An Approach of a Decision Support and Home Monitoring System for Patients with Neurological Disorders using Internet of Things Concepts

IULIANA CHIUCHISAN, OANA GEMAN
Faculty of Electrical Engineering and Computer Science
"Stefan cel Mare" Universityof Suceava
13 Universitatii Street, 720229 Suceava, ROMANIA
iulia@eed.usv.ro, geman@eed.usv.ro

Abstract: -The Internet of Things and information and CommunicationTechnologies applied in development of health care systems have reached an evolutionary process. This paper presentsthe development of an integrated intelligent system for Parkinson's disease Screening.The Decision Support and Home Monitoring System aredesigned to assist and support physicians in diagnosis, home monitoring, medical treatment, medical prescriptions, rehabilitation and progress of his patients with Parkinson's disease. The system will be extended in future research for other Neurological Disorders.This paper has an interdisciplinary character and includes areas such as e-Health, Internet of Things, Information and Communication Technologyand Artificial Intelligence with their application in medical domain.

Key-Words: -Health Monitoring, ExpertSystem, Internet of Things, Neurological Disorders, sensors, Artificial Intelligence.

1 Introduction

Worldwide, one billion people are affected by neurological disorders, including 50 million who have epilepsy and 24 million with Alzheimer disease and other neurological diseases [1]. Many neurological disorders affect aperson's functioning resulting in disabilitiesor limited activities.

According to Parkinson disease Foundation [2], in the USA,nearly one million people are living with Parkinson's disease. This disease occurs in approximately 100-250 cases per 100.000 people. In Europe, approximately 1.2 million people with Parkinson's disease have been reported [2].Although there is presently no cureand the cause is still unknown, there are treatment options to manage its symptoms including medication and surgery.Worldwide, it is estimated that four to six million people suffer from the Parkinson's disease and in the USAcomplications from Parkinson's disease are the 14th leading cause of death [3].

Early diagnosis of Neurological Disorders, such as Alzheimer, epilepsy, Parkinson's disease, and other dementias that influence the lives of patients, their families and society, helps them to have a better and healthier life.

As a health-care strategy, screening and rehabilitation of people suffering of neurological disorders aims to achieve optimal functioning, autonomy and self-caring in the interaction with the larger physical, social and economic environments.

The research in the field of information and communication technology has led to the development of a large series of new tools and intelligent devices that can be used inthe field of health services.As the computer-based patient monitoring systemexpands to support medical activities and at-distance monitoring, doctors/medical experts/medical assistantsmust interact with computer systems and use specialized applications in order to assure a better quality of healthservices [4].

Health care applications facilitate exchange of information between doctors and patients or between institutions, reduce costs, extend the scope and reach of medical facilities, and enhance the quality of services.

The new medical devicesare equipped with sensors, actuators, RFID tags, microcontrollers, mobile-communication devices, nano-pumps and more, in order to allow patients, doctors, or other medical specialists to make health monitoring, diagnosis and treatment more personalized, timely and convenient, while also lowering costs of health services.

In this paper we propose a system for monitoring, screening and rehabilitation of patients with Parkinson's disease or other Neurological Disorders, because there is still no reliable screening test for PD early identification.

In section 2, we present some general information aboutheath care systems and their advantages. Section 3 presentsInternet of Things concepts and technologies. In section 4, we describe, in details, the development of the Decision Support and Home Monitoring System for patients with Parkinson's disease andsection 5 provides a conclusion and some future perspectives.

2 Healthcare systems

Advances in computers, telecommunication and network technologiesled to thedevelopment of a revolutionary new paradigm for health care that refers to as *e-Health*, and to the integration of networking capabilities in medical procedures. In the last decades the link between engineering and medicine become closer, and mechanical parts are developed to substitute damaged or missing human parts, micro-devices are used as implants, miniature cameras are utilized to avoid pervasive diagnostic examinations,real-time systems for home monitoring of patients are developed, and intelligent systems are created in order to automatically process medical data and provide support for medical decisions.

Over the past several decades, Information Technology (IT) has produced major breakthroughs in healthcare and has had a great impact on transforming it from in-hospital health services to more advanced at-home healthservices using Internet of Things (IoT) and related technologies (homecare, home monitoring, personal wearable and portable devices etc.).

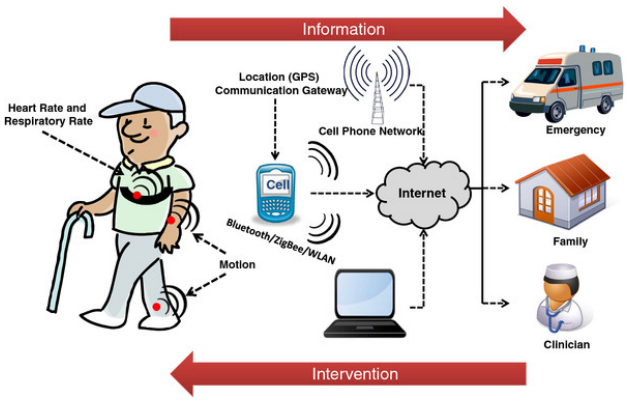

Fig. 1 Health monitoring system

The factors that contribute to the health care transformation include: the nature of new diseases and their treatments; demographic changes; demand for low cost healthcare services; increased availability of complex healthcare medical equipment and services for home monitoring; increased focus on self-care,rehabilitation services and quality of life.

Health care systems are being developed to provide support for medical decisions using health information networks, health portals, tele-health services,electronic health records (EHR), personal wearable and portable communicable systems combined with many other ICT-based tools and applicationsin order to assist physicians/medical experts in disease prevention, diagnosis, treatment, health monitoring and management [4 ÷ 6].

In the case of patient suffering from neurological disorders, such as Alzheimer disease, epilepsy, Parkinson's disease, multiple sclerosis and other dementias influence, the information flow between the patient and doctors is complex and challenging.

In reference [7] is presented a home monitoring that monitor patients with Parkinson's disease who have severe motor fluctuations usinga web-based application and wireless sensors. A web-application was designed in order to provide access to sensor data and that has video conferencing capability to facilitate interaction between patient and physician.

New models for healthmonitoring systems are needed, especially systems that are more patient-centered, not focused primarily on treatment, that assurethe continuity of health services, screening, rehabilitation and prevention on various levels.

3 Internet of Things

Internet of Things canbe viewed „as a global infrastructure for the information society,enabling advanced services by interconnecting (physical and virtual)things based on, existing and evolving, interoperable information andcommunication technologies" [8].

IoT-related healthcare systems are based on the essential definition of IoT as „anetwork of devices that connect directly with each other to capture and share vital data througha secure service layer that connects to a central command and control server in thecloud" [9].

The potential for the convergence of technologies and systems is vast, as can be seen in Figure 2. This development will generate changes in many vertical industries, from health care to manufacturing, from energyto smart buildings and cities [10].

In references [11] ÷ [19] are presented some examples ofcontrol of energy systems such as:

interactive multimedia systems; methods on physical polluting agents and environment modeling and simulation; computational techniques for trading systems, time series forecasting, stock market modeling, and financial assets modeling;recent advances in defense system.

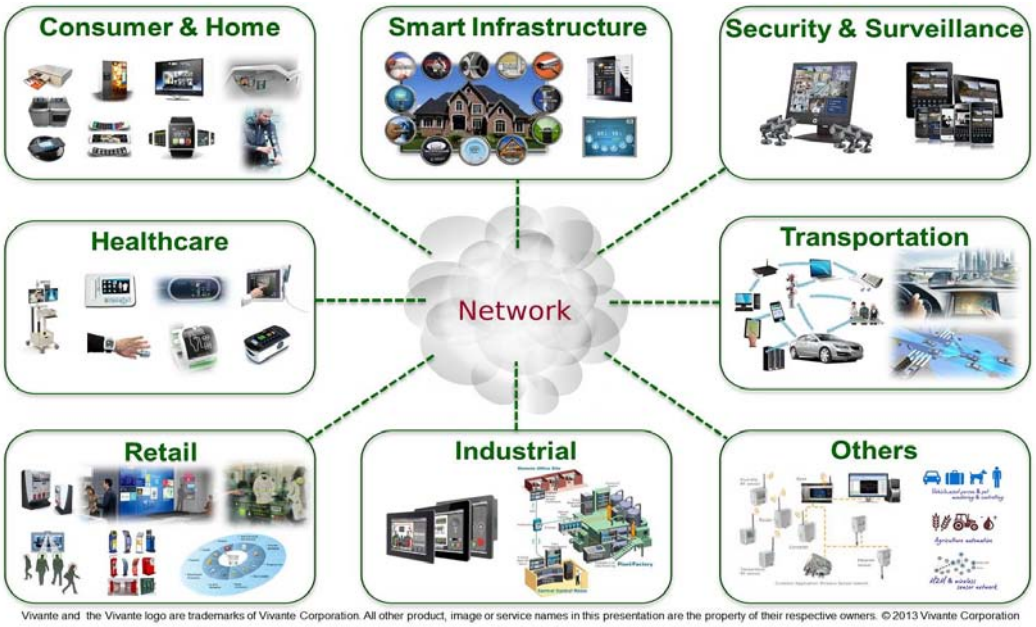

Fig. 2 Internet of Things areas [10]

The IoT offer greater promise in the field of health care, where its principles are already being applied to improve access to healh care services, increase the quality of health services and reduce the cost of thisservices [10].New developments and concepts in ICT lead to innovative smart and portable devices able to identify, locate, sense and connect anytime and anywhere between themselvesleading to a new form of communication and network.

Considering all the medical devices that uses technology for collecting, alaysing, processing, and transmitting data from a system, we can specify that the „Internet of Things" (IoT)concept continues to maturein healthcare domain. Innovative smart devices can collect and share information directly with each other and store it to the cloud, making it possible to collect, record and analyze data faster and more accurately.

In health care field, the possibilities of IoT are so many, because includes systems that facilitate a new concept and support physicians/medical experts/medical assistants and patients in managing the health care process in order to achieve an optimal health status and to avoid a worsening of the illness as long as possible.

4 Decision support and home monitoring system

This paper presentsadecision support system forNeurological Disorders, in particular the Parkinson's disease.This isanexpert system that process tremor data collected from patientswith Parkinson's disease, and alsoassists medical specialists in diagnosis and treatment.

In most cases the estimations are based on the analysis of a large amount of medical history that medical personnel cannot possibly process. Such systems cannot substitute the medical specialist but the information that system provide is extremely useful as an independent source of evidence concerning the correct diagnosis[21].

Although a decision support system is a very complex software system, its operation in the framework of e-Health, as well as the steps typically followed in its design and development, can be generally broken down as illustrated in Figure3.

The information extracted from a patient home monitored and running various medical tests is processed by the doctor in order to reach a conclusion regarding the diagnosis.

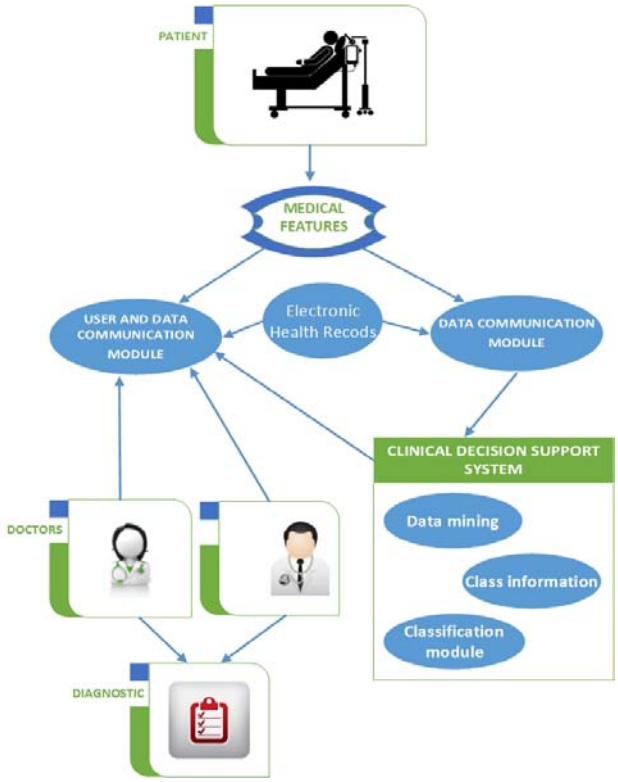

Fig. 3A general architectureof an expertsystem

The collected information could be from a simple body temperature to detailed blood analysis results, MRI images, or, in Parkinson's disease screening, the trajectory of hand movement.

In the process of diagnosis and treatment the doctor may use the networking capabilities offered by the decision support system to retrieve data from distributed electronic health records and/or consult other medical specialists who may be located at different locations [21].

The systemprocess the collected information from patients in order to reach a conclusion regarding a diagnosis and support the medical experts in treatment and home monitoring of patients.The diagnosis is provided by the classification module, which maps available information to one of the known classes of diagnoses. This information about the known classes is either provided manually by human experts or extracted automatically through processing of the medical history contained in the distributed electronic health records by a data mining module.The most important processes in the development of a decision support system arecollecting information regarding the diagnosis classes and classifying of a given case to a diagnosis.

The type of classifier chosen indicates the training methodology.The most applied approaches can be summarized as follows:

- Compare the current case directly to other cases in the medical history, and usesimilarities in order to provide a most probable diagnosis.
- Train different types of Artificial Neural Networks (ANNs), based on medical history, so that data patterns are automatically identified and utilized to provide classification.
- Combine multiple classifiers to minimize the error margin.
- Use a fuzzy system to evaluate the examined case based on information provided by medical experts in the form of simple rules [21].

4.1 Parkinson's disease symptoms

In this paper we present a decision supportsystemfor home monitoring of patients with Parkinson's disease or other Neurological Disorders.

Parkinson's disease is aneurodegenerative brain disorder that progresses slowly, in most cases, and occurs due to loss of a neurotransmitter (dopamine)that induce a slow destruction of neurons responsible for controlling movements.Patients with Parkinson's disease reveal tremor or shaking of a body part, have trouble with moving or walking, postural instability,have rigid and uncontrollable gestures[22], and small handwriting. After many new discoveries and research about the biology of the Parkinson's disease and after almost 200 years since PD was discovered, a diagnosis still depends on identifying the main featuresdescribed by James Parkinson.

The diagnosis of PDrequires a detailed medical history and a physical examination in order to detect the cardinal signs of this disease [23]. The threecardinal signs of Parkinson's disease are resting tremor, rigidity and bradykinesia, from which the first two are essential for PD diagnosis.Thepostural instability is the fourth sign, but occurs late, in disease evolution.

It's a real challenge to develop new methods in order to extract features that can help setting an early diagnosis in case of Parkinson'sdisease or other neurological disorder [22].In Parkinson's disease we can analyze two types of motor symptoms [23]:

- Motor symptoms generated by the diseaseitself and its natural evolution;
- Motorsymptoms generated by complications ofdrugs therapy.

Tremor is usually the first symptom noticed by the patient at rest, although it may be absent in up to 30% of patients. Parkinson's tremor has a regular frequency of 4-6 Hz.The PD tremor has been

observed mainly in the fingers (thumb has a rhythmic movement relative to the index movement associated with "counting money" - "pill rolling") and in the leg movements described as "cycling".

There are two main classifications of tremor:

- Rest tremor that occurs when relevant muscles are not activated
- Actiontremor thatoccurs when relevant muscles are activated,including postural, kinetic, intention and specific tremors.

In 70% of cases, the first symptom isan uncontrollable rhythmic gesture of the hands, head and feetand usually appears at rest when a person's muscles are relaxed, when it is not performing any actions and becomes less evident in progress of the disease [24].

In the research conducted by the Geman O. et al. in [22]÷[26], the physiological information have been combined with time series parameters measured from gait and tremor in order to develop an automatic diagnosis system for Parkinson's disease. The results demonstrate that nonlinear dynamics parameters of gait and tremor signals can be used in PD diagnosis.

4.2System architecture

Our study focuses onthe use of remote tremor measurement devices, data recording, and real-time monitoringin order to help medical specialist in diagnosis. . Remotely located users (physicians and patients) can connect to the database and access information about the patient present condition and his progress, using any device such as PC, laptop, tablets or smartphone. Themeasurements provided by the systemare uploaded and saved on the Internetin order to help medical staff to provide relevant medical counseling and advice to patients according to the measured data

The hardware requirements for the decision support system for home monitoring of patients with Parkinson's disease or other Neurological Disorders can be broken down into three main parts:

1. Smart device that is a special modified mouseequipped with three pressure sensors and an accelerometer sensor;
2. Screening system that includes data acquisition module, tremor data module, feature extraction module using ANN classification algorithms; this component provides tremor measuring via Bluetooth wireless transmission;
3. Web-based Home Monitoring Portal that allows users access to their personal medical information and medical history andfacilitates interaction betweendoctor and patient.

The general architecture of the decision support system for home monitoring of patients with Parkinson's disease or Neurological Disorder is presented in Figure4.

4.2.1Smartdevice

For the tremor acquisition we propose a low-cost, easy to use, and non-invasive smart device. The main feature of this modified mouse is its motion sensing capability, which allows the users to manipulate items.

This device is a trivial mouse modified for sampling the hand tremor as well as to process the accelerometers signals. This device used for tremor acquisition has mounted, on the bottom ofinside surface, some capacitive sensorsbased on the methodology described in reference [27] and an accelerometer sensor.

The 3-axis accelerometer sensor(ADXL345) [28] collects 3D signalsand acceleration data are transferred via I2C bus to an Acquisition and Processing Unit (APU) that incorporates several registers to set the sensor measurement parameters as the resolution, measurement range, and data rate[27]. The acceleration data are grouped in three 16-bit words and the stream data are acquired by APU, as six 16-bits words and stored in a flash memory. APU was implemented in a microcontroller (ADuC7026)[29] responsible with the managementacquisition.

The results of acquisition and processed data are transferred to a local server via Bluetooth wireless transmission. The convertors (C/N), APU and flash memory are grouped in an Acceleration Sensorial Unit and integrated in our smart device.

The device records both acceleration induced by hand movement and by gravitational force. Therefore, this smart device (modified mouse) is conceived as an intelligent multi-sensors structure dedicated to perform a real time tremor assessment by identifying pathological frequencies of the hand tremor.

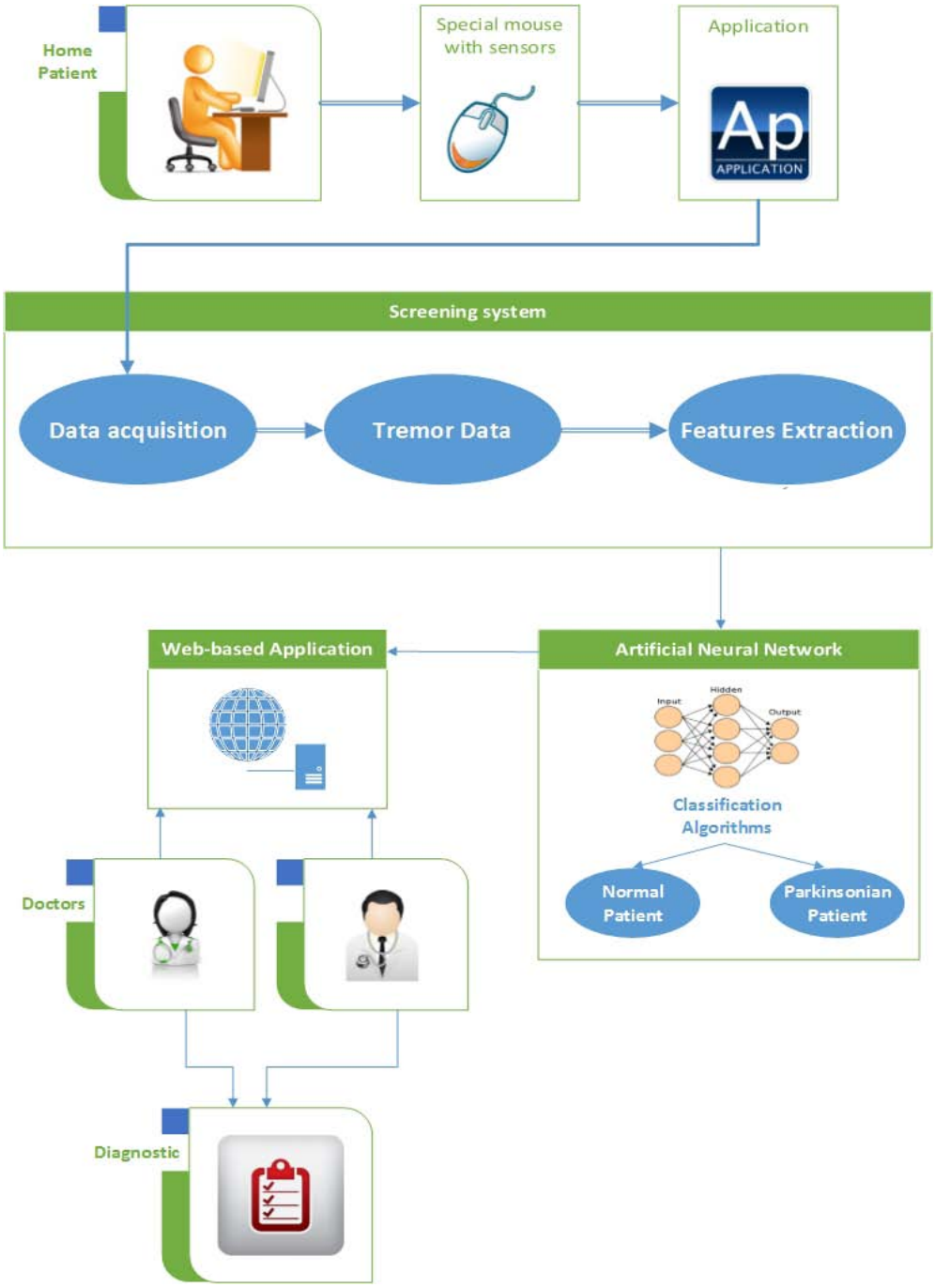

Fig. 4 An overview of architecture of decision support system for home monitoring of patients with Parkinson's disease

4.2.2Screening system

In our study, a number of 10 patients with Parkinson's disease (Parkinson's tremor) and 10 normal persons (Normal tremor) were analyzed. All patients are suffering from a moderate or severe postural tremor.

The smart device and PC were connected via Bluetooth™. The application for tremor processing and analysis was developed using Microsoft Visual C, illustrated in Figure5.

The data information was analyzed using nonlinear dynamics tools, and the next steps in our research will consist in feature extraction and classification. We will analyze two types of Artificial Neural Networks (ANN): the Multilayer Perceptron and a Radial Basis Functions Network and the Adaptive Neuro-Fuzzy Classifier, described by O. Geman et al. in references [30]÷[32]. The Artificial Neural Networks can be used to identify a "normal" subject or a "Parkinson" subject (fig. 5).

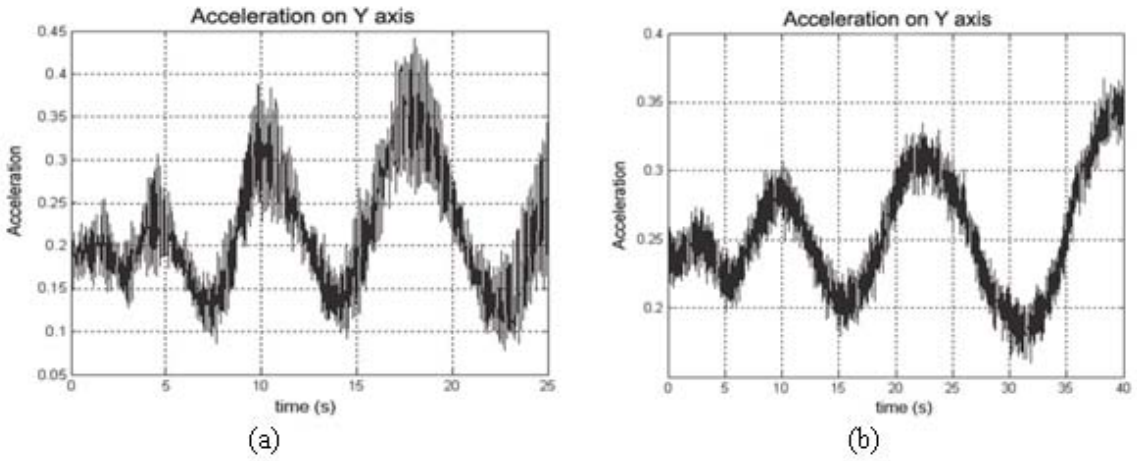

Fig. 5Examples of tremor measurement: (a) Patient with tremor; (b) Normal patient.

More investigations about tremor acquisition and processing techniques in early prediction of Parkinson's disease are presented in references [33] ÷ [35].

4.2.3 Homemonitoring portal

The Web-based Home Monitoring Portal enables the patients to receive health care at home,to stay informed about their current status and progress, to access their own health information, to record the tremor using a smart device, and to contact hisdoctor.PD specialists could access anytime and anywhere the record of the patients' tremor results, increasing the accuracy of diagnosis and improving the quality of healthcare.

Home health monitoring systems of patients with Neurological Disorders has the potential to improve healthcare and provide an efficient and cost effective process. Keeping the patients under observation for a certain period of time in order to evaluate the severity of symptoms helps the differential diagnosis between Parkinson's disease and other similar diseases.

The design of an e-Health portal is a challenging task during to its unique functionality and security requirements. Using HTMLand PHP language, combined with database management with MySQL,wedevelopeda Web-based Home MonitoringPortalwhich includesan expertsystemwhich acquire, analyzeand process data information collected from sensors in orderto support medical specialists in diagnosis and monitoring.

The Home Monitoring Portal facilitates communication in real time between doctor and patients through a friendly User Interface that is accessible at any time and from any device such as PC, tablet or smartphone.

Using this portal, the doctor can analyze and process data received from the patient, and also can prescribe a medical treatment. The patient has access to his personal data and medical history and can communicate with his doctor using text messages or Skype sessions. Users are not required to have sophisticated computer skills in order to use services provided by portal.

Data collected using the above-described system were analyzed, segmented, filtered, and processed using ANN in order to derive features associated with movement characteristics of Parkinson's disease (e.g. the periodic component from 4 to 7 Hz associated with Parkinson's tremor).

Figure 6 presents some screen captures of Home Monitoring Portal for patients with Parkinson's disease or other Neurological Disorders.

5 Conclusions

Combining the Internet of Things and Information and Communication Technology enables the development of health care systems, personalized home management systems. The new methods of collecting patients' assessment and measurement data via wireless transmission, helps the patients to conduct tests on themselves in the comfort of their own homes.

This paper presents the development of an expert system that can be used to gather, analyze, process relevant information for assisting medical specialists in diagnosis of Parkinson's disease. Also a Web-based Home Health Monitoring Portal for patients with Parkinson's disease or other Neurological Disorders is presented.

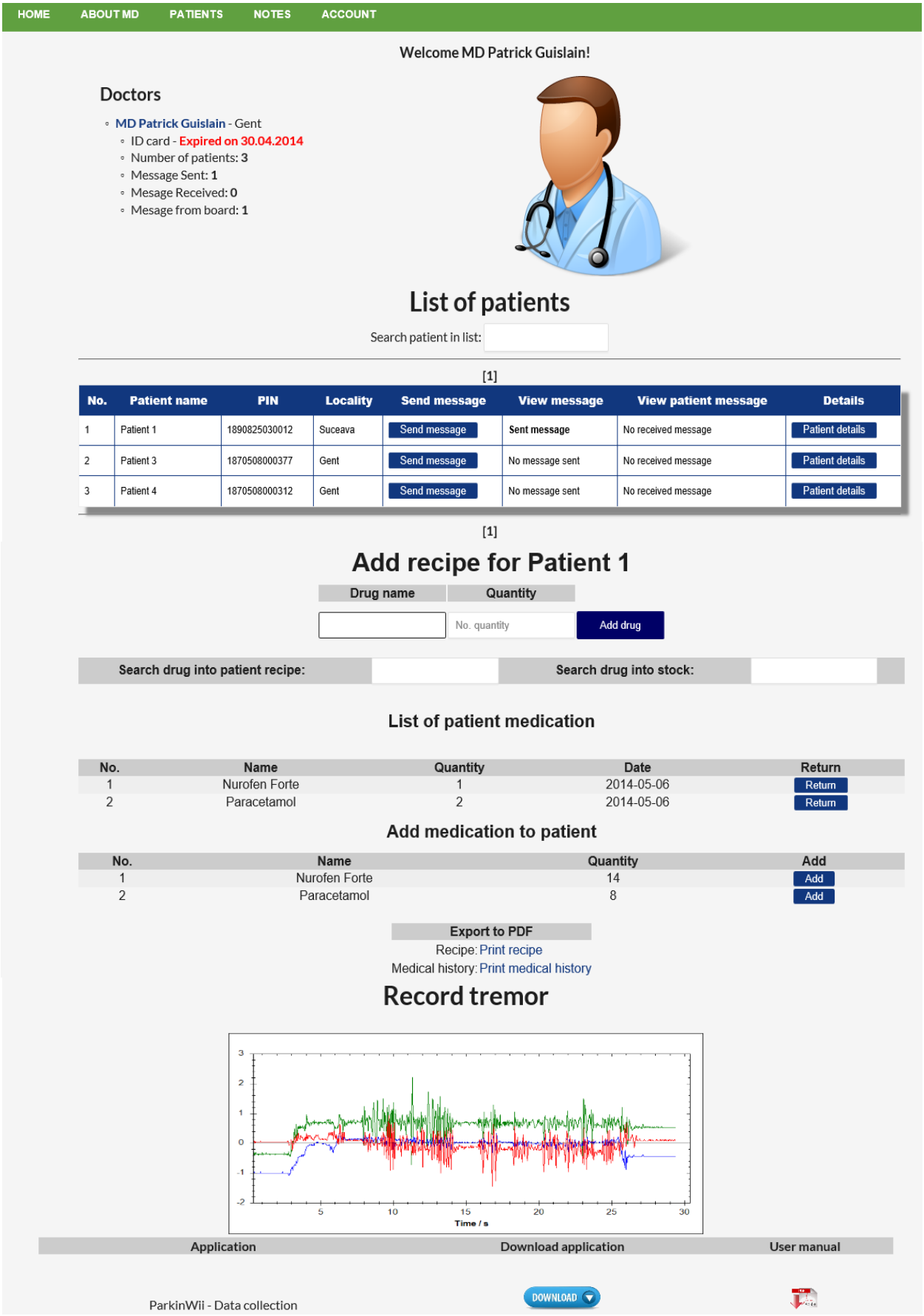

Fig. 6 Screen captures ofDecision Support and Home Monitoring System for patients withParkinson's disease

In the development of the described decision support system we used Information and Communication Technology (ICT) and Internet of Things (IoT) concepts such as: sensors that collect patient data; microcontrollers that process, analyze and wirelessly communicate the data; health care gateways through which sensor data is further analyzed and sent to the Internet.

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