Chapter 24
Anomaly Detection in Medical Wireless Sensor Networks using SVM and Linear Regression Models

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ABSTRACT

This paper details the architecture and describes the preliminary experimentation with the proposed framework for anomaly detection in medical wireless body area networks for ubiquitous patient and healthcare monitoring. The architecture integrates novel data mining and machine learning algorithms with modern sensor fusion techniques. Knowing wireless sensor networks are prone to failures resulting from their limitations (i.e. limited energy resources and computational power), using this framework, the authors can distinguish between irregular variations in the physiological parameters of the monitored patient and faulty sensor data, to ensure reliable operations and real time global monitoring from smart devices. Sensor nodes are used to measure characteristics of the patient and the sensed data is stored on the local processing unit. Authorized users may access this patient data remotely as long as they maintain connectivity with their application enabled smart device. Anomalous or faulty measurement data resulting from damaged sensor nodes or caused by malicious external parties may lead to misdiagnosis or even death for patients. The authors' application uses a Support Vector Machine to classify abnormal instances in the incoming sensor data. If found, the authors apply a periodically rebuilt, regressive prediction model to the abnormal instance and determine if the patient is entering a critical state or if a sensor is reporting faulty readings. Using real patient data in our experiments, the results validate the robustness of our proposed framework. The authors further discuss the experimental analysis with the proposed approach which shows that it is quickly able to identify sensor anomalies and compared with several other algorithms, it maintains a higher true positive and lower false negative rate.

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1. INTRODUCTION

With the continual growth in expected duration of the average human lifetime (Kumar & Lee, 2012), the rise in population and number of elderly persons has led to inflated healthcare costs and shortage of professionals able to provide the care and treatment necessary to satisfy this increase in demand.

Today, healthcare professionals and caregivers are very interested in remote monitoring of elderly people and patient vital signs, as well as their surrounding environment. These requirements have sparked enormous interest in the utilization of Wireless Sensor Networks (WSNs).

Scientists and researchers have developed networks of wireless sensors, known as Wireless Body Area Networks (WBANs), which are composed of a set of small miniaturized sensors with wireless transmission capabilities, and may be externally attached or implanted. These devices are used to continuously gather physiological signals from patients or elderly people at home or in hospitals, and transmit collected data to a Local Processing Unit (LPU).

The LPU (e.g., smart phone, tablet, etc.) has superior processing power, batteries with increased energy resources and greater transmission range and bandwidth than the individual WBAN nodes. LPUs must be robust and able to process received measurements in real time, and raise medical alarms for caregivers upon sensing the deteriorating health state of patients to quickly react by taking appropriate actions (Otto, Milenkovi, Sanders, & Jovanov, 2005). Data may also be transmitted by the LPU to remote databases (DB) for storage and long term analysis.

WBANs have several advantages such as enabling doctors to monitor specific attributes of patients regardless of location, improving diagnosis accuracy and efficiency, and reducing the overall cost of health care by permitting doctors to constantly monitor patient health.

WBAN may also improve the chances of discovering diseases which further reduces risk and impacts the lifespan of individuals on a global scale. In this paper, we look to increase the usefulness of WBAN systems used in the healthcare industry by creating an application which is capable of "intelligently" discerning between patient health irregularities and sensor node failure.

There exist many medical WBAN systems which are publicly available for purchase including MICAz, MICA2, Tmote Sky, TelosB, IRIS, Imote2, and Shimmer. These types of WBANs are used to monitor and collect various physiological parameters of individuals such as Heart Rate (HR), pulse, oxygen saturation (SpO2), Respiration Rate (RR), Body Temperature (BT), ElectroCardioGram (ECG), ElectroMyoGram (EMG), Blood Pressure (BP), Blood Glucose Levels (BGL), Galvanic Skin Response (GSR), etc.

The ECG sensor, for example, is connected to three electrodes each of which is attached to the patients' chest for real time monitoring of the heart. Another type of sensor, the pulse oximeter, using infrared light and a photo sensor, simply clips to a patient finger and measures the pulse and blood oxygenation ratio (SpO2). While it may seem simplistic, the SpO2 sensor may detect asphyxia, insufficient oxygen (hypoxia), pneumonia and other blood oxygen related anomalies. The average human SpO2 ratio naturally exceeds 95%, but when this ratio drops below 90%, the pulse oximeter will trigger an alarm due to possible lung problems or respiratory failure. Prior to the assistance of these types of WBAN sensors, healthcare providers were reliant on big, expensive machines which were in short supply and required that the patient is observed directly while situated at the location of the machine.

The use of WBANs has been extended to monitor patients diagnosed with chronic illnesses and cognitive disorders such as Parkinson's, Diabetes, Alzheimer's, Asthma, and Epilepsy. WBANs have proven to be great assets to both patients and