A Review on Artificial Intelligence methods and Signal Processing for EEG-Based lie and Truth Identification

Hamza Waleed Hamza*, Ammar A. Al-Hamadani**

*Department of Computer Engineering, College of Engineering, Al- Iraqia University, Iraq
Email: hamzah.w.hamzah@aliraqia.edu.iq
https://orcid.org/0009-0000-7884-6661

**Department of Computer Engineering, College of Engineering, Al- Iraqia University, Iraq
Email: ammar.aladin@aliraqia.edu.iq
https://orcid.org/0000-0001-9951-5431

Abstract

A false statement made with the goal of tricking someone is called a lie. Given how little there is to separate a falsehood from the truth, it can be difficult to tell the two apart. Lying requires more mental effort than telling the truth because the liar has to work hard to make the lie seem believable. When a person feels fear, anxiety, or extreme excitement, their oxygen consumption rate, blood pressure, galvanic skin resistance, and other physiological responses increase significantly. This is the basis for lie detection. In recent years, lie detection techniques have advanced beyond polygraphs to include methods such as electroencephalography, and analysis of eye blink patterns. In this work, we shall institute inspecting accurately Artificial Intelligence (AI) algorithms (Deep learning (DL) and machine learning (ML)) for built for EEG signal processing for lie detection. In this article, we reviewed literature from 2014 to 2023 to take previous and existing classification manner for EEG based-on the lie detection to focus and highlight newest in this field. In this review, we calculating more than 40 papers that utilized AI to EEG data for lie detection. The significance point of this paper is to helping the researchers and those interested in the field of deception detection to develop this field and make him more powerfully and effectively.

Keywords- Electroencephalogram, Deep learning, Machine learning, lie detection.

I. INTRODUCTION

The problem of recognize deception has be more worthy due to the rise in crime rates. The major function is to categorize Electroencephalogram data to detecting lies into two groups: innocent and guilty. A convolutional neural network used to automatically identified truth from EEG signals using a deep learning approach. The model pick 14-channel Electroencephalogram (EEG) signals as the input and classifies them as either honest or fraudulent statements. This research introduces a deep learning (DL) paradigm to discover deception without need to monitoring emotions and physiological expressions. The paradigm uses a time-finite EEG signal and applies time-domain filtration to remove noise. To evaluate its performance, the paradigm was train and validate using an empirical setup.[1]The Second research aimed into compare brain activity over falsehood and honest reaction by building brain functional networks using partial mutual information at the source level. To obtain such, independent component analysis (ICA) and clustering technique were used for generate origin signals from EEG signals recorded from subjects who were deception and those who were being truthful.[2]Another article present how mixing multiple features that extracted from EEG signal device can effectively disclose untruth using Support Vector Machine (SVM).[3] For that article was propose a fuzzy integrator system (FIS) for classifying EEG signal recorded for a Concealed Information Test (CIT). The system uses the execution of classifiers as input and begets a classification value as output. The classification outcome is determined using a unique defuzzification function called generalized mean of maxima (GMoM).[4] This research present a new classification algorithm that use wearable EEG headsets and machine learning (ML). It newest type for find out information concealment and powerfully process wide amounts of data.[5] This article was introduces a test platform that employ the V-TAM interest model to identify untruth person harness EEG signal. The system strongly scales accuracy and time complication, and was able of execution multiple tasks by classified brain data. The system it an appropriate option for intelligent criminology expert systems.[6].such article propose illustrate for cooperated with unbalanced data in EEG data process the SMOTE mechanism. By utilize ML way, it objective to support in the analysis of large data for lied detection. The was employ the SMOTE method to treat imbalanced EEG recording datasets and use several classified included KKN, DT, LR, RM, and SVM methods to grow the accuracy of lied detection in the system.[7].In this article, search for improved of Brain Computer Interface

(BCI) for deception detection by tested bio signals data from five subject and stratify distinct DL algorithms. The major goal of research is to locate the chance of DL method in improving BCI system for lie detection.[8].this paper recorded EEG signal over the LD test. Were then use the PS approach to anatomize the EEG data and identify the grade of synchronized through diverse brain area. The point was to look if changes in the timing and position of brain electrical activity was attached to the cognitive process of lie. To estimate the PS of EEG signals over various brain sites, the used a plain measure called PLV.[9] Another article was use EEG signals to detect liars and was suggest a modern algorithm KPCA_ELM to improve the classified accuracy. [10]A new deceit identification test (DIT) was suggest the EEG data to distinguish and analyze the person attitude.[11] This paper search for the possibility of used EEG recording signal to develop a high-performing machine learning-based untruth identification system.[12] This article offered a complication method to distinguish untruth from truth saying. [13]A novel machine learning structure, GSVM was proposed for distinguish through guilty and innocent person, mixed strict validated mechanism and generic best parameters. [14]the laboratory research goal to examine the use of EEG data to predict password reminiscence.[15]This article suggests a new ICA based on ASD to efficient SNR and bestow ML algorithm to separate lied and truth person. [16] A modern way called (EMD) for recognize features in EEG recorded for Detection of laying. [17]these paper find out an substitutional algorithm for lied detection spend EEG recorded.[18]A deep learning algorithm used for distinguish EEG recorded from subject based on visual stimuli, to demonstration usual and unfamiliar faces. [19] A framework was used that merge STFT manner and BBAT algorithm and ELM for classified lied and truth person.[20] Investigate deception detection with EEG-P300 analysis for classified untruthful based on ANFIS. [21]The research goal to develop a high handling speed that segregation for EEG data and produce a standalone system for deception detection .[22]This research dispute a new manner for detecting lie used EEG-P300 analysis for lied and truthful person .[23]This paper used EEG variability and fuzzy theory to made a deception detection system, determine critical EEG frequency bands for accurate spectral analysis.[24]a hybrid method combined unsupervised and supervised techniques to categorize EEG Signals into guilty and honest was proposed.[25]The research attend a manner for classified EEG information to untruth and honest group over a deceit identification test (DIT). [26] A deep learning algorithm used deep belief network (DBN) was developed system to classify EEG signal untruth and honest set.[27]EMD feature extraction was presented on individual EEG the utilize 4-classifierd to classify person as lie or honest . [28]The research hire EEG to test the cognitive operation of instructed guilty and honest-retailer midst interviews. [29]This article used (EEG) data composed by implementation a concealed information test. In addition, applying binary particle swarm optimization and support vector machine for deception detection. [30] This article was discuss distinction in the WDFBN of dishonest and honest subject. [31]This paper intent to generate unprecedented detection manner that allow various stimuli to recognize fraud and improve individual diagnostic rate and strength. [32] This research core on studying the EEG signal and noticing if used blink rate acquired from recording EEG data display regular results when a subject was untruth.[33] This article suggest finding lied using the P300 indicative and SVM classifier. [34]This article generate algorithm for contrast brain signals activity for honest and sinful subject by applying k-nearest neighbor classifier. [35]This paper bid a capable framework to detect liar. By using Deceit Identification Test (DIT) and BCI P300 data and KNN classifier with 20 subject.[36] This work developed classification paradigm based on independent component analysis (ICA) and Extreme learning machine (ELM) for detect untruth and truth person. [37]The work objective was to find out variation in event of truth and deception via compute the alpha waveform .[38]This article studied the link between lied and truth in the anterior lobe over comparatively certain function by means of mapping their EEG signals. [39]This article give a modern multimodal data to lie detection system such that , gaze, audio, EEG, and video data. [40]The reason of use EEG signal rather than other mechanism to studied brain task are cheap , ability to tolerate of motion from person to another , and the are no radiation risks. In another hand, EEG involve low spatial accurate and week signal-to-noise ratio.[41]This paper recognize recent research on using EEG signals for deception detection from 2014 to 2023. It gives an overview of EEG systems, their dataset, number of subject, feature extraction and classification methods, and Channel used and devices in literature, and highlights research fields in the region. This review paper major point to give a good overall understanding of the field of deception detection and to be a beginning for every researcher interested in this felid.

II. DEVICES AND DATASETS

Acquisition of Electroencephalogram (EEG) signal is a meticulous process that requires careful and accurate attention to electrode placement, signal goodness, and experimental conditions. To get authoritative and useful EEG the most of researcher to get a good signal at the beginning, EEG signals was acquired by placing (10-20) standard electrodes. A low-lying spatial resolution and non-fixed EEG Eye peep, eye locomotion, heartbeat, and interference of power of line can destroyed EEG recording signal .The method of recording data including, put the devices of EEG that has electrode in the person head the location of electrode is depending in placing (10-20) standard system .after that amplifying and filtering the data. Before that should be sampling data to suitable sampling rate. Table 1 below show the number of channel and devices used .there are some observations that were concluded from reading research on deception detection:

- The number of channel can increase the accuracy of data recorded in the most research 16-channel is the most widely used as in the figure 1 below.
- Neuroscan synAmps is the most widely used devices to recording signal in scientific research in the field of deception detection as in the figure 1 below.

- Most of studied is recording their own dataset and used around 10 subject, with the exception of research [1], he used the dryad dataset recorded from 30 subject using Neuroscan synAmps.

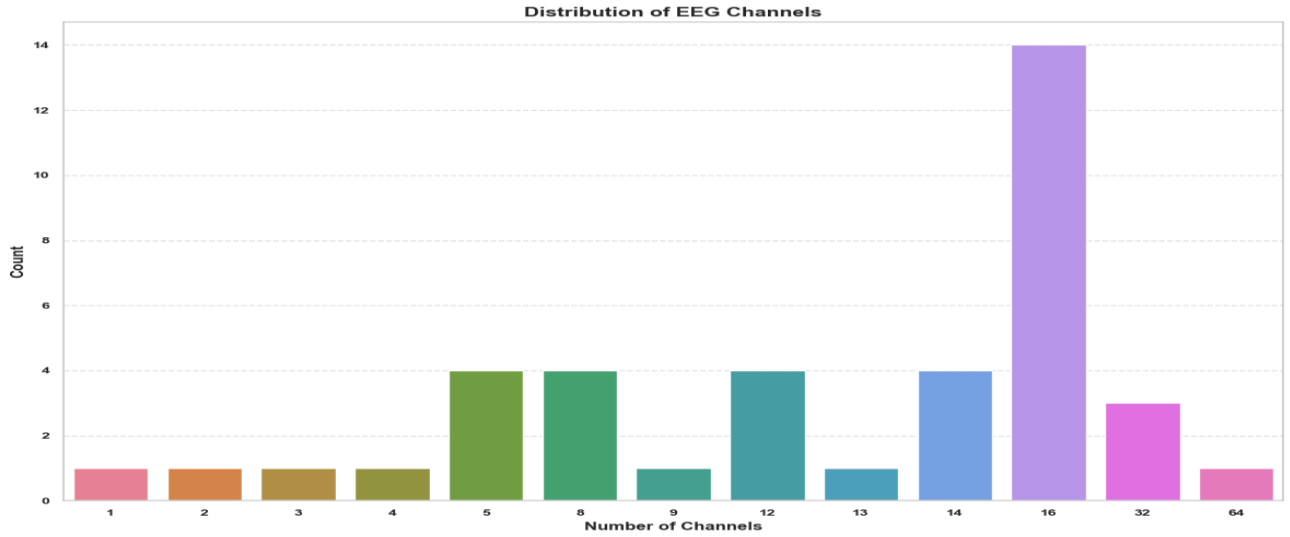

Figure 1: The Distribution of number of channel that used in the researcher

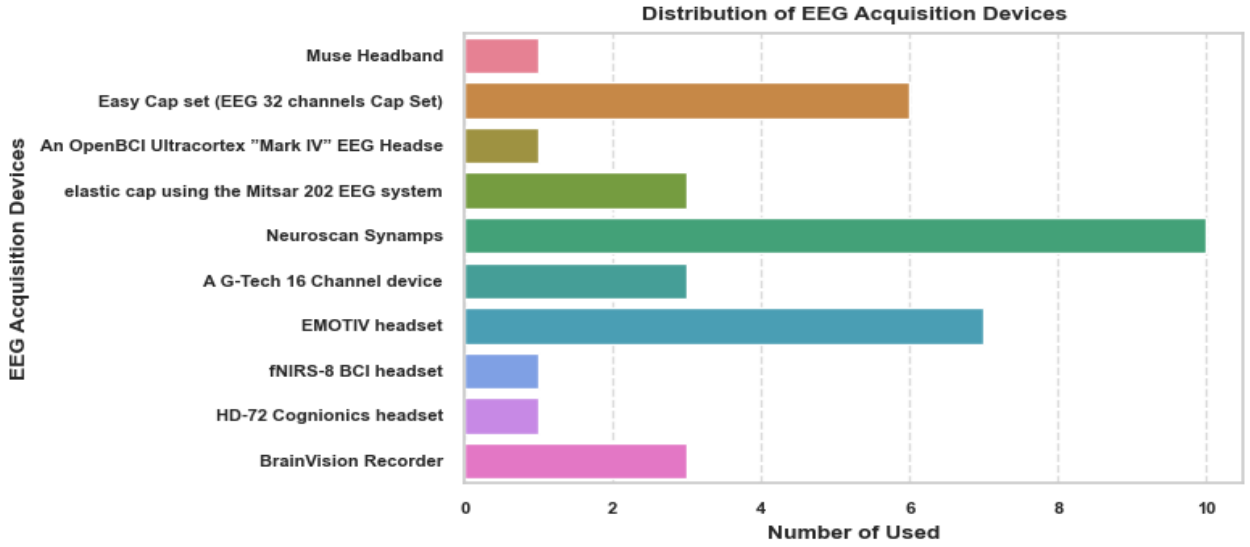

Figure 2: The Distribution of Devices that used in the researcher

III. FEATURE EXTRACTION

The use of feature extraction techniques and the use of feature selection are important analyzes in analyzing EEG data, and classification techniques help in increasing classification accuracy and reaching the best results. The objective of using this technique is to transformation of EEG data after preprocessing to the beneficial features that was input to the DL/ML to gain the result. They are various technique of feature extraction included: first, Time Domain features this technique has three type firstly, Amplitude features: this these method assistance to recognize the total level and allocation of the data amplitude. [23][37]. Secondly, statistical feature this features prepare datum about the propagation of the signal values and randomness or predictability of the data signal, and total power take in the signal. [2][15][34][37].last but not least, temporal feature: this feature measure the aggregate level of signal activity and measurement the rate of variation of the data, and the irregularity or complication of the data. [33][34][35]. Second, Frequency domain this method also has three type: firstly, power spectral density (PSD) this method presented power distributed upon multiple

frequency bands. [15][16][22].Secondly, spectral band power: this method measures the specific power in specific band such as alpha.[31][36][3]. Finally, Spectral entropy: This method quantifies the allocation the power different frequency bands.[13][14][32]. Third, Time-frequency domain also this technique has three type, firstly, Short-time Fourier transform (STFT): aid to represent the signal's frequency content as it change together time.[20][38][39] Secondly, Wavelet transform: this manner give representation of the data, aid to test of transient variation in frequency.[7] 27][30]. At last, Continuous and discrete wavelet transform: This manner are helpful for catch together time and frequency information. [5][12][21] Fourth, Spatial features: this show shrewdness to the scuttle of brain activity over various region of the scalp. These method involve the power distribution, channel solidarity, and features derived of spatial patterns.[4][18][36][24]. Fifth, Phase features: there are two method in this manner Phase locking value (PLV) and phase coherence. These method assist amount the level of concurrence and unity of phase link through several EEG channels.[9][31] Sixth, Deep learning features: In deep learning, the network itself is capable of learning features automatically from EEG data so do not need to make feature extraction separately for example, CNNs model this presenting automatically features from signal. Feature maps in CNNs capture patterns and structures at different levels of abstraction.[1][40] Seventh, Morphological features point to attribute linked with shape, amplitude, and period of the EEG waveforms.[16][22]..

IV. CLASSIFICATION

Classification stage is the importance steps because it determine the performance of system it good or not signals it used to predict a result or class of the data such as (EEG) signals based on their attribute. Various kind of classification techniques exist that help to analysis of EEG signal for example machine learning (ML) or deep learning (DL) and Fuzzy logic FL and this kind has a lot of method in the field of lie detection. First, The Machine learning (ML) has captured the most of the researcher in this domain, including many algorithm such as, SVM (support vector machine) supervised learning algorithm. SVM is especially functional in high-dimensional extent and appropriate for both linear and nonlinear data.[3][5][7][9][13][14][15][16][23][28][31][32][34] .Second, Deep learning fasten on neural networks through multiple layers. DL are able to learning hierarchical impersonation of information, give them ability to catch complicated patterns and features. [1][2][11][25][27][38][39].Third Fuzzy logic, Fuzzy logic is a mathematical structure that transact with uncertainty and imprecision in decision. FL allocate for reasoning with point of truth, where statements can accept truth amount amidst (0-1).[4][24]. Through the three kinds of Artificial Intelligent (AI), we can conclude that it is so significant to apply classification therefore; it is critical stage to analyze the EEG data. The selection of a suitable classification model should be chosen carefully to obtain acceptable result. As well as other techniques like preprocessing stage, feature extraction stage, and model validation must be in consideration to increase the accuracy of result. Figure 3 shows the work proposed by different researchers and the accuracy achieved. Figure 4 explains the structure of lie detection system start from recording data after that employ preprocessing and stratify the features extraction and feeding to ML/DL to classify it to truth or lie depending on their characteristic.

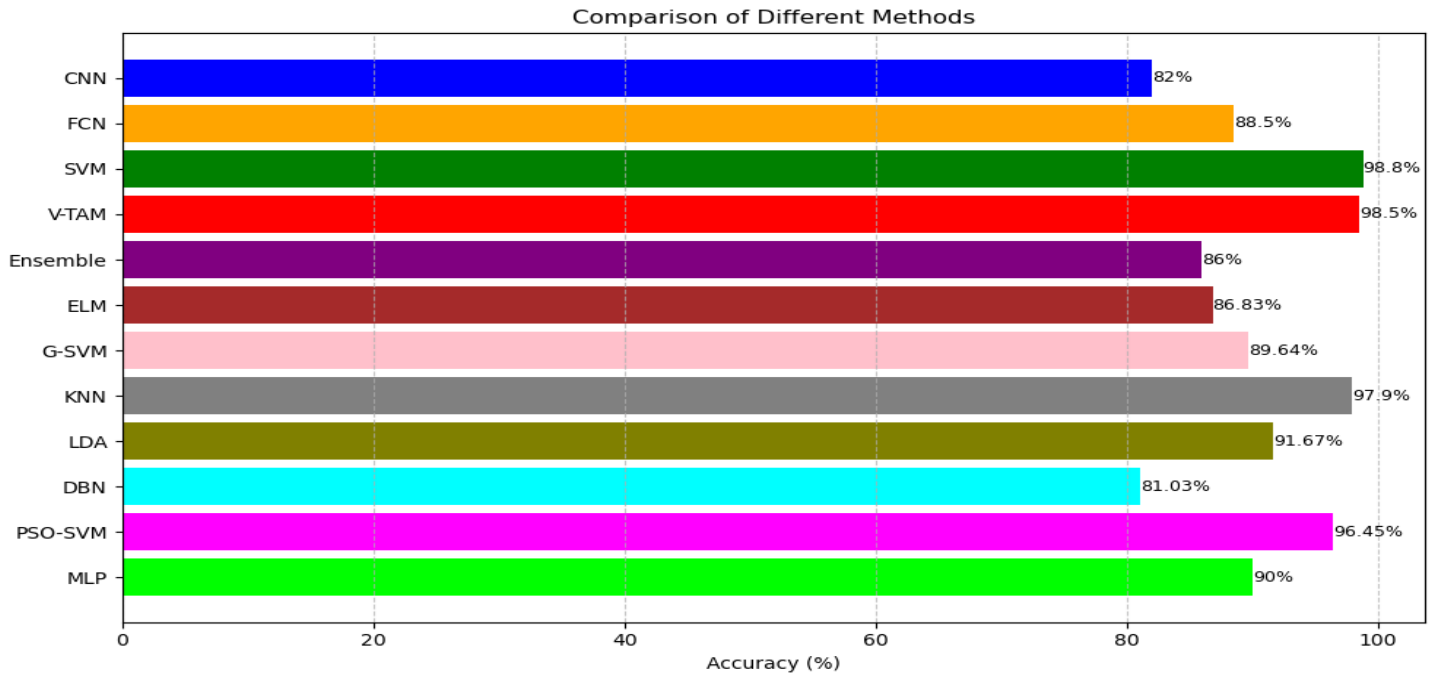

Figure 3: Comparison of method performance in accuracy terms for lie detection

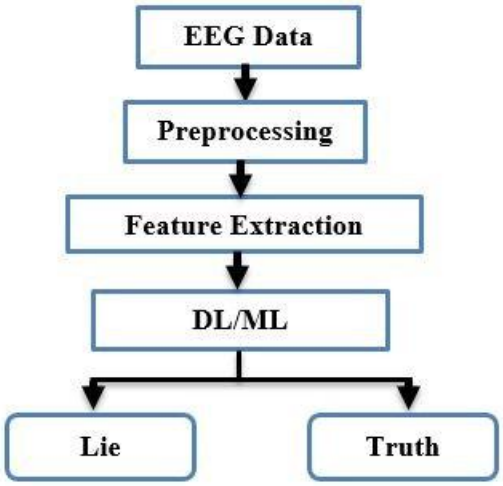

Figure 4: The steps of EEG signal processing

V. DISCUSSION

EEG analysis depends primarily on choosing an algorithm and extraction features appropriate. Sometimes we need deep learning algorithms for complex and relatively large signals. However, if it is of medium complexity and not relatively large, it is possible to use machine learning algorithms such as SVM. In this review, many recent researches from reliable sites such as (Springer, Science Direct, IEEE Explore) were discussed, and a table was created showing the results and details of this research and the latest findings in analyzing brain signals in lie detection applications. An analysis was conduct of the number of channels used in the research, the number of volunteers, and the methods used to classify signals and extract features. Through the study, it was conclude that the highest accuracy achieved was 98.8% using SVM. Given that this topic represents a challenge and privacy for individual volunteers, most researchers collected their data themselves and analyzed it. Finally yet importantly, the issue of lie detection using brain signals is a topic under study and a recent topic that needs improvement and application in real time due to the urgent need for it at the present time with the increase in the crime rate. Table 1 below shows an overview of the latest research on deception detection that was included in our review. Figure 5, shows the distribution of years of researches used in this study. We notice from the figure below the growth in the number of research in recent years; due to the urgent need to discover a reliable system that can distinguish the guilty from the innocent.

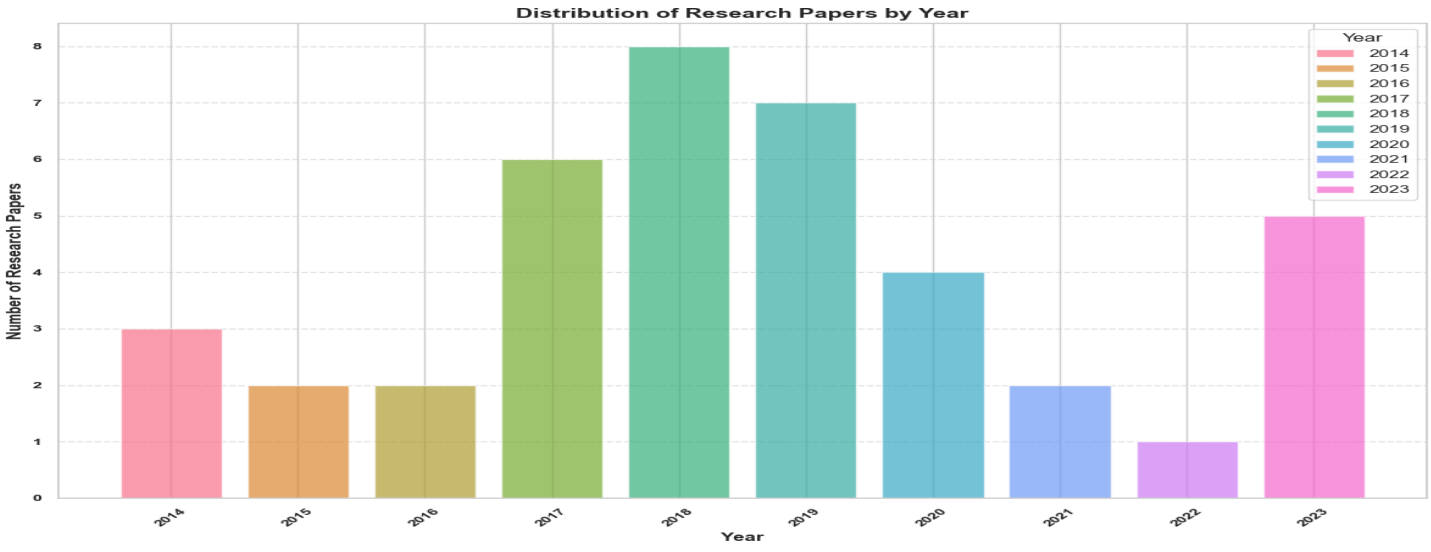

Figure 5: Displays the distribution of the years of research utilized in this study

TABLE 1: Summary of most recent research in the field of deception detection used in our review.

No.	Year	Dataset	No. Subjects	No. Channel	Devices	Feature extraction technique	Classification technique	Result
[1]	2020	Author Prepared & Dryad dataset	30 Dryad dataset 10 Author Prepared	14	EMOTIV headset	Convolutional Neural Network	Convolutional Neural Network	82.00% accuracy
[2]	2023	Author Prepared	36 subjects	64	NeuroScan recording system	A t-test (statistical test)	Fully Connected Network	88.5 % accuracy
[3]	2019	Author Prepared	33 subjects	9	Neuroscan Synamps	Empirical Mode Decomposition	Support Vector Machine	98.8% accuracy
[4]	2021	Author Prepared	10 subjects	16	EEG acquisition device	Common Spatial Pattern	Fuzzy integrator	Classification score is 1
[5]	2019	Author Prepared	30 subjects	16	EMOTIV headset	Discrete Wavelet Transform and Principal Component Analysis	Support Vector Machine	83% accuracy
[6]	2022	Author Prepared	931 subjects	32	HD-72 Cognionics headset	Convolutional Neural Network	Visual-Temporal Attention Model	98.5% accuracy
[7]	2023	Author Prepared	9 subjects	16	Easy Cap set (EEG 32 channels Cap Set)	Fourier transform, frequency-time domain features, and wavelet transformation	Decision Tree (DT) ,K-Nearest Neighbors(KNN), Random Forest , Logistic Regression,.	highest accuracy 95.64% using SVM
[8]	2023	Author Prepared	5 subjects	16	fNIRS-8 BCI headset	without feature extraction	Tree, discriminant, logistic regression, ensemble, and neural network.	highest accuracy of 86.0% using Ensemble
[9]	2020	Author Prepared	10 subjects	14	Neuroscan Synamps.	Phase Locking Value (PLV)	Support Vector Machine	88.05% accuracy
[10]	2014	Author Prepared	30 subjects	1- EEG 2- EOG	Neuroscan SynAmps.	Wavelet Transform and Kernel Principal Component Analysis	Extreme Learning Machine	86.83 % accuracy
[11]	2021	Author Prepared	30 subjects	16	BrainVision Recorder	Wavelet Packet Transform	A Deep Neural Network (DNN)	95% accuracy
[12]	2018	Author Prepared	15 subjects	4	Muse Headband	Fast Fourier Transform	without Classification techniques	Truth mental : increase Theta wave and Lie mental : decrease
[13]	2018	Author Prepared	35 subjects	5	Neuroscan Synamps	Wavelet Entropy	Support Vector Machine	89.64% accuracy

[14]	2017	Author Prepared	52 subjects	8	gUSBamp, g.tec, Austria	Bootstrapped Correlation Difference ,Skin Conductance Response,Respiration Line Length,Heart Rate,	Genetic Support Vector Machine	95.45% accuracy
[15]	2019	Author Prepared	19 subjects	14	The Emotiv EPOC headset	Power Spectrum, Statistics, and Wavelet Coefficient	Support Vector Machine	88 % accuracy
[16]	2018	Author Prepared	15 subjects	12	Neuroscan Synamps	Morphological features, frequency-based features, and wavelet frequency-based features.	Support vector machine. Linear discriminant analysis. K-nearest neighbor. and back propagation neural network	(SVM), (LDA), (KNN), (BPNN), achieving the accuracy of 74.5%, 79.4%, 97.9% and 89%, respectively
[17]	2016	Author Prepared	62 subjects	3	Brain electrical activities	Empirical Mode Decomposition	Linear Discriminant Analysis (LDA)	92.73% accuracy
[18]	2017	Author Prepared	12 subject	14	The Emotiv EPOC headset	Common Spatial Patterns (CSP)	Logistic regression classifier	76% accuracy
[19]	2018	Author Prepared	10 subjects	8	An OpenBCI Ultracortex ”Mark IV” EEG Headse	autoencoder network	Autoencoder	82.21% accuracy
[20]	2019	Author Prepared	20 subjects	16	BrainVision recorder	Short-Time Fourier Transform	Extreme Learning Machine	88.3% accuracy
[21]	2017	Author Prepared	12 subjects	5	elastic cap using the Mitsar 202 EEG system	Discrete Wavelet Transform	Adaptive Neuro Fuzzy Inference System (ANFIS)	64.27% accuracy
[22]	2017	Author Prepared	20 subjects	16	Emotiv EPOC headset	Morphological Features and Frequency Features	Linear Discriminant Analysis	85% accuracy
[23]	2017	Author Prepared	11 subjects	5	elastic cap using the Mitsar 202 EEG system	Time, Frequency, And Amplitude	Support Vector Machine	70.83% accuracy
[24]	2017	Author Prepared	10 subjects	1	NeuroSky Inc. Mindwave Mobile	Analysis Of Variance Test (ANOVA)	fuzzy rules	89.5% accuracy
[25]	2020	Author Prepared	10 subjects	16	Easy Cap set (EEG 32 channels Cap Set)	wavelet transform and k-means clustering	Multilayer Feed Forward Neural Network	83.1% accuracy
[26]	2019	Author Prepared	20 subjects	16	BrainVision Recorder	Wavelet packet transform	Linear Discriminant Analysis	91.67% accuracy
[27]	2018	Author Prepared	10 subjects	16	Easy Cap set (EEG 32 channels Cap Set)	Wavelet transform	Deep belief network	81.03% accuracy
[28]	2018	Author Prepared	10 subjects	16	Easy Cap set (EEG 32 channels Cap Set)	Empirical Mode Decomposition	Quadratic Discriminant Analysis, Support Vector Machine, k-Nearest Neighbors, Decision Tree	Highest accuracy with SVM are 81.71%
[29]	2019	Author Prepared	40 subjects	32	A G.Tec Amplifier	Coherence, direct Directed Transfer Function, Generalized Partial Directed Coherence, Principal Component Analysis	Linear Discriminant Analysis	86.25% accuracy

[30]	2023	Author Prepared	10 subjects	12	Brain electrical activities	Wavelet Transform	Particle swarm optimization-Support Vector Machine	96.45 % accuracy
[31]	2023	Author Prepared	80 subjects	32	Synamps amplifier	Direct Phase Transfer Entropy in the Whole-Brain Directed Functional Brain Network (WDFBN)	Support Vector Machine, LR Logistic Regression, and CatBoost.	92.83% for the delta band, 94.17% for the theta band, 85.93% for the alpha band, and 92.25% for the beta band
[32]	2014	Author Prepared	30 subjects	12	Neuroscan Synamps.	Time Domain, Frequency Domain, Wavelet Analysis	Spatial Denoising Method for P300 (SDA): A hybrid model including F-score_SVM, F-score_FDA, and F-score_BPNN.	F-score_SVM highest classification accuracy of 96.08%
[33]	2018	Author Prepared	10 subjects,	16	A G-Tech 16 Channel device.	The Blinker algorithm (blink rate)	Analyzing the extracted features to distinguish between truthful and deceptive responses	95.12% accuracy
[34]	2015	Author Prepared	11 subjects.	5	Mitsar EEG 202 system	Time and frequency domain	Support Vector Machine	70.83 accuracy
[35]	2018	Author Prepared	10 subjects.	16	Easy Cap set (EEG 32 channels Cap Set)	Hjorth parameters	k-Nearest Neighbors	81.9 % accuracy
[36]	2020	Author Prepared	20 subjects	16	Easy Cap set (EEG 32 channels Cap Set)	Non-parametric Weighted Feature Extraction (NPWFE)	k-Nearest Neighbors	92.46 % accuracy
[37]	2014	Author Prepared	30 subjects	12	Neuroscan synamps	Time-domain and frequency-domain	Independent Component Analysis - Extreme Learning Machine	Training accuracy of 95.40%
[38]	2015	Author Prepared	3 subject	8	Emotive EPOC 8-channel	Short-Time Fourier Transform	Multi-layer Perception	90% accuracy
[39]	2016	Author Prepared	3 subject	8	Brain electrical activities	Short-Time Fourier Transform	Multi-layer Perception	The accuracy ranged from 88% to 96%.just 46% for subject three in round three.
[40]	2019	Author Prepared	35 subject	13	Emotive EPOC 8-channel	Convolutional Neural Network	Random Forest and k-Nearest Neighbors	just EEG 58.71%, Gaze + Video + Audio+EEG is 66.17%

VI. CONCLUSION

Brain Signal have entered many applications, such as handicapped people to move their hands.[42]. In the past few years, the amount of studies that employ artificial intelligence (AI) to analyses EEG signals for lie detection was rise. In this review, we calculate extra than 40 articles published amidst 2014 and 2023 that used AI to EEG data in the field of lie detection. The objective was to verify the latest current articles in the lie detection field. We concentrate on various significant side of these studies, including the datasets and number of channels used, the methods for analyzing EEG data, the AI models used, the grade of accuracy achieved. Our review discover different key point included the following, first, ML were the most algorithm, used for classified the EEG signal in lie detection system. In addition, CNN, DBN, and MLP are generality used for deep learning model algorithm. The number of subject ranging from (3 – 931) subjects, but a majority of subjects being around 10 subject in almost research and the all research used their own datasets. Generally used features include wavelet transform (WT), wavelet packet transform (WPT), short time Fourier transform (STFT), and common spatial pattern (CSP). Most studies focus on 16-channel data. The usability of a system is greatly affected by the number of electrodes used for data collection. Recent research using artificial intelligent techniques has discover varying scale of accuracy, with many studies achieving high scores. Another worthy finding is that researchers in this field have newly focus on merge multiple methods for EEG-based lie detection to get better classification accuracy. This review directed to provide an overview of the updated methods used in this field to create an efficient fraud detection system using EEG. Based on the review conducted, this

technology holds immense chance for improve lie detection validation. In the future, through the study he conducted, we find that the use of deep learning algorithms is few, so it is possible to work on improving and developing them to obtain acceptable results,. On the other hand, many techniques, algorithms and methods can be combined, to increase the accuracy of classification of electroencephalography (EEG) data for lie detection to achieve excellent classification results.

REFERENCES

[1] Institute of Electrical and Electronics Engineers. Region 8, Institute of Electrical and Electronics Engineers., and Vysoké učení technické v Brně. Faculty of Electrical Engineering and Communication, "2020 43rd International Conference on Telecommunications and Signal Processing (TSP) : July 7-9, 2020, Milan, Italy," p. 702.
[2] Q. Kang, F. Li, and J. Gao, "Exploring the Functional Brain Network of Deception in Source-Level EEG via Partial Mutual Information," Electronics (Switzerland), vol. 12, no. 7, Apr. 2023, doi: 10.3390/electronics12071633.
[3] N. Saini, S. Bhardwaj, and R. Agarwal, "Classification of EEG signals using hybrid combination of features for lie detection," Neural Comput Appl, vol. 32, no. 8, pp. 3777–3787, Apr. 2020, doi: 10.1007/s00521-019-04078-z.
[4] A. Bablani, D. R. Edla, V. Kupilli, and R. Dharavath, "Lie Detection Using Fuzzy Ensemble Approach with Novel Defuzzification Method for Classification of EEG Signals," IEEE Trans Instrum Meas, vol. 70, 2021, doi: 10.1109/TIM.2021.3082985.
[5] M. Zafar-uz-Zaman, National Centre for Physics, Centres of Excellence in Science & Applied Technologies, Institute of Electrical and Electronics Engineers. Islamabad Section, and Institute of Electrical and Electronics Engineers, Proceedings of 2019 16th International Bhurban Conference on Applied Sciences & Technology (IBCAST) : 8th-12th January, 2019.
[6] A. A. AlArfaj and H. A. H. Mahmoud, "A Deep Learning Model for EEG-Based Lie Detection Test Using Spatial and Temporal Aspects," Computers, Materials and Continua, vol. 73, no. 3, pp. 5655–5669, 2022, doi: 10.32604/cmc.2022.031135.
[7] P. Singh, D. Singh, V. Tiwari, and S. Misra, "Lecture Notes in Electrical Engineering 998 Machine Learning and Computational Intelligence Techniques for Data Engineering."
[8] M. A. Khalil, J. Can, and K. George, "Deep Learning Applications in Brain Computer Interface Based Lie Detection," in 2023 IEEE 13th Annual Computing and Communication Workshop and Conference, CCWC 2023, Institute of Electrical and Electronics Engineers Inc., 2023, pp. 189–192. doi: 10.1109/CCWC57344.2023.10099109.
[9] Institute of Electrical and Electronics Engineers and Shenyang shi fan da xue, Proceedings of 2020 IEEE International Conference on Power, Intelligent Computing and Systems : ICPICS 2020 : Shenyang, China, July 28-30, 2020.
[10] G. Junfeng, Q. Jianhui, Z. Wenjia, and Y. Yong, "Feature Optimize and Classification of EEG Signals: Application to Lie Detection Using KPCA and ELM," 2014. [Online]. Available: http://www.sensorsportal.com
[11] D. R. Edla, S. Dodia, A. Bablani, and V. Kuppili, "An efficient deep learning paradigm for deceit identification test on EEG signals," ACM Trans Manag Inf Syst, vol. 12, no. 3, Sep. 2021, doi: 10.1145/3458791.
[12] S. Chakrabarti, Institute of Electrical and Electronics Engineers, and I. Institute of Engineering & Management (Kolkata, 2018 IEEE 9th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON) : 1st-3rd November, 2018, University of British Columbia, Vancouver, Canada.
[13] J. Gao et al., "Deception Decreases Brain Complexity," IEEE J Biomed Health Inform, vol. 23, no. 1, pp. 164–174, Jan. 2019, doi: 10.1109/JBHI.2018.2842104.
[14] E. D. Farahani and M. H. Moradi, "Multimodal detection of concealed information using Genetic-SVM classifier with strict validation structure," Inform Med Unlocked, vol. 9, pp. 58–67, 2017, doi: 10.1016/j.imu.2017.05.004.
[15] R. Alomari, M. Vargas Martin, S. MacDonald, and C. Bellman, "Using EEG to Predict and Analyze Password Memorability," in Proceedings - 2019 IEEE International Conference on Cognitive Computing, ICCC 2019 - Part of the 2019 IEEE World Congress on Services, Institute of Electrical and Electronics Engineers Inc., Jul. 2019, pp. 42–49. doi: 10.1109/ICCC.2019.00019.
[16] S. K. Haider, A. Jiang, M. A. Jamshed, H. Pervaiz, and S. Mumtaz, "Performance Enhancement in P300 ERP Single Trial by Machine Learning Adaptive Denoising Mechanism," IEEE Networking Letters, vol. 1, no. 1, pp. 26–29, Nov. 2018, doi: 10.1109/lnet.2018.2883859.
[17] A. Arasteh, M. H. Moradi, and A. Janghorbani, "A Novel Method Based on Empirical Mode Decomposition for P300-Based Detection of Deception," IEEE Transactions on Information Forensics and Security, vol. 11, no. 11, pp. 2584–2593, Nov. 2016, doi: 10.1109/TIFS.2016.2590938.
[18] International Fuzzy Systems Association, Nihon Chinō Johō Fajī Gakkai, M. IEEE Systems, Institute of Electrical and Electronics Engineers, and J. International Conference on Soft Computing and Intelligent Systems (9th : 2017 : Ōtsu-shi, IFSA SCIS 2017 : the 17th World Congress on International Fuzzy Systems Association and the 9th International Conference on Soft Computing and Intelligent Systems : June 27-30, 2017, Otsu, Japan.
[19] A. V. Nair, K. M. Kumar, and J. Mathew, "An Improved Approach for EEG Signal Classification using Autoencoder," in Proceedings of the 2018 8th International Symposium on Embedded Computing and System Design, ISED 2018, Institute of Electrical and Electronics Engineers Inc., Jul. 2018, pp. 6–10. doi: 10.1109/ISED.2018.8704011.

[20] S. Dodia, D. R. Edla, A. Bablani, and R. Cheruku, "Lie detection using extreme learning machine: A concealed information test based on short-time Fourier transform and binary bat optimization using a novel fitness function," Comput Intell, vol. 36, no. 2, pp. 637–658, May 2020, doi: 10.1111/coin.12256.
[21] D. E. Kusumandari, A. Turnip, M. Faizal Amri, and M. A. Suhendra, "Lie Detection Based EEG-P300 Signal Classified by ANFIS Method," 2017, [Online]. Available: https://www.researchgate.net/publication/342198879
[22] S. Kamran Haider, A. Jiang, Z. Khan, and M. Imran Daud, "Evaluation of P300 based Lie Detection Algorithm," Electrical and Electronic Engineering, vol. 2017, no. 3, pp. 69–76, 2017, doi: 10.5923/j.eee.20170703.01.
[23] A. Turnip, M. F. Amri, H. Fakrurroja, A. I. Simbolon, M. A. Suhendra, and D. E. Kusumandari, "Deception detection of EEG-P300 component classified by SVM method," in ACM International Conference Proceeding Series, Association for Computing Machinery, Feb. 2017, pp. 299–303. doi: 10.1145/3056662.3056709.
[24] Y. F. Lai, M. Y. Chen, and H. Sen Chiang, "Constructing the lie detection system with fuzzy reasoning approach," Granular Computing, vol. 3, no. 2, pp. 169–176, Jun. 2018, doi: 10.1007/s41066-017-0064-3.
[25] A. Bablani, D. R. Edla, V. Kuppili, and D. Ramesh, "A multi stage EEG data classification using k-means and feed forward neural network," Clin Epidemiol Glob Health, vol. 8, no. 3, pp. 718–724, Sep. 2020, doi: 10.1016/j.cegh.2020.01.008.
[26] S. Dodia, D. R. Edla, A. Bablani, D. Ramesh, and V. Kuppili, "An efficient EEG based deceit identification test using wavelet packet transform and linear discriminant analysis," J Neurosci Methods, vol. 314, pp. 31–40, Feb. 2019, doi: 10.1016/j.jneumeth.2019.01.007.
[27] A. Bablani, D. Reddy Edla, and V. Kuppili, "Deceit Identification Test on EEG Data using Deep Belief Network."
[28] A. Bablani, D. R. Edla, D. Tripathi, and K. Venkatanareshbabu, "Subject based Deceit Identification using Empirical Mode Decomposition," in Procedia Computer Science, Elsevier B.V., 2018, pp. 32–39. doi: 10.1016/j.procs.2018.05.056.
[29] M. Daneshi Kohan, A. Motie NasrAbadi, A. sharifi, and M. Bagher Shamsollahi, "Interview based connectivity analysis of EEG in order to detect deception," Med Hypotheses, vol. 136, Mar. 2020, doi: 10.1016/j.mehy.2019.109517.
[30] V. Boddu and P. Kodali, "PSO-based optimization for EEG data and SVM for efficient deceit identification," Soft comput, vol. 27, no. 14, pp. 9835–9843, Jul. 2023, doi: 10.1007/s00500-023-08476-3.
[31] S. Wei et al., "Analysis of Weight-Directed Functional Brain Networks in the Deception State Based on EEG Signal," IEEE J Biomed Health Inform, vol. 27, no. 10, pp. 4736–4747, Oct. 2023, doi: 10.1109/JBHI.2023.3295892.
[32] J. Gao, H. Tian, Y. Yang, X. Yu, C. Li, and N. Rao, "A novel algorithm to enhance P300 in single trials: Application to lie detection using F-score and SVM," PLoS One, vol. 9, no. 11, Nov. 2014, doi: 10.1371/journal.pone.0109700.
[33] IEEE Staff, 2018 International Conference on Computer Communication and Informatics (ICCCI). IEEE, 2018.
[34] 2015 International Conference on Automation, Cognitive Science, Optics, Micro Electro-Mechanical System, and Information Technology (ICACOMIT). IEEE, 2015.
[35] A. Bablani, D. R. Edla, and S. Dodia, "Classification of EEG data using k-nearest neighbor approach for concealed information test," in Procedia Computer Science, Elsevier B.V., 2018, pp. 242–249. doi: 10.1016/j.procs.2018.10.392.
[36] S. Thakur, R. Dharavath, and D. R. Edla, "Spark and Rule-KNN based scalable machine learning framework for EEG deceit identification," Biomed Signal Process Control, vol. 58, Apr. 2020, doi: 10.1016/j.bspc.2020.101886.
[37] Y. Xiong, Y. Luo, W. Huang, W. Zhang, Y. Yang, and J. Gao, "A novel classification method based on ICA and ELM: A case study in lie detection," in Bio-Medical Materials and Engineering, 2014, pp. 357–363. doi: 10.3233/BME-130818.
[38] Institute of Electrical and Electronics Engineers, IEEE Robotics and Automation Society. Malaysia Chapter, and Universiti Teknologi MARA. Centre of Excellence Humanoid Robots and Bio-Sensing, IEEE IRIS 2015 : 2015 IEEE International Symposium on Robotics and Intelligent Sensors : symposium digest : 18-20 October 2015, Berjaya Langkawi Resort, Malaysia.
[39] IEEE Control Systems Society. Chapter Malaysia and Institute of Electrical and Electronics Engineers, Proceeding, 2016 IEEE 12th International Colloquium on Signal Processing & Its Applications : (CSPA2016) : 4-6 March 2016, Hatten Hotel, Hatten Square, Jalan Merdeka, Bandar Hilir, 7500 Melaka, Malaysia.
[40] V. Gupta, M. Agarwal, M. Arora, T. Chakraborty, R. Singh, and M. Vatsa, "Bag-of-Lies: A Multimodal Dataset for Deception Detection." [Online]. Available: http://iab-rubric.
[41] Riyadh Salam Mohammed and Ammar A. Al-Hamadani, "Electroencephalographic (EEG) based Deep Learning (DL): A Comparative Review," Al-Iraqia Journal of Scientific Engineering Research, vol. 2, no. 1, Mar. 2023, doi: 10.58564/ijser.1.2.2023.70.
[42] M. Z. Al-Faiz and A. A. Al-Hamadani, "ANALYSIS AND IMPLEMENTATION OF BRAIN WAVES FEATURE EXTRACTION AND CLASSIFICATION TO CONTROL ROBOTIC HAND," 2018. [Online]. Available: https://ijict.edu.iq