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Application of Internet of Things and Machine Learning in Healthcare

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***Abstract*—The advent of the Internet of Things (IoT) has enabled efficient communication among the things we see around us. The utility of a few machine learning techniques coupled with the power of IoT can be an effective solution to many real world problems. This paper provides a brief review of some of the existing systems in smart health monitoring. It also emphasizes the possible advantages of using both IoT and machine learning techniques in smart health monitoring with a view of enhancing the existing system. Machine learning helps in understanding large amount of data, categorize them and learn to predict outcomes or recommend treatments to patients. It can also help clinicians and epidemiologists to perform analysis across patient populations. The data acquired can also be used in determining the public health status of a country or a state.**

***Index Terms*— Internet of Things (IoT); Supervised Learning; Big Data Analytics; Naïve Bayes Classifier**

I. INTRODUCTION

Advancement in the field of sensor and wireless technology has enabled an efficient means of communication among diverse devices. This led to the emergence of the Internet of Things which finds one of its applications in healthcare.

An efficient real-time health monitoring system is needed for the elderly. The system shall also be used to monitor patients in remote areas. To fulfill this requirement, wearable sensors can be used. These sensors can be connected to a device used to communicate the health status of a patient to a nearby monitor or a doctor.

The sensors can acquire the temperature, heart rate, activity and other physiological parameters of the patient. These acquired data can be sent to a monitor that alerts in case of an emergency.

Apart from being utilized in monitoring, the data acquired can be stored in a local database. This enables keeping an account of the patient’s medical history.

Maintaining the patient records is a crucial task in many hospitals. The data maintained will serve in clinical performance measurement and statistical analysis. The potential capabilities of big data analytics and machine learning techniques can be used in predicting the potential outbreaks of a disease by observing the symptoms in the patients.

This paper hence describes the joint contribution of IoT and machine learning techniques of big data analysis in healthcare.

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II. LITERATURE SURVEY

Omar Boursalie et al. [3] designed a Mobile Machine Learning Model for Monitoring Cardiovascular Disease (M4CVD) to facilitate monitoring of cardiovascular disease. This system uses SVM (Support Vector Machine) to classify the patients with or without risk. The SVM then creates a hyper-plane to separate the input vectors into their specific classes (*with risk* or *without risk*). The system provided an accuracy of 90.5% in classification.

T. Saraswathi et al. [4] described an IoT based wireless healthcare monitoring system which uses Bluetooth, NRF (Network Radio Frequency) and Wi-Fi module. It uses temperature and pressure sensor to acquire data and send it to a monitoring system through a mobile device connected to a GMS/GPRS modem. It uses supervised learning techniques – Support Vector Machine (SVM) and Naïve Bayes Approach.

Abderrahim Bourouis et al. [5] designed a Ubiquitous Mobile Health Monitoring System for Elderly (UMHMSE) monitor the mobility, location, and health status of the elderly. It used Wireless Wearable Body Area Network to collect, gather and analyze the data from the biosensors.

Becher K. et al [6] has proposed a Wireless Sensor Gateway (WSG), which monitors the cardiovascular health status of a patient using the pulse rate and other physiological parameters.

Joon-Soo Jeong et al. [7] described a smart healthcare system iotHEALTHCARE. The medical data collected by sensors are gathered by a mobile and intelligent network. The data then goes to the cloud where it is analyzed to make complex treatment recommendations.

J. Wiens et al. [8] explains an active learning algorithm that can be applied to the binary classification task of identifying ectopic beats. This algorithm classifies ventricular ectopic beats (VEBs) in the ECG data of MIT-BIH Arrhythmia Database with a mean sensitivity of 96.2% and specificity of 99.9%.

Vidya Zope et al. [9] describes a Smart Health Prediction using Machine Learning provides an overview of data analytics and other techniques to predict the chances of a person to be prone to a disease.

Ngo Manh Khoi et al. [10] identifies several network-related requirements of a remote health monitoring system. It also proposes an architecture called IReHMo which is capable of incorporating several types of home automation sensors and healthcare IoT devices.

Meria M. George et al. [11] depicted a method involving Android with IoT used by healthcare professionals to monitor, diagnose, and advice the patients.

III. PROPOSED SYSTEM

The model uses a combined approach involving the IoT component as well as the machine learning component. The robustness and connectivity of the IoT coupled with the analytical and reasoning capability of machine learning algorithms serves to enhance the current healthcare monitoring system.

The below diagram shows an overview of the system:

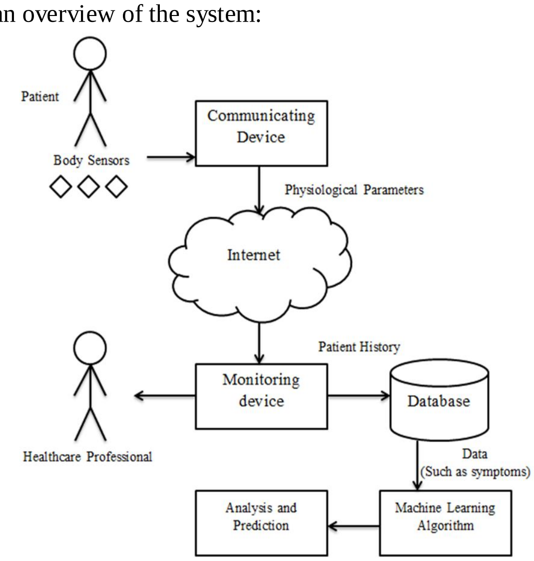

Figure 1. System Overview

The body sensors are connected to a communicating device. This can be an Android device. The connection can be through a Bluetooth or an NFC (Near Field Communication).

The physiological characteristics of the patient are sent over the Internet to the monitoring device. The healthcare professional such as a doctor in a nearby hospital can view the status of the patient by the data obtained. These data include the temperature, pulse rate, activity level, and other physiological parameters of the patient.

The system can also be used to intimate a clinical professional in case of an emergency. Thus, care is taken to ensure safety to the patient.

The data received at the monitoring device shall store the medical history of the patient for further analysis. This analysis can be an algorithm summarizing the clinical advancement of the healthcare organization or a prediction related to a possible outbreak of a disease. This prior information can be used to take corrective actions to control the spread of the disease.

The machine learning component plays an important role in the prediction. The supervised learning methods such as Naïve Bayes Classifier can be used to predict the possibility of a disease. The basic idea of a Naïve Bayes classifier is to measure the posterior probability based on the prior probability and the likelihood.

Given a dataset *X* with $[X_1, X_2, \ldots, X_n]$ which represent *n* symptoms or the physiological conditions, the probability *P(Disease|X)* is the (posterior) probability of the patient having a disease and *P(NoDisease|X)* be the probability of the patient not having the disease. Given the set of symptoms and physiological conditions, this probability can be found using,

$$P(Disease|X) = \frac{P(X|Disease) * P(Disease)}{P(X)} \quad (1.1)$$

Or

$$P(Disease|X) \ \alpha \ P(X|Disease)P(Disease) \quad (1.2)$$

But, in Naïve Bayes Classifier, every symptom is considered independent of the other. No symptom is considered an effect of any other symptom. Hence, the above equation becomes,

$$P(Disease|X) \ \alpha \ \prod_{i=1}^{n} P(X_i)P(Disease) \quad (1.3)$$

Similarly,

$$P(NoDisease|X) \ \alpha \ \prod_{i=1}^{n} P(X_i)P(NoDisease) \quad (1.4)$$

Also, if probability of having the disease is only 50%, i.e.,

$$P(Disease) = P(NoDisease) \quad (1.5)$$

Then, the posterior probabilities depend only on the prior probabilities, i.e.,

$$P(Disease|X) \ \alpha \ \prod_{i=1}^{n} P(X_i) \quad (1.6)$$

The decision on whether a patient has a given disease can be found using the maximum of the posterior probabilities. If

$$P(Disease) < P(NoDisease) \quad (1.7)$$

the prediction is made that the patient does not have the disease; otherwise, the prediction is made that the patient has the disease.

The effectiveness of the Naïve Bayes Classifier depends on the quality of the training examples provided.

The below table can be considered as a training set where each X_i corresponds to an observed symptom and has a yes or no value. The value ‘Disease = Yes’ corresponds to the class *Disease* indicating that the patient has the disease, and the value ‘Disease = No’ corresponds to the class *NoDisease*.

TABLE I. EXAMPLE OF A TRAINING SET

Symptom 1	Symptom 2	…	Symptom n	Disease
Yes	No	…	Yes	Yes
Yes	No	…	No	Yes
No	Yes	…	No	No
Yes	No	…	No	No
		. . .		
No	Yes	…	No	No

The aim is to find the class for a test set like

TABLE II. EXAMPLE OF A TEST DATA

Symptom 1	Symptom 2	…	Symptom n	Disease
No	No	…	Yes	?

IV. CONCLUSION

The combined approach of using both IoT and Machine Learning Algorithms in the healthcare monitoring is illustrated in this paper. The IoT component is mainly involved in sensing the parameters and communicating it to a monitoring device. The monitoring device can use a machine learning approach to respond back or can intimate a doctor in case of an emergency. The paper specifies how Naïve Bayes Classifier can be used in predicting the disease based on the symptoms.

FUTURE WORK

The current system can be made less prone to errors by including validation processes. Also, Naïve Bayes approach can be coupled with other machine learning algorithms to create an ensemble which is more efficient than individual machine learning algorithms.

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