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ORIGINAL PAPER

Buildout of Methodology for Meticulous Diagnosis of K-Complex in EEG for Aiding the Detection of Alzheimer's by Artificial Intelligence

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Abstract
Application of artificial intelligence (AI) in health-care detection is a domain of exceptional research and interest in today's world. And hence among this domain, a considerable inclination is toward creating a smart system that is AI for aiding identification of brain-related disease—Alzheimer's—using electroencephalogram (EEG). Certain AI-based techniques as well as systems have been created for EEG examination and interpretation, but they have a common drawback that is lack of shrewdness and acuteness. Therefore, to overcome these drawbacks, a different methodology or technique is suggested in this paper which is able to mold the AI technique for better EEG Cz strip K-complex identification. This suggested method and structure of AI detection system is relied on quantitative scrutinization of Cz strip and embedding-established EEG explication principles for detection of K-complex and Alzheimer's. This technique unconditionally relied on facts and information of neuroscience that are applied by expert in health care such as neurologist to create a detailed review of sick person's EEG. The suggested technique also allots a potential of learning on its own to the AI so that it can apply the events in future examinations.

Keywords Electroencephalogram (EEG) · Mild cognitive impairment (MCI) · Dementia · Artificial intelligence (AI) · K-complex · Sleep spindle · Neurology · Alzheimer's disease

Introduction

Artificial intelligence is one of the most trending fields in many expertise like automation, IOT, image processing, machine learning, and also it is the most crucial growing field toward the fourth industrial revolution [1]. The artificial intelligence could be elaborated as "A computer library that can perform tasks, do reasoning, and think the way human does." Beyond general usages, there is a domain in which AI is flourishing path breaking innovations is medical science [2, 3]. The motive of applying artificial intelligence in medical science is to achieve services similar to that of medical specialists. These services are broadly classified into two aspects. First is disease diagnoses and prognoses, and the latter is actual curing of disease. The medical therapy is performed by specialists, surgeons or doctors entirely. Yet the disease detection is entirely relied upon proved theories, history, understanding and facts or events. Generally, the specialists recognize the core symptoms of particular disease and accordingly prescribe necessary medication and cure as facts and events.

The EEG diagnosis facility in today's world is majorly done by neurologists. The electroencephalogram (EEG) test is utilized to detect disorders-related electrical activity of the brain. The neurologist studies the EEG with respect to the reference EEG explication principles and constructs an overview of brain's electrical patterns and neurological disorders and then prescribes medication accordingly. By

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taking into consideration these major EEG explication principles as a finite domain of conditional assertions for all possible geography of EEG, a library has been created which gives the necessary understanding of desired artificial intelligence for execution of EEG explication principles in K-complex diagnosis function. By issuing such library, acute artificial intelligence system could be created and up-skilled to execute K-complex diagnosis as dexterous as human specialist does.

The methodology for EEG diagnosis system, utilizing AI software, generally has a library of images of EEG which have typical K-complexes found in Alzheimer's disease. In order to find similar K-complexes in patients, the EEG comprising such typical K-complexes from the library is compared with that of the patient's EEG. The approach used by AI software is to utilize comparison algorithm and this yields shrewdness, distinctness and proficiency of diagnosis task. However, this class of AI is able to diagnose Alzheimer's based only on K-complex. These constraints thwart the application for EEG diagnosis task and make AI system vulnerable regarding relevance in real-world usage. Therefore, it is crucial to generate an intelligent EEG diagnosis methodology using AI which ensures the shrewdness and precision in EEG examination task and considerably suitable for AI in health-care diagnosis service.

Overview of Alzheimer's Disease

Alzheimer's disease is a brain-related disease, for instance coronary artery is a heart-related disease. Also, it is a disease which becomes worse gradually as time passes. This type of disease is also called deteriorating disease. It is observed that Alzheimer's disease embarks 20 years or more prior to beginning of symptoms, with compact modifications in the brain which are unnoticeable to the individual affected [4–10]. Just after many years of brain modifications, the persons start to get affected by the noticeable symptoms, like loss of memory and language complications. Such symptoms happen because nerve cells or neurons which are constituents of the brain play a crucial role in thinking, learning and memory functions have been vandalized. Generally, people suffering from Alzheimer live with its symptoms for years. As time passes, the symptoms increase, become more severe and hinder the capability of people to undertake everyday activities. At this instant, the person is observed to have dementia because of Alzheimer's disease. Alzheimer's [4] disease facts and figures determines three levels of Alzheimer's disease—preclinical, mild cognitive impairment (MCI), and dementia [4, 11–14]. But in the second and third stage, symptoms exist to transitional degrees.

Preclinical

In this level, which is still exposed to research, persons have derivable alteration in the brain. The first of the signs is noticed by cerebrospinal fluid and blood examination (biomarkers). Yet these examinations could not give symptoms relative to memory loss. It is crucial to observe that not each and every person suffering from Alzheimer's biomarker proceed to develop MCI or dementia yet some do in rare cases [4, 15, 16].

Mild Cognitive Impairment

There is a biomarker evidence of change in brain related to Alzheimer's that the percentage of beta-amyloid has increased. Patients having MCI because of Alzheimer's disease have shown more cognitive decrease than the regular declination rate calculated on the basis of age. Such declination does not notably hinder with the regular activities, i.e., day to day activities [17]. Generally, for MCI, the modifications in the capabilities to think are observable to close people such as friends and family, but not similar for other persons.

Dementia

Third stage of Alzheimer's is identified by observable cognitive thinking and behavioral symptoms that buttresses an individual's capability to operate in day-to-day life, accompanied with the proof of Alzheimer's-related brain modifications. People having Alzheimer's dementia suffer more than one symptom that alter over a span of years. Such symptoms depict the intensity of destruction to neurons in various sections of brain. The speed at which the symptoms of third stage make transition from perfunctory to medium to severe varies from individual to individual.

Medical Overview

Electroencephalogram

The brain's electrical fluctuations within the neurons create currents that emit through the scalp. As electrodes of electroencephalograph are adhered to the scalp; they detect particular interpretable electrical currents and convert them into corresponding electric waveforms widely acknowledged as in electroencephalogram which depicts induced seizures. Hence, an EEG showcases the succinct timeline of electrical activities happening in the cerebral cells. A set of EEGs could be utilized as a baseline differentiation to scrutinize cerebral function. Identification of various traits

of EEG patterns is necessary for evaluation of sleep and its abnormalities. The phenomenon of EEG is showcased by frequency in cycles per second (hertz [Hz]), amplitude [microvolts (μv)] and shape [18].

Electrodes

The information regarding electric signals produced by brain from different scopes is extracted in an EEG record. These distinct scopes are called electrodes technically. The primary EEG electrodes are attached on different lobes of the brain—frontal, frontopolar, temporal, central, parietal, occipital, auricular. All these lobes are shown in Fig. 1. The effects of Alzheimer's majorly hinder the frontal lobe of the brain. The three leads that show major impact due to Alzheimer's are Cz, Fz and Pz [19–22]. Figure 1 depicts positioning of electrodes respective to brain.

Cz Strip

The examination of EEG widely relies on examination of rhythm strip, which is produced by brain's electrical momentum during the observation period. Mainly for the analysis during the detection of Alzheimer's, the Cz lead is used. The interpretation of Cz is done from the data extracted from the EEG. The observation period of Cz strip.

Cz Complexes

The EEG complex depicts the electrical impulses occurring in the EEG periodic cycle. In stage 2 of NREM sleep, there are 2 complexes which mainly occur in the Cz lead. Those complexes are sleep spindle and K-complex.

K-Complex

Actually, K-complex is a type of waveform usually observed in EEG. This phenomenon is the authentication mark of stage 2 of NREM sleep [4fall]. It is the biggest and one of the most prominent events in EEG. K-complex has a couple of functions—first is the oppressing cortical aroused in reaction against stimuli that the sleeping brain assesses not to trigger danger. And second is aiding sleep relied memory consolidation. K-complex is interpreted as an acute negative waveform quickly accompanied by a positive waveform with the following traits: (1) at least 0.5 s period [20, 22–24], (2) a minimal amplitude of 75 μV for negative waveform from the baseline of EEG [20, 23, 24].

Sleep Spindle

Sleep spindle are tears of neural oscillatory which are produced by the interaction of the thalamic reticular nucleus and other thalamic nuclei occurring in stage 2 NREM sleep having a frequency domain of approximately 11–16 Hz, having a period of 0.5 s or more. Figure 2 represents complexes of Cz lead with patterns of K-complex and sleep spindle in graphical form. Figure 2 shows the voltage versus time graph in which 2 complexes are visible, namely K-complex and sleep spindle.

Proposed System for Diagnosis of K-complex in EEG

The computerized AI takes input of an image of an EEG of the sick person and executes ideal EEG interpretation algorithm. The diagnosis of EEG is relied upon rhythm strip, because this strip is utilized for regular checkups.

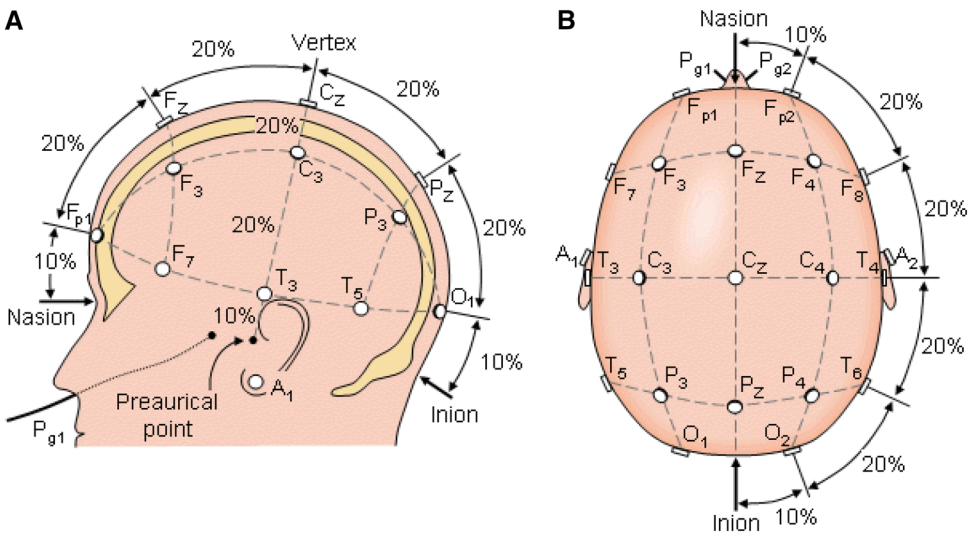

Fig. 1 Positioning of electrodes [25]

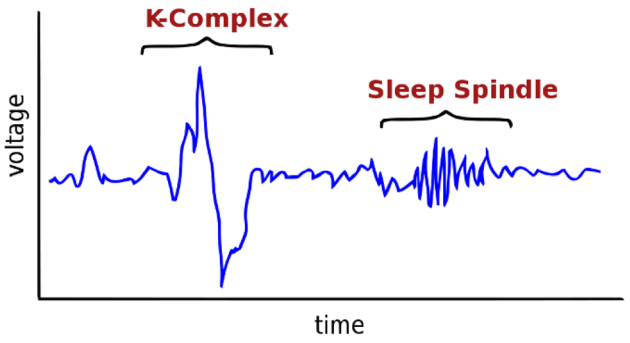

Fig. 2 Complexes of Cz lead

Specific characteristics are seen in waves of EEG complexes like shape, period, placement, deflection, amplitude. A neurologist thoroughly studies the structure of waves of all EEG complexes. The most important function of examination is to juxtapose the values of the characteristics, stated above, of the Cz lead of the EEG report of the patient to be examined with the characteristics of the K-complexes found in the reference EEG reports. The reference EEG comprises the characteristics of K-complexes of patients already having Alzheimer's. During the diagnosis, if the Cz wave matches the criteria of that into the reference library then the disease will be detected. The aberrant conditions in the characteristics of K-complexes in Cz wave can be:

- The amplitude of the K-complex is lower than the general constraints of amplitude (unit of amplitude is μV).
- The period is shorter than general constraints (unit of period is μs).
- The density of K-complex of the patient is examined to be reduced by equal or greater than 36% [19].
- Also, the displacement of the waveform of Cz with respect to the normal Cz waveform

The EEG explication principles are taken as finite domain of constraint statements regarding all possible EEG structures. Hence, utilizing these explication principles a library comprising constraint statements is created which can only be accessed and used by AI as a health-care protocol.

Blueprint

The presented blueprint of AI examination system braces conveyable AI application that is developed in Python 2.7 accompanied by image processing library OpenCV which is a free source and PyGTK GUI framework.

The EEG K-complex examination by AI performs the job which is majorly divided into 3 levels.

1. Scrutinizing the image.
2. Deduction of K-complex.
3. Identifying Alzheimer's.

Scrutinizing the Image

The analog data is imported from the dataset into the library. This dataset includes coordinates which are plotted using numpy, scipy, matplotlib, seaborn and mne. These coordinates which are plotted correspond to the Cz strip of EEG statistical data. Imported statistical data is actually the brain's electrical activity with respect to time (unit of time is μs). This plotted graph is taken input as an image into the AI software. Scrutinizing the image, the AI software accepts input of the image (.jpeg or.png) of Cz waveform. Greedy search algorithm is used to withdraw the quantitative data of electrical activities of Cz strip of an EEG. Figure 3 demonstrates stepping blocks of analysis of an image for EEG complex.

The above-mentioned figure depicts that input EEG image, information library and image scrutinization are crucial parts in the phenomena of analysis of image. It can be seen that information library is jointly bonded with input image process and image scrutinization process. Further, image scrutinization consists of tasks such as recognition of various EEG complex elements and construction of a lucid database having object-oriented properties.

Image scrutinization comprises the following levels in serial manner:

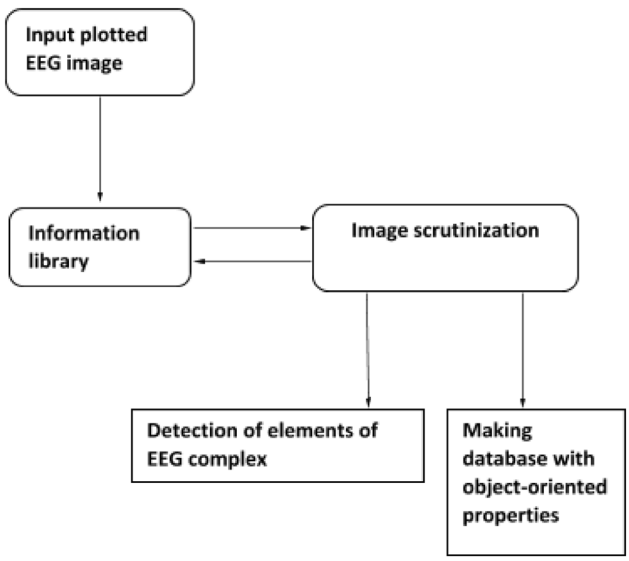

Fig. 3 Analysis of image

Recognition of the waveforms in Cz strip

This is the most basic form of image which is the Cz strip of an EEG record. This image is further required to be processed at many levels to extract desired output.

Further, this above-mentioned image showcases the gray scaled form of its preceding image. This grayscale conversion is essential to generate acute and precise output by the AI. Hence, this grayscale image of Cz strip is suitable and preferred more than its previous version.

This above-mentioned image is the version of its previous image after undergoing the process of grid filtering. Grid filtering is the process of elimination of all the grids in the image so that the AI does not consider them during the generation of output. Hence, this is a crucial process for generating errorless output.

Figures 4, 5, 6 and 7 show how EEG image is scrutinized and processed to get K-complex. Also, these images are the results of analysis of the image using AI. The resulting image shows the detection of K-complex from the strip which is provided as an input.

Development of database with object-oriented properties

Followed by the recognition of electric waves, the complete Cz strip is divided further into marshaled EEG Cz complexes. The purpose of creating the database with

Fig. 4 Cropped Cz strip from EEG

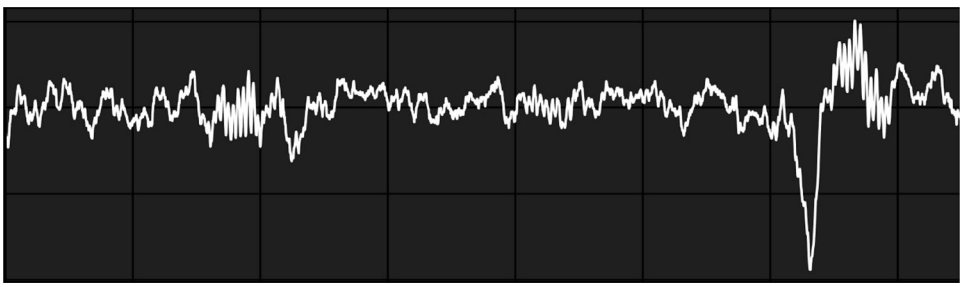

Fig. 5 Grayscale of Cz strip

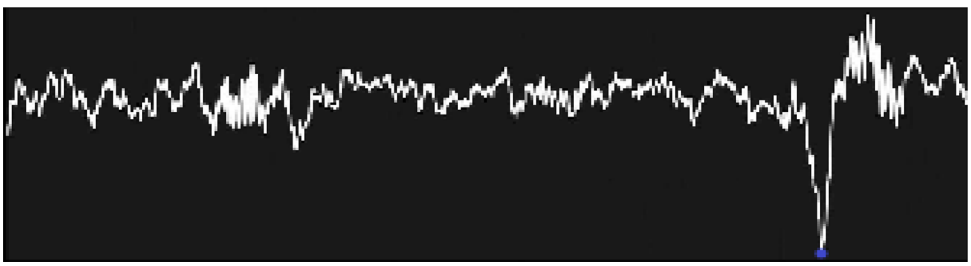

Fig. 6 Grid-filtered image

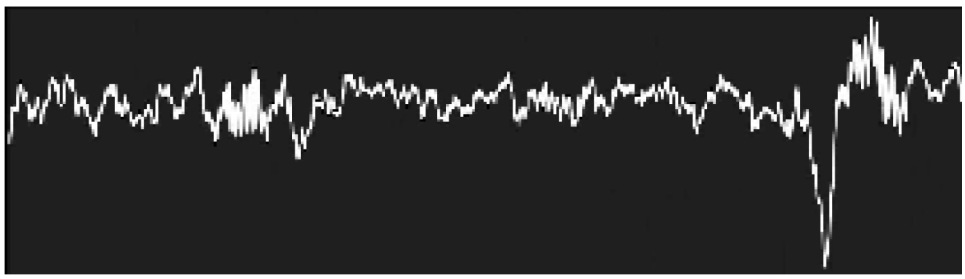

Fig. 7 Image of identification of K-complex

object-oriented properties is to construct objects of Cz strip assisted by objects of its EEG complexes. The objects of Cz complexes have their own objects of electric waves. Therefore, every object of database has an admissible hereditament.

Deduction of K-complex in Cz strip

For determination of Alzheimer's, the recognition of Cz strip is the primary step. During this level of examination, the tempo of all the electric waves and their characteristics are thoroughly checked by AI. Throughout the examination, the AI checks whether the characteristics of the K-complexes of Cz wave are in their regular standards or not. If not then the status shown by AI will be "Abnormal tempo" or else it will show as "Normal tempo."

The methodology used by the AI for recognition of K-complex of Cz strip is shown above. The AI uses data library built on the principles used by the neurologists. The major benefit of this image scrutinization is to foresee the standards of possibility of Alzheimer's and thereby it lessens the number of tasks to do in the last level of determination of Alzheimer's.

Steps of Deduction of K-complex:

1. Compute the rate of complexes in Cz strip.
2. Recognition of K-complexes in Cz strip.

Identifying Alzheimer's

The definition of Alzheimer's with respect to its influence on K-complex is stored in the data library. The steps involved in the deduction of K-complex and identification of Alzheimer's both simultaneously use the data library by collecting the quantitative data. The AI accomplishes the final step toward only those Cz strips which were stated abnormal by the deduction of K-complex. This in-turn saves the time as well as space. Therefore, it gives an optimized output of the examination step. The following block diagram (Fig. 8) illustrates detection of K-complex for examination.

Figure 8 depicts the process of detection of K-complex. During this process, the data from the information library is used. And hence, due to this the K-complex is detected and the process ends at the detection of K-complex section.

The terminal level of examination yields whether it is Alzheimer's or not. The constraints are being checked thoroughly from the reference stored in the data library. Figure 9 represents block diagram to detect whether a person is suffering from Alzheimer disease or not using K-complex density and information library.

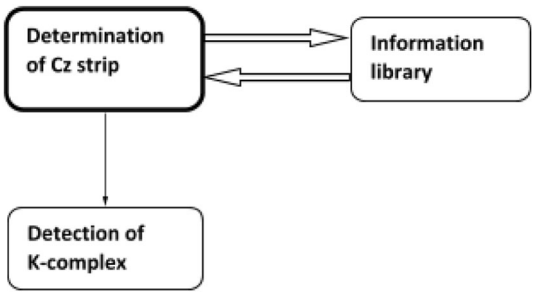

Fig. 8 Detection of K-complex

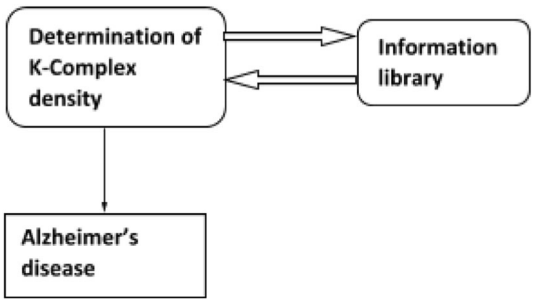

Fig. 9 Detection of Alzheimer's disease

Figure 9 states that detection of K-complex and then determining its density helps in the diagnosis of Alzheimer's disease. It is visible that determination of K-complex density process uses the information library process for the examination of constraints. At last, this whole process is used in aiding the detection of Alzheimer's disease.

The ultimate examination outline is assembled after the terminal level of Cz strip examination. The outcome comprises the rate of Cz strip and deduction of whether the patient has Alzheimer's or not.

Discussion

The suggested methodology for EEG K-complex identification developed by artificial intelligence device is constructed to emulate the shrewdness and experience of an expert or skillful neurosurgeon into the device to undertake the process of diagnosis. In today's world, the identification and detection of various complexes such as K-complex and sleep spindle in Cz strip in an EEG is done by a doctor or neurosurgeon. Hence, these facilities are embedded in the suggested technique which consists of characteristics of AI. This presented methodology has a need of personal data of the patient such as age, gender, weight, etc.

A further facet of this technique is machine learning that is the ability of this system to learn on its own, which can be implemented by a doctor who scrutinizes the behavior of the AI device and helps to assess the AI to engage in

receiving some irregularity as extra information. This quality of artificial intelligence would make the system more applicable to execute intelligence-based job compared to different AI techniques. A constant effort is being made by the authors in a legitimate manner accompanied by health-care institute for future vision and expansion of proposed methodology and its firm execution in this scope.

Conclusion

To recapitulate, this study comes to the point that artificial intelligence can be utilized to explicate standard EEG principles for K-complex examination. The suggested methodology implemented using AI assures shrewdness and acuteness on a better extent relatively. Because of such benefit, the suggested methodology could be embedded in future research works and also real-time application for neurology.

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Compliance with Ethical Standards

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Ethics Approval and Consent to Participate Not applicable.

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