Probabilistic Early Warning Systems for Detecting Patient Deterioration in the Home

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Abstract—This paper describes the development of a reliable multi-sensor data fusion system for monitoring patient vital signs and activity in the home, and alerting a remote carer whenever patient deterioration occurs. Our approach is based on developing and validating the technology within a controlled hospital environment, and then testing it thoroughly in the context of (i) home monitoring of haemodialysis patients in order to personalise treatments such that their quality of life between treatments is improved, and (ii) home monitoring for managing the care of low-acuity patients with chronic conditions, in a novel region-wide community hospital setting.

I. INTRODUCTION

Wireless sensor technology for monitoring a patient’s vital signs (heart rate, breathing rate, blood pressure, oxygen saturation, and temperature) in the home is now available, and improved sensors, with lower power requirements and smart communications, are under development. However, the real challenge for this technology is not taking the measurements, but working out how they should be processed, such that the number of false alarms generated is sufficiently low for the system to be used in practice. We argue that home monitoring of vital signs will only be possible with a combination of multiple wireless sensors and data fusion techniques, to drive the rate of false alerts down to an acceptably low level and deliver the potential benefits of remote monitoring, both in terms of patient outcomes and health economics.

II. METHODOLOGY

We have previously shown that the integration of continuously-monitored parameters in data fusion models can provide early warning of adverse events. This has been demonstrated both in jet engine health monitoring [1] and in the monitoring of acutely ill hospital patients [2]. The patient monitoring data fusion system is based on a probabilistic model of normality learned from a dataset of vital signs acquired from a representative group of high-risk hospital patients. This system alerts the nursing staff whenever the combination of vital sign parameters is indicative of physiological abnormality, and has undergone clinical trials in UK and US hospitals. It has reduced three-fold the percentage of patients requiring emergency care, from 18% to 5% [3]. Such techniques provide a low false-positive alarm rate (one every three days, in US trials) such that they are suitable for monitoring patients in the home, where false alarms are particularly costly in terms of clinical resource.

A. Home monitoring of haemodialysis patients

Current patient monitoring of haemodialysis patients only takes place during the treatment session itself, and such information is only used retrospectively. The quality of life of patients between sessions can vary greatly according to the individual’s response to treatment, and we aim to determine if treatments can be personalised to the patient more effectively by performing monitoring of the patient in their home, between sessions, using a probabilistic data fusion method trained using data acquired from haemodialysis patients in hospital.

B. Home monitoring of community hospital patients

With major UK hospitals becoming ever-more focussed on the care of high-acuity patients, those patients of a lower-acuity must be treated in a community hospital or other local community settings. In collaboration with the Oxford Radcliffe Hospitals Trust, we are initiating a novel county-wide scheme in which Emergency Medical Units (EMUs) are created in key community hospitals, which will use data fusion systems for the monitoring of these lower-acuity patients, who would otherwise have been referred to a major NHS hospital. Patients deemed fit for discharge to their own home will be monitored remotely using data fusion systems via telemetry, with clinicians able to monitor cohorts of patients in conjunction with a dedicated team of home nursing staff.

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REFERENCES