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Fast track article

PEACE-Home: Probabilistic estimation of abnormal clinical events using vital sign correlations for reliable home-based monitoring

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HIGHLIGHTS

- We developed a clinical event prediction system using vital sign correlations.
- We developed a probabilistic estimator using Hidden Markov Model.
- We utilized Principal Component Analysis for clinical event identification.
- We utilized cloud computing framework for model training and classification.
- Our developed is suitable for personalized and real-time patient monitoring.

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ABSTRACT

The objective of this study is to develop a probabilistic model for predicting the future clinical episodes of a patient using observed vital sign values prior to the clinical event. Vital signs (e.g. heart rate, blood pressure) are used to monitor a patient's physiological functions of health and their simultaneous changes indicate a transition of a patient's health status. If such changes are abnormal then it may lead to serious physiological deterioration. Chronic patients living alone at home die of various diseases due to the lack of an efficient automated system having prior prediction ability. Our developed system can make probabilistic predictions of future clinical events of an unknown patient in real-time using the learned temporal correlations of multiple vital signs from many similar patients. In this paper, Principal Component Analysis (PCA) is used to separate patients with known medical conditions into multiple categories and then Hidden Markov Model (HMM) is adopted for probabilistic classification and prediction of future clinical states. The advantage of using dynamic probabilistic model over static predictor model for solving our problem is analysed by comparing the results obtained from HMM with a neural network based learning model. Both the learning models are trained and evaluated using six vital signs data of 1023 patient records collected from the MIMIC-II database of MIT physiobank archive. The best HMM models are selected using maximum likelihood probabilities and further used in personalized remote monitoring system to forecast the most probable forthcoming clinical states of a continuously monitored patient. The scalable power of cloud computing is utilized for fast learning of various clinical events from large samples. Our results suggest that the developed technique using multiple physiological parameter

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trends can significantly enhance the traditional home-based monitoring systems in terms of clinical abnormality detections and predictions.

1. Introduction

Due to significant advances in body sensor [1], wireless sensor and smart phone technologies and availability of cloud resources at low cost it is now possible to develop personalized remote health-monitoring [2] applications with greater flexibility [3]. In modern healthcare monitoring, the data from different biological signals of a patient are obtained continuously using wearable sensors and analysed in the cloud [4] to identify patient-specific knowledge [5]. The distributed resources of the cloud simplify the knowledge build up process from large biomedical data using computationally intensive machine learning methods [6]. The accurate and early anticipation of health-related abnormalities [7] is an essential functionality of a remote monitoring system to support clinicians in diagnostic decision making [8]. Timely intervention of symptoms is also very important in preventing clinical deterioration before an emergency situation [9].

Chronic lifelong diseases are increasing with growth of population and already created intensified pressure on overall healthcare infrastructure. They are major causes of deaths in Australia and throughout the world. Recent reports indicate that hospitals are getting overcrowded and are having difficulties in treating the patient even in emergency situation due to increasing population. A recent news shows that, patients (including elderly people aged over 80) in Western Sydney hospitals waited more than two days in the emergency department and had to leave without treatment [10]. According to that report, there was up to 40 h waiting time on average to be admitted to the hospital. The capacity in hospitals is inadequate to make place for all patients. The situation will become worse for the patients as well as for the healthcare providers unless self-care, preventive, predictive and protective home-based monitoring system [4] is adopted. The establishment of continuous clinical event prediction system for disease diagnosis [11] will also reduce the healthcare cost. It provides flexibility for patients by allowing them to do regular activities while biomedical data are continuously collected and fully relying to remote monitoring systems. Moreover, it can support healthcare professional to monitor patients health condition in anytime and from anywhere.

Wearable sensors (e.g. Shimmer) with wireless communication capability are available in market at a very low cost. These sensors are able to collect various vital signs such as heart rate (HR), blood pressure (BP), respiratory rate (RR), O_2 saturation (SPO_2), pulse, body temperature and electrocardiogram (ECG) [12]. One sensor can monitor one or multiple biological attributes (e.g. pulse oximeter can monitor both pulse and SPO_2). HR assess patient's cardiovascular health, BP is used to determine vascular resistance to blood flow, RR measures the rate of breathing and SPO_2 is a measure of patient's blood oxyzen intensity. The measured values of these vitals can be exploited to detect different clinical events (e.g. Tachycardia, Hypotension, Hypoxia or more than one of these at the same time). For example, continuous heart rate value above 100 bpm is a sign of abnormality and known as Tachycardia [13]. Vital parameters are also correlated in time and space. Such correlations are sometime patient-specific and help to predict future clinical conditions at early stage. The accurate prediction requires the right interpretation of individual's vital parameters using past and current data. This is also beneficial for monitoring systems in order to avoid unnecessary false alerts.

1.1. Vital sign correlations

The presence of various correlations in vital parameters may contain valuable information that can be utilized to avoid future clinical dangers [14]. For example, when a patient is experiencing a medical health crisis, such as in stroke, or heart attack, the heart beat may slow down due to the failure of the heart muscle to contract or too much blood has been lost. Such changes make really difficult to tell about patient's actual clinical situation if all vital signs are not examined. Therefore, it is essential to monitor patients vital signs under the remote supervision of a doctor. An example of strong correlation between HR and BP is shown in Fig. 1. Fig. 2 shows a three-dimensional correlations among HR, MBP and RR values of a single patient. Here all 3 vitals goes high and low at the same time in most of the cases.

1.2. Motivations

We are motivated by our previous works [4,5,15,16] where we developed a cloud-based model for ambient assisted living (AAL) that can discover patient-specific anomalies and predict future medical situation. In those works we ignored the correlations among vitals which contain useful patterns for the progression of some chronic diseases. In this work, we focus on clinical knowledge discovery based on such interactions among multiple vitals. Some part of methodology and analysis of this work was described in our previous work [17]. We are also encouraged by our previous studies in biomedical data analysis [2,11,18] and disease diagnosis [8] to develop this probabilistic leaning model for predication of abnormal clinical events in real-time personalized monitoring.

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