients normally requires the use of imaging or external sensors around the body. This imposes a significant burden on the overall requirements of the system. The suitable sampling rates for different types of sensor can be significantly different. This, along with the large amount of sensor data due to real-time continuous sampling, has raised the need for appropriate multi-sensory data fusion techniques, such as application-specific classifiers, feature selection and data synchronization.

For UbiMon, the body sensor network relies on wireless technology which can be affected by noise and mis-sampling of data. To integrate these multi-sensory data, a model that is capable of representing a possibly incomplete and noisy dataset has been investigated. The method is based on the unsupervised clustering algorithms [2, 3, 4] combined with a novel feature selection strategy for optimal sensor positioning and resource utilization. This further enhances the generalization capability of the classifier.

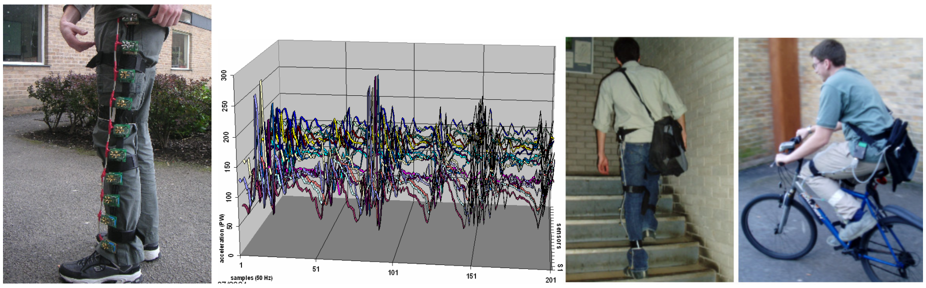

Figure 2. Scenes and data from the activity monitoring experiments

Figure 2 shows the current prototypes of motion sensors that are worn at different places on the body, while the wearer performs certain activities of interest (such as walking, sitting down, running, climbing stairs, cycling, etc.). The datasets recorded with these platforms are important for characterising optimal sensor types and their corresponding locations. Once determined, only minimal numbers of sensors need to be deployed for patient activity monitoring for context aware body sensing.

5 Relevance to the UbiHealth Workshop

The UbiMon project proposes to apply hybrid sensor networks that combine wearable and implantable sensor nodes to monitor patients in their daily lives. The studies undertaken so far have been a merger between typical wearable and ubiquitous sensor research and traditional clinical monitoring (underpinned by medical companies, surgeons and clinicians in the project). We feel that this project's topic and experience could contribute to valuable discussion topics and issues in pervasive healthcare applications.

6 Acknowledgements

We would like to thank all partners involved in UbiMon: Cardionetics, Medtronic, Toumaz, Tyco Electronics, and Docobo for providing us with their expert knowledge and feedback. UbiMon is part of the UbiCare [5] centre, which is funded by the Department of Trade and Industry's Next Wave research initiative in the UK.

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Biographies

Kristof Van Laerhoven has Computer Science degrees from the University of Limburg and the University of Brussels (Belgium). After a two-year stint as researcher in private research lab Starlab, he joined Hans Gellersen's Ubicomp team at the University of Lancaster in 2001, where he is now finishing his PhD on sensor-based context awareness in wearable and ubiquitous computing.

Benny Ping Lai Lo received the BASc. degree from the University of British Columbia Canada. After finishing the degree, he worked as an engineer in Cybermation System Inc. (Canada) and MTRC (Hong Kong) for a few years. Then, he moved to London and completed his MSc. with distinction from King's College London. Later he worked as a research associate in King's College London and a senior researcher in Kingston University on 2 EU projects. He is currently working as a research associate in Imperial College London on the DTI project UbiMon while pursuing his PhD. His current research interests include gait/posture recognition, articulated object modeling/tracking, data fusion and motion analysis.

Jason Wee Peng Ng is currently a Research Associate employed by the Imperial College Surgical Oncology and Technology Department to undertake the UbiMon project. He received his PhD from the Imperial College London and BEng (first class honors) from the National University of Singapore. He was a Research Engineer at the Centre for Wireless Communications and a night-class Lecturer in the School of Engineering, Nanyang Polytechnic, Singapore. He presently holds two patents and is the author of several notable software packages. His primary research interests are in the area of wearable/implantable sensors, wireless sensor network, and array communications & signal processing. His other interests include microwave integrated circuit (MIC) and miniaturized printed-circuit antenna designs.