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An Early Warning System for Parkinson Disease Diagnosis

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Abstract*: With the rise in population and increase death rate, medical expert system can prove to be beneficial in providing medical service to anybody who needs continuous monitoring and care. Technological development regarding the use of wireless body sensor (WBS) to provide seamless approach to gather early information on health rated challenges has continued. In this paper an early warning system for Parkinson disease diagnosis was proposed. The developed system comprised wearable sensors, SIM800L module, and wireless network interface. It is designed to detect body movement and vibration such that the resulting data gathered from the WBSs are processed and sent to a module that subsequently transmits same to the mobile phone or personal computer (PC) of a doctor as a message alert. The received message shows the medical status as well as personal information such as name, age, and address (mobile number). A message alert based on stated threshold of the logic used in developing the system is sent to case of any deviation in health status.*

Keywords— Diagnosis, Disease, Early warning, Parkinson, Wearable body sensor

1. Introduction

The past few decades have witnessed a dramatic rise in life expectancy due to the significant development in technology and medicine. A good number of elderly people live at home. The elderly are known to be prone to certain diseases occasioned by their age. One of such diseases that are frequent in elderly is Parkinson disease. The overall challenge of neurological disease is its rising cases in the developing countries. It has been argued that most neurological diseases or disorder occur in developing countries, and that the risk of death increases rapidly among adults whose age are 60 and above. It is surprising to know that about 50% of the adult disease burden in developing countries is linked to non-communicable disease [1]. These diseases like Parkinson's disease are often under diagnosed or not recognized in the elderly, this could be as a result of the fact that more attention is given to infectious diseases such as malaria, HIV/AIDs and tuberculosis. Hence there is need to develop a system that will be able to monitor and provide early warning on neurological diseases in elderly. Also, there is little knowledge about the clinical pattern and treatment status of Parkinson's disease in developing countries. Despite the many advances recorded in the past decades, there is still a problem of an all-inclusive system capable of providing reliable assessment of the status of Parkinson's disease in patients and at the same time being economically assessable and affordable especially to people living in developing countries, where the majority of the population are financially challenged.

In most cases, expert systems are developed and implemented on computer for diagnostic purposes. A situation where these systems are implemented on a wearable sensor network for the purpose of providing early warning and consequently diagnosis of deadly disease especially in the elderly will be worthwhile. It is required to develop a system that will help in monitoring and giving early warning on Parkinson's diseases in elderly using electronic sensor nodes placed on the body. Hence, the goal of this paper is to develop an early warning system for Parkinson disease diagnosis.

2. Wearable Expert System

In this section, some of the works regarding medical expert system based on the use of wearable sensors are discussed. Almarashdeh et al [2] presented an expert system for an Elderly Health Care (EHC) at elderly home tailored for the specific needs of Elderly. The proposed EHC aimed to develop an integrated and multidisciplinary method to use communication technologies and information for covering real health needs of elderly people, mainly of people at high risk as a result of social and geographic isolation in addition to specific chronic diseases. The proposed EHC provides personalized intervention plans covering chronic diseases such as (body temperature (BT), blood pressure (BP), and Heart beat rate (HR)). The processes and architecture of the proposed EHC are based on the server side and three main clients, one for the elderly and another two for the nurse and the physician's who takes care of them. The authors stated that the proposed EHC model proved the usefulness and effectiveness of the expert system. Aminian and Naji [3] presented hospital healthcare monitoring system using WSNs. The study proposed a monitoring system that can monitor physiological parameters from the bodies of several patients. A wireless body sensor network (WBSN) is formed by sensors attached on the body of patient, which are capable of detecting the heart rate, blood pressure and others. Once abnormal conditions are detected, an alarm notified the patient and SMS/E-mail is sent to a doctor. Gogate and Bakal

[4] proposed 3-tier architecture healthcare monitoring system using WSN that provides continuous monitoring of some parameters of patient's body. The arrangement is such that different body sensors that measure heart rate, body oxygen level and temperature were attached to Arduino Nano board and logged signals were transmitted to server via wireless communication node. Data is received on remote servers for physician and healthcare workers using an IoT application called ThingSpeak. Kumar et al. [5] presented wearable sensors healthcare monitoring system that collect physiological data from patients and transmit same to intelligent personal digital assistant. The proposed system consists of 3-tier: wireless body area network (WBAN), personal server using IPDA, and medical server for healthcare monitoring. Patient's biological data is collected by wearable body sensors attached to the body that formed WBAN. A personal server that interfaces the WBAN nodes receives data from body sensors and transmits the received data to medical server. Bourouis et al. [6] proposed a real time mobile health system for monitoring elderly patients from home. The system incorporates a wearable body biosensor for collecting physiological parameter and a smartphone device that served as base station or gateway node. The data collected by sensor is transmitted to intelligent server via GPRS/UMTS for evaluation. The movement of elderly, location and essential signs such as Sp02 and heart rate were monitored. Kumbhare and Rangaree [7] developed a wireless body area sensor network (WBASN) that measures and monitors health parameters such heart rate, blood pressure, temperature and respiration of patient using GSM modem to transmitted collected data to mobile phone. The mobile phone acts as a gateway and transmits received data to physician's server. The proposed system is equipped with an alarm to alert patient and subsequently send SMS to doctor. Rushambwa et al. [8] developed a system that provides continuous monitoring of health of the elderly and disabled while offering them independent, safe and secure living enabled by wearable wireless body area network (WWBAN). Parameters monitored by the WWBAN system included blood oxygen saturation using a pulse oximeter sensor (SpO_2), heart rate pulse sensor, temperature, hydration, glucose level, and fall detection. The sensors monitor and measure the parameters and if parameter values falls below or goes above the desired level, remote alert is triggered such that SMS is sent to a physician via mobile network utilized by GSM module. Perumal and Sankar [9] carried out an assessment of gait and tremor for Parkinson disease (PD) patients using wearable sensors. The effect of employing the features of gait and tremor for an early detection and monitoring of PD was examined. Wearable sensors were used to collect data. Extraction of various features from the collected data was done using statistical analysis and machine learning algorithms to determine the features that were most significant that distinguish between subjects with PD and healthy control subjects. The analysis of results indicated that features such as step distance, stance and swing phases, heel and normalized heel forces contributed more considerably to getting better classification between the groups compared with other features. Frequency domain characteristics of signal was carried out to identify PD tremor from a typical Parkinsonism tremor. It was observed that subject with PD had a huge peak (or overshoot) at the frequency between 4-6Hz, and about 91.92% of the overall power in the spectrum concentrated within this frequency range. The authors maintained that this provided the means of distinguishing PD tremor and other tremor. Patel et al. [10] developed wearable body sensor system for home monitoring of patients with Parkinson's disease that are experience severe motor disorders. The system uses wearable wireless sensors whose data are sent to remote hospital server via a web-based application. The study examined three symptoms of PD namely, tremor, bradykinesia and dyskinesia. Imran et al. [11] proposed a monitoring system for elderly patients based on an intelligent task mapping technique for a closed-loop Internet of Things (IoT) healthcare environment. The system measures and alerts deteriorating health conditions to healthcare providers using biomedical sensors attached to patients that monitor and collect data regarding body temperature, heart rate, blood glucose level, and patient body position. The study used threshold and machine learning based algorithms to detect anomalies in the measured sensor data. The performance of the proposed system was analyzed in terms of round trip time, reliability, task drop rate, and latency performance metrics. The authors maintained that results indicated that the system is capable of providing reliable solution for critical tasks in IoT environment.

Although expert system using wearable technology has contributed greatly in the development of healthcare monitoring systems, there are obvious concerns that may affect performance of the healthcare monitoring systems. Some of the concerns raised are: failing to use real-time data in the monitoring systems during testing of application, challenges surrounding the ability to use low power energy battery with appreciable, the security and privacy of data collected from patient, requirement of medical professional's recommendations at each step of the development, clinical validation or experts' acceptability, and user friendliness for the patients and for healthcare professionals. Nevertheless, the combination of wearable expert technology with mobile network is capable of providing new possibilities of fast, reliable, and secured data communication from the patient to the medical expert (doctor).

It is intended to integrate a wearable sensor network with mobile technology by developing a remote monitoring system for neurological patient. Hence, the paper has proposed a location based real-time monitoring system comprising a wearable sensor, mobile application, and a web interface to aid interaction with a remote physician. The wearable sensor will be used to generate patient's diagnostic data which is then sent to a GSM/GPRS module. Also, the data sent to the transceiver module is transmitted to a web server interface via GSM/GPRS communication. The proposed system is capable to generate emergency alerts on the basis of predefined values by comparing patient's data to inform the doctor if there is a requirement of check-up or investigation via a message alert.

3. METHODOLOGY

In this paper it is intended to develop a wearable expert system (WES) using sensor technology for detecting deadly diseases in elderly. In this case, the deadly diseases in elderly considered are neurological disorders with emphasis on Parkinson's disease. In order to achieve the objective of the paper, a remote monitoring diagnostic scheme to detect possible neurological diseases in elderly is proposed. The WES is a real time monitoring system which is compatible to use with various wearable sensor network that collect medical data concerning patient neurological conditions. The essence of the wearable expert system using sensor network, is to help in finding out multiple symptoms of neurological disease such as tremor, bradykinesia, gait, dyskinesia, and motor fluctuations. This approach helps early detection of diseases like Parkinson's disease and others (Epilepsy, stroke etc.) through alarming system in terms of lower and upper threshold values. The proposed system possesses two interfaces –one for patients and the other for medical expert (doctor). The interface of the patients consists of wearable sensor network that extract medical data of the patient and send same to a SIM800L module.

3.1 Structure of Proposed System

The developed system is capable of using multiple sensor technologies which support simultaneous monitoring of several neurological parameters. The use of multiple wearable body sensors (WBS) at the same time to extract needed data enhances the applicability of the proposed system and helps in comparing performance accuracy of the sensor network. The concern of this work is to develop a real-time medical expert system that provides diagnostic function for patients living in remote location suffering from Parkinson's disease (PD) by measuring the motor imbalance using wearable sensor network. The system configuration is basically of three level, which are: a) wearable body sensor network that interface with patient, b) Sim800l module (Home gateway), and c) web server that interfaces with doctor. The proposed system architecture for three level communications in healthcare monitoring for early warning on Parkinson disease (neurological disorder) implemented in this work is shown in Fig. 1.

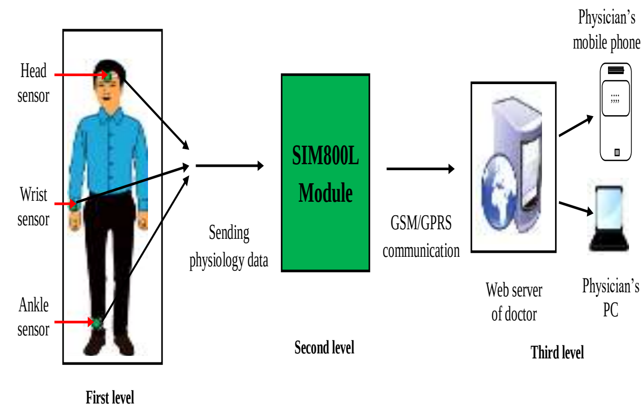

Fig. 1 *Proposed system architecture*

3.2 Hardware Components

The hardware components consist of wearable body sensors (WBSs) and SIM800L module (GSM/GPRS communication). The WBSs interface with patient and are used to collect physiological data that serves as medical information of patient's status. The sensor attached to the head measure and detects patient's anxiety; wrist sensor senses tremor and gait symptoms; while ankle sensor detects bradikeniesia and rigidity symptoms. This arrangement forms the first level communication in the system. The GSM/GPRS module used is SIM800L. This module is a digital global mobile communication technology with wide coverage and reliability. Being a quad-band module, GSM uses short message service (SMS) supported by mobile phone service provider SIM card to send text messages to doctor. The GPRS on the other hand, provides internet for data transmission. The operation at the stage represents the second level communication. The basic characteristics of SIM800L are presented in Table 1.

Table 1: Basic Features of SIM800L

Feature	Implementation
Power supply	3.4V~4.4V
Power saving	Sleep mode power consumption: 0.7mA
Frequency bands	900GHz ~1800GHz
Transmitting power	• 2W at GSM 850 and EGSM 900 • 1W at DCS 1800 and PCS 1900
GPRS connectivity	• GPRS multi-slot class 12 (default) • GPRS multi-slot class 1~12 (option)
Temperature range	• -40ºC ~ +85ºC (normal operation) • -45ºC ~ +90ºC (normal operation)
Data GPRS	• Max. 85.6 kbps (GPRS data downlink/ uplink transfer) • 2.4, 4.8, 9.6, 14.4 kbps (Circuit Switch Data, CSD)
SMS	SMS storage: SIM card
SIM interface	1.8V, 3V
Physical characteristics	15.8 × 17.8 × 2.4 mm (size) 1.35g (Weight)

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3.3 Software Components

The Visual Basic-based software has been used for developing a programme to establish communication between wearable body sensors and the SIM800L GSM/GPRS module and the computer. The structure of the proposed system software is shown in Figure 2.

The properties of the developed programme are stated as follows:

- Reception of task (command) in accordance with measured or collected data from sensor.
- Reply to sensor signal and connect automatically.
- Monitor and measure Parkinson's disease data in real-time.
- Send SMS to doctor for received Parkinson's disease data.
- Select USB com port of SIM800L GSM/GPRS communication module.

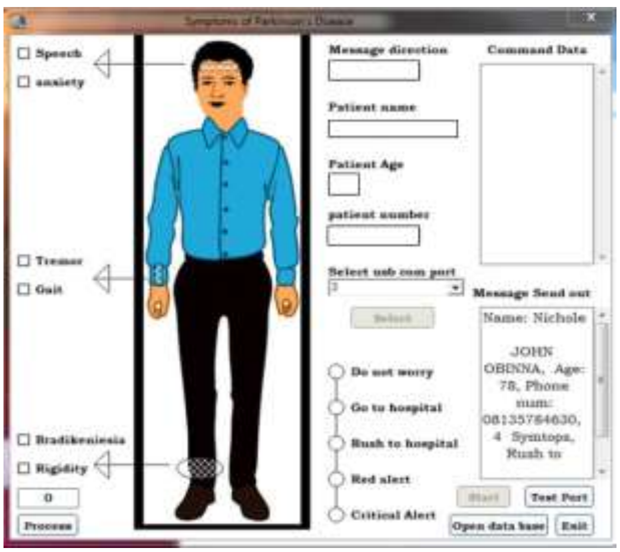

Fig.2 *Proposed system simulation software environment*

The flowchart of the Visual Basic-based software developed and used for the implementation of the proposed system is shown in Figure 3.

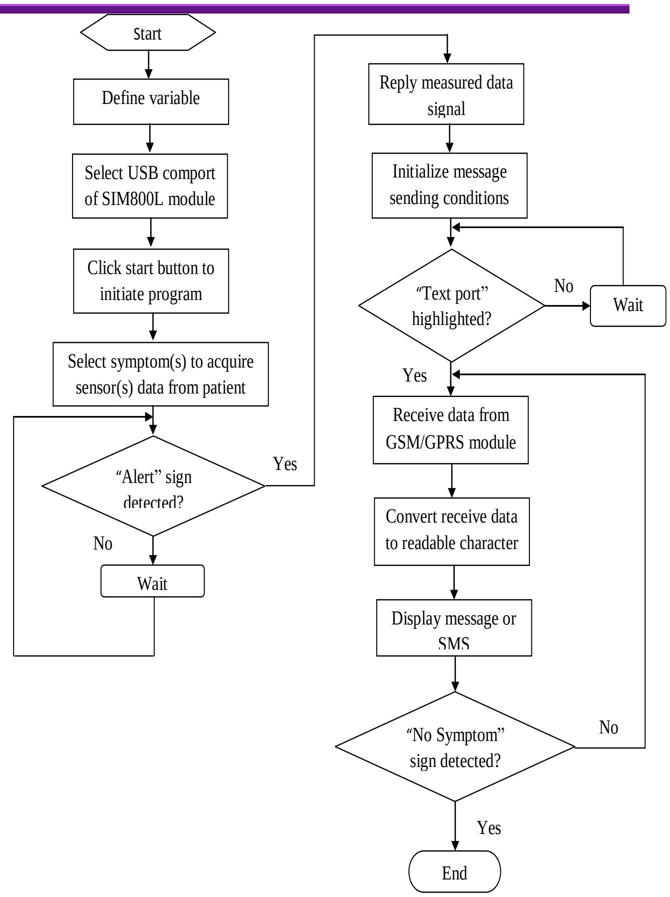

Fig. 3 Flowchart of proposed Visual Basic-based algorithm for e-health monitoring

3.4 Experimental Parameter

The parameters used for the simulation test carried out in this paper to validate the effectiveness of the proposed Wearable body sensor system for e-health monitoring for early warning sign detection of Parkinson disease were collected from randomly sampled 19 patients in a Teaching Hospital (TH). Table 2 shows the details of patients. The names of patients are not listed for ethical purpose.

Table 2: Data of Parkinson disease patients

Name of Patient	Card No.	Age	Gender	Four Motor Symptoms of Parkinson			
				Tremor	**Gait**	**Rigidity**	**Bradikenesia**
A1	THN 1	60	Male	Yes	Yes	No	Yes
A2	THN 2	63	Female	Yes	Yes	Yes	Yes
A3	THN 3	72	Male	Yes	No	Yes	No
A4	THN 4	82	Male	Yes	Yes	Yes	Yes
A5	THN 5	70	Female	Yes	Yes	Yes	Yes
A6	THN 6	85	Male	No	No	Yes	Yes
A7	THN 7	58	Male	No	Yes	Yes	Yes
A8	THN 8	49	Male	Yes	No	No	Yes
A9	THN 9	65	Female	Yes	No	No	Yes
A10	THN 10	79	Male	Yes	Yes	Yes	Yes
A11	THN 11	47	Male	Yes	No	No	No
A12	THN 12	75	Female	No	No	Yes	Yes
A13	THN 13	71	Male	Yes	No	Yes	Fair
A14	THN 14	88	Male	Yes	Yes	Yes	Yes
A15	THN 15	62	Female	Yes	Yes	No	Fair
A16	THN 16	74	Male	Yes	No	Yes	Yes
A17	THN 17	64	Male	Yes	No	No	Yes
A18	THN 18	73	Male	Yes	Yes	Yes	Yes
A19	THN 19	75	Male	Yes	No	No	No

Note: THN stands for Teaching Hospital Neuro

4. Results and discussion

In this section, experimental implementation of the developed real-time wearable system for early warning on Parkinson disease is examined to determine the system performance capacity and accuracy. The implementation process consists of real-time execution of the system to Parkinson probe patients in a university teaching hospital.

Implementation of the system involves the enrolment of twenty Parkinson disease patients. The statistical information of each patient considered in the study is presented in Table 2 of section 3.4. The system is designed to send text/alarm message immediately after sensing certain health conditions of the patient such as speech impairment, anxiety, tremor, gait bradikeniesia and rigidity. The patient on himself is alerted with any of the following message: “Do not worry,” “Go to hospital,” Rush to hospital,” Red alert,” and critical alert,” depending on the severity of the health status.

The alert/text message system compares health status based on information gathered by the wearable body sensor and considering certain threshold values, a text message is generated if the measured value crosses the limits (lower or upper) of the required medical information. Typical 4G used by mobile telecommunication networks in Nigeria has been used on SIM800L module. Furthermore, the performance of the proposed system was checked in terms of the time it takes for sending an SMS/alert message from patient to doctor.

4.1 Results Analysis

The results obtained from some of the experiment conducted with the developed system are presented in Figures 4 to 5 in terms of the nature of the alert message sent from patient to doctor. The performance analysis showing the various time intervals a doctor receives the alert SMS from patient is shown in Table 3 and the rule table for a typical message to be sent to a doctor is shown in Table 4.

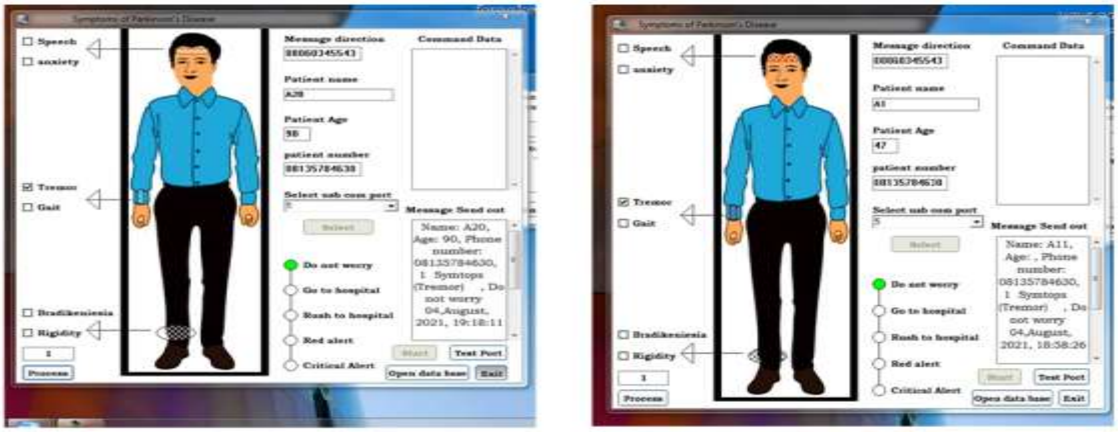

Fig. 4 *"Do not worry" message sent to physician*

Figure 4 shows the test environment of patient being remotely monitored via message alert received from the information gathered by the wearable body sensors attached to various parts of the body. The figure shows the case for different scenarios of patient age: 90, and 47. The system displayed and sent "Do not worry" alert message as an SMS to a medical expert mobile device via wireless communication link. It can be seen that with one level symptom (tremor) detected, the patient information comprising name, age, phone number, symptom, date, and time are sent as well to the doctor.

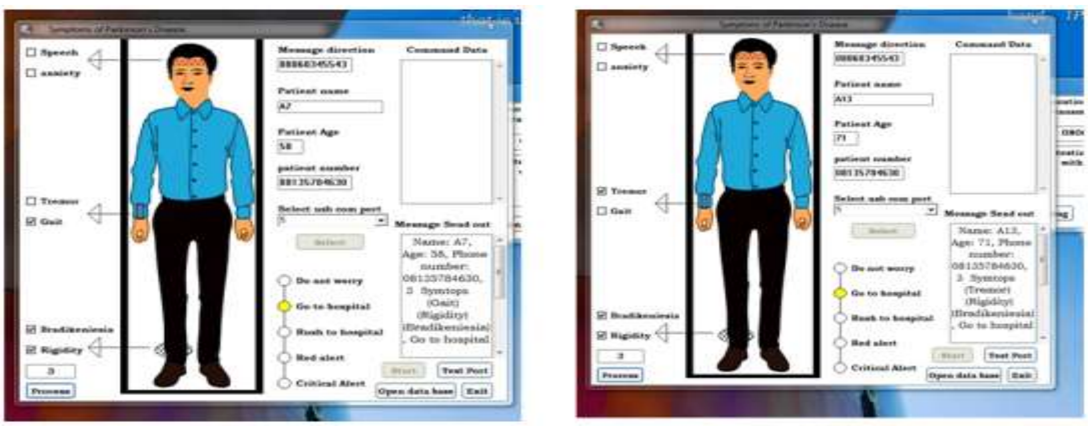

Fig. 5 *"Go to hospital" message sent to physician*

In Figure 5, with three level symptoms (gait, bradikeniesia and rigidity or tremor, bradikeniesia and rigidity) detected, the system sends "Go to hospital" SMS message/alert to physician mobile phone or any remote server wirelessly connected to system at the hospital. The figure shows the patient age: 58 and 71.

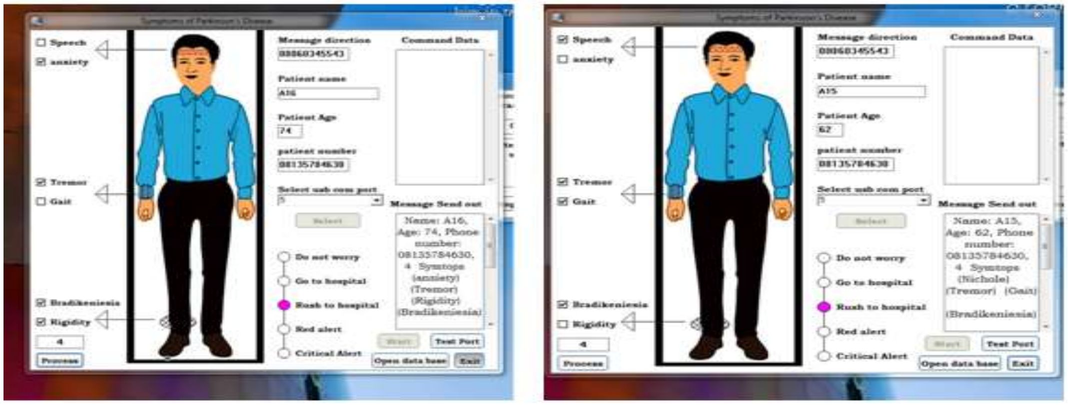

Fig. 6 *"Rush to hospital" message sent to physician*

The physician in the case shown in Figure 6 received a "Rush to hospital" message/alert from the remote monitoring system attached on the patient body due to the detection of four level symptoms (anxiety, tremor, bradikeniesia and rigidity or speech, tremor, gait and bradikeniesia). The ages of the patients are: 74 and 62.

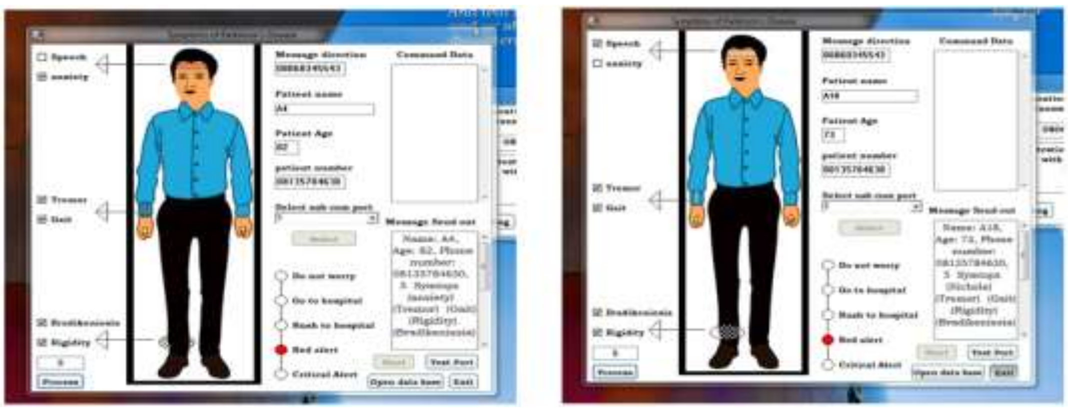

Fig. 7 *"Red alert" message sent to physician*

The case shown in Figure 7 is that of patients' age: 82 and 73, with five level symptoms (anxiety, tremor, gait, rigidity and bradikeniesia or speech, tremor, gait, rigidity and bradikeniesia) are detected; a message/alert that reads "Rush to hospital" is received by a web server of the physician.

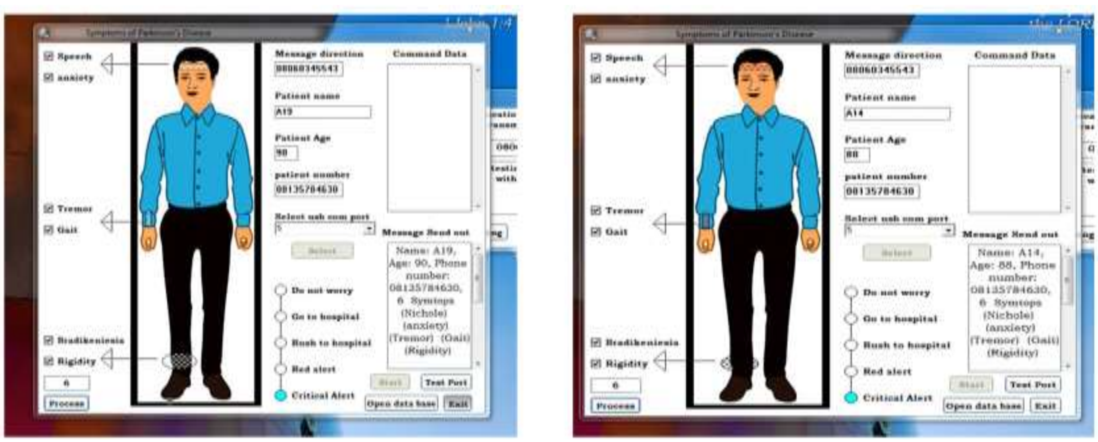

Fig. 8 *"Critical alert message sent to physician*

Figure 8 shows six level symptoms (speech, anxiety, tremor, gait, rigidity and bradikeniesia or speech, anxiety, tremor, gait, rigidity and bradikeniesia) detection by the system; a message/alert that reads "Critical alert" is received by a web server or mobile of the physician. The ages of the patients are: 90 and 88.

In this subsection, the various messages sent out to doctor during the implementation of the proposed system are presented as follow in Table 3. The table shows various experimental results of the test conducted considering different scenario using the proposed system. The time at which message was received by the physician is considered a measure of the system's efficiency and the average timing in second is presented in Table 4.

Table 3*:* Performance analysis of experimental result

Name	**Age**	**Phone No.**	**Symptoms**	**message**	**Date**	**Time** (pm)
A20	90	0803xxxx	Tremor	DNW	04/08/21	19:18:11pm
A1	47	0801xxxx	Tremor	DNW	04/08/21	18:58:26pm
A8	49	0801xxxx	Speech, Tremor	DNW	15/08/21	12:13:28pm
A9	65	0803xxxx	Anxiety, Rigidity	DNW	19/08/21	22:56:41pm
A7	58	0806xxxx	Gait, Bradikeniesia, Rigidity	GTH	17/08/21	22:34:16pm
A13	71	0806xxxx	Tremor, Bradikeniesia, Rigidity	GTH	19/08/21	23:05:20pm
A17	64	0801xxxx	Speech, Tremor, Bradikeniesia	GTH	21/08/21	20:52:56 pm
A12	75	0803xxxx	Speech, Rigidity, Bradikeniesia	GTH	21/08/21	20:41:50 pm
A16	74	0801xxxx	Anxiety, Tremor, Bradikeniesia, Rigidity	RTH	21/08/21	20:49:43pm
A15	62	0801xxxx	Speech, Tremor, Gait, Bradikeniesia	RTH	15/08/21	12:08:55pm
A5	70	0801xxxx	Tremor, Gait, Rigidity, Bradikeniesia	RTH	17/08/21	22:29:19pm
A4	82	0801xxxx	Anxiety, Tremor, Gait, Bradikeniesia, Rigidity	Red alert	21/08/21	20:45:12pm
A18	73	0801xxxx	speech, Tremor, Gait, Bradikeniesia, Rigidity	Red alert	23/08/21	7:14:40am
A19	90	0801xxxx	Speech, Anxiety, Tremor, Gait, Bradikeniesia, Rigidity	Critical alert	04/08/21	19:18:11pm
A14	88	0801xxxx	Speech, Anxiety, Tremor, Gait, Bradikeniesia, Rigidity	Critical alert	04/08/21	19:07:31

Note: Number of symptom (NoS), Do not worry (DNW), Go to hospital (GTH), Rush to hospital (RTH)

Table 4: Average time for data transmission over GSM network

Message/alert for various level	**Average time between sending and receiving message/alert in wireless mobile network (minute)**
Do not worry	00:04:51
Go to hospital	00:04:55
Rush to hospital	00:04:56
Red alert	00:04:58
Critical alert	00:04:59

It should be noted that the average time was taken for 10 messages

4.2 Discussion

Figures 4 through 8 have shown the performance of the proposed system for different levels of symptoms detected by the wearable sensors. Looking at the Figures two type of symptoms have been included (speech and anxiety) other than the common symptoms associated with Parkinson disease – tremor, gait, bradikeniesia, rigidity. The addition of these symptoms was to make the system more robust and based on information gathered from medical experts and hospital visits made during the course of conducting the research. Hence, speech and anxiety are not severe symptoms but detecting any of them or both and with any other main symptom of Parkinson disease, a message level "Do not worry" is sent to a remote physician as shown in Figure 4. When the body sensors detect two to 2 to 3 of the main symptoms as shown in Figure 5, the message level "Go to hospital" is sent to a doctor. In Figure 6, when either of speech or anxiety or both are detected along with at 2 or 3 other main symptoms, the message level "Rush to hospital" is sent to medical personnel. However, it should be noted that message levels "Go to hospital" and "Rush to hospital" are the practically the same but are separated in the platform for the purpose of simplifying the design. In practice, a patient having two of the main symptoms will certainly have to be taken to hospital with high urgency.

In Figure 7, on detecting either of speech or anxiety including tremor, gait, bradikeniesia, rigidity, a doctor at the hospital receives a message level "Red alert" on his mobile or web server. The message level "Critical alert" is received on the mobile phone of a medical expert when the wearable body sensors detect all symptoms shown as Figure 8. Just as stated earlier, in Figures 7 and 8, “Red alert and Critical alert” are two extreme cases of severity and as such are considered the same in practice.

In Table 3 the performance analysis of the system is presented considering some of the messages sent to a medical expert. The message is generated by the system comparing the patient’s medical information with stated logic statement. It is observed that sending a message from patients to medical expert over wireless mobile network takes nearly 5minutes as shown in Table 4.

The experiments conducted showed that a doctor, if solely appointed on proposed, can monitor 10 to 20 patients. Nevertheless, this number can decline to 5 to 10 patients if the doctor is to monitor patients through proposed system, while also engage with regular work in hospital. Though, it should be noted that the number of patients depends on those available at a given time both from remote location and in the hospital.

5. CONLUSION

The rate at which Parkinson disease is increasing among aging population ageing population has called for serious and urgent concern as a result of lack of facilities and very expensive diagnosis, management and treatment cost. Those living in remote areas far from hospital or medical facilities are even more affected by this situation as delay in diagnosis, management and treatment may cause death. Early awareness or timely diagnosis and treatment can remedy this problem to a large extent. The improvements in wearable sensor technology leveraging wireless communication has opened up the possibility of real-time healthcare system that enables early detection and monitoring of patients. In this work, a real-time system for early warning of patients regarding their Parkinson disease status has been developed. The proposed system consisted of wearable sensors, SIM800L module, and wireless network interface. The system can detect body movement and vibration and using to send message to doctor. The message received on web server or mobile phone of a doctor shows patient’s medical status as well as the personal information such as name, age, and address (mobile number). A message alert based on stated threshold of the logic using in developing the system is sent to the doctor in case of any deviation in health status and the message received can take of the category: “Do not worry,” Go to hospital,” “Rush to hospital,” Red alert,” and “Critical alert.” These categories are chosen because the developed system functions to provide early warning message to doctors regarding the health status of the patients.

In order to assess and demonstrate the practical implementation of the proposed system, medical status and personal information about 20 Parkinson disease patients was used to ascertain the effectiveness. Also in validating the remote monitory capability, the system was tested under wireless network (4G) to ascertain the effect of time delay, which is the time taken to send message from the interface of the patient to doctor’s interface. It was found that the message sending and receiving time is nearly 5 minutes on average.

Generally, the scope of this paper is concerned with the development of a concept that can be implemented with wearable sensors enabled early warning system that will provide doctor with information on medical status of Parkinson disease patients when implemented as a prototype form. The proposed system would inform the medical expert in case of emergency through message alert at significantly reduced time. However, this paper was limited to real-time implementation based on computer simulation and with communication with mobile phone via the SIM800L, which was connected to a PC computer by USB port. Further, study is being designed to include the prototype implementation for onward deployment in hospital.

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