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A Comprehensive Study on Machine Learning Algorithms for detection and Classification of Parkinson's disease

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Abstract: In recent years, significant progress has been made in developing more accurate and efficient machine learning algorithms for detection of medical images. This study highlights the imperative role of machine learning & deep learning algorithms in enabling efficient and accurate detection in the field of medical imaging. It focuses on several key studies pertaining to the application of machine learning methods to the Parkinson's disease. PD is a neurodegenerative disorder that affects voluntary movements. The movement difficulty is due to lack of a chemical called dopamine produced by doparninergic neurons in brain. Henceforth the study is based on the classical machine learning algorithms such as supervised, unsupervised and reinforcement algorithms. In addition, several problems and research objectives which is related to the Parkinson's disease are probed.

Keywords: Parkinson's disease, Machine learning, Deep learning.

I. INTRODUCTION

Parkinson's disease is a progressive disorder that affects the nervous system and parts the body controlled by the nerves. The impact on the patient starts very slowly. The initial symptom is at the early stages of Parkinson's disease, the patient may render less or no expression over the progression time the condition gets worsened. According to the medical history Parkinson's disease is not curable. It could be treated by medications that can reduced the worsening of symptoms [3]. Occasionally doctors may advice for surgery to balance the brain functioning and elevate the patient's health condition. Since it is neurodegeneration disorder that affects the release of dopamine which is responsible for the significant of body functions like movements, memory, pleasurable reward and motivation. The levels of dopamine release are associated with mental health and neurological disorders. Most of the symptoms registered for Parkinson's disease are very similar to the normal chronic and acute diseases alike a diabetic or a blood pleasure patient sustains the same symptoms respectively. MRI Images, means scanning of brain is the only accurate way to diagnose the initial stage of Parkinson's disease, rather analysing the physical conditions, using machine learning algorithms it is possible to learn the images with more detailing and more lucid diagnosing o the affected brain region can be established [12].

II. DETECTING TECHNIQUES

Machine Learning algorithms are used to recognize the data with less clarity and examine the output to elevate the performance from learning experiences of their own. Various algorithms are used in the machine learning for performing different tasks such as simple linear regression that can be incorporated for prediction problems, KNN algorithm can be incorporated for classification problems.[5] The Machine Learning algorithms are majorly categorised into 3 types, Supervised, Unsupervised and Reinforcement learning algorithms. As far as image classification is concerned, it is prominent way to encompass classification algorithms that comes under supervised learning where various techniques like KNN, Trees, Logistic Regression, Naïve Bayes and SVM. The classification algorithm under supervised learning is used to recognize and examine new observations on the basis of trained data.[8] Since its supervised learning technique, it includes only labelled input with corresponding output. Since it has 2 classifiers like binary classifier and multi-classifier respectively. The classification of the data set is done even before the test data set is received by using eager learners' model which would highly help the early detection of Parkinson's disease. However, it takes high time learning and low time prediction, it is prominent to use decision trees, Naïve Bayes and ANN. Eventually to reduce the learning time KNN classification is also suggested to reduce the learning time KNN Classification is also suggested to predict the related data sets, since all comes under the Non-Linear models.

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2.1 NON-LINEAR MODELS

K-Nearest Neighbour Algorithm is a supervised learning technique that predicts and valuates the similar new cases/ new data and encompasses the category of similar categories that are available based on the availability of well suite category of data set is classified that can be utilised for regression.[11] It does not make any assumption on underlying data since it is non-parametric algorithm, which is also known as Lazy Learner algorithm since it is does not learn from trained set, it relies upon the stored data set at the time of classification. It compares the new data set with much similar data features, based on the similarity measure the image classification is established [17].

2.2 NAIVE BAYES

Naïve Bayes algorithm is supervised learning and probabilistic classifier that incorporates a high-dimensional training data set, which is one of the very promising classification techniques. It helps in aggressive building of models. It relies on independent occurrence is the reason why it is called as Naïve but depends on Bayes theorem which determines the probability of hypothesis with anticipated insight that depends on the conditional probability.[21]

$$P(A|B) = \frac{P(B|A)\,P(A)}{P(B)}$$

P(A|B)- Posterior Probability
P(B|A) – Likelihood Probability
P(A) – Prior Probability
P(B) – Marginal Probability

2.3 SUPPORT VECTOR MACHINE

Support Vector Machine is a most promising and flexible machine learning algorithms. It comes under the category of supervised learning algorithms which is used for Machine Learning Classification with SVM is to acquire best decision boundary, n-dimensional space into classes. This will elevate the system at an ease level to establish a new data point in the proper category in the future. The best decision boundary is called a hyperplane.[18] SVM opts the extreme points/vectors that supports in promoting the hyperplane. The extreme cases are called support vectors. Hence the algorithm is termed as support vector machine. There 2 major categories in SVM. Linear SVM and Non-Linear SVM. Linear SVM is used for linearly separable data which means a data set can be separated into two classes by using a straight line. They are defined as linearly separable data and classifier is called as Linear SVM classifier. Non Linear SVM is used for non-linear separated data which means the data set cannot be classified by using a straight line, it is termed as non-linear data, and is called Non-Linear classifier.[20]

2.4 K-NEAREST NEIGHBOR

K-Nearest Algorithm is one of the easiest Machine Learning algorithms which is grounded on Supervised Learning technique. The feature of this algorithm is to analyse the similarity between the existing cases and the current cases and escalating the new cases which are more analogous to the existing group of cases. This feature of KNN algorithms will elevate the possibility of easy classification of new data based on the similarity. It can be used for regression as well as for classification. Since it does not make any supposition based on the fundamental data it is also termed as non-parametric algorithm. Moreover, instead of learning from the training data set proximately, stores it and performs action only at the time of classification, hence it is called Lazy Learner Algorithm. The value of k plays a vital role in the K-NN algorithm, it defines the number of nearest neighbours in the algorithm.[13] It is selected based on the input data. If the input has more outliers, the higher value of K will be greater. It is suggested to choose odd value of k to avoid ties in classification. Cross-Validation method benefits us to select best k value for the given dataset. The input data can be of any format (in our case it would be images). For images, the comparison is done by converting that image into vectors in a multi-dimensional plane. KNN in Image classification helps in getting 50 % accuracy in image classification.[23]

2.5ARTIFICIAL NEURAL NETWORK

An artificial neural network is a pursual of simulating the brain neurons so that the computer can determine things alike a human being and will be able to make decisions like a person. It uses various mathematical processing to enrol the sense of information it given to it. It consists of dozens of artificial neurons termed as units which are arranged in series of layers. Most of the neural networks are interconnected with layers. ANN in image processing will elevate the process of contrast enhancement, noise reduction with the same dimensions of original image. [9] It helps in improving, restoring and rebuilding the images which will meet the standard of various computational tasks like classification of images, object detection and image recognition. It optimises the input images based on the stimulation of single neuron, a feature map or a whole layer of the network. But then there is a problem in classification of images since the 2-dimensional

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images need to be converted to 1-dimensional vectors.[1] Hence there are various types of ANN that can be considered as an alternative methodology to rectify the drawback with the basic methodology

1. Modular Neural Networks,
2. Feed Forward Neural Network,
3. Radial basis function neural network,
4.Korhonen Self Organizing,
5. Recurrent Neural Network,
6. Convolutional Neural Network,
7. Long/Short Term memory.[8]

2.6 CONVOLUTION NEURAL NETWORKS

Convolutional Neural Networking is a type of Artificial Neural Network which can elevate the process of image classification. CNN can proficiently extract the features from image and learn to recognize patterns. It will make them more suitable for obtaining tasks such as object detection, image segmentation and classification, and also it can process massive amounts of data and establish highly accurate predictions. It learns the features of an object establish multiple iterations and reduces the need for manual featuring tasks like extraction, detection and segmentation.[10]

2.7 TYPES OF CNN:

1. LeNet,
2. Visual Geometry Group,
3. ResNet,
4. R-CNN,
5. Fast R-CNN,
6. GoogLeNet,
7. AlexNet,
8. MobileNet,

In the above-mentioned category VGG (Visual Geometry Group) is a research group within the Department of Engineering Science at the University of Oxford. The VGG Group is established for its work in computer vision, exclusively in the area of CNN. It is a deep neural network that has won the state-of-the art performance on the Image net challenge in 2014 and became notorious benchmark for image classification and object detection tasks. It is featured by small convolutional filters (3*3) and deep architecture (up to 19 layers) which encourages the characterisation of learning complex features from input images.[14] It also uses max pooling layers which assists the model to reduce the spatial resolution of the feature maps which will improve its ability to recognize objects of various scales and orientations.

2.7.1 LeNet:

LeNet is a convolutional neural network structure developed by Le Cun in the 1998. It is a feed forward neural network where artificial neurons can respond to the surrounding cells. It is suitable for coverage range of cells and performs well in large scale image processing.

2.7.2 Visual Geometry Group:

It is a type of deep convolutional neural network. It is designed with numerous layers VGG-16 or VGG-19 having 16 or 19 convolutional layers respectively. The VGG-16 has 16 layers that can classify photos into various object categories. This model mostly accepts images with a resolution of 224/ 224.7. VGG-19 has extra 3 layers that can establish greater detail and features of the classified images. The convolutional layers are used to transform the input linearly.

2.7.3 Residual Neural Network:

It is a suitable deep learning model which will promote learning with weight layers of the residual functions with reference to the layer inputs.

2.7.4 Regions with Convolutional Neural Network:

It helps in cropping and resizing the regional proposals.

2.7.5 Fast Regions with Convolutional Neural Network:

It detects and processes the entire image corresponding to each region proposal, since it promotes computations for overlapping regions are shared which makes it more efficient that R-CNN.

2.7.6 GoogLe Net:

It is a typical convolutional neural network. It has 22 layers deep. It promotes high quality image classification and renders 10-10% high object detection and Quantization. Quantization is a process of sampling the image to finite number of distinct values. GoogleNet is faster when compared to VGG in classifying the image.

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2.7.7 AlexNet:
It is an established neural network used primarily for image recognition and classification tasks. The 3 max pooling layers and 2 normalization layers 2 fully connected layers and 1 soft max layer which helps in boosting the performance.

2.7.8 Mobile Net:
It is a computer vision model open sourced by Google. It is used for training the classifiers and uses in deep convolutions to significantly reduce the number of parameters associated with other networks.

2.8 REINFORCEMENT ALGORITHM

Reinforcement learning is a type of machine learning algorithm. It helps in solving a multi-level problem by incorporating more trial and error methods. The machine is trained based on real-life instances and scenarios which will make possible decisions and chooses the optimal instances to perform an appropriate action and establishes maximum reward. The common variety of reinforcement learning is positive learning and negative learning by working with the interacting environment whereas the supervised learning performs action to establish an instance or sample data two widely used learning models are

1. Markov Decision Process
2. Q- Learning
3. Artificial Neural Network
4. SARSA
5. DQN
6. Monte Carlo Method.

The image, based reinforcement learning helps in achieving more critical factors based on the algorithm satisfying the condition for achieving more accurate results. The reinforcement learning takes the image observations a s input and transfers the real world with domain randomization.[22]

III. RESEARCH PROBLEM AND OBJECTIVES

It is highly predominant to achieve the broad goals in a research. Since Parkinson's disease is a health-related issue it is inevitable to approach the problem with more standards and high utilization of accurate results and clear classification of processed images is required. The disease does not cause the people to die fast, but it would create worse clinical condition if it is left undiagnosed. But with early detection and advanced treatment can save some patients who are more vulnerable to serious infections, which would put them into a strategy of normal life expectancy. In order to classify the MRI Images Machine-Learning algorithms were encompassed under various strategies. It has emerged as a promising field in doing early detection of PD by rendering relevant information in the disease biomarkers that are extracted and analysed through scanning. ML algorithm that comes with supervised and reinforcement learning have achieved a milestone in diagnosing PD due to their calibre to develop with free assumption on data distribution many researches have been carried out to establish to extract accurate and early detection over PD by MR Images which would neglect the progression of this neurodegenerative disease. Neural Network algorithm with reinforcement learning techniques. Eventually a large number of research and study made to focus on PD Prevention. The objective of this review is to illustrate how neural networks and machine learning embraces their mechanism to read the image as input and clarify it to derive an elevated output to line up the best data set types to achieve high accurate results based on the following aspects:

1) Significance of neural network.
2) Highlights of Machine Learning Algorithms
3) Role of Reinforcement Learning
4) Achieving accurate classification of images using the best methodologies incorporated with neural networks.

IV. PERFORMANCE MEASURES

Accuracy – It is a metric that is used for classification models. Thus, the classification accuracy provides the percentage of correct predictions. These values are generated based on trained machine learning model on the basis of giving some new input data.

$$\text{Accuracy} = \frac{TP+TN}{TP+FP+TN+FN}$$

Sensitivity – It is measured as the proportion of actual positive cases that have been predicted as positive. Sensitivity is also termed as recall. Then there will also be found those proportion of actual positive cases, which would be predicted incorrectly as negative.

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$$\text{Sensitivity} = \frac{TP}{TP+FN}$$

Specificity – It is measured as the proportion of actual negative cases that have been predicted as negative. Then there will also be found those proportion of actual negative cases, which would be predicted incorrectly as positive.

$$\text{Specificity} = \frac{TN}{TP+FP}$$

F1 Score – F1 score is the harmonic mean of the precision and sensitivity.

$$\text{F1 Score} = \frac{2TP}{2TP+FP+FN}$$

V. STRENGTH AND LIMITATIONS OF MACHINE LEARNING MODELS

5.1 STRENGTHS

The reinforcement learning is one of the most modern machine technologies in which learning is carried out through active interacting environments. It incorporated efficient vision tasks like feature detection, image segmentation, object recognition and tracking. Neural Networks and machine learning yields accurate analytics and high rate of successful predictions.

5.2 LIMITATIONS

There is lack of transparency and interpretability. The yield of results might be biased and discrimination underfitting. It proposes problem in ethical considerations. The process become time consuming and the storage of data requires more space. Though the neural network algorithms are best and effective for pattern recognition and classification the duration of development is high and its computationally expensive. Moreover, it depends lot in training data. This goes hand in hand with the problem of overfitting and generalization

VI. CONCLUSION

Parkinson's Disease requires early diagnosis and intervention to minimize the impact of this degenerative condition and ensure that affected individuals can remain self-sufficient as long as possible. However, the imprecise nature of clinical diagnoses, and a lack of neurologist's expert in PD diagnosis worldwide, often results in delayed diagnosis and suboptimal management of PD. In this paper, the methods, models and performance measures are summarized. Finally, the paper has framed the problem definition and suggests some of the research objectives based on the study. It is probed to conclude that machine learning and deep learning algorithms are best for detection of Parkinson's disease.

REFERENCES

[1] Berg D., Godau J., Walter U., "Transcranial sonography in movement disorders." The Lancet Neurology. 2008. Vol. 7 (11). P.1044–1055.

[2] K. Thangavel, R. Manavalan, Laurence Aroquiaraj, "Removal of Speckle Noise from Ultrasound Medical Image based on Special Filters: Comparative study", ICGST-GVIP Journal, Vol. 9, Issue:3, pp. 25-32, June 2009.

[3] Khaled Z. AbdElmoniem, Yasser M. Kadah and AbouBakr M. Youssef, "Real Time Adaptive Ultrasound Speckle Reduction and Coherence Enhancement", 078032977/00/$10© 2000 IEEE, pp. 172-175.

[4] Kier C., Seidel G., Bregemann N., Hagenah J., Klein C., Aach T., Mertins A., "Transcranial sonography as early indicator for genetic parkinson's disease". 4th European Conference of IFMBE. 2009. P. 456-459.

[5] Chen L., Hagenah J., and Mertins A, ". Texture Analysis Using Gabor filter Based on Transcranial Sonography Image". Proceedings of 2011 Bvm bildverarbeitung fur die medizing. 2011.P. 249-253.

[6] Chen L., Seidel G., Mertins A., "Multiple Feature Extraction for E]rly Parkinson Risk Assessment Based on Transcranial Sonography Image" . Proceedings of 2010 IEEE 17th International Conference on Image Processing. 2010. P. 2277-2280.

[7] Kumar, Anil, Rajabov Sherzod Umurzoqovich, Nguyen Duc Duong, Pratik Kanani, Arulmani Kuppusamy, M. Praneesh, and Minh Nguyen Hieu. "An Intrusion Identification and Prevention For Cloud Computing: From The Perspective Of Deep Learning." Optik (2022): 170044.

[8] Napoleon, D. & Praneesh, M. (2013). Detection Of Brain Tumor Using Kernel Induced Possiblistic C-Means Clustering. International Journal of Computer & Organization Trends, 3(9), pp. 436 – 438.

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[9] M Praneesh and Jaya R Kumar. Article: Novel Approach for Color based Comic Image Segmentation for Extraction of Text using Modify Fuzzy Possiblistic C-Means Clustering Algorithm. IJCA Special Issue on Information Processing and Remote Computing IPRC(1):16-18, August 2012. Published by Foundation of Computer Science, New York, USA.

[10] Boonsatit, N.; Rajendran, S.; Lim, C.; Jirawattanapanit, A.; Mohandas, P. New adaptive finite-time cluster synchronization of neutral-type complex-valued coupled neural networks with mixed time delays. Fractal Fract. 2022, 6, 515

[11] Napoleon, D., et al. "An efficient modified fuzzy possibilistic c-means algorithm for segmenting color based hyperspectral images." IEEE-International Conference On Advances In Engineering, Science And Management (ICAESM2012). IEEE, 2012.

[12] A. Sakalauskas1, A. Ludovici's, K. Laučkaitė, "Texture analysis of transcranial sonographic images for Parkinson disease ISSN 1392-2114 ULTRAGARSAS (ULTRASOUND), Vol. 66, No. 3, 2011.

[13] X.S. Zhang, J. Chou, F. Wang, Integrative Analysis of Patient Health Records and Neuroimages via Memory-based Graph Convolutional Network, ArXiv180906018 Cs Stat, 2019

[14] E.C. Neto, et al., Detecting confounding due to subject identification in clinical machine learning diagnostic applications: a permutation test approach, ArXiv171203120 Stat, 2017.

[15] J. S. Almeida, P. P. R. Filho, T. Carneiro, W. Wei, R. Damaševičius, R. Maskeliunas, and V. H. C. de Albuquerque, ''Detecting Parkinson's ¯ disease with sustained phonation and speech signals using machine learning techniques,'' Pattern Recognit. Lett., vol. 125, pp. 55–62, Jul. 2019.

[16] Y. Li, L. Yang, P. Wang, C. Zhang, J. Xiao, Y. Zhang, and M. Qiu, ''Classification of Parkinson's disease by decision tree-based instance selection and ensemble learning algorithms,'' J. Med. Imag. Health Informat., vol. 7, no. 2, pp. 444–452, Apr. 2017.

[17] M. Wodzinski, A. Skalski, D. Hemmerling, J. R. Orozco-Arroyave, and E. Nöth, ''Deep learning approach to Parkinson's disease detection using voice recordings and convolutional neural network dedicated to image classification,'' in Proc. 41st Annu. Int. Conf. IEEE Eng. Med. Biol. Soc., Berlin, Germany, Jul. 2019 pp. 717-720

[18] T. J. Wroge, Y. Özkanca, C. Demiroglu, D. Si, D. C. Atkins, and R. H. Ghomi, ''Parkinson's disease diagnosis using machine learning and voice,'' in Proc. IEEE Signal Process. Med. Biol. Symp. (SPMB), Philadelphia, PA, USA, Dec. 2018, pp. 1–7,

[19] J. R. Orozco-Arroyave, J. C. Vásquez-Correa, J. F. Vargas-Bonilla, R. Arora, N. Dehak, P. S. Nidadavolu, H. Christensen, F. Rudzicz, M. Yancheva, H. Chinaei, A. Vann, N. Vogler, T. Bocklet, M. Cernak, J. Hannink, and E. Nöth, ''NeuroSpeech: An open-source software for Parkinson's speech analysis,'' Digit. Signal Process., vol. 77, pp. 207–221, Jun. 2018

[20] S. Grover, S. Bhartia, A. Yadav, and K. R. Seeja, ''Predicting severity of Parkinson's disease using deep learning,'' Procedia Comput. Sci., vol. 132, pp. 1788–1794, May 2018.

[21] V. Delić, Z. Peric, M. Secujski, N. Jakovljevic, J. Nikolic, D. Miškovic, N. Simic, S. Suzic, and T. Delic, ''Speech technology progress based on new machine learning paradigm,'' Comput. Intell. Neurosci., vol. 219, pp. 1–19, Jun. 2019

[22] Faturrahman, M., Wasito, I., Hanifah, N., Mufdah, R (2017) Structural mri classifcation for alzheimer's disease detection using deep belief network. In: 2017 ICTS, pp. 37–42

[23] Qiu et al, Classifcation of schizophrenia patients and healthy controls using ica of complex-valued fmri data and convolutional neural networks. In: Tang, H., Wang, Z., Lu, H. (eds.) Proc. ISNN 2019, pp. 540–547,2019

[24] Silver D, Huang A, Maddison CJ, Guez A, Sifre L, Van Den Driessche G, Schrittwieser J, Antonoglou I, Panneershelvam V, Lanctot M, et al (2016) Mastering the game of go with deep neural networks and tree search. nature 529(7587), 484

[25] Kaiser MS, Lwin KT, Mahmud M, Hajializadeh D, Chaipimonplin T, Sarhan A, Hossain MA (2018) Advances in crowd analysis for urban applications through urban event detection. IEEE Transactions Intelligent Transportation Syst 19(10):3092–3112

[26] Kim J et al (2015) Deep nn with weight sparsity control and pre-training extracts hierarchical features and enhances classifcation performance: Evidence from whole-brain resting-state functional connectivity patterns of schizophrenia. NeuroImage 124:

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified ⁜ Impact Factor 8.102 ⁜ Peer-reviewed / Refereed journal ⁜ Vol. 12, Issue 7, July 2023
DOI: 10.17148/IJARCCE.2023.12707

[27] Rudin C (2019) Stop explaining black box machine learning models for high stakes decisions and use interpretable models instead. Nat Mach Intell 1(5):206–215

[28]D. Napoleon, M. Praneesh, S. Sathya, and M. Sivasubramanian, "An efficient numerical method for the prediction of clusters using k-means clustering algorithm with bisection method," in Global Trends in Information Systems and Software Applications, P. V. Krishna, M. R. Babu, and E. Ariwa, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2012, pp. 256–266.

[29] National Institutes of Health: The Federal Interagency Traumatic Brain Injury Research (FITBIR) informatics system datasets. https://ftbir.nih. gov/ Accessed 2019-12-26

[30] Faust O, Hagiwara Y, Tan JH, Oh SL, Acharya UR (2018) Deep learning for healthcare applications based on physiological signals: a review. Comput Methods Prog Biomed 161:1–13

[31] Acharya UR, Fujita H, Oh SL, Muhammad A, Tan JH, Chua KC (2017) Automated detection of coronary artery disease using different durations of ECG segments with convolutional neural network. Knowledge Based Syst 132:62–71