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Advanced Computerized Automated Seizure Detection and Prediction System

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Abstract

Epilepsy is a focal neurologic disorder which badly effects the central nervous system of an individual.It results in various different types of seizures which can be classified as Atonic ,Myoclonic,Tonic-Clonic,focalseizures.Patients suffering from epileptic seizures shows various unusual symptoms like shaking of arms and legs,having unconscious state of mind during seizure,loss of memory and various uncountable body movements which all lead to unrecoverable losses ,bad injuries and even death of several patients.Though medical treatment like anti-epileptic drugs called anti-convulsants and brain surgeries are available,but still an Advanced Computerized Automated Seizure Detection and Prediction System is required which constantly monitors the epileptic patients,processes their medical variates like blood pressure,strokerate,etc. and accordingly predicts and sends the prior notifications before seizure occurrence via alarms or SMS to the concerned medical staff.
The term Wireless indicates that patient regular monitoring will be based on Wireless Sensor Networks(WSN's) like advance technology.Patient's hands and legs movements will be monitored through a wireless-connection network constituting of sensors,mobile cloud computing(MCC),wireless sensor nodes and k-nearest neighbor algorithm for further computations of received data from inertial sensors.

Keywords: Seizures,Wireless Sensor Networks,KNNalgorithm,Accelerometers,HR sensors

Introduction

Epileptic Seizures are caused due to electrical disturbance in transmission process of signals from neuron to neuron.While,some convulsions occur due to large intakes of glutein sources like barley,wheat which comes under the category of celiac disease while other occurs due to insufficiency of oxygen to brain muscles.But the root cause of this disease is still unknown.

This paper aims in developing an Autonomous Seizure Detection System using Wireless Communication as its backbone.Over the last few decades,many researchers have shown heterogeneity in their proposed solutions in the detection of epileptic seizures.The most commonly used techniques for detection purpose were magnetic resonance imaging (MRI) and computed tomography(CT) which are most common medical imaging techniques.The more advanced techniques used were electroencephalogram(EEG),electrocardiography(ECG) which includes the domain area of image processing. Though,the results obtained for seizure detection by EEG were highly accurate ,this technique requires the patient to wear the complex headset constituted of electrodes that acquires the whole scalp area which makes the patient feeling uncomfortable while performing its normal daily-routine activities.Such complex wired architectures also hampers the continuous monitoring of patients on real-time basis.Also,limitations to their work were further extended to real-time data gathering,implementing cost of proposed designs,energy efficiency problem.

This paper includes most of the data receiving and processing part within the MCC unit,i.e.in smartphones itself.This will lead to less storage, more computational capacity and highly power efficient system.Collected data from BAN/wearable devices/Patient's kit is sent wirelessly to local static node which acts as a router in deployed WSN and further sends the data to MCC unit for processing task.Hence,this research work proffers the methodology of constant monitoring of an epileptic patient by not confining him/her to constrained space within the room/clinic itself but by including the concept of mobility using Wireless Communication technology .So,to collect the real time data for monitoring by not hampering the patient's normal routine activities.This BAN is composed of mobile sensors which collect real time data of patient under surveillance.Actually,the sensors collect data from physical parameters and share it with the central/gateway node wirelessly,therefore,more friendly with patient's resting and ambulant movements

Algorithm used for Classification technique is KNN which is highly accurate one. Moreover,KNN algorithms provides feasibility in terms of training data(data required to train the classifier to distinguish seizure data with non-seizure data) as their is no requirement to again train the classifier for new epileptic patients.KNN is a machine learning algorithm which works on feature extraction technique which further leads to respective classification using k-nearest sample points.Parameters used for the detection of seizures includes:temperature,humidity,shaking of arms and legs,heart-rate variability,bloodpressure,respiration and gas metabolism.Accordingly,sensors are used to take real-time data.This paper uses Wagyromag(wireless 2D triaxialaccelerometer,gyroscope,magnetometer),HR and sound detector sensors.Sensors placed over patient's body forms the Body Area Network (BAN's).Data Analytics and Graphics part is performed by KNN classifier.KNN classification is a more sophisticated and accurate tool than Artificial Neural Networks(ANN's) if 50% of received data in form of electrical signals contains seizure data.

Proposed Work

This paper aims in designing a detection system for seizures using Wireless Sensor Networks(WSN's) as its base technology.Though there is lot of research going on in this field and many researchers are working in this domain to have an effective solution as a cure for epilepsy patients using various technolgiesspecially,EEG.This project proposes new approach in way of technolgy used in the system.The Detection System proposed for seizures in this paper uses WSN and IOT as its foundation.
The research work includes WSN technology for collecting ,sharing and again receiving of data whereas IOT technolgy for computational capacities of MCC unit.
The proposed system will efficiently work on these parameters:
1. Mobility: As system includes the use of Wireless Sensor Networks(WSN's),patients are free to move and perform their daily activities without wearing any cumbersome headset device.Thisleds to efficient collection of patient's data and hence,improves the computational algorithms for better prediction.
2. Less Computations: In comparison with the workperformed in last few decades on epilepsy and seizure detection techniques,there is always the involvement of Cloud Network for processing of data.Therefore,the layout goes in such a manner that the static node which is responsible for collection of data from mobile sensors will send the data altogether to MCC unit which further sends the preprocessed data to Cloud unit for further processing.This process causes a lot of complex computations involvement and thus makes the system more complex.In the proposed system ,new approach of IOT as a compuational unit is used which reduces the system complexity.
3. Power Savage: As system proposes the major part of processing in MCC unit ,it saves the power consumption of system and makes it an energy efficient system.

Research Methodogy

The research Layout includes the following steps:

1. Attachment of Wearable Devices(WD's) with patient :

For the effective monitoring of patient under surveillance some basic inertial sensors should be tied with the patient body that will ultimately form the patient's Toolkit.The sensors used will be

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triaxialaccelerometer,HR sensor and Temperature sensor. The sensor module used for Wireless connection will be MICAz motes sensor module.

2. Data Collection:

For collection of data one central node is required which will take all real-time data collected by the sensors .Such connection built between Patient's Body Area Network(BAN) and Central/Gateway Node will come under the category of PAN's,i.e. Personal Area Networks.

3. Data Gathering to the processing unit:

Data gathering includes the process of reception of data to the main processing unit of built Wireless Sensor Network(WSN's),i.e. MCC.The collected data over central/gateway node will be sent to local MCC unit like smartphone which will be connected via internet facility for processing of data.

4. MCC Integration:

MCC Integration involves the installation process of all the required Apps which are desired for further computations of data.

5. Data Processing:

Data processing includes refinement of data like feature extraction,computational algorithms using KNN Algorithms.The received data in processing unit compares the value with threshold values set by user and accordingly generate notification for user.

6. Notification Generation:

This process includes sharing the result of computations with the local user/medical staff.

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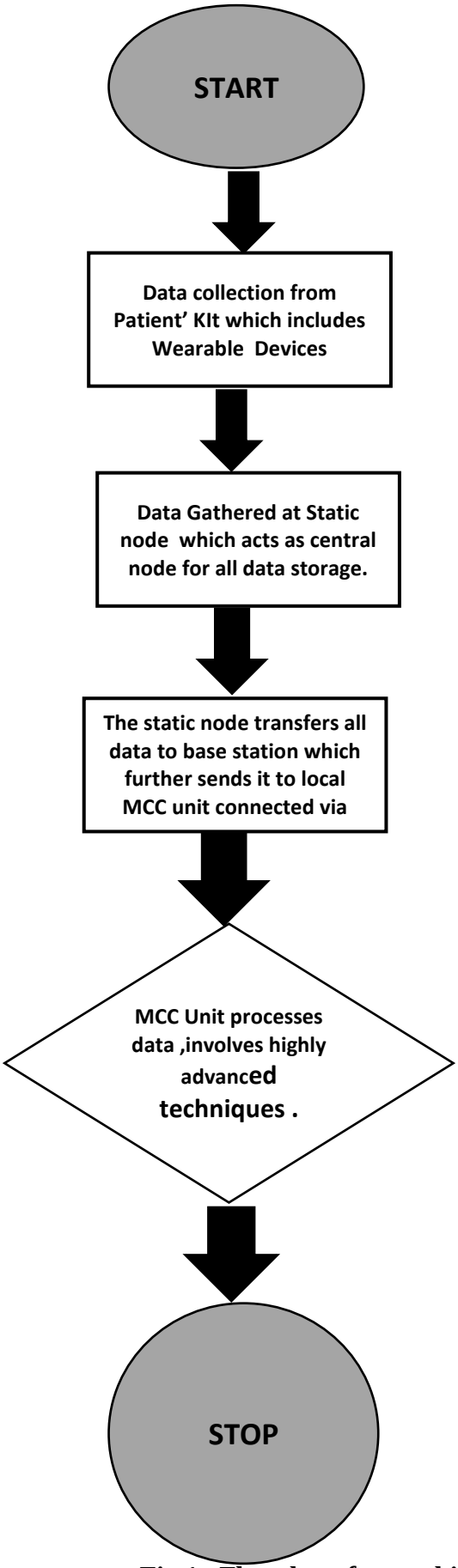

Fig.1. Flowchart for working mechanism of project

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-Detailed description of Designing Methodogy of project :STEP 1. Initial step:Formation of Sensor network by pacing sensors on patient's body:-Two Biaxial (2D) Accelerometers are placed on right arm and left thigh of epileptic patient.-Sampling frequency of ACM used is 3 Hz.
The effective wireless communication of devices in system shown in fig.[2]

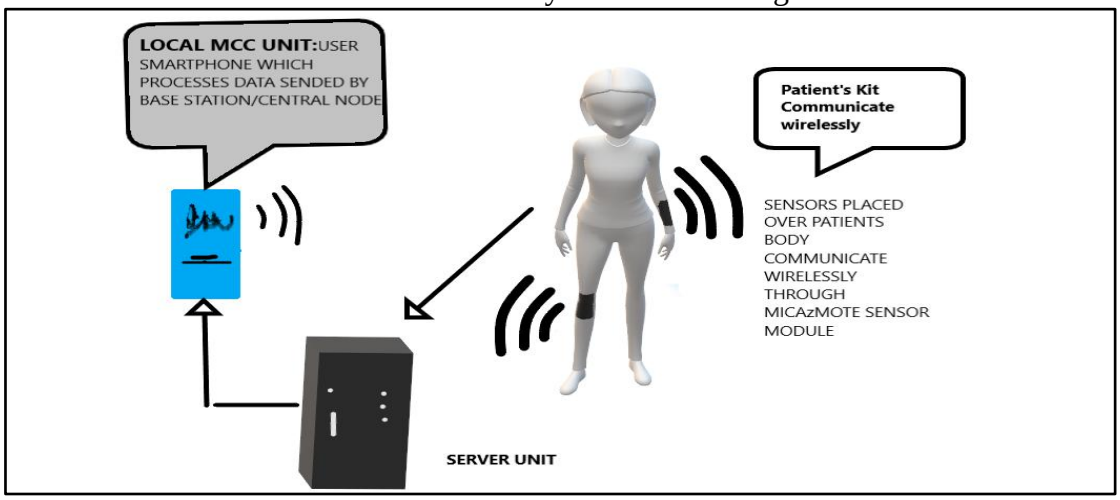

Fig.2. System working methodology

STEP 2. Data Collection and Transmission:
-The BAN(i.e. Body Area Networks) formed by patient's kit sendsReal-time data collected by sensor unit to near-by base station or Gateway node.This network area constituting the BAN and central/Gateway node forms PAN(I.e. Personal Area Networks).
-The Gateway node acts as transceiver node which transmits data collected from BAN to MCC unit,i.e. user's smartphone whereasafter processing of data within MCC unit itself ,it receives thecurrent status of patient and generate alarm/notification messages
Accordingly.-This means Gateway node acts as interfacing layer between BANand MCC unit.

STEP 3. Data Processing in MCC unit:
-After successful reception of raw data in MCC unit,the need is to
Process the raw data.
-Data Processing includes three major steps:
(i) Data preprocessing: This process includes the removal of all unnecessary disturbances that are recorded by sensors while collecting the real time data.These disturbances can be:Noise signals from environment,Gravitational Acceleration recorded by ACM,and sometimes the high stroke rate is recorded as movement of patient's body.It's important to remove all these disturbances from raw data for accurate predictions and real-time computations.The proposed solution in paper[1],includes the use of average filters to remove these disturbances.

(ii)Feature Extraction: Feature Extraction is one of the most important process of Data processing technique.Features can be extracted by the processing machine(I.e. MCC unit)itself depending on the computational algorithm user has chosen and on which parameters ,the algorithm is trained.
In this paper,features used are:
A) **Variance:**Variance represents the variation amount by which the signal deviates from average value considered.
It can be represented as :
$Var(x)=E(x^2)-\{E(u)\}^2$

Where x=input signal sample
u=average/mean value of data point samples

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B) **Correlation:** As used Accelerometer in project is Biaxial,so it is very important in data processing to anlayze and compare the data collected in both the axes of accelerometer.For the same purpose ,used feature is Correlation.
Mathematically,correlation can be defined as:

$$\mathbf{Cxy}=\frac{\sum(x-u)(y-v)}{\sqrt{\sum(x-u)\hat{}2\sum(y-v)\hat{}2}}$$

C)Energy: Energy is the summation of squared magnitude values of FFT algorithm expression.
Let for length of samples inwindow:N
The DFFT is given as :

$$X(k)=\sum_{n=0}^{N-1} x(n)e^{\frac{-j2\pi kn}{N}}$$

Whereas Energy is defined as:

$$E=\sum_{k=1}^{n-1}[X(k)]\hat{}2$$

(iii)Classifier: In this project ,algorithm used is KNN algorithm.This algorithm is more efficient than ANN in terms of accuracy and computational efficiency.
Working Mechanism of KNN algorithm:
KNN stands for k-nearest neighbors.Here,a simple illustration is done in fig.[3]to describe the mechanism of KNN algorithm.

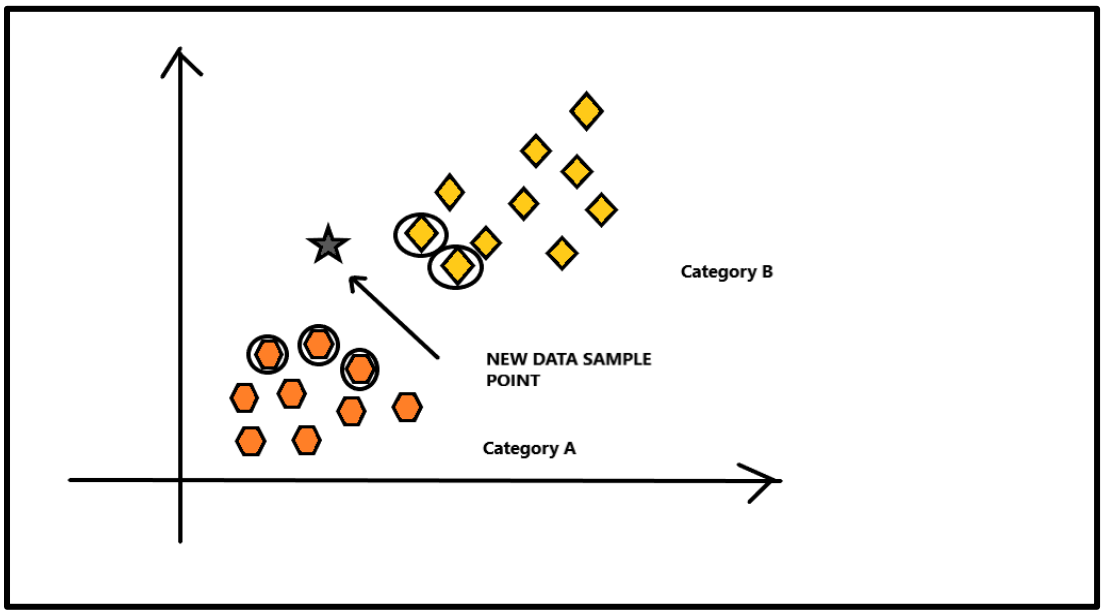

Fig. 3. KNN ALGORITHM Mechanism

1. Firstly,let the number of neighbours chose are (say),k=5.
2. Then,Euclidean distance is calculated between two data samples.
   Consider fig.[4], Euclidean distance between data points A and B can be given as:

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$$Dxy=\sqrt{(x2-x1)^2+(y2-y1)^2}$$

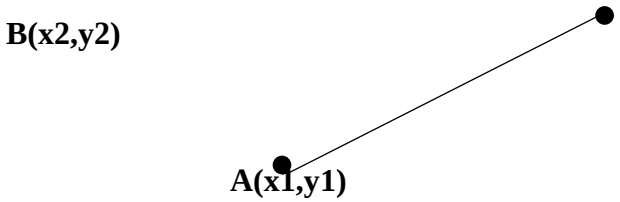

Fig.4. Line drawn in 2-D plane of coordinate system

3. After Calculation of Euclidean Distances, the 5 data samples are considered which are nearest to the new data sample,(see fig. [3]).
4. The most of the data samples nearest to new data sample are from category A.Therefore, new data sample should be from category A.

STEP 4. **Deployment of Architecture :**
Implementing system into practical usage and deploying architecture includes various important parameters like battery backup,energyefficiency,networktopology,Internetconnectivity,sensortesting,etc.

-**Network layout** used in the proposed system is XMesh Network Protocol[1].Each Network topolgy has its advantages and disadvantages associated with it,however,in Mesh Topolgy each node/device is connected with all the other devices in the network .
-XMesh protocol is advanced networking protocol which constitutes:
(i) Mesh Network Topology
(ii) Multi-hopping Communication Technique
(iii) Wireless ad-hoc communication

The Muti-hopping technique has its own advantages in deployed network. It increases the network coverage area or range of network and hence ,works on scalability factor of network.Though all the nodes whether mobile sensors or static nodes acting as gateway are fixed,but yes range of communication increases and also power consumption reduces.
-**Required Hardware:**
Wireless connection nodes-MICAz Motes sensor node Module
Wearable Device to constitute sensor network-MTS310 Sensor board

STEP 5.Notification Generation in accordance with processed data:
The inertial sensors wore by patients communicate through MCC via the base stations.But data received by base stations is only possible because of static nodes which are fixed at particular location.After processing of data which also includes computations based on pre-trained KNN algorithm which further compares the collected data samples with the threshold values and accordingly shares the information with the local static node.
-Each static node should be connected to wearable devices of one and only one patient,sothat,it's processed information is shared to only that particular static node by MCC.Therefore,no issues in identifying the patients.
-The Medical staff/Doctors get alarm notifications for that particular patient which is predicted by short while seizure attack.

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Experimental Results

Results show that system is highly accurate for value of k=5.For small values of k,there is possibility that system will generate some false alarms whereas large values of k causes high computational complexity of KNN classifier in designed system.

Also,KNN classification technique is much more efficient than ANN technique.In KNN Classifier,there is no need to train the model again and again for each new epileptic patient.Hence,it solves the problem of pre-collected datasets always and is adaptable for new data samples. For atleast 50% of seizure data constituted by the data signals,the system ensures to predict the seizure accurately[1].

Conclusion

This paper includes a methodolgy to design an efficient and practically feasible system for seizure detection using highly advanced prediction algorithms like KNN.Epileptic patients are monitored wirelessly by successful deployment of WSN Technology.The wireless connections are made possible including data transmission,reception and processing using IOT technology.This paper considers new approach in sense of using WSN and IOT as the base technology which is slightly different from the previous work of researchers which involves ZigBee,Bluetooth,Wi-Fi and Cloud Computing like technologies in their research work.

Hence,through the proposed model/system,
-range of communication is increased
-Less Computations involved
-Less Power Consumption
-Highly Accurate

Future Scope

The research work successfully builts an Advanced Computational System which is able to detect seizures.So that the medical staff can reach the desired location at or before the time of need for relief purposes.But there is a requirement of system which prevents serius injuries and harms to patients like fatal unconciousness,unwantedmovements,unstable mind condition,etc.To prevent all these symptoms of epileptic patients by making them not to come into existence,a technique is required which after detection of seizure(i.e. by the proposed sytem in this paper) which possibly works to prevent upcoming seizure attack.This can be done by trying to make patient calm,happy or by making the patient mind more stable,i.e.bycooling.As already known,seizures occur due to electrical disturbances and dissipations of signals in brain .This causes extra heating of nerve cells and possible the scalp area as well.**The Focal Cooling technique**[3] may prevent the seizure attack from occurrence by making the epileptic patient more calm.

The system can be made more accurate and efficiency can be increased by considering more number of biological parameters like stroke rate,respirationrate,respiration and gas metabolism,etc.Though with deployment of each sensor module with its corresponding parameter respectively,cost and power consumption like issues will be the matter of concern.Thus,a system is required which works for the problem efficiently with taking the challenges and issues of WSN's into consideration.

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