Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 2461-2488
Received 25 April 2021; Accepted 08 May 2021.

Survey and Analysis of Preprocessing Of EEG Signal

Ashok Vajravelu[1*,] Muhammad Mahadi Bin Abdul Jamil,[2] Wan Suhaimizan Bin Wan Zaki,[3] MurugesanGovindasamy[4]

[1*,3]*Lecture, Faculty of Electrical and Electronic Engineering (FKEE), University Tun Hussein Onn Malaysia (UTHM), Malaysia.*

[2]*Associate Professor, Faculty of Electrical and Electronic Engineering (*FKEE*), University Tun Hussein Onn Malaysia (*UTHM*), Malaysia.*

[4]*Professor, Kongu Engineering College, Tamil Nadu, India.*

ashok@uthm.edu.my

ABSTRACT

Preprocessing of the EEG sign, which is largely a group of sign interaction in steps going earlier than number one EEG data examinations, is essential to get just cerebrum movement from the boisterous EEG debts. it's been proven that the plan of preprocessing strategies can impact ensuing EEG records investigation consequences. Preprocessing of EEG to amazing extent consists of diverse cycles, for example, line clamor expulsion, trade of referring to, give up of horrible EEG channels, and antique evacuation. This part provides define of the techniques reachable for each interaction and examines practical contemplations for applying those techniques to the EEG alerts. in particular, staggering consideration is paid to the nice in magnificence antiquity expulsion strategies on account that there are nevertheless a whole lot of freedoms to improve the curio evacuation strategies for EEG, inside the points of view of both sign making ready and neuroscience. it is fascinating that this segment gives the peruses a fashionable perspective on EEG preprocessing pipelines and fills in as a guide manipulate for the act of EEG preprocessing.

Keywords:Artifacts,Electroencephalogram (EEG),Filtering,Noise,SignalProcessing,Wavelet Transform.

INTRODUCTION

Preprocessing of the EEG signal is an integral increment for the exploration of EEG all things considered. notwithstanding reality that there may be as but a lack of the standard, worn out pipeline of EEG preprocessing [8, 37, 58] it for the maximum element carries any essential advanced signal managing obligations to clean up crude EEG alerts with a plan to go away just cerebrum motion indicators for ensuing investigations. Often, EEG preprocessing similarly carries systems to enhance spatiotemporal traits of the EEG sign associated with the assignment carried out in take a gander at [65].

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages.
Received 25 April 2021; Accepted 08 May 2021.

Special exams have proven the affects of EEG preprocessing on the following data studies results [8, 33, 90, 110, 112]. For example, the grouping of diverse mental states from EEG or the control execution of a issues laptop interface (BCI) is probably situation to how EEG preprocessing took care of the recorded EEG recommendations. Indeed, surely any logical outcome from the EEG indicators containing important commotion and genuine rarities is maximum likely going to reach deceptive inferences. Continuous reviews similarly complement the standardization of preprocessing plans for multi-internet site page insights collection in divergent initial conditions [8, 37].

On the point of convergence of EEG making ready lies the departure of any needless mystery and clean components of the EEG indicators. On this level, we mean such unnecessary sections as fuss and fantastic rarities. Following the preceding idea [65], upheaval is taken into consideration as neurological donning sports unnecessary to an investigated social errand concurrently as relics are trustworthy to start from outside assets disengaged to neurological sporting sports, for example, eye patterns, breath or electric difficulty. As maximum EEG preprocessing techniques acknowledgment on doing away with artifacts, we will in like manner Nar-line our consideration on the techniques used to clean out vintage rarities to easy up the EEG cautions. Word that the variables covered by way of this component bar the extraction of highlights from the EEG signals for specific programs, which ought to be inspected freely.

This fragment gets going advanced with the depiction of beginning component techniques to put off essential noteworthy rarities, perceive out corrupted channels and probably change references. It at that issue discusses an volume of methods to cast off artifacts from the EEG signals, observed by way of making use of brief verbal change on EEG preprocessing.

PRE-STAGE PREPROCESSING

Starting phase EEG preprocessing incorporates of predominant and semi-robotized affiliation of signal preparing limits. Its miles analyzed from normal artifact departure structures as this phase of preprocessing is generally liberated from a selected doodad. This fragment portrays key bits of beginning segment preprocessing which incorporate the removal of line upheaval, alluding to and the elimination of appalling channels. Previous to portraying them, anyways, it deserves surveying basis qualities of the EEG signals.

EEG CHARACTERISTICS AND ITS BACKGROUND

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 2461-2488
Received 25 April 2021; Accepted 08 May 2021.

“A basic and brief summary of the characteristics of background EEG activity is given as follows [104]. The frequency range of EEG is reportedly limited approximately from 0.01 to 100 Hz. The amplitudes of EEG generated from the brain typically rangewithin100 µV. The power spectral density of EEG is known to follow the powerlaw [44]. Background brain rhythms are present in EEG, generally being classified in terms of oscillatory frequency into five disjoint bands: delta (0.5–4 Hz), theta(4–8Hz),alpha(8–13Hz),beta(13–30Hz)andgamma(30–100Hz).More detailsof the implications and functions of these rhythms can be found in other resources(e.g. see[10,41,63, 98])”.

It is reasonable to keep in mind the EEG sign as stochastic due to the shortfall of actual EEG tests [93]. Moreover, over a drawn out time period, the EEG signs and symptoms must be considered as a non-fixed time association [57, 66]. Regardless, EEG inward a brief time frame window can be quite fixed with static true properties. The span of the sort of window containing fixed EEG cautions modifications with situations, for the most additives going from positive seconds to mines [51].

POWER LINE NOISE REMOVAL

Maximum endeavors to kill line commotion from the EEG signal rely upon rating sifting at 60 Hz. An indent channel is generally completed with a selected recurrence width Sure-adjusting 60 Hz (as an instance a width of 10 Hz). eventually, score sifting, albeit efficaciously putting off line commotion, should reason unintentional contortions in sign components swaying someplace in the variety of fifty and 70 Hz. moreover, the indent channel can supposedly create a brief wavering in gauge movement, prompting a possible problem in records translation [18]. observe-up low-bypass setting apart with a cutoff recurrence decrease than 50 Hz can also cure this trouble, but rather result in specific troubles, as an instance, alternate of worldly designs of EEG [106] or deceptive connections between EEG channels [40].

One concept to overcome this trouble is evaluating line upheaval embedded within the recorded EEG alarms as precise as should definitely be expected and deducting it from the statistics [8, 80]. This system makes use of multi-fix rot to find line upheaval elements in the signal. A brief period of time window slides at some stage in the sign wherein the exchange of EEG time plan situation to multi-fixes is done [5]. This alteration can fairly test horrendous electricity interior each repeat band. At that issue, a back slide model is completed to survey the adequacy and duration of sinusoidal line upheaval (as instance sinusoids in the modified repeat area. The Thompson F-look into evaluates a methods for the quantity of the surveyed line upheaval. A length courting of sinusoidal line upheaval is reproduced if the measurement is sizable. This cycle is repeated ludicrous windows. The reproduced line upheaval sign is deducted from the most important EEG sign. The entire transaction is reiterated until the importance on the repeat of line noise receives non-fundamental (Fig. 2.1). Close by those traces, line upheaval additives is probably taken out without hurting establishment supernatural sections [83].

FIXING-UP OF REFERENCE

We often eliminate a reference (with a comparable time purpose because the recorded EEG signals) from the first EEG signal at each channel. The reference sign need to

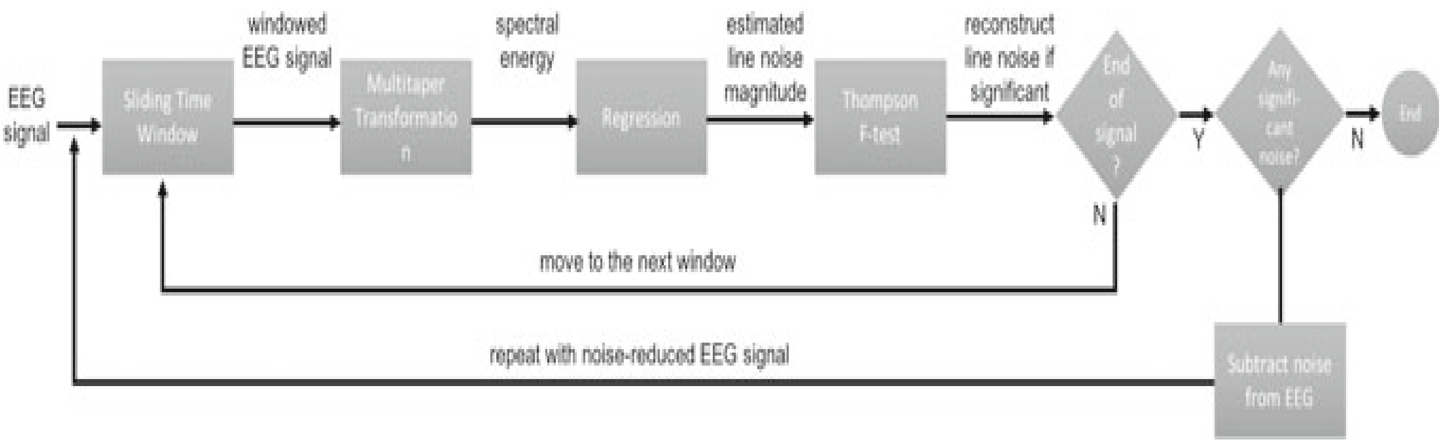

Fig. 1 Line noise removal using the multilayer transformation

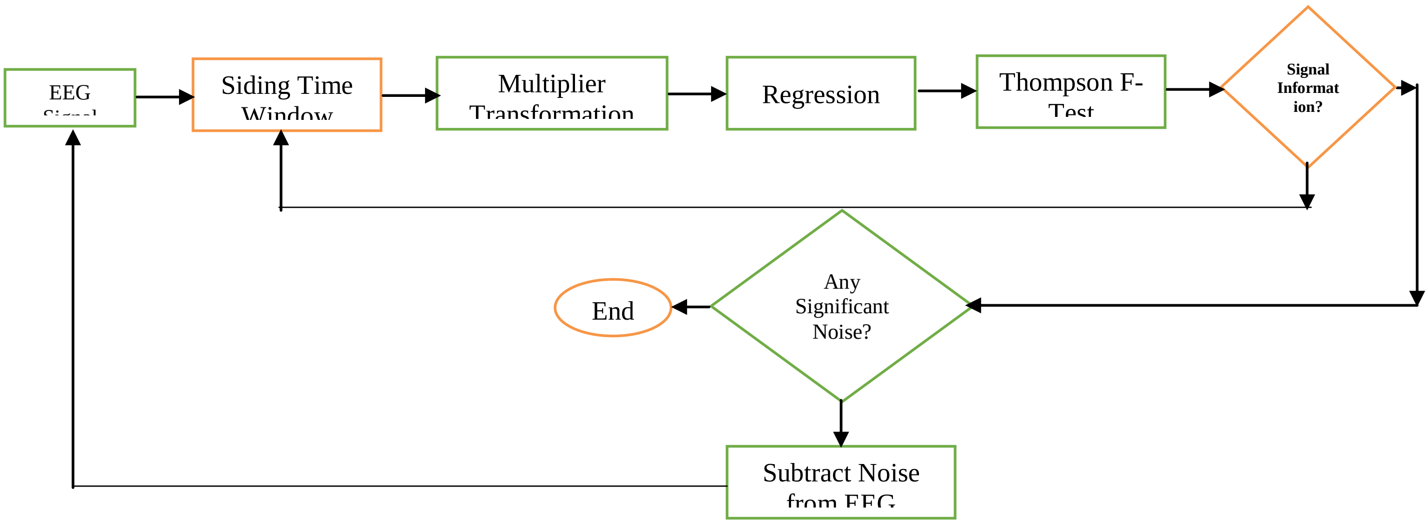

Fig.2 Removal of Power Supply Noise using the multilayer transformation

Live unaltered comparative with the EEG indicators for the duration of the account to such an extent that difference of the EEG signals from reference can efficaciously address

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 2461-2488
Received 25 April 2021; Accepted 08 May 2021.

cerebrum action diagnosed with an exam. Normal choices of reference contain a sign recorded at a mastoid channel, an EEG sign at a selected channel, and the more often than not of mastoid facet consequences or the regular of the whole EEG channels. In any case, its miles solidly proposed that a researcher want to survey a picked reference signal warily to ensure that its plenitudes diploma is likened to the ones of other EEG signs and facet results and it has no dating with assignment-initiated frontal cortex hobby.

Referring to a mastoid channel has an ability problem since it produces a solitary mark of unhappiness. At the off danger that the touch to a mastoid receives terrible anytime at some point of the account, referring to the mastoid can expand signal fluctuation extremely, bringing approximately irreversible tainting of EEG facts. A tant amount issue exists for relating to a specific EEG channel. Utilizing the fundamental traditional reference (automobile) can also furthermore lessen the impact of single-point bitterness [9], yet admire the evil outcomes of a special case channel. One honest solution for this difficulty is recognizing and pushing off ghastly channels previous using car [8]. There may be other particular re-figuring out with techniques made to manipulate the problems of reference, contemplating real thoughts and electrodynamics [38, 113, and 114] or on quantifiable procedures [48, 69, and 73].

POOR QUALITY CHANNELDETECTION

It's far habitually vital to separate a loud or loathsome channel that offers an infected EEG indication [8]. To perceive a horrible channel, we can display screen every channel to separate EEG alerts with nonsensically massive amplitudes. The outstanding z-rating may be implemented to pick preposterous amplitudes. As a case, an awful channel is settled whilst it recommends an awesome z-rating of the usual deviation greater exceptional than an attitude.

An awful channel can be additionally recognized by using exploring dating of a solitary channel with others. Regular EEG bills display throughout-direct relationships within the low-recurrence segments. Eventually, the affiliation of one channel with certainly one of type channels after low-bypass disconnecting can permit us to recognize lousy channels. If horrendous channels are abruptly associated with one another, we will try and count on one channel the usage of chooses channels. The marker channels may be inconsistently chosen from the overabundance channels. Often, a corrupted channel shows genuinely vital energy in unreasonable repeat gatherings. Therefore, we are able to gauge a share of the pressure of high-recurrence parts to that of Low-recurrence segments and apprehends an awful channel displaying a share higher than A restrict. Every time being diagnosed, awful channels are supplanted with digital sound channels made by using the addition from adjoining channels,

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages.
Received 25 April 2021; Accepted 08 May 2021.

to reproduce the worldwide thoughts reactions [8, 31]. There exist different growth plans helpful for channel propagation, such as roundabout spines [87], better-demand polynomials [4], nearest neighbor averaging [15] and prolonged cause work [53]. The usage of spherical spines permits actual assessment of scalp openings if the anode arranging is satisfactorily thick [38, 97]. Inclusion using a quantifiable method, as an example, winding cause limits has blessings of rate sufficiency with extensively less computational weights.

REMOVAL OF ARTIFACTS

In this section, we momentarily audit the viable wellsprings of historical rarities blended within the EEG signal and the procedures to put off or lessen curios. We basically control antiquity evacuation procedures, renouncing different strides of curio the board like relic identity. Though, it doesn't suggest that special strategies such as ancient rarity recognition or curio evasion are less pivotal than vintage expulsion. Indeed, relic expulsion is frequently joined via historic rarity discovery for productive dealing with of antiquities. There have been numerous techniques for curio discovery that the intrigued per users can allude to [3, 14, 32, 52, 81, 84].

ARTIFACTS AND ITS SOURCES

The wellsprings of EEG ancient rarities may be arranged into two lessons: indoors and outside resources. The internal sources start from the physiological frameworks of self and incorporate electromagnetic sports of heart, eyes, muscle, and so forth. The outdoor assets incorporate any closing potential signs from conditions that could pollute EEG, for example, far flung media transmission indicators, terminal connection, recording gear and link traits [93]. As of overdue. The remedy of outside antiques has gotten greater huge as EEG packages will in fashionable move out of labs toward in-home scientific offerings frameworks [100]. However, the outer resources, on account of their beginning points, may be restrained each time being prominent. Then again, the interior relics physiologically penetrate EEG, making it difficult to keep them from taking place ahead of time. Therefore, maximum antique expulsion techniques have been centered round dealing with the internal historical rarities and right here we likewise give our consideration to the most articulated inside relics which have been sorted via EEG relic evacuation techniques.

Visible historical rarities include electric exercises created by using eye trends or eye flickering [22, 23]. Obstruction by visible ancient rarities is adequately capable of be obvious in EEG waveforms. EEG channels proximal to eyes are extra helpless towards visual

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 2461-2488
Received 25 April 2021; Accepted 08 May 2021.

antiquities. Visible antiquities can be prominent via electrooculogram (EOG) estimations. EOG recorded all the whilst with EEG gives a chance to directly put off visible historic rarities from EEG as it distinguishes true profiles of curios. When understanding the waveforms of visible curios, expulsion calculations may be created to deduct them from the EEG sign without a want to disregard polluted EEG sections. To quantify EOG for visual curio evacuation, it is prescribed to report vertical (vEOG), degree (hEOG) and spiral (rEOG) oculomotor indicators [88].

Muscle relics comprise electric powered physical activities starting from muscle constriction of the body components, consisting of face, head, neck, appendages and others. Contrasted with visual relics, muscle curios produce greater one-of-a-kind systems depending of the wellsprings of muscle tissues and associated traits. The electrical signs and symptoms associated with muscle antiquities can be estimated by way of electromyogram (EMG). anyways, inescapable wellsprings of muscle curios over the body make it attempting to distinguish authentic profiles of relics. Additionally, the unearthly houses of cranial muscle antiques fluctuate throughout sources, tainting excessive-recurrence EEG parts simply as low-recurrence ones [93, 105]. The spatial appropriation of muscle historic rarities is extra enormous than visual relics, almost uniform over the complete scalp [44]. Fleeting examples of muscle antiquities are frequently linked with undertakings as traits of topics typically show up because of task prerequisites [95]. Considering each this kind of troubles, it truly remains a essential test to take away muscle relics from EEG [76, 77, 95].

Cardiovascular historical rarities start from electric powered sporting activities of the coronary heart. Cardiovascular historic rarities for the maximum element show low amplitudes contrasted with unique antiques. Heart electric activity may be anticipated with the aid of electrocardiography (ECG). They've splendid commonplace attributes, which appear to be epileptic EEG action and consequently potentially prompting incorrect seizure locating [30]. Be that as it is able to, for the point of view of evacuation calculations, standard coronary heart waveforms make it simpler to cope with in EEG. on the point whilst an EEG terminal is situated over a scalp conduit, its contact with the pores and skin can regulate every now and then due to intermittent motion of a throbbing vessel, which might be going to cadenced electric powered motion like EEG motions [68]. Yet, this throb effect shows periodicity synchronous with the coronary heart, delivering itself being prominent by way of ECG.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages.
Received 25 April 2021; Accepted 08 May 2021.

METHODS OF ARTIFACTS REMOVAL

Relic expulsion techniques mean to drop or cope with antiques in EEG with insignificant bends in the cerebrum sign. Right here we momentarily define the computational strategies to dispose of curios from EEG [52, 104]. along this manner, we try no longer to depict the subtleties of numerical foundations hidden each method (as an example dazzle supply detachment (BSS), relapse, direct trade of multivariate Gaussian, and so on) In general, an EEG antiquity expulsion approach has an area with one of the two types: a meeting of techniques that treatments a solitary channel freely or another collecting that measures the complete channels all collectively. The unmarried-channel handling strategies make use of exceptional methods which includes instantly relapse, separating, wavelet trade and experimental mode disintegration (EMD). The entire channel coping with techniques depend upon BSS to gauge a group of concealed assets from a observed aggregate of those resources with just restricted data. Underneath we gift some critical strategies from the 2 gatherings which have been most typically applied in EEG contemplates.

LINEARREGRESSION

Accepting that curio reference channels are available and include extensive wave-forms of curios, direct relapse has been one of the essential cars used to drop relics from the EEG signal due to its straightforwardness and comfort. An crucial procedure is to appraise a bit of EEG polluted through curios utilizing relapse and to eliminate the relapsed partition from the debased EEG [22, 23, 45]. Immediately relapse expects that an EEG sign is the quantity of a unique thoughts signal and a negligible a part of the relic addressed in reference. It gauges this partial thing from both the observed EEG sign and reference channel. The good sized hazards of straight relapse are that at the least one reference channels ought to be accessible (as an example EOG or ECG), that it expects a right away combination of EEG and antiquities where the EEG sign may additionally have indoors nonlinear elements and non-fixed, and that it just applies well to multiple styles of historical rarities like EOG and ECG. Notwithstanding, if reference channels are reachable, direct relapse is as but a compelling solution for remove antiquities [36, 107].

Straight relapse strategies work specifically well with visual curios considering that EOG may be straightforwardly envisioned or with the aid of implication brought about from EEG [13, 42]. In any case, straightforward deduction of a relapsed part of visual curios from EEG can likewise take out cerebral segments. This trouble is called bidirectional defilement [91]. Several techniques were proposed to address bidirectional tainting amongst which the

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 2461-2488
Received 25 April 2021; Accepted 08 May 2021.

adjusted vintage everyday technique reveals promising consequences of canceling relics from eye trends or flickers at the same time as limiting EEG pollution [21–23].

REMOVAL OF ARTIFACTS

“Filters used for artifact removal build a statistical machine whose parameters areadaptivelyestimatedwithcertainobjectives,learningrules,modelstructuresaswellasdata.Threetypesoffiltershavebeenprimarilyadoptedfor EEGartifactremoval[104].

AdaptivefiltersmodelthewayartifactscontaminatetheEEGsignalbyadjustingthe filter weights according to a learning rule formed by an optimization algorithm[47].TheyassumenocorrelationbetweentheEEGsignalandartifacts.Forexample,letx[n] be an observedEEG signal mixedwithan unknownclean EEG signally[n]and dative artifactsignalz[n](i.e.x[n]y[n]+z[n]).Ifthereferencetoartifact,r[n],isavailable,theadaptivefilteradjustsitsweights,w,tominimizeerrorbetweenx[n]andwTr[n].Sincer[n]isassumedtobeuncorrelatedwithy[n],theoptimalweights would make wT r[n] as close to z[n] as possible.

Then, a difference, {x[n]wTr[n]}willbecomeclosetoy[n](Fig.3).Manylearningalgorithmsareavailable” to adjust weights, including least mean squares (LMS) and recursive least squares(RLS) [47].

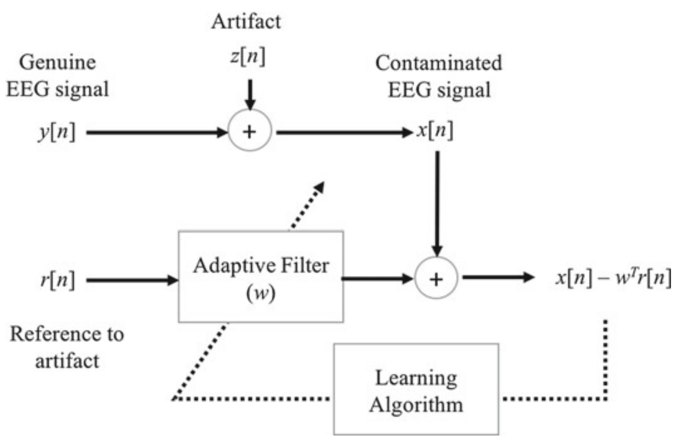

Fig.3 EEG de noising with adaptive filtering and reference to artifacts

It has been shown that adaptive filters are superior to linear regressionbecause proportion factors are less constrained [91]. However, as in linear regression,adaptivefiltersstillrequirereferencechannels.

The Wiener channel is a right away time-invariant (LTI) channel that limits the imply squared blunder between desired response and channel yield [47]. Perfect loads of the channel are assessed dependent on the Wiener Hope situation. Gaining knowledge of the loads is done disconnected with getting ready exams that comprise EEG and curio signals. Having taken in its hundreds, the Wiener channel can work with the tainted EEG alerts without reference. notwithstanding, the Wiener channel execution may collapse over the long haul if an extent of EEG debased by way of curios changes after a while(i.e.non-stationary).

Bayesian channels in a instantly or nonlinear shape can defeat a few inadequacies of each direct relapse and the Wiener channel as they could consecutively refresh the states online without the need of reference channels. Here the states surmised difficult to understand clean EEG indicators. The framework model in Bayesian channels approximates the consecutive trade of clean EEG information as indicated with the aid of the fundamental request Markov degree and the perception model gauges the returned likelihood conveyance of easy EEG information subsequent to noticing defiled EEG information making use of a opportunity version and Bayesian estimation. the bounds of the framework and notion fashions should be received from the guidance records as resulting from the Wiener channel. Regardless of the reality that it is computationally expensive to appraise likelihood disseminations most often, for certain presumptions, Bayesian channels can lower to greater trustworthy systems, as an instance, the Kalman channel or the molecule channel. Mainly, the Kalman channel has been widely carried out for antiquity expulsion for EEG [50, 59, 82].

EMPIRICAL APPROACH OF DECOMPOSITION AND WAVELETTRANSFORM

EEG denoising can be completed by using disintegrating a solitary channel EEG sign into a group of primary premise indicators, with a cause that a few premise signs and symptoms can also contain the statistics of historical rarities as it were. Thusly, we will find out those antique related premise signals and dispose of them from the decayed set. Delegate strategies for deterioration of an EEG signal are introduced under.

Wavelet alternate convolves a given sign with a scaled and moved variation of mother wavelet paintings. It brings approximately a bunch of coefficients comparing to every scale and time shift. The coefficients address closeness among a fraction of the sign and the mom wavelet at a given scale. The discrete wavelet exchange (DWT) is gotten from consistent wavelet trade with discrete-time examining. An essential method of the DWT is sifting a sign with low-and excessive-pass channels, one after the other, in which the low-pass channel works like the scaling capability and the excessive-pass channel works like the mom wavelet work [52]. At that factor, the low-pass separated yield is handed to a higher diploma of sifting with low-and excessive-skip channels another time. This machine is rehashed as much as *k*

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 2461-2488
Received 25 April 2021; Accepted 08 May 2021.

levels and yields one estimation coefficient and *k* element coefficients where the wager coefficient is received from the last low-bypass sifting and the element coefficients are gotten from a development of the outstanding bypass setting apart via *k* tiers. At that point, for denoising, a restriction is implemented to the detail coefficients to parent out those with little extents. It attracts upon a theory that the sign can be unequivocally related with an accurately picked mother wavelet premise at certain ranges though historic rarities cannot be [104]. At final, the relic decreased signal is reproduced by means of the subtle detail coefficients and the guess coefficient [94]. Efficient techniques of selecting a restriction may be found in positive

"Empirical model decomposition (EMD) is a data-driven technique that decom-poses a signal into a sum of the band-limited basis functions, called intrinsic modefunctions(IMFs)[49].TheIMFshavezeromeansandare amplitude andfrequencymodulated.EMDhasbeenshowntoperformwellwithnonlinearrantnon-stationarysignals. If different sets of IMFs can separately represent the signal and artifacts,we can reconstruct a clean EEG signal by removing artifact-related IMFs from thedecomposed set. EMD has been successfully applied to artifact removal of EEG[70,94,115].MoreadvancedmethodstoovercomeshortcomingsofEMD(e.g.lowrobustness against noise, no mathematical background), including ensemble EMD(EEMD) [99, 116] and multivariate EMD (MEMD) [108], have also been adoptedforartifactremoval.

SEPARATION OF BLIND SOURCES

Blindsourceseparation(BSS)has been maximum usually utilized for curio evacuation whilst the statistics about historical rarities is restricted—for example, no reference is given. The fundamental BSS techniques utilized for relic evacuation be given an immediate combination version wherein the observed multi-channel EEG alerts are concept to be an instantly mixture of obscure resources with little facts about assets or a mixing lattice. The perfect gauge of assets and a blending grid, consequently, is performed by using precise presumptions on the sources to such an quantity that the resources are typically self reliant or uncorrelated.

Forinstance,let**x**beanobservedEEGsignalvector,whichisamixtureofanunknownsourcevector**s**withamixingmatrix*A*,givenby:

$$\mathbf{x} = A\mathbf{s} + \mathbf{n} \quad (2.1)$$

Where**n**denotesad dative whitenoise.

Then, BSS methods estimate A to make sources in **s** as independent as possible.Once the estimate of A is obtained, its inverse matrix $\bar{\bar{W}}A^{-1}$ is used to find thesourcesgiven by:

$$\mathbf{s}=W\mathbf{x}. \qquad (2.2)$$

Those assessed sources are then tested either observationally (by visual inspection, for instance) or clearly (through programmed source dedication calculations [109, 111, 119]) to apprehend antiquity associated resources. The faded arrangement of sources after removing art factual ones are then used to remake antique free EEG records utilizing A.

Notwithstanding its predominance in EEG preprocessing, BSS studies limits that it requires multi-channel EEG statistics and that there is continually a chance that removed sources may additionally likewise convey data about cerebrum motion. Additionally, specialists need to think about the suspicions every BSS approach works underneath, consisting of autonomy, uncorrelatedness, and non Gaussianity [54, 71]. A collection of BSS strategies, however, had been correctly carried out to do away with historical rarities from biomedical signs. The subsequent are depicted a few strategies that have been widely utilized for EEG antique expulsion.

Independent component analysis (ICA) is a BSS method based on assumptionsomutuallinearindependencebetweensourcesandnon-Gaussianity[7].ICA algorithms rely upon both 2nd-request and better-request insights [54]. The ICA calculations depending on better request insights gauge W through augmenting genuine autonomy of the probability thickness elements of character assets using shared records or negentropy [7, 19]. The ICA calculations depending on 2nd-request statist spasms gauge W by way of decor relating the time-arrangement facts utilizing the second one-request dazzle identity (SOBI) [20, 103]. ICA has been accounted for to carry out nicely in EEG art-truth evacuation due to its realistic presumption of genuine freedom between the EEG signs and relics (as instances see [2]). Be that as it can, to analyze authentic freedom, ICA needs the adequate degree of EEG facts [56]. Likewise, ICA works pleasant when the relics and the EEG signals live fixed for the duration of the time of examination, which won't be the state of affairs most of the time. To assure stationary, examines have √suggested an age of 10 s or much less, or an example size in the request for merchandise of C where C is the quantity of channels [56, 92]. On the point when just a predetermined variety of records tests are available, contemplates have advocated utilizing the ICA calculations with 2d-request insights [28, 55].

Principal component analysis (PCA) has been proposed as a manner to eliminate

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 2461-2488
Received 25 April 2021; Accepted 08 May 2021.

antiquities from EEG [39, 67, 102]. PCA changes apparently associated multi- channel EEG statistics to normally uncorrelated head segments (desktops) that shield change of the EEG data but a good deal as may be expected. a group of computers can cope with relics if antiques and cerebrum signals are uncorrelated with each other. PCA likewise accepts joint normal circulations of the records. regularly, it reviews its restricted suspicion that resources including cerebrum sporting events are symmetrical to one another [39]. as a consequence, PCA is currently best occasionally utilized straightforwardly for antiquity expulsion but as a substitute applied for different essential preprocessing, as an example, brightening [35].

Canonicalcorrelationanalysis(CCA)has likewise been extensively utilized for vintage expulsion from EEG [29, 43, 118]. Basically, CCA appears for typical elements that amplify relationships amongst two multivariate datasets. For EEG denoising, CCA discovers fashionable factors between the primary facts and now could be the right time moved variant (typically one degree behind). In doing as such, authoritative elements precipitated in arrangement address the autocorrelation from the maximum noteworthy to the least. By using accepting that thoughts exercises are greater related on agenda than antiquities, CCA recognizes and gets rid of sanctioned com-ponents with decrease autocorrelations that may relate to curios. The gain of CCA over ICA is that it may take into account worldly connections of the symptoms and utilize less computational property [52].

Aside from the three BSS techniques portrayed above, there are different BSS strategies as of overdue proposed for EEG antiquity expulsion. Morphological component analysis (MCA) can spoil down historical rarities from EEG if the morphological format of the goal antiques is available [96]. precise variety exam (SSA) is a projective sub-space strategy that projects a solitary channel EEG sign onto a better-dimensional area by time placing, breaks down the implanted signal vector into uncorrelated segments and remakes the EEG signal by using extending the mounted indicators within the methods with large Eigen values [24, 25, 101]. The scanty time curio expulsion calculation distinguishes and eliminates art factual parts of EEG which are meager in both existences [27].

HYBRID METHODS TO REMOVE ARTIFACTS

Ongoing investigations have proposed half of and half methodologies for EEG historic rarity expulsion with the aid of com-binning more than one relic evacuation calculations. Several investigations blend one calculation from the BSS family and the opposite with disintegration (as an instance wavelet trade or EMD). A move breed technique may be portrayed by the request for the utilizations of the chose calculations. One gathering

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages.
Received 25 April 2021; Accepted 08 May 2021.

of strategies to start with decays an EEG signal and in a while applies a BSS calculation later even as a change collecting of techniques first gauges segments utilizing a BSS calculation observed by way of a deterioration calculation. The preceding normally amends a solitary channel EEG signal whilst the remaining cycles multi-channel EEG signals (Fig. 4). The crossover approaches are for the maximum part meant to conquer the regulations of a solitary antiquity evacuation technique and consequently display higher execution, but require more careful selections of calculations that in shape satisfactorily to the statistics or probably framework stipulations (for example computational intricacy). The test plus of the fundamental accumulating of 1/2 and half strategies for ancient rarity expulsion, decay BSS for single channels, can be determined in specific structures, making use of wavelet exchange observedby(f.b.)ICA[11,74,75],EMDf.b.ICA[79,117]andEMDf.b.CCA[16,99].

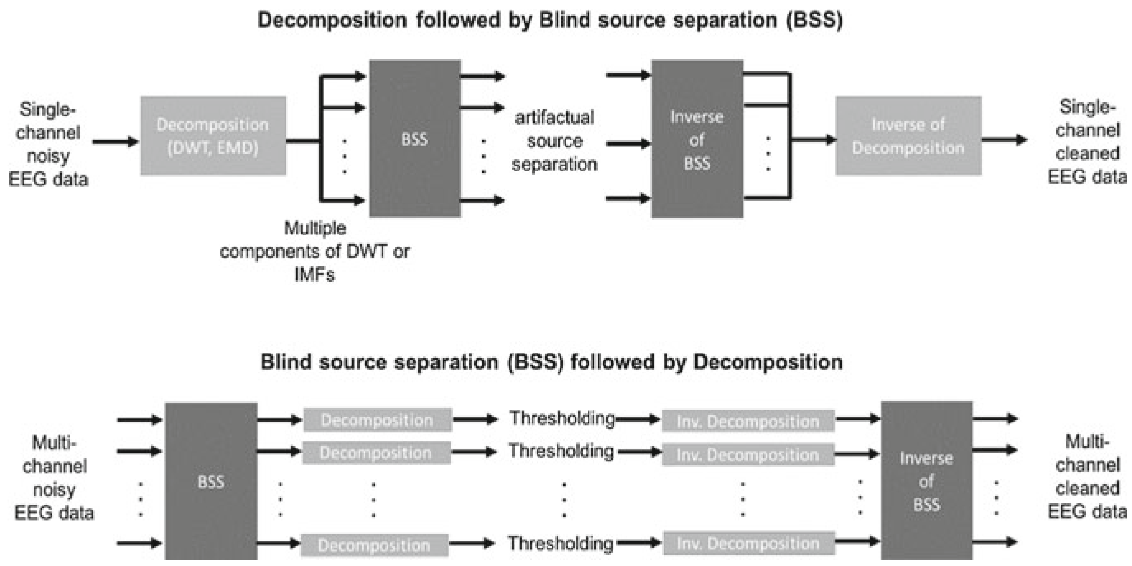

Fig.4 Types of hybrid methods for EEG artifact removal

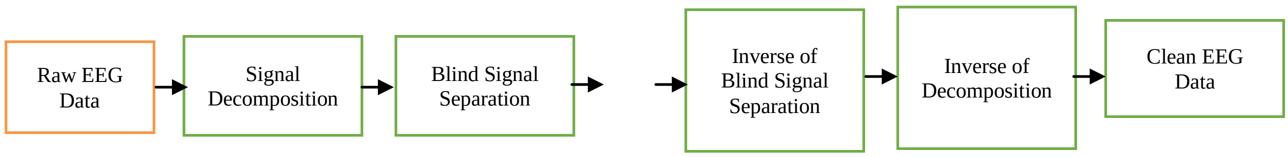

Fig.5 Single Channel Decomposition followed by Blind Source Signal Separation (BSS)

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 2461-2488
Received 25 April 2021; Accepted 08 May 2021.

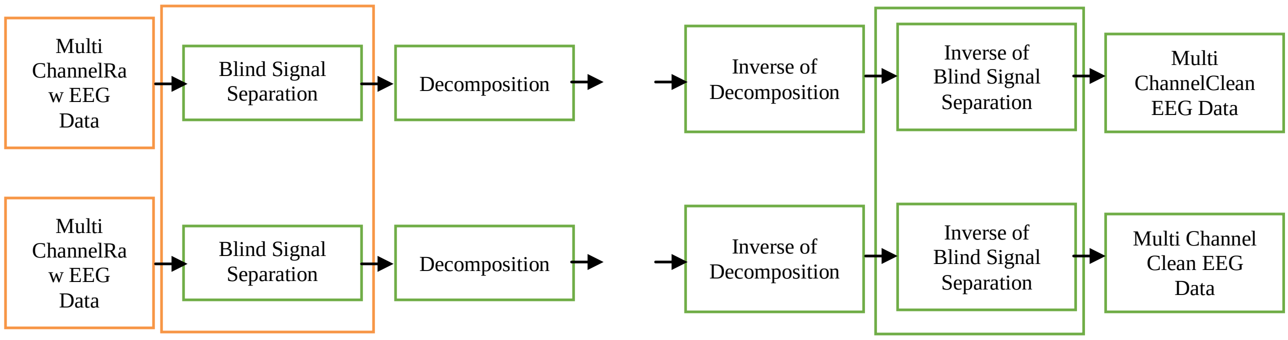

Fig.6 Multi Channel Blind Source Signal Separation (BSS) followed by Decomposition

"Theexamples of the second group, BSS-decomposition for multiple channels, can alsobefoundindifferentforms,includingICAf.b.wavelet[1,12],stationarysubspaceanalysisf.b.EMD[115],ICAf.b.EMD[70],ICAf.b.regressionanalysis[61]andICAf.b.adaptive filtering[46]."

DISCUSSION

This segment gives an outline of essential preprocessing ventures for EEG. More precise rules of reasonable preprocessing techniques can be located in existing writing (for instance, see [8, 52, 100, 104]). No matter the reality that there was full-size advancement inside the improvement of EEG preprocessing strategies up so far, continuous progresses in EEG-based exploration retain asking for developments in preprocessing processes. For instance, inescapable and wandering programs utilizing EEG inspire the development of preprocessing techniques which could work with more than one diverts progressively [78, 86]. late neuroscience approaches to deal with use multi-modular cerebrum measurements request better methods for preprocessing EEG along different signals, for example, beneficial attractive reverberation imaging (fMRI) [17]. EEG hyper scanning techniques recording cerebrum physical activities at the identical time in more than one man or woman, perhaps over diverse destinations, want a greater orderly preprocessing strategy [6]. Right here, we momentarily talk about a few non-stop issues and ideas in the examinations which include EEG preprocessing.

When looking at the historic rarity expulsion execution of diverse calculations, frequently for the exhibit of the superiority of a recently proposed calculation over current ones, we will revel in the issue of the absence of floor fact. in view that it's far via and big difficult to understand about the unique waveform of an true EEG signal of hobby, it is difficult to survey how an awful lot an uproarious EEG signal turn out to be filtered with the

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages.
Received 25 April 2021; Accepted 08 May 2021.

aid of an antique expulsion calculation [52]. One method to deliver this problem is to combine mimicked signals combined in with putative real EEG signs and historical rarities and check a calculation with the reproduced alerts [60, 64, 92]. Others have proposed making use of a outstanding EEG waveform evoked with the aid of a set up intellectual errand to test historical rarity evacuation strategies [104]. for instance, a well-known media mission summoning the pay attention-capable N100 event associated capability might also supply an approval dataset which professionals can assess range ent vintage evacuation strategies by evaluating N100 waveforms in the wake of wiping out curios by way of diverse strategies.

Aside from execution assessment pointed out above, there are one of a kind troubles to deal with for the development of an EEG antiquity expulsion method. Initially, numerous new EEG applications request net based totally preprocessing of antiques [26, 43, 86]. Such on-line pre-getting ready is geared up for recognizing and casting off historic rarities in any event, for non-fixed conditions with the purpose that it may adaptively refresh the limits of calculations via tracking ecological adjustments. All matters considered, the need of net primarily based getting ready right here and there debilitates the upsides of unique calculations that rely upon the evaluation of model boundaries utilizing a bit of the practice information (as an instance ICA or EMD). Additionally, calculation associate highly-priced AI calculations (as an example those with profound studying calculations) may additionally require similarly avocation to be applied for net preparing. However, over the span of the advancement of every other curio evacuation calculation, it would be more viable to think about on-line execution if potential. a totally robotized relic expulsion calculation will guide on line execution [26, 84]. 2d, the accessibility of reference channels have to be contemplated for historic rarity expulsion. Within the event that no reference channel is obtainable, we want to apply earlier data approximately historical rarities or acquire antiques straight forwardly from EEG records [62, 72, 86].

For the maximum element, utilizing an unequivocal reference channel may help tweaking calculations for every person, yielding a extra precise preprocessing approach. Contingent upon the styles of curios, it is able to be beneficial for enhancing EEG preprocessing to use reference channels, frequently gained with a one-of-a-kind device, as an example, EOG channel [22, 23, 61], ECG channel [30], eye tracker [85], accelerometer [24, 25], and phone impedance [119]. Third, it is urgent to coordinate with the properties of a calculation with measurable and physiological characteristics of the antiques to cast off. The per users may also allude to Origen et al. [104] for the ideas of historic rarity expulsion calculations affordable for diverse kinds of antiquities. Fourth, analysts often pick to apply

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 2461-2488
Received 25 April 2021; Accepted 08 May 2021.

public programming units for EEG preprocessing just as different EEG information examinations (see [52] for the rundown of accessible programming devices).

Regardless of the truth that various programming apparatuses offer overall preprocessing schedules and user interfaces for EEG contemplates, it's far prescribed to significantly investigate the theoretical foundations and specialized subtleties of a tool being applied. Else, it's far tough to see how EEG indicators are organized at each preprocessing step. 5th, it's miles beneficial to light up examine participants approximately the issues of historical rarities in EEG fileings with the quit intention that individuals can restrict their traits for the duration of the number one assignments [89]. despite the fact that it might be likewise risky if participants provide plenty of consideration to improvement predicament at some point of the complete research, a quick preparing level for participants to limit trends for the duration of the errand time frames interleaved with greater adaptable breaks can help securing first-rate EEG information at the segment of recording.

This steerage could be especially critical for the examinations enlisting extra youthful well-known tic pants. Sixth, profoundly debased channels as well as fantastically tainted preliminaries are often wiped out from the investigation. The disposal of tainted preliminaries is normally led after all of the preprocessing steps yet its operational rule is like other preprocessing techniques. For the most element, the preliminaries containing the EEG signal extent more prominent than a restrict degree (as an instance 150 µV) are named being debased [89]. Right here, the restriction should be determined depending upon experimental situations. Dismissal of the sort of big range of preliminaries could cause a loss of the degree of facts inside the resulting examinations, so a careful clever exam between preprocessing strategies and preliminary dismissal should be notion of. At lengthy remaining, a developed preprocessing pipeline might also name for appraisals dependent on criticisms from the assigned applications(e.g. classification of the user intention for brain-computer inter faces). Consequently, it is worth deliberating an end-to-end design of EEG signal processing, from there cording to the interpretation of EEG as a whole.

Few of the applications in the analysis using the deep learning technique for the detection of retinal area from scanning laser ophthalmoscope images (SLO) using deep neural network [120]. Similarly, another application to analysis the behavioral changes in the intellectual disability of the individuals through EEG pattern with the help of brain computer interfacing techniques [121,122]. According to the activity and attitude how a person can fit in to a specific work [123] and positioning of electrodes placement in the electrical stimulus [124]. To learn how thekNN and SVM classification for EEG as a review [125] gives a clear picture with the demonstration how the gender difference can be addressed [126] in solving based on the analysis of Electroencephalogram (EEG) wave patterns.

ACKNOWLEDGEMENT

The authors wish to thank the **Research Management Centre (RMC)** of **University Tun Hussein Onn Malaysia** for supporting this work through the **TIER H764** research grant. The authors would also like to thank and appreciate the Management, Administrative Officials of Univerisiti Tun Hussein Onn Malaysia [UTHM], Malaysia, Kongu Engineering College [KEC], India, National Institute for Empowerment of Persons with Multiple Disabilities (Divyangjan) [NIEPMD], Chennai, India, The Institute of Neurological Sciences [TINS] at Voluntary Health Services [VHS], India., for their support to carry out the research work successfully.

REFERENCES

1. M.T. Akhtar, W. Mitsuhashi, C.J. James, Employing spatially constrained ICA and waveletdenoising,forautomaticremovalofartifactsfrommultichannelEEGdata.Sig.Process.**92**,401–416(2012)
2. L.Albera,A.Kachenoura,P.Comon,A.Karfoul,F.Wendling,L.Senhadji,I.Merlet,ICA-based EEG denoising: a comparative analysis of fifteen methods. Bull. Pol. Ac: Tech. **60**,407–418(2012)
3. M.N.Anastasiadou,M.Christodoulakis,E.S.Papathanasiou,S.S.Papacostas,G.D.Mit-sis,Unsupervised detection and removal of muscle artifacts from scalp EEG recordingsusingcanonicalcorrelationanalysis,Waveletsandrandomforests.Clin.Neurophysiol.**128**,1755–1769(2017)
4. H.Ashida,J.Tatsuno,J.Okamoto,E.Maru,FieldmappingofEEGbyunbiasedpolynomialinterpolation.Comput.Biomed.Res.**17**,267–276(1984)
5. B.Babadi,E.N.Brown,Areviewofmultitaperspectralanalysis.IEEETrans.Biomed.Eng.**61**,1555–1564(2014)
6. F.Babiloni,L.Astolfi,Socialneuroscienceandhyperscanningtechniques:past,presentandfuture.Neurosci.Biobehav.Rev.**44**,76–93(2014)
7. A.J.Bell,T.J.Sejnowski,Aninformation-maximizationapproachtoblindseparationandblinddeconvolution.NeuralComput.**7**,1129–1159(1995)
8. N.Bigdely-Shamlo,T.Mullen,C.Kothe,K.-

M.Su,K.A.Robbins,ThePREPpipeline:standardizedpreprocessingforlarge-scaleEEGanalysis.Front.Neuroinform.**9**,16(2015)

9. C.Binnie,R.Cooper,F.Mauguiere,J.Osselton,P.Prior,B.Tedman,EEG, Pediatric euro-physiology,specialtechniquesandapplications,in*ClinicalNeurophysiology*,vol.2,ed.byR.M.F.Cooper,J.W.Osselton,P.F.Prior,B.M.Tedman(Elsevier,Amsterdam,2003)
10. G. Buzsáki, X.-J. Wang, Mechanisms of gamma oscillations. Annu. Rev. Neurosci. **35**,203–225(2012)
11. S. Calcagno, F. La Foresta, M. Versaci, Independent component analysis and discrete wave let transformforartifactremovalinbiomedicalsignalprocessing.Am.J.Appl.Sci.**11**,57(2014)
12. N.P. Castellanos, V.A. Makarov, Recovering EEG brain signals: artifact suppression withwavelet enhanced independent component analysis. J. Neurosci. Methods **158**, 300–312(2006)
13. W.-D. Chang, H.-S. Cha, K. Kim, C.-H. Im, Detection of eye blink artifacts from singleprefrontalchannel electroencephalogram. Comput. Methods Programs Biomed. **124**, 19–30(2016)
14. M. Chaumon, D.V. Bishop, N.A. Busch, A practical guide to the selection of independentcomponents of the electroencephalogram for artifact correction. J. Neurosci. Methods **250**,47–63(2015)
15. N. Chauveau, J. Morucci, X. Franceries, P. Celsis, B. Rigaud, Resistor mesh model of asphericalhead:Part1:Applicationstoscalp potentialinterpolation.Med.Biol.Eng.Comput.**43**,694–702 (2005)
16. X. Chen, C. He, H. Peng, Removal of muscle artifacts from single-channel EEG based onensemble empirical mode decomposition and multiset canonical correlation analysis. J. Appl.Math.**2014** (2014)
17. M.E. Chowdhury, K.J. Mullinger, P. Glover, R. Bowtell, Reference layer artefact subtraction (RLAS): a novel method of minimizing EEG artefacts during simultaneous fMRI. NeuroImage84,307–319 (2014)
18. J.L. Cole, G. Goldberg, Central nervous system electrophysiology, in *Physical Medicine&Rehabilitation:PrinciplesandPractice*,4th edn.,ed.ByJ.A.DeLisa,B.M.Gans, N.E.Walsh(LippincottWilliams&Wilkins,Philadelphia,2005)
19. P. Comon, Independent component analysis, a new concept? Sig. Process. 36,287–314 (1994)
20. M.Congedo,C.Gouy-

Pailler,C.Jutten,Ontheblindsourceseparationofhumanelectroencephalogram by approximate joint diagonalization of second order statistics. Clin. Neuro-physiol.**119**,2677–2686 (2008)

21. R.J.Croft,R.J.Barry,EOGcorrection:anewaligned-artifactaveragesolution.Clin.Neuro-physiol.**107**,395–401 (1998)
22. R.J.Croft,R.J.Barry,EOGcorrectionofblinkswith saccade co efficient:at stand revisionofthealigned-artefactaveragesolution.Clin.Neurophysiol.**111**,444–451(2000)
23. R.J.Croft, R.J.Barry, Removal of ocular artifact from the EEG: are view. Neurophysiol.Clin.**30**,5–19(2000)
24. I.Daly,M.Billinger,R.Scherer,G.Muller-Putz,OntheautomatedremovalofartifactsrelatedtoheadmovementfromtheEEG.IEEETrans.Neural.Syst.Rehab.Eng.**21**,427–434(2013)
25. I. Daly, N. Nicolaou, S.J. Nasuto, K. Warwick, Automated artifact removal from the electroencephalogram:acomparativestudy.Clin.EEGNeurosci.**44**,291–306(2013)
26. I.Daly,R.Scherer,M.Billinger,G.Müller-Putz,FORCe:fullyonlineandautomatedartifactremovalforbrain-computerinterfacing.IEEETrans.Neural.Syst.Rehab.Eng.**23**,725–736(2015)
27. A.deCheveigne,Sparsetimeartifactremoval.J.Neurosci.Methods**262**,14–20(2016)
28. A.deCheveigne,L.C.Parra,Jointdecor relation,a versatiletoolformultichanneldataanalysis.NeuroImage**98**,487–505 (2014)
29. W.DeClercq,A.Vergult,B.Vanrumste,W.VanPaesschen,S.VanHuffel,Canonical correlationanalysisappliedtoremovemuscleartifactsfromtheelectroencephalogram.IEEETrans.Biomed.Eng. **53**,2583–2587 (2006)
30. M.DeVos,W.Deburchgraeve,P.Cherian,V.Matic,R.Swarte,P.Govaert,G.H.Visser,S.VanHuffel,Automatedartifactremovalas preprocessingrefinesneonatal seizuredetection.Clin.Neurophysiol. **122**,2345–2354(2011)
31. A. Delorme, S. Makeig, EEGLAB: an open source toolbox for analysis of single-trial EEGdynamics including independent component analysis. J.Neurosci. Methods 134,9–21(2004)
32. A. Delorme, T. Sejnowski, S. Makeig, Enhanced detection of artifacts in EEG data usinghigherorder statistics and independent component analysis. NeuroImage**34**,1443–1449(2007)
33. A. Doering, H. Jäger, H. Witte, M. Galicki, C. Schelenz, M. Specht, K. Reinhart, M. Eiselt,AdaptablepreprocessingunitsandneuralclassificationforthesegmentationofEEGsi

gnals.Meth.Inform. Med.**38**,214–224 (1999)

34. D.L. Donoho, I.M. Johnstone, Adapting to unknown smoothness via wavelet shrinkage. J.Am.Stat.Assoc.**90**,1200–1224 (1995)
35. D.A. Engemann, A. Gramfort, Automated model selection in covariance estimation and spatial whitening ofMEGandEEGsignals.NeuroImage**108**,328–342(2015)
36. I.D.Evans,G.Jamieson,R.Croft,T.T.Pham,EmpiricallyvalidatingfullyautomatedEOGartifact correction using independent components analysis, in *Abstracts of the ACNS-2012AustralasianCognitiveNeuroscienceConference*(2012)
37. F.Farzan,S.Atluri,M.Frehlich,P.Dhami,K.Kleffner,R.Price,R.W.Lam,B.N.Frey,R. Milev, A. Ravindran, Standardization of electroencephalography for multi-site, multi-platform and multi-investigator studies: insights from the canadian biomarker integration network kind epression. Sci.Rep.**7**,7473 (2017)
38. T.C.Ferree,Sphericalsplinesandaveragereferencinginscalpelectro encephalography. BrainTopogr.**19**,43–52(2006)
39. S.P. Fitzgibbon, D.M. Powers, K.J. Pope, C.R. Clark, Removal of EEG noise and artifactusingblindsourceseparation.J.Clin.Neurophysiol.**24**,232–243(2007)
40. E.Florin,J.Gross,J.Pfeifer,G.R.Fink,L.Timmermann,Theeffect of falteringonGrangercausalitybasedmultivariatecausalitymeasures.NeuroImage**50**,577–588(2010)
41. W.J. Freeman, Mechanism and significance of global coherence in scalp EEG. Curr. Opin.Neurobiol.**31**,199–205 (2015)
42. G.Gomez-Herrero,W.DeClercq,H.Anwar,O.Kara,K.Egiazarian,S.VanHuffel,W.VanPaesschen,AutomaticremovalofocularartifactsintheEEGwithoutanEOGreferencechannel,in*AbstractsoftheProceedingsofthe7thNordic*(2006)
43. J.Gao,C.Zheng,P.Wang,Onlineremovalofmuscleartifactfromelectroencephalogramsignalsbasedoncanonicalcorrelationanalysis.Clin.EEGNeurosci.**41**,53–59(2010)
44. I.I.Goncharova,D.J.McFarland,T.M.Vaughan,J.R.Wolpaw,EMGcontaminationofEEG: spectralandtopographicalcharacteristics.Clin.Neurophysiol.**114**,(2003)
45. G.Gratton,M.G.Coles,E.Donchin,Anewmethodforoff-lineremovalofocularartifact.Electroencephalogr.Clin.Neurophysiol.**55**,468–484(1983)
46. C. Guerrero-Mosquera, A. Navia-Vázquez, Automatic removal of ocular artifacts using adaptive filteringandindependentcomponentanalysisforelectorencephalogramdata.IETSignalProc.**6**,99–106 (2012)

47. S.O.Haykin, Adaptive Filter Theory, 5th ed. (Pearson Higher(ed.), Upper Saddle River, New Jersey,2013)
48. S.Hu, M. Stead, G.A. Worrell, Automatic Identification and Removal of Scalp Reference Signal forIntracranialEEGsBasedonIndependentComponentAnalysis.IEEETrans.Biomed.Eng.**54**,1560–1572 (2007)
49. N.E.Huang,Z.Shen,S.R.Long,M.C.Wu,H.H.Shih,Q.Zheng,N.C.Yen,C.C.Tung,H.H. Liu, The empirical mode decomposition and the Hilbert spectrum for nonlinear andnon-stationary time series analysis, in *Abstracts of the Proceedings of the Royal Society ofLondonA:Mathematical,PhysicalandEngineeringSciences* (1998)
50. M.H.In,S.Y.Lee,T.S.Park,T.-S.Kim,M.H.Cho,Y.B.Ahn,BallistocardiogramartifactremovalfromEEGsignalsusingadaptivefilteringofEOGsignals.Physiol.Meas.**27**,1227(2006)
51. T.Inouye,S.Toi,Y.Matsumoto,AnewsegmentationmethodofelectroencephalogramsbyuseofAkaike'sinformationcriterion.Cogn.Brain.Res.**3**,33–40(1995)
52. M.K.Islam,A.Rastegarnia,Z.Yang,MethodsforartifactdetectionandremovalfromscalpEEG:areview.Neurophysiol.Clin./Clin.Neurophysiol.**46**,287–305(2016)
53. J. Jager, A. Klein,M. Buhmann, W.Skrandies, Reconstruction ofelectroencephalographicdatausingradialbasisfunctions.Clin.Neurophysiol.**127**,1978–1983(2016)
54. C.J.James,C.W.Hesse,Independentcomponentanalysisforbiomedicalsignals.Physiol.Meas.**26**,R15(2004)
55. C.A.Joyce,I.F.Gorodnitsky,M.Kutas,Automaticremovalofeyemovementandblinkartifacts from EEG data using blind component separation. Psychophysiology **41**, 313–325(2004)
56. T.-P.Jung,S.Makeig,C.Humphries,T.W.Lee,M.J.Mckeown,V.Iragui,T.J.Sejnowski,Removingelectroencephalographicartifactsbyblindsourceseparation.Psychophysiology**37**,163–178(2000)
57. J.P. Kaipio, P.A. Karjalainen, Simulation of nonstationary EEG. Biol. Cybern. **76**, 349–356(1997)
58. A.Keil,S.Debener,G.Gratton,M.Junghofer,E.S.Kappenman,S.J.Luck,P.Luu,G.A.Miller, C.M.Yee, Committee report:publicationguidelinesandrecommendationsforstudiesusingelectroencephalograp

hyandmagnetoencephalography.Psychophysiology**51**,1–21(2014)

59. J.J.Kierkels,J.Riani,J.W.Bergmans,G.J.VanBoxtel,Usinganeyetrackerforaccurateeyemovementartifactcorrection.IEEETrans.Biomed.Eng.**54**,1256–1267(2007)
60. J.J.Kierkels,G.J.vanBoxtel,L.L.Vogten,AmodelbasedobjectiveevaluationofeyemovementcorrectioninEEGrecordings.IEEETrans.Biomed.Eng.**53**,246–253(2006)
61. M.A.Klados,C.Papadelis,C.Braun,P.D.Bamidis,REG-ICA:ahybridmethodologycombiningblindsourceseparationandregressiontechniquesfortherejectionofocularartifacts.Biomed.SignalProcess.Control **6**,291–300(2011)
62. A.Klein,W.Skrandies,Are liable statistical methodtodetecteyeblink-artefactsfromelectroencephalogramdataonly.BrainTopogr.**26**,558–568(2013)
63. W. Klimesch, P. Sauseng, S. Hanslmayr, EEG alpha oscillations: the inhibition–timing hypoth-esis.BrainRes.Rev.**53**,63–88 (2007)
64. P.Krishnaswamy, G.Bonmassar, C.Poulsen, E.T.Pierce, P.L.Purdon, E.N.Brown, Reference free removalofEEG-fMRIballistocardiogramartifactswithharmonicregression.NeuroImage **128**, 398–412 (2016)
65. D.J.Krusienski,D.J.McFarland,J.C.Principe,BCIsignalprocessing:featureextraction,in *BrainComputerInterfaces: Principles andPractice*, ed.by J.R. Wolpaw,E.W.Wolpaw(OxfordUniversityPress,Oxford,2012)
66. A.D.Krystal, R.Prado, M.West, New methods of time series analysis of non-stationary EEG data:Eigenstructuredecompositionsoftimevaryingautoregressions.Clin.Neurophysiol.**110**,2197–2206(1999)
67. T.D. Lagerlund, F.W. Sharbrough, N.E. Busacker, Spatial filtering of multichannel electroen cephalographic recordings through principal component analysis by singular value decom-position.J.Clin.Neurophysiol.**14**,73–82 (1997)
68. J.-P.Lanquart,M.Dumont,P.Linkowski,QRSartifacteliminationonfullnightsleepEEG.Med.Eng.Phys.**28**,156–165(2006)
69. K.Q.Lepage,M.A.Kramer,C.J.Chu,AstatisticallyrobustEEGrereferencingproceduretomitigatereferenceeffect.J.Neurosci.Methods **235**,101–116(2014)
70. J.P.Lindsen,J.Bhattacharya,Correctionofblinkartifactsusingindependentcomponentanalysisandempirical modedecomposition.Psychophysiology**47**,955–960(2010)
71. G. Lio, P. Boulinguez, Greater robustness of second order statistics than higher order

statisticsalgorithms to distortions of the mixing matrix in blind source separation of human EEG:implicationsforsingle-subjectandgroupanalyses.NeuroImage**67**,137–152(2013)

72. J.Ma, P. Tao,S. Bayram, V.Svetnik, Muscle artifactsinmultichannelEEG: characteristicsandreduction.Clin.Neurophysiol.**123**,1676–1686(2012)
73. N.Madhu,R.Ranta,L.Maillard,L.Koessler,Aunifiedtreatmentofthereferenceestimationp roblemindepthEEGrecordings.Med.Biol.Eng.Comput.**50**,1003–1015(2012)
74. N.Mammone,F.LaForesta,F.C.Morabito,Automaticartifactrejectionfrommultichannels calpEEGbywaveletICA.IEEESens.J.**12**,533–542(2012)
75. N.Mammone,F.C.Morabito,Enhancedautomaticwaveletindependentcomponentanalysi sforelectroencephalographicartifactremoval.Entropy**16**,6553–6572(2014)
76. B.W.McMenamin, A.J.Shackman, L.L.Greischar, R.J.Davidson, Electro my ogenic artifacts and electro encephalographic in ferencesre visited.NeuroImage**54**,4–9(2011)
77. B.W.McMenamin,A.J.Shackman,J.S.Maxwell,D.R.Bachhuber,A.M.Koppenhaver,L.L. Greischar,R.J.Davidson,ValidationofICA-basedmyogenicartifactcorrectionforscalpand source-localizedEEG.NeuroImage**49**,2416–2432(2010)
78. V.Mihajlovic B.Grundlehner, R.Vullers, J.Penders, Wearable, wireless EEG solutions in daily life applications: what are we missing? IEEEJ. Biomed. Health Inform. 19,6–21(2015)
79. B. Mijovic, M. De Vos, I. Gligorijevic, J. Taelman, S. Van Huffel, Source separation fromsingle-channel recordings by combining empirical-mode decomposition and independentcomponentanalysis.IEEETrans.Biomed.Eng.**57**,2188–2196(2010)
80. P.P. Mitra, B. Pesaran, Analysis of dynamic brain imaging data. Biophys. J. **76**, 691–708(1999)
81. A.Mognon,J.Jovicich,L.Bruzzone,M.Buiatti,ADJUST:anautomaticEEGartifactdetector based on the joint use of spatial and temporal features. Psychophysiology48,229–240(2011)
82. F. Morbidi, A. Garulli, D. Prattichizzo, C. Rizzo, P. Manganotti, S. Rossi, Off-line removalof TMS-induced artifacts on human electroencephalography by Kalman filter. J. Neurosci.Methods**162**, 293–302 (2007)
83. T.Mullen,NITRC:CleanLine:Tool/ResourceInfo(2012)
84. H. Nolan, R. Whelan, R. Reilly, FASTER: fully automated statistical thresholding for EEGartifactrejection.J.Neurosci.Methods **192**,152–162 (2010)
85. B.Noureddin,P.D.Lawrence,G.E.Birch,OnlineremovalofeyemovementandblinkEEGar

tifactsusingahighspeedeyetracker.IEEETrans.Biomed.Eng.**59**,2103–2110(2012)

86. H.Peng,B.Hu,Q.Shi,M.Ratcliffe,Q.Zhao,Y.Qi,G.Gao,RemovalofoculárartifactsinEEG AnimprovedapproachcombiningDWTandANCforportableapplications.IEEEJ.Biomed. HealthInform.**17**,600–607 (2013)
87. F.Perrin,J.Pernier,O.Bertnard,M.Giard,J.Echallier,Mappingofscalppotentialsbysurface splineinterpolation.Electroencephalogr.Clin.Neurophysiol.**66**,75–81(1987)
88. T.T.Pham,R.J.Croft,P.J.Cadusch,R.J.Barry,AtestoffourEOGcorrectionmethodsusingan improvedvalidationtechnique.Int.J.Psychophysiol.**79**,203–210(2011)
89. T. Picton, S. Bentin, P. Berg, E. Donchin, S. Hillyard, R. Johnson, G. Miller, W. Ritter, D.Ruchkin, M. Rugg, Guidelines for using human event-related potentials to study cognition:recording standardsandpublicationcriteria.Psychophysiology**37**,127–152(2000)
90. I. Rejer, P. Górski, Independent Component Analysis for EEG data preprocessing-algorithms comparison, in Computer Information Systems and Industrial Management, vol. 8104,ed.by K.Saeed, R.Chaki, A.Cortesi, S.Wierzchon (Springer,Heidelberg,2013)
91. S.Romero,M.Mananas,M.J.Barbanoj,OcularreductioninEEGsignalsbasedonadaptivefil tering,regressionandblindsourceseparation.Ann.Biomed.Eng.**37**,176–191(2009)
92. S. Romero, M.A. Mañanas, M.J. Barbanoj, A comparative study of automatic techniquesforocularartifactreductioninspontaneousEEGsignalsbasedonclinicaltargetva riables:asimulationcase.Comput.Biol.Med.**38**,348–360 (2008)
93. L. Sornmo, P. Laguna, *Bioelectrical Signal Processing in Cardiac and Neurological Applications* (AcademicPress,Elsevier,Amsterdam,2005)
94. D. Safieddine, A. Kachenoura, L. Albera, G. Birot, A. Karfoul, A. Pasnicu, A. Biraben, F.Wendling, L. Senhadji, I. Merlet, Removal of muscle artifact from EEG data: comparisonbetweenstochastic(ICAandCCA)anddeterministic(EMDandwaveletbased) approaches.EURASIPJ.Adv.SignalProcess.**2012**,127(2012)
95. A.J.Shackman,B.W.McMenamin,H.A.Slagter,J.S.Maxwell,L.L.Greischar,R.J.Davidson ,Electromyogenic artifacts and electroencephalographic inferences. Brain Topogr. **22**, 7–12(2009)
96. B. Singh, H. Wagatsuma, A removal of eye movement and blink artifacts from EEG datausingmorphologicalcomponentanalysis.Comput.Math.MethodsMed.(2017)
97. A.C.Soong,J.C.Lind,G.R.Shaw,Z.J.Koles,Systematiccomparisonsointerpolationtechni

quesintopographicbrainmapping.Clin.Neurophysiol.**87**,185–195(1993)

98. M. Steriade, Grouping of brain rhythms in corticothalamic systems. Neuroscience **137**,1087–1106(2006)
99. K.T. Sweeney, S.F. McLoone, T.E. Ward, The use of ensemble empirical mode decomposition with canonical correlation analysis as a novel artifact removal technique. IEEETrans.Biomed.Eng.**60**,97–105 (2013)
100. K.T.Sweeney,T.E.Ward,S.F.McLoone,Artifactremovalinphysiologicalsignalspracticesandpossibilities.IEEETrans.Inf.Technol.Biomed.**16**,488–500(2012)
101. A.R.Teixeira,A.M.Tome,K.Stadlthanner,E.W.Lang,(eds.),Nonlinearprojectivetechniquestoextractartifactsinbiomedicalsignals.SignalProcessingConference,200614thEuropean; IEEE(2006)
102. E.M. terBraack, B. de Jonge, M.J. van Putten, Reduction of TMS induced artifacts in EEG using principal component analysis. IEEETrans. NeuralSyst. Rehab.Eng.21,376–382(2013)
103. K. Ting, P. Fung, C. Chang, F. Chan, Automatic correction of artifact from single-trial event-related potentials by blind source separation using second order statistics only. Med. Eng.Phys.**28**,780–794 (2006)
104. J.A. Uriguen, B. Garcia-Zapirain, EEG artifact removalstateoftheart and guidelines. J.NeuralEng. **12**,031001(2015)
105. A.VanBoxtel,OptimalsignalbandwidthfortherecordingofsurfaceEMGactivityoffacial,jaw,oral,andneckmuscles.Psychophysiology**38**,22–34(2001)
106. R.VanRullen,Fourcommonconceptualfallaciesinmappingthetimecourseofrecognition. Front.Psychol. **2**,365 (2011)
107. G.L. Wallstrom, R.E. Kass, A. Miller, J.F. Cohn, N.A. Fox, Automatic correction of oculartartifacts in the EEG: a comparison of regression-based and component-based methods. Int.J.Psychophysiol. **53**,105–119 (2004)
108. G.Wang,C.Teng,K.Li,Z.Zhang,X.Yan,TheremovalofEOGartifactsfromEEGsignalsusingindependentcomponentanalysisandmultivariateempiricalmodedecomposition.IEEE J.Biomed.HealthInform.**20**,1301–1308(2016)
109. I.Winkler,S.Brandl,F.Horn,E.Waldburger,C.Allefeld,M.Tangermann,Robustart factual in dependent component classification for BCI practition ers.J. NeuralEng. 11,035013(2014)
110. I.Winkler,S.Debener,K.-R.Muller,M.Tangermann,Ontheinfluenceofhigh-passfiltering on ICA-based artifact reduction in EEG-ERP, in *Abstracts of the Engineering*

inMedicineandBiologySociety,EMBC,37th AnnualInternationalConferenceoftheIEEE(2015)

111. I. Winkler, S. Haufe, M. Tangermann, Automatic classification of artifactual ICA-componentsforartifactremovalinEEGsignals.Behav.BrainFunct.**7**,30(2011)
112. D. Wu, J.-T. King, C.-H. Chuang, C.-T. Lin, T.-P. Jung, Spatial filtering for EEG-basedregressionproblemsinbrain-computerinterface(BCI).IEEETrans.FuzzySyst.(2017)
113. D. Yao, A method to standardize a reference of scalp EEG recordings to a point at infinity.Physiol.Meas.**22**,693(2001)
114. D.Yao,L.Wang,R.Oostenveld,K.D.Nielsen,L.ArendtNielsen,A.C.Chen,Acomparativestudyofdifferentreferencesfor EEGspectralmapping:theissueoftheneutralreferenceandtheuseoftheinfinityreference.Physiol.Meas.**26**,173(2005)
115. H. Zeng, A. Song, R. Yan, H. Qin, EOG artifact correction from EEG recording using stationary subspace analysis and empirical mode decomposition. Sensors**13**,14839–14859(2013)
116. K. Zeng, D. Chen, G. Ouyang, L. Wang, X. Liu, X. Li, An EEMD-ICA approach to enhancing artifact rejection for noisy multi variateneural data. IEEETrans. NeuralSyst. Rehab.Eng.24,630–638(2016)
117. C.Zhang,J.Yang,Y.Lei,F.Ye,Singlechannelblindsourceseparationbycombiningslopeensemble empirical mode decomposition and independent component analysis. J. Comput.Inf.Syst.**8**,3117–3126(2012)
118. C. Zhao, T. Qiu, An automatic ocular artifacts removal method based on wavelet-enhancedcanonicalcorrelationanalysis,in*AbstractsoftheEngineeringinMedicineandBiologySociety,EMBC,AnnualInternationalConferenceoftheIEEE*(2011)
119. Y. Zou, V. Nathan, R. Jafari, Automatic identification of artifact-related independent components for artifact removal in EEG recordings. IEEEJ. Biomed. Health Inf.**20**,73–81(2016)
120. Ashok, V., and G. Murugesan. "Detection of retinal area from scanning laser ophthalmoscope images (SLO) using deep neural network." *International Journal of Biomedical Engineering and Technology* 23.2-4 (2017): 303-314.
121. Janarthanan, P. P., Ashok, V., Karthik, R. P., &Keerthana, K. M. (2018, December). Analysis on Behavioural Changes in the Intellectual Disability of the Individuals. In *2018 International Conference on Intelligent Computing and Communication for Smart World (I2C2SW)* (pp. 178-180). IEEE.

122. Ashok, V., Karthik, R. P., Keerthana, K. M., &Roshinee, A. R. (2018, December). The Survival of Intellectual Disabled Subjects in Social Environment Using BCI. In *2018 International Conference on Intelligent Computing and Communication for Smart World (I2C2SW)* (pp. 181-184). IEEE.

123. Kumar, S. P., Bhaumik, A., Janani Selvam, D., & Vajravelu, A. (2020). Role of Person-job fit (PJ fit) in operations environment: A Bibliometric Analysis and Literature Review. *Psychology and Education Journal*, *57*(9), 3255-3258.

124. Rahman, K. A. A., Ibrahim, B. S. K. K., Jamil, M. M. A., Nasir, N. H. M., Sherwani, F., Ahmad, M. I., &Masdar, A. (2014, September). Positioning of EEG electrodes for BCI-FES control system development of knee joint movement for paraplegic. In *2014 IEEE 19th International Functional Electrical Stimulation Society Annual Conference (IFESS)* (pp. 1-6). IEEE.

125. Sha'abani, M. N. A. H., N. Fuad, Norezmi Jamal, and M. F. Ismail. "kNN and SVM classification for EEG: a review." *InECCE2019* (2020): 555-565.

126. Safri, N. M., Sha'ameri, A. Z., Samah, N. A., &Daliman, S. (2018). Resolving Gender Difference in Problem Solving Based On the Analysis of Electroencephalogram (EEG) Signals. *International Journal of Integrated Engineering*, *10*(7).