International Journal of Progressive Research in Science and Engineering
Volume-1, Issue-4, July-2020
www.ijprse.com

Detection of Alzheimer's disease using BCI

Hemanth S R[1], Dhanush Rajagopal[1], Yashaswini N[1], Sachin M K[1], Suryakanth M N[1]

[1]*Student, Department of Computer Science and Engineering, Maharaja Institute of Technology Mysore, Karnataka, India.*

Corresponding Author: raja.r.dhanush18@gmail.com

Abstract: - Alzheimer's disease is a neuro degenerative and progressive Disease which has no cure that is it worsens over time. This Disease is Observed in people above 65years of age and it is not a normal part of aging. Difficulty in remembering newly learned information is the most common early symptom shown by Alzheimer patient and this is because Alzheimer Disease initially affects learning part of the brain. As the Disease progress through the brain it heads to increasingly severe symptoms like disorientation, confusion about events, more serious memory loss, behavioral and mood change, trouble in speaking and walking. Our project is meant to be a part of the progress of humanity where we detect Alzheimer's Disease making use of BCI, IOT and machine learning techniques. Here patient's is asked some questions and we observe the answers the patients give. We make use of BCI which uses EEG signals from patient's brain during this activity. This data is given to IOT devices and apply a machine learning technique which detects Alzheimer's in a patient. The delay in EEG signals would help us to categorize patients whether they have Alzheimer's or no**t.**

Key Words: — IOT, EEG, BCI, Alzheimer's, Machine Learning

I. INTRODUCTION

Alzheimer Disease is an irreversible brain disorder disease and it is common form of dementia. This Disease has no cure, it has temporary treatment to manage the symptoms of patient. People with early symptom of Alzheimer will find it hard to recognize it and also there is no single test to detect Alzheimer disease. So doctor use some of the assessments like blood test, MRI scan, urine test and screening of depression to detect Alzheimer. The cost of diagnosis for a person with Alzheimer's is 329,360USD this huge amount of burden on patients led us to propose a system that could cut down such huge expenses.

we propose a cost effective model where we use BCI and machine learning algorithm(SVM) for detecting Alzheimer's disease. In this IOT model the subject is fixed with brain sensor that is BCI where it reads signals based on the input questions and identifies the risk of Alzheimer's disease based on the EEG delay to each responses and classifies the patient to 3 stages of Alzheimer's. The main aim of the system is to create a working environment for the subject at home and reduce health expenses and also put fewer burdens on health care professionals.

II. LITERATURE SURVEY

Muazzam masqood et.al.[1] claimed that early stage detection of Alzheimer's disease using OASIS, data set which is publically available had serious class imbalance problem. So to overcome and handle this class imbalance problem for Alzheimer's stage detection they used framework which was a data augmentation based. Author mainly thought of developing efficient and effective classification model which employed transfer learning-based technique I.e, Convolutional Neural Network(CNN). Author came up with two models for Alzheimer's Disease Classification. The first model had utilization of a single main MRI (magnetic resonance imaging) view of the brain. Whereas, the second model incorporated 3Dimensional views. Both models comprised three steps pre-processing of data, data augmentation and classification using transfer learning.

The first model proposed by author was pre-trained by CNN transfer learning. This model had main view with data augmentation and performed well and achieved an accuracy of 98%. The second proposed model which was 3D view model had accuracy of 95.11%. This shows the first proposed model had better results and this is because of data augmentation which has improved the accuracy of testing. This model was also able to overcome overfitting problems. Even though there were improvements in early stage detection of Alzheimer disease, author observed some of the challenging tasks in structural MRI for prediction of progression of aliment. So author suggested that model needs further exploration.

Dilek Manzak et al. [2] stated that when the cost of MRI technique and risk of the procedure is considered there is a need for finer, inexpensive and empirical different solution for the detection of Alzheimer's Disease. Therefore, author proposed a model which was quick and victorious. This model used deep Neural network (DNN) method to detect Alzheimer disease. In order to lower the difficulty of the algorithm and also to remove some of the features proposed system used a method called random forest method. The proposed model acquired a most applicable features from ADNI data using baseline measurement as training and for testing purpose model used 24 months' measurements and later the selected features is applied with deep neural network. The proposed model mainly eliminated the MRI (magnetic resonance imaging) measurements in order to make the model simple and also reduced the price of the data. But the accuracy of the proposed model was just 67%.

Yi Ren Fung et al. [3] explored an another way to break the data into training and testing sets because existed system stated that the ADNI data set which reported high performance using CNN, when this data set was split into training and testing sets the performance was not similar. So the approach used was to split the MRI dataset into 3 ways giving accurate results when applied to CNN. Firstly, data was split by patients, where either a training set or testing data set was assigned all of the available visits of a patients. Secondly the data was split by visit history, where the first n-1 visits of a patient's data was used for training and the nth visit was used for testing. Finally, data was split randomly by MRI. When MRI was used to randomly split the training and testing sets they observed accuracy of the model which was of 84%. When the splitting of training and testing sets were done by visits, the model attained accuracy around 81% which was slightly lower. Finally, when patient's id was used to split the training and testing sets the model attained low accuracy that is around 51%. Author has also discussed some main technical challenges in working with the ADNI dataset.

Aunsia Khan et.al.[4] emphasized mainly on machine learning techniques for early diagnosis of Alzheimer's Disease. The single modality approach and multimodal approach were the existing approach that was used to classify and diagnosis of Alzheimer's Disease. The most common problem with the existing approach was input size, attributes and validation has pathological verification was not provided which consequently introduced uncertainty in the predicted results. The proposed model included pathologically proven data and overcomes the class imbalance and overtraining issues. Proposed model consisted of four steps, first one is pre-processing where the pathologically proven data set is processed to avoid class imbalance. Second one is attribute selection which involved searching all possible combinations of attributes which worked best for prediction and classification. Third one was classification which used AR mining with minimum support and minimum confidence. Fourth one is class threshold which was used over resultant rules where it classified instances into control and AD. The proposed model therefore improved the performance prediction and covered the limitations of existing system.

Zhi Hao Kevin CHONG et.al.[5] noticed the conventional methods of Alzheimer's disease detection which included detecting linguistic deficits, combining biomakers with Machine learning algorithms. But this existing approach was prolonged and tedious process which made the approach more challenging and includes limitations of patient time and conscientious participation. Therefore, author proposed the new approach where this proposed model was developed using IOT sensors data and was able to predict possible Alzheimer conditions in the initial stage. The proposed model mainly considered three key variables that is excess active level, sleeping patterns and repetitive actions. This is because people with Alzheimer disease usually go through same activity, make same signalling, say the same thing or ask the same question repeatedly. In the proposed system RFID that is Raad combined active wearable Radio Frequency Identification(RFID) wristband was used in combination with IR room locators, which was used to monitor the whereabouts of the elderly at room level. Therefore, the proposed model was able to predict the potential early diagnosis to Alzheimer Disease. But this was not necessary mean that the elderly is a definite alzheimer patient and the author suggested this required further medical evaluations by doctors to confirm the risk.

Samruddha D. Shirude et.al.[6] suggested that novel technologies like DIMENSION, NAT which were based on fluctuations in EEG, but these therapies were only applicable for the limited data set. Also using fourier transforms for feature extraction would cause problems in classifications.

Hence The proposed system was to classify the brain signals (EEG)based on frequency as alpha (0.5HZ to 4HZ), beta(4HZ to 8HZ), gamma(8HZ to 13HZ), theta(>13HZ) respectively and used wavelet transform which is a mathematical model to understand highly dimensional and non-stationary EEG signals to represent EEG signals in time as well as in frequency domain. Finally applied machine learning SVM algorithms for classification where the patients EEG frequency>30HZ was classified as normal person and the patients EEG signal frequency<30HZ was classified as AD. Since proposed model used SVM algorithm it gave highest accuracy of 90.9% and had less error rate. But proposed model had high complexity of O(n^2) and memory wastage has EEG signals frequency was divided.

Giulia Fiscon et.al.[7] stated that an analysis of EEG signal, especially automated, took a major role in detecting dementia in an initial stage and also in classifying the Alzheimer disease severity. This is because compared to other imaging devices like MRI and PET, EEG signal was non-invasive, cheaper, simpler and quick to use. Therefore, author proposed a model which made use of EEG signals to detect Alzheimer's Disease.In the Proposed model it was able to distinguish between healthy, mild cognitive and AD subjects and provide a model which was a tree based. In this method author applied fourier transform as well as wavlet transform on 109 samples and these samples belonged to all the three classes and finally performed a time-frequency analysis. The following steps were used to design a classification procedure: (i) EEG signals pre- processing; (ii) feature extraction by means of the Discrete Fourier and Wavelet Transforms; and (iii)classification with tree-based supervised methods. With the help of this procedure, they were able to extract reliable human-interpretable classification models that allow to automatically assign the patients into their belonging class. when dealing with HC vs AD the observed accuracy was 83%, when dealing with HC vs MCI the observed accuracy was 92%, and when dealing with MCI vs AD classification problems the observed accuracy was about 79%.

Giulia Liberati et al. [8] proposed a method in order to help AD patients. With this method AD patient was able to communicate with simple yes or no question. In order to extract the answer from AD patient author used a device called brain computer interface (BCI). The proposed method was able to overcome the limitations of existing method by using a classical conditioning paradigm and was able to help Alzheimer's patients who have lost their ability to communicate verbally to convey basic thoughts example 'yes' or 'no' and emotions. In order to obtain high classification accuracy, the proposed model used linear SVM.

But the proposed classical conditioning paradigm model for communication application of AD had some challenges in the implementation. Firstly, the duration of the acquisition phase may not be enough to elicit a conditioning effect in AD patients. Secondly the conditioning effect extinguished very quickly.

Nuria Mendoza Laiz el at. [9] proposed a model of cognitive training and domotic control program that can be used as a tool to prevent a cognitive impairment. Standard neuro psychological tests was used in an existing system to prevent cognitive impairment in which before and after training process it was able to measure a general cognitive capacity, verbal memory also executive functions, and other faculties. But this existing system was not always effective therefore author proposed a model which overcomes the limitation of existing system. The proposed model made use of BCI computer program which includes a program like visual perception, expressive and receptive speech, immediate and logical memory, picture recognition and concepts, as a tool to reduce a cognitive impairment. This method was able to prevent cognitive impairment, which was caused by aging, when this program was applied within reduced timeframe. From this proposed model the BCI program opened a new horizon with the aim of educating and instructing people to prevent cognitive impairment, and ultimately improved a quality of life.

Natasha Padfield et.al.[10] said about the benifits of BCI which were cost effectiveness and higher time resolution of brain signal acquisition, it is also more portable compared to MRI, furthermore it discusses about the working of BCI and how feature extraction happens.

Nilesh Kulkarni et.al.[11] proposed automated diagnosis of Alzheimer's disease using EEG spectro-temporal modulation energy. The present paper work was carried out on 100 patients (50 AD patients and 50 healthy patients). The paper also highlighted that SVM classifier gave sufficiently better results considering accuracy, specificity and sensitivity on present dataset.

XIANG ZHANG et.al.[12] was a survey article about the advances in the BCI(Brain computer interface) in the recent years with deep learning it mainly addressed the need of BCI and listed out various applications of it importantly BCI worked directly on raw brain signals avoiding time Consuming engineering. Furthermore this article explained how BCI works and the work flow of it,It also specified the usage of BCI in mental disease field mentioning extraction of suitable features of EEG signals to classify Alzheimer's disease.

Aarón Maturana-Candelas et.al.[13] suggested a method that characterized the progression of AD though the irregularity and the complexity of the brain activity. This method applied entropy based measures throughout the multiple temporal scales to study both irregularity and complexity in brain activity. The proposed model considered EEG signals from 51 control subjects, 51 MCI subjects, 51 AD(mil) patient, 50 AD(mod) patient and 50 AD(sev) patients and calculated multiscale sample entropy (MSE) and refined multiscale spectral entropy (rMSSE) from EEG signals. Statistically significant differences were observed between five different groups at each temporal scale. Average slope values and areas under MSE and rMSSE curves revealed significant changes in the complexity mainly for control vs MCI, MCI vs AD(mil) and AD(mod) vs AD(sev) comparisons. These results indicated that MSE and rMSSE reflected the neural disturbances associated with the development of dementia, and it also contributed to the development of the new tools to track the AD progression. But the proposed system had heavily gender unbalanced (177 females against 76 males).

Saraswati Sridhar et.al.[14] proposed a BCI that analyses steady-state visually evoked potentials (SSVEPs) elicited in subjects of varying age to detect cognitive aging(AD), predict its magnitude, and identify its relationship with SSVEP features. The method used was to display light of different frequencies on the screen and compare the identification done by the subjects thereafter classifying them. The results were accurate but did not allow subjects with eye disorders. It was found that though MRI approach gave good accuracy using ADNI data set, the approach was still challenging as results varied in train and test performance and there were over fitting problems. One of the important factor we considered was cost, neuro imaging was not cost effective and AD detection in MRI would take more time in detection.

This made us to look upon other ways of detection, IOT sensors like GPS and video surveillance was used to track cognitive impairment but it was not reliable and needed future medical tests also the patient would feel uncomfortable knowing he/she is tracked all the time. So the BCI was a barrier breaking technology which was cost effective, it took raw signals from the brain (EEG signals), then there was a SSVEP technique which was not acceptable as it ignored people with eye disorder or blind. Detection by splitting EEG signals and comparing with the healthy and AD subjects and using machine learning algorithm(SVM) for classification was interesting as there was higher accuracy obtained but then it was more complex. Then there was questionnaires approach which helped in communication for AD patients so signals generated from these questionnaires in the brain would help us in better classification ,later on there was entropy based detection but the subjects were not classified based on gender and we studied that gender classification was needed and in getting better results this made us to further classify them based on gender and we also studied surveys, articles on BCI which helped us in better understanding of its applications and feature extraction.

III. Methodology

A BCI (Brain Computer Interface) is used as an IOT device, the extraction of behavioural data is achieved by placing this brain sensor on the user's head. The EEG(Electroencephelogram) are the signals that the BCI extracts from the subject's head when a series of questionnaire is asked to him/her. The response time or latency time for the subject's response is considered the signals generated is taken and is then passed to the Arduino nano which is an open source micro controller board which is interfaced with the Node MCU which is an open source IOT platform it contains a WIFI module which enables the connection to the cloud. The cloud storage enables portability and can be easily accessible, the data extracted is compared with the trained data set in the cloud furthermore the data set is classified based on gender to get better results, An SVM(Support Vector Machine) classification machine algorithm is used as it is easy to classify when the data set can be split into two and the result will be a graph representation indicating how severe is the Alzheimer's in the subject and it also gives preventive measures that the subject should take based on the severity of the Alzheimer's disease. The data set we have taken for classification purposes is from UPI repository which contains the patient's records, age, gender, their disease state and response time for questionnaire, their education, MMSE score and we Incorporated only needed features patients age, gender and response time for questionnaires for classification.

The objectives of our system are:

1. Extraction of behavioural data, to extract or read the EEG signals from the brain via BCI when the patient responds to a questionnaire.
2. Taking the response time and the signals when the subject responds and mapping it with the data set in the cloud.
3. Comparison of test data with trained data set with the help of machine learning algorithms(SVM).
4. To classify the results based on gender and To provide accessible, relevant and affordable way to predict Alzheimer's and to suggest solutions based on the results.

The components used in our system are as follows:

1. BCI: Brain computer Interface which is used to collect behavioural data from the patient
2. Arduino nano: It is a micro controller which is used to collect the data from the BCI via Bluetooth.
3. Node MCU: Is a WIFI module which is used to send the data received from the micro controller to the cloud.

International Journal of Progressive Research in Science and Engineering
Volume-1, Issue-4, July-2020
www.ijprse.com

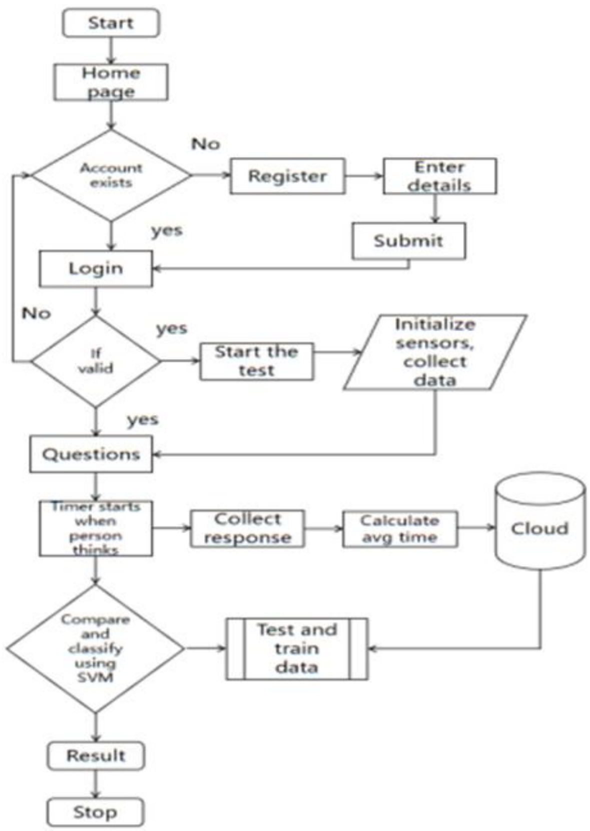

Fig.1. Flow Chart

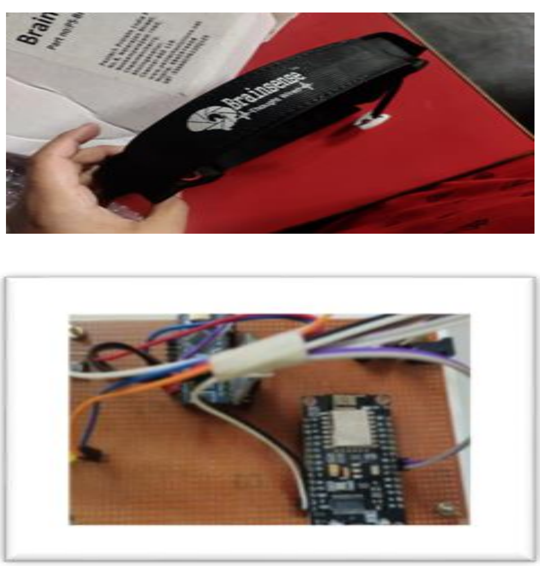

Fig.2.Brain Computer Interface, Arduino nano and WIFI module.

Coming to the user interface where the questionnaires appear we have created a web application using flask frame work and using python as the back end this user friendly web app enables patients to login and take the test.

Fig.3. User interface

After the test is completed the response time for each question is taken and stored. The response time is the delay in generation of EEG signals from the brain, this data is sent to the classifier i.e., SVM which is a machine learning algorithm it classifies or categorizes the patient into 4 different groups the SVM takes mainly 3 parameters for classification C, gamma, epsilon. C is the penalty parameter it tells the algorithm how much classification matters so higher value of it indicates we care more about classification so we have set value of C to 1000. Gamma is a used for nonlinear classification just in our case the gamma value tries to exactly fit the training data. Epsilon defines tolerance where no penalty is given to errors hence the larger value of epsilon indicates we permit large errors to our solutions. Therefore, epsilon value should be small we have taken 0.1 value to epsilon. After initializing the 2 parameters we have used a kernel function in SVM which is used to detect the pattern in ours data so we make use of RBF kernel for this the equation is

$$K(x_i,x_j)=EXP(-\gamma||x_i-x_j||^2) \quad (1)$$

Here RBF kernel is used as we have no prior knowledge about the data as it is a medical record and thus this expression to kernel function will be the most suitable and input to this is the response time, age using this it creates a boundary and classifies each support vector to different classes alzheimer's or no alzheimer's and different stages of alzheimer's .

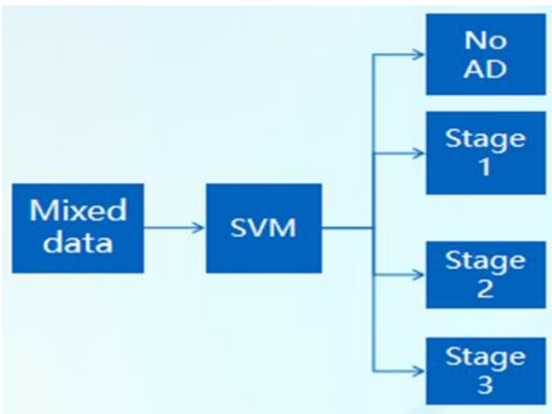

Fig.4. SVM Representation

So the whole process in our system is:

1. The patient should login with correct credentials to the web application, if he is a new user he needs to register.
2. Once logged in he will be asked some personal information (ID, name, age and gender).
3. He should place the BCI on his forehead and should be ready to take test.
4. Once he starts responding to the questionnaires there will be button and after its pressed the electrode on the BCI will start to capture the EEG signals the delay in the generations of those EEG signal will be taken and this will repeat for other questions too.
5. This will be sent to the cloud which contains the classifier SVM which in turn gives the final result.
6. The response time (delay in generation of EEG signals) with the result will be accessible to the doctor via cloud.
7. The patient can also view his disease state and the whole process can be done remotely.

Fig.5. Flow diagram

IV. Results and Discussion

The main aim of our project is to reduce the expensive cost faced by the alzheimer's patients for examination of their memory level. Our system overcomes existing system drawbacks by providing

1. Cost effective solution.
2. Tests can be done remotely.
3. Doctors can access the data through cloud.
4. More accurate.
5. User friendly solution.

Our system predicts whether the patient is diseased or not and further into 3 stages and suggest medications.

Now comparing KNN and SVM algorithms that we used in the system

Table.1. Algorithm accuracy comparison

Classifier	Train data	Test data	Accuracy
KNN	500	100	94%
SVM	500	100	97%

The results showed that SVMs were a more reliable classifier. However, KNN was less computationally expensive than SVM. As, KNN was easy to implement, in the classification of Multi-class data KNN are more preferable. The SVM guarantees reliable detection in unpredictable situations depending upon the data. If the data points are heterogeneously distributed. If the data is homogeneous we might be able to classify better by putting in a kernel into the SVM. For practical problems, KNN is a bad choice because as it scales badly and also in situations where there is no prior knowledge about the data set SVM are more preferable and gives more accurate outcomes.

We were however could not test this with real alzheimer patients due to pandemic we tested it on ourselves and we tried to mimic the alzheimers patients thinking by increasing the focus level needed to trigger the generation of EEG signals and were able to produce accurate results.

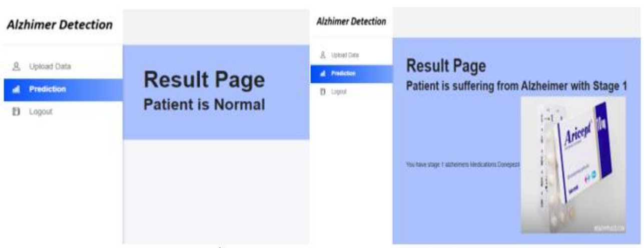

Fig.6. Result Pages

V. Conclusions and Future Scope

There are almost 4 million people affected by Alzheimer's in India and 5.8 million people affected by the same annually in the US. It is a degenerative disease which affects the elderly mostly people above 65years and it worsens as the time progresses. It is one of the expensive disease in America and it costs around 341,000$ on average for a person from diagnosis to death. As we know there is no cure for it and knowing this spending huge amount of money would not make sense. So using the BCI approach to gather signals when asked questionnaires and classifying them based on gender and suggesting medications for cognitive disability would help the patient know where they stand. Thanks to machine learning algorithms such as SVM which help in classification of the signals and give accurate results.

So our system was able to aid in detection of alzheimer's in early stages and prevent the huge expenses the patient has to go through in diagnosis. Although the BCI used in the system was able to accurately detect the disease there are better BCI devices which are capable of detecting the same with further accuracy and testing with real patients will solidify our claims.

References

[1]. "A Data Augmentation based Framework to Handle Class Imbalance Problem for Alzheimer's Stage Detection", Muazzam Maqsood, IEEE 2019.

[2]. "Automated Classification of Alzheimer's Disease using Deep Neural Network (DNN) by Random Forest Feature Elimination", Dilek Manzak, ICCSE 2019.

[3]. "Alzheimer's Disease Brain MRI Classification: Challenges and Insights", Yi Ren Fung,arXiv 2019.

[4]. "Early Detection of Alzheimers Disease Using Machine Learning Techniques", Aunsia Khan and Muhammad Usman, IC3K 2015.

[5]. "Classification of Electroencephalograph Signal Using Support Vector Machine for Alzheimer Disease", Samruddha D. Shirude, Human journals 2017.

[6]. "Combining EEG signal processing with supervised methods for Alzheimer's patient's classification", Giulia Fiscon, BMC Medical Informatics and Decision Making 2018.

[7]. "Predicting potential Alzheimer medical condition in elderly using IOT sensors", Zhi Hao Kevin CHONG, IRC conference on science 2017.

[8]. "Toward a Brain-Computer Interface for Alzheimer's Disease Patients by Combining Classical Conditioning and Brain State Classification", Giulia Liberati,2012, IOS press.

[9]. "Efficacy of a cognitive training and domotic control program(BCI) to prevent cognitive impairment", Nuria Mendoza Laiz,2016, iMedPub.

[10]."EEG-Based Brain-Computer Interfaces Using Motor-Imagery: Techniques and Challenges", Natasha Padfield, 2019, MDPI.

[11]."Spectro-Temporal EEG Modulation Energy based Diagnosis of Mild Alzheimer's Disease", Nilesh Kulkarni, Coimbatore Institute of Information Technology 2018.

[12]."A Survey on Deep Learning based Brain-Computer Interface: Recent Advances and New Frontiers", XIANG ZHANG, arXiv 2018.

[13]."EEG Characterization of the Alzheimer's Disease Continuum by Means of Multiscale Entropies",Aarón Maturana-Candelas, MDPI 2019.

[14]."Assessment of Cognitive Aging Using an SSVEP-Based Brain-Computer Interface System", Saraswati Sridhar, MDPI 2019.