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A Systematic review on Application based Parkinson's disease Detection Systems

Angana Saikia[1], Vinayak Majhi[1], Masaraf Hussain[2] and Sudip Paul[1]
[1]Department of Biomedical Engineering, North-Eastern Hill University Shillong, India.
[2]Department of Neurology, North-Eastern Indira Gandhi Regional Institute of Health and Medical Sciences, India.

(Corresponding Author : Sudip Paul)
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ABSTRACT: Detection of any neurological disorder is very much necessary. Various tools and techniques are nowadays available worldwide. These techniques are mainly based on mobile and web based application as these are cost-effective and easily accessible. These techniques are also user friendly as it can also be used by the disease caregivers by sitting at home and can monitor the disease progression. These applications are also used by clinicians to monitor the disease progressions and can also be used by researchers who wish to extend and work on any kind of neurological disorders like Parkinson's disease (PD), Alzheimer's disease (AZ), Huntington disease (HD) etc. It is also very much less time consuming. In a fraction of second once the data is fed to the application it will detect stage of disease the person is suffering from. The various parameters like Electroencephalography (EEG), Electromyography (EMG), Tremor, Grip Strength, SpO_2 etc can be used as the disease detecting parameters in PD. This type of detection system can diagnosis Parkinson's disease in its early stage as well as diagnose disease progression in later stages. This paper emphasizes on a systematic review of various types of applications used worldwide for the detection and diagnosis of Parkinson's disease and also proposed a detection system based on mobile and web application for Parkinson's disease. The module will not only detect the stage of the PD but also will give the patients various brain and muscle complicacies of the patients. It is a portable one solution system for patients suffering from PD to detect as well as monitor disease progression.

Keywords: Neurological Disorder, Parkinson's disease (PD), Web application, Mobile application, Disease detection system.

I. INTRODUCTION

Parkinson's Disease (PD): PD is a neurodegenerative defect due to less production of a neurotransmitter called dopamine in the substantia nigra of the human brain. Hence, the person loss its coordination between brain and muscle which leads to disturbed limb movements. Loss of dopamine results in the motor symptoms like tremor, rigidity, and bradykinesia. The graphs below shows the prevalence of PD in India [1] (Fig.1) and in worldwide [2] (Fig. 2).

Causes:

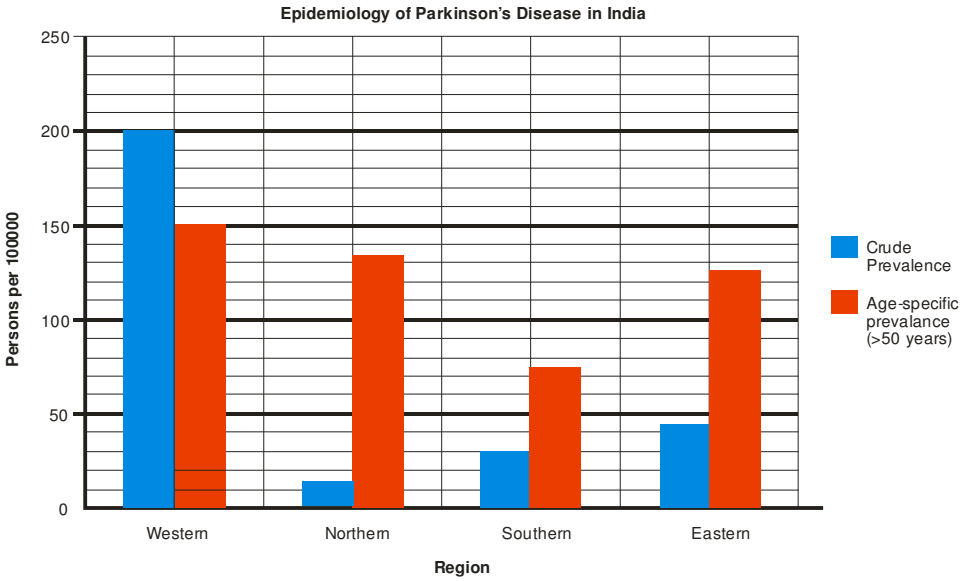

Fig. 1. PD Epidemiology in India.

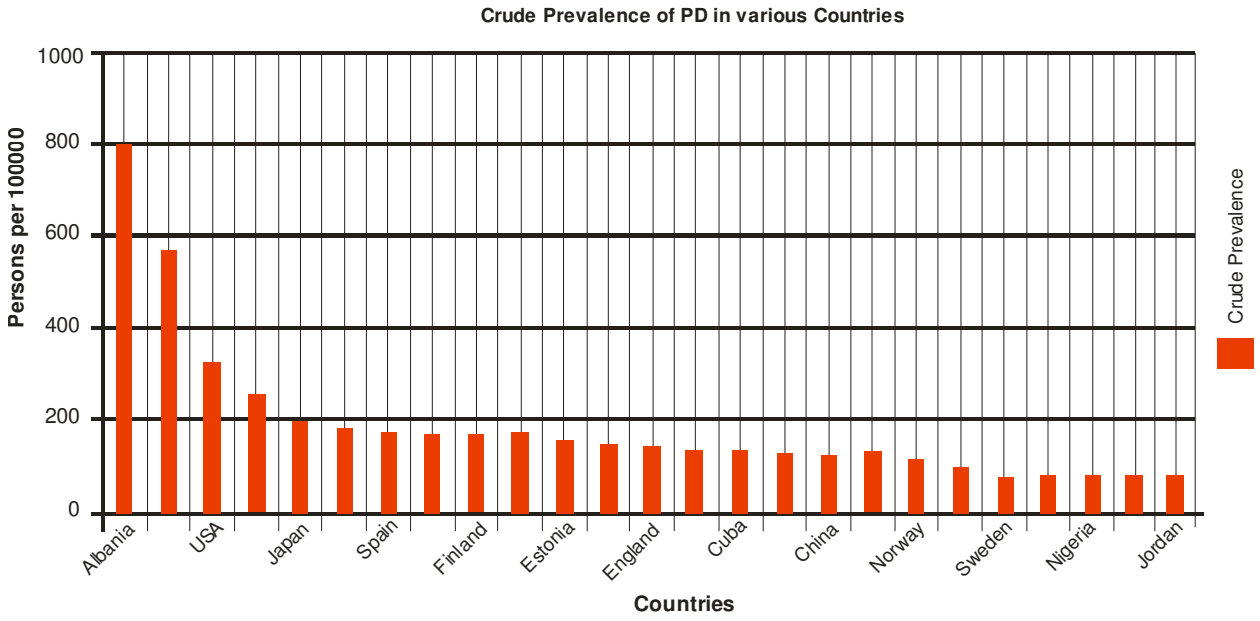

Fig. 2. PD Epidemiology worldwide.

The signature cause of PD is decrease in the level of dopamine in the brain. Dopamine controls a person's movement. In a person suffering from PD, their brain produces very less amount of dopamine. Hence, the person losses its coordination between his brain and muscles. The linkage between the motor cortex and brain stem or spinal cord gets disconnected. Detectable abnormalities called Lewy bodies are present in the neurons of the patients with PD. They are the abnormal protein (α-synuclein) that occurs in the form of a reddish-pink cytoplasmic inclusion.

Harmful metals and gases such as carbon disulfide, manganese, and few drugs may also result to destruction of substantia nigra cells. This also leads to PD. MPTP (1-methyl-4-phenyl-1, 2, 3, 6-tetrahydropyridine), is also extremely toxic to substantia nigra cells. Parkinson's disease genetics are still under research. Genetic mutations leads to Parkinson's, but they involved in a very less percentage of cases.

Symptoms:

Motor Symptoms:

Bradykinesia: It is the slowness of one's spontaneous movement which leads to difficulty with repetitive movements like finger tapping.

Rigidity: It leads to stiffness of various body parts like limbs, neck and trunk.

Tremor: It occurs when one is in awaken state and sitting or standing still which is known as resting tremor. Tremor is the most signature symptoms in Parkinson's disease which is notices by the people around them.

Postural instability: It is a tendency of the person to be unstable when he is standing upright position.

Non-Motor Symptoms:

Neuropsychiatric: These symptoms have important effects in the person life and daily works.

Impulse control disorders (ICDs): ICDs are mainly related to excessive gambling, eating, and shopping.

Sleep disorder: It is very much seen in most of the PD cases. Their sleep cycles are disturbed which leads to nighttime sleep disturbances and hence they get daytime sleepiness.

Autonomic dysfunction: Some of these problems seen in PD are sexual dysfunction, swallowing and gastrointestinal disorders etc.

Sensory: Most of PD patients suffers from sensory impairments' like numbness, coldness, burning, or pain.

Role of applications in detection and monitoring of Parkinson's disease:

Parkinson's disease detection and diagnosis is very much important. To monitor the disease diagnosis various types of system has been designed [3]. Among them mobile and web applications are very much trending at present scenario. As PD is neurodegenerative disorder, its progression must be monitored frequently by the clinicians, disease care givers and also sometime by the patients themselves. Hence, a cost effective and portable user-friendly system helps for disease detection in its early stage as well as monitoring the disease progression in the later stages. Various biophysical parameters like EEG, EMG, SpO_2 and grip strength etc can be incorporated in the mobile applications so that the person in a remote location can also monitor its disease progression using a smart phone having an internet connection to it.

II. MOBILE DEVICES FOR DISEASE DIAGNOSIS

With the advancement of technology, smart phone based applications has widely been used for disease diagnosis.

The various status and conditions of neurodegenerative disorders like PD can be monitored by smart phone applications. Nowadays this mobile phone based systems are known as mHealth (mobile health) which is a wireless technique in medical area. mHealth makes the use of mobile devices to educate consumers about various areas of healthcare sectors. For disease diagnosis various applications are built in the smart phones to diagnosis different types of parameters of that particular disease. These parameters enable the users to monitor the disease progression by themselves by staying in remote location [4]. There are very much user friendly and handy.

These applications can help the people to manage their own health themselves and lead a happy life also by gaining access to various health related information whenever and wherever they need it [5].
Some of the available mobile health care devices are:
Palmtop, Personal digital assistant, Pocket PC,
Smartphone, Tablet, Smart watch, Bluetooth headset.

III. PARKINSON'S DISEASE DETECTION USING MOBILE DEVICES

Parkinson's disease is also detected using various mobile techniques like smart phone based and web applications. Various symptoms of PD like: Tremor, Rigidity, Postural Instability, depression, disease severity etc can be detected from various applications which includes different disease diagnose parameters. A person suffering from PD, its caregiver can easily monitor the disease progression by themselves wherever and whenever required. Some of the work done in this area is given below.

In 2019, Le Moyne *et al*., worked on various wireless systems for diagnosis and detection of PD using smart phone. Initially, the smart phone represented a wearable and wireless accelerometer system that is mounted through gloves on the hand. This smart phone's wireless connectivity to the internet has made it accessible from worldwide and its location is based on the preference of the patient's. This type of emerging trends provides opportunities that Network Centric Therapy with the inertial sensor signal data can store in a Cloud computing database [6].
Klimova *et al*., carried out a research study on the usefulness of Internet of Things (IoT). IoT can act as a efficient platform for health care management for PD [7]. It is also a cost-effective approach. Its objectivity and portability and user friendly approach with its wearable sensors connected becomes a novel approach for chronic neurological disease diagnosis. Some of the clinical trial taking place in this area is illustrated in the Table 1 below:

Table 1: Work done on PD detection based on IoT.

Author	Experiment	Conclusion
Ellis *et. al*., [8]	Designed a smart phone based application to assess the gait variability in PD using various sensors.	Concluded that this application can be used as a diagnostic method for conventional gait analysis.
Ferrari *et al*., [9]	Described a novel technique for estimating various spatio-temporal gait parameters using shoe-worn inertia sensors.	This wearable sensors works as a tool for tutoring and guiding gait execution in patients suffering from PD.
Kostikis *et al*., [10]	Designed a smart phone based application to detect upper limb tremor using accelerometer and gyroscope.	The proposed method is an effective tool for the clinicians in the hospitals and also evaluates the patients from remote location and results can be assessed by the doctors.
Marx *et. al*., [11]	They worked on video-oculography to a head-mounted device using an Eye See Cam.	This device can be used to differentiate clinically a Progressive Supra nuclear Palsy patient from a PD patient. The use of this wearable eye tracking system, various uncertain diagnoses can be carried out in the patients.
Ozinga *et. al*., [12]	Carried out experiment on kinematic data which was measured by a tablet with motion capture system to characterize postural stability.	The hardware provided sufficient data which is much accurate to determine the postural stability in PD.

Falodar *et al*., [13], designed a system containing three different modules in a single a system.
Following were the modules:
Storing information of distinct data, Managing the data acquired from the Unified Parkinson's Disease Rating Scale (UPDRS), Promoting various innovated technological in healthcare. The designed system manages the patient database in a single screen containing various parameters which is very much user-friendly.
Stamate *et al*., designed an application known as the cloud UPDRS app. This app mimics the Part III of the UPDRS. The patient performs a sequence of iterated movements that was recorded by the sensors in phone. Their main aim was to ensure high-quality data collection and to reduce the test duration to below 4 min. To achieve their goal they combined a bespoke design with Recurrent Convolutional Neural Networks. They also developed a machine learning technique to personalize the patients assessments through selecting those parameters of the test that matches person's symptom and finally estimated the patent's score [14].
Doerr *et al*., [15] designed a self administered Smart phone based e-consent system. They carried out a qualitative analysis of patients responses to daily works for around 6 months of time within Parkinson mPower app. The priori codes were used for informed consent and emergent codes for various other self accessed consent methodology. They also used self-reported demographic data for the patients. 9846 subjects completed the e-consent process. This is a novel approach that acts as self administered informed consent process using a mobile application for the PD patients.
Ozinga *et al.,* developed a mobile device system which is validated with a 3-D balance metric that detects postural instability. The app can detect biomechanical signals using an inertia sensor. It characterizes various movement of center of masses in three different directions.

They are medial-lateral, anterior-posterior and trunk rotation directions. 27 PD and 27 control subjects were recruited for the study which had to perform different types of balance tasks and their peak to peak voltages of sway acceleration for each task were compared. They also calculated the Cleveland Clinic Postural Stability index for each individual. The balance metric peak to peak was higher in PD compared to the control subjects. This system with the balance metric and mobile device sensor acts as a diagnosis system for detecting postural instability in PD [16]. Vladimir *et al.,* worked on finding the efficiency and limitations of tactile cues (TC) for modulating heel tapping and walking for a period of different cueing intervals and with/without a secondary task like holding a tray with a cup of water. They studied the modalities of TC usage in movement modulation and motor integration in person suffering from PD. The designed Smartphone TC is a handy and effective movement modulation tool [17].

Bot *et al*., acquired data through a research kit from apple using an iPhone. The device was known as mPower. They recordings were sensor based clinical observations from PD as well as non PD patients. This study can be used as a standard for various real world measurements through mobile phones which will lead to distinguish various PD symptoms. The source codes of the application were available free for study purposes [18].

Fraiwan *et al*., designed a system for mobile phone applications for Parkinson' disease. The system detects the PD hand tremor with a mobile phone accelerometer. 21 PD and 21 healthy subjects were recruited for the study. Various features were determined using 2 level wavelet packet analyses. Classification done using neural network showed an efficiency of 95% with a Kappa coefficient of 90%. This system can efficiently detect the resting tremor in PD [19].

Arora *et al*., experimented with PD patients by giving them smart phones with an Android operating system which included some of the parameters like voice, posture, gait, finger tapping, and response time. All the tasks were done 4 times a day for a period of 30 days. Statistical parameters of the all the tasks recorded using the smart phone from 10 PD and 10 controls subjects each. They concluded that PD symptoms measured using smart phone is feasible and acts as a PD diagnostic tool [20].

Pan *et al*., developed a mobile cloud-based mHealth app, which collects various diagnostic parameters of Parkinson's disease. It would also find various quantitative information. The application is known as "PD Dr". It is a home based application where one can monitor the disease symptoms from home. The application captured various motion features that detect the PD severity and critical symptoms. The results of hand resting tremor showed a sensitivity of 77% and accuracy of 82% while gait analysis showed a sensitivity of 89% and accuracy of 81%. The PD motion features showed a strong correlation between PD severity stages, tremor severity, and gait difficulties [21].

Kim *et al*., designed a smart phone based system to detect the Freezing of gait symptom of PD. It senses the gait characteristics from different body positions like ankle, trouser, waist and chest pockets. The measurement was done using accelerometer and gyroscope in the smart phone where machine learning categorized freezing episodes from normal walking condition. Ada Boost. M1 classifier recognized a sensitivity of 86% for waist, 84% for trouser and 81% for ankle [22].

Ferreira *et al*., [23] developed a system known as Sense-Park System that comprised of wearable sensors, an app based on smart phone, and a balanced board with computer software. Testing was done for 12 weeks for 22 no. of PD patients. This study based on the Sense-Park System is an effective home based tool for monitoring the disease which is also very much user friendly device.

Pepa *et al*., designed a smart phone based architecture that collects the data and information's needed to detect freezing of gait system in PD patients. The parameters used were freeze index, energy, cadency variation and the ratio of the derivation of energy. Algorithm using fuzzy logic reduces false negative detection and hence it improves the sensitivity of the system [24].

Lopez *et al*., designed a glass system consisting of portable auditory device known as Listenmee to detect the effects of gait in PD patients. It gives 100 types of sound with an adjustable metronome and a smart watch connected to an accelerometer that detects the magnitude and direction, tracks the patient weight, patterns of sleep, and also the step counts and daily distance covered by the patient. Efficiency was found from the gait laboratory. The result showed an improvement in gait performance for all the patients for the following parameters: walking speed (38.1%), cadence (28.1%) and stride length (44.5%). Hence, they concluded that Listenmee® is a novel finding to increase a PD patients gait abilities [25].

Chen *et al*., designed a application called Mercury Live, that monitors the disease condition of the PD patients from home using wearable sensors. It consist of data collection engine using the sensor, web based application for live streaming and storing the data collected from the sensor and a graphical user interface that have video conferencing system. It can also check the tremor, bradykinesia and dyskinesia severity by giving a clinical score. The result detected an average of data latency less than 400ms and video latency of 200ms. The video frame rate was13 frames/sec when 800kb/s bandwidth was available. They used 40% video compression and the uploading time of the data was 1 min followed by 10 min interactive sessions. This designed approach is very much effective for patient monitoring in the later stages of the disease when the person becomes bed ridden mostly [26].

Some of the characteristics of mobile applications for PD based on android operating system are shown in Table 2 [27].

Table 2: Mobile based Apps on PD.

Name of the system	Use
ARAT Action Research Arm Test DAF Assistant	Upper limb assessment
DAF Professional	Improves the speech and oral expressions
DAF Professional Lite	Clears the speech and reduces stuttering
Brain Injury	Guidelines and advice for the patients
Tremor	Information about tremor
Help talk	Assistance for oral communication
MedOcloc Pill Reminder	Self managing medication
My Therapy Pastillero	Medication self management
ParkPen	Pen for PD patients.
Response Measurement	Response time to external stimulus
Speech Comparison	Speech therapy exercise
Word or Color Dot	Cognitive exercise
Parkinson's Disease Facts	PD statistics and treatment information.
Early stimulus	Deep brain stimulation criteria's
Dopa Fit	Exercises for PD
Listen Mee App	Cueing to improve gait
PD Warrior	PD Exercises
My Parkinson's	Detection of upper limb resting tremor
Parkinson: Symptom Graph Create	Graphs to monitor PD patients
Parkinson's Test	Diagnosing and assessing PD
For Insight App	Monitoring of various PD related activities, tremor and sleep

Table 3: Work done on web application in PD.

Author	Experiment	Conclusion
Kraepelien *et al.*, [29]	Studied the effects of ICBT for PD patients with depression and anxiety	ICBT is a technique to diagnose depression and anxiety in PD
Yang *et al.,* [30]	They compared the virtual reality balance training in the patients from home.	This technique is effective than any other home based balancing techniques.
Sarkar *et al.*, [31]	2-round Delhi study was carried out to select core of parameters and assessment tools.	Measuring parameters, tools, and devices were used to evaluate patients at home.

IV. WEB APPLICATION FOR PARKINSON'S DISEASE DIAGNOSIS

There are various web based studies that is based on web application which can detect PD. It can monitor the disease progression. An application that is stored in any remote server and is delivered through internet which is interfaced with a browser is known as web application. Internet-based applications mostly consist of self-help texts, homework assignments, queries and guidance by an online expertise.

Rovini *et al.*, designed a system known as DAPHNE for early detection of PD using information and communication technologies (ICTs), like mobile Health (mHealth) apps and Internet of things (IoT) protocols [28]. This system aimed at Ambient Assisted Living (AAL) that assisted the doctors for early detection of the disease.

It also had a home monitoring service which is patient friendly that helps them to initiate accurate medicinal approach. It reduces the costs of disease diagnosis in relation to tests and hospitalization. This novel approach maximizes the drug therapy efficiency.

The applications are subdivided into following categories as per its usage [27].

Information apps: These apps provide information's on the disease whose main target is healthcare professionals, PD patients and caregivers.

Assessment apps: These apps include different types of tests for monitoring the disease progression. For example: gait analysis, tremor, speech and limb coordination.

Treatment apps: These apps provide treatment guidelines which may include neuro-rehabilitation, physiotherapy, cognitive and speech therapy.

Some of the work done in this area is shown in Table 3 below.

V. MATERIAL AND METHODOLOGY

The proposed system for detection and monitoring of Parkinson's disease is shown in Fig. 3 below. It consist of unit which comprises of module of various sensors like Tremor detection sensor, EEG and EMG sensor, SpO_2 and grip strength sensor. All these sensors will acquire and record the biophysical parameters from the Parkinson's disease patients. The acquired data will be furthered processed in a microcontroller unit. This unit will send the data to any mobile device which further send to the server for processing through Bluetooth module. It will also contain patients demographic as well as clinical assessment data. As a result the patients report will be available online to the patients anywhere either through mobile or web application. Overall the module will give all the biophysical parameters as well as show the stage of PD the patient is suffering from.

The inclusion criteria's are:

Any stage (Stage 1-5) of Parkinson's disease.

Patients' above the age of 50 years.

The exclusion criteria's are:

Patients' with any metallic or other implants on the body.

Patients' below the age of 50 years.

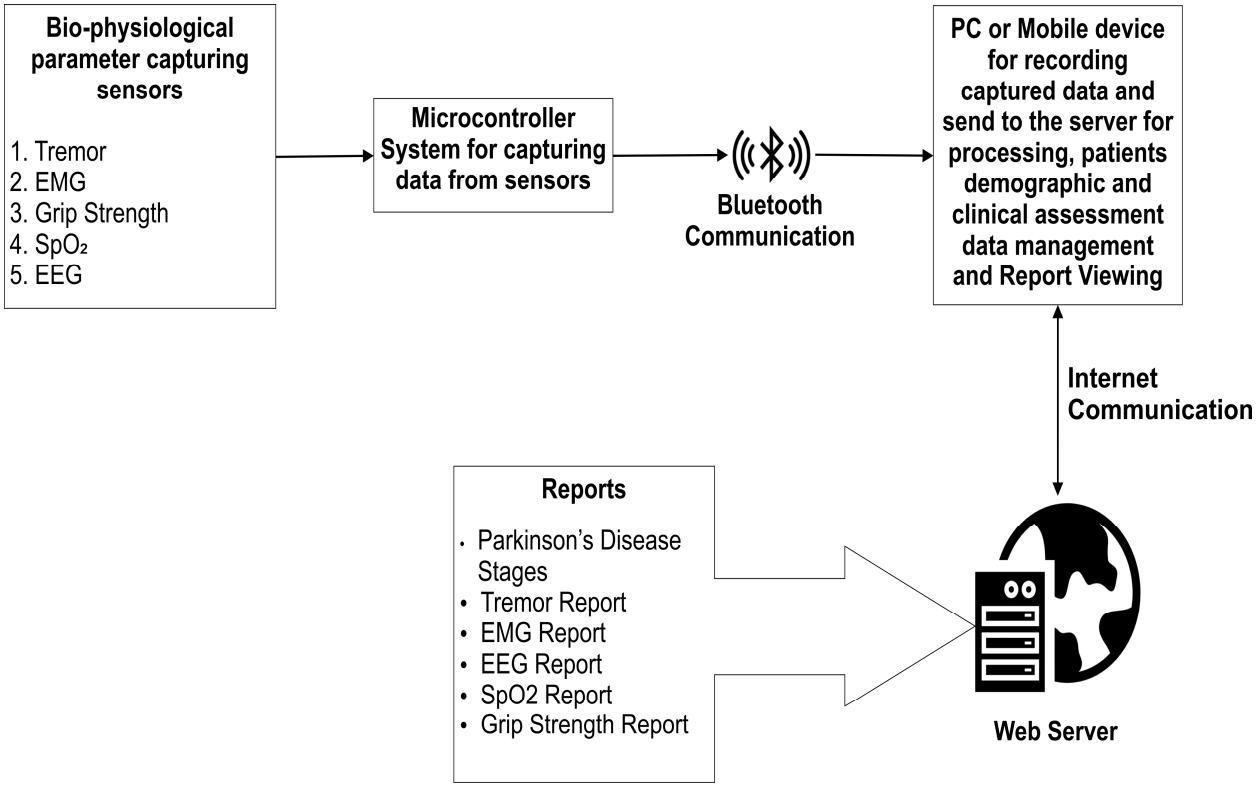

Fig. 3. Block diagram on Parkinson's disease detection system.

VI. ADVANTAGES OF WEB AND MOBILE DETECTION SYSTEM

Some of the advantages of this type of disease diagnosis system are as follows:
Efficient coordination, Uninterrupted data flow, Effective patient management, Increase doctor efficiency, Efficient diagnostic technique and accuracy, Provides convenience, Caters to customizations.
This kind of detection system is very much effective for disease diagnostic. They have a very strong impact in the healthcare sector. This helps in easy diagnosis of disease and prevents the likelihood of developing various medical conditions. The use of these techniques has made a higher patient engagement. It makes people more focused on improving their health as well as wellness. They get to access their own health conditions in their finger tip and get routine check up as well as remedies. In the hospitals and various health centers mobile application/ web applications are used to store various patients records which enables the clinicians to access the disease progression of each patient.

VII. DISCUSSION

Neurodegenerative disease like Parkinson's disease cannot be cure completely. A patient with PD suffers throughout their life with the disease and with the growing stages the appearance of several motor and non motor symptoms become more predominant. In final stage of PD a patient becomes completely bed ridden and unable to perform his daily necessary task which makes the patient more dependent to their family. As it is incurable, so the best way is the prevention of PD progression and also the early detection of the PD before it becomes severe. Some research also shows that the use of Levodopa based drug also accelerates the rate of neuronal degeneration. So during medication the monitoring of patients becomes more important.
In modern days Smartphone becomes a daily essential gadget to our life. So the monitoring of PD patients becomes easier. The web based application also help in these scenario by making the doctors easily available to the patients through distance. Now one patient can be monitor with these developed instruments all the time.

The application of machine learning also helps us in predicting the symptomatic correlation with PD which opens a new window to identify PD patient even in early stages.
Finally we can conclude that all the devices developed have its specific task basis which is capable of detecting one or two different symptoms of PD like tremor of different position like hand or finger, postural instability, rigidity and so on. There is also clinical symptomatic analytical software that also discussed. The complete detection of PD symptoms including motor and non-motor symptoms for identifying PD with its stages has been proposed in our model. The actual cause of occurring PD is still not justified, so the implementation of Artificial Intelligence in patients symptomatic historical data to find the root cause of PD can be a promising developing application in this field.

Conflict of Interest. None declared.

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