Detection and Classification of MRI Images using Multistage Classifier for Early Prediction of Alzheimer's Disease

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Abstract. The term "neuro imaging" describes a set of procedures used for studying, diagnosing, and treating neurological disorders as well as for basic scientific research into the human brain. In order for medical professionals to make early diagnoses for their patients, they must investigate the signs of various neuro imaging kinds; among the most important elements in this process is the problem of neuro image classification. No effective treatment has been found for Alzheimer's disease (AD), a degenerative brain ailment that has no known cure. It is not possible to halt the progression of the disease once it has begun. But there are medications that can slow it down. Nevertheless, with the use of sophisticated prediction, the disease-influencing protein functions can be reduced. Because of shared neural networks and pixel strength, Alzheimer's disease diagnosis in the elderly is discretely challenging and calls for the portrayal of a discriminating element separately. Several writers attempted to apply machine learning to make early disease diagnoses, but they were unable to get reliable classification accuracy. To that end, we set out to develop a model that would combine deep neural networks with multistage classifiers in the hopes that it would be able to efficiently and effectively extract characteristics from input data. Better and more effective detection and classification of Alzheimer's disease was achieved in this study by employing a multistage classifier that made use of deep learning techniques. Using a benchmark database supplied by the Alzheimer's Neuro Imaging Institute, the suggested strategy achieves better outcomes than individual techniques.

Keywords: Diagnostics, neuro imaging, deep learning, Alzheimer's disease

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1 Introduction

Millions of individuals throughout the world suffer with Alzheimer's disease, a crippling condition that has terrible effects on both the sufferer and their loved ones. A devastating experience for the sufferer and their loved ones, this condition slowly erodes cognitive abilities like memory, language, or perception [1]. In the early stages of Alzheimer's disease, symptoms such as forgetfulness, lethargy, and trouble with basic motor skills may manifest [2]. Symptom management, including a reduction in the course of AD, depends on early detection and intervention, since there is still no effective treatment for the disease despite years of research. A person's ability to think, behave, speak, swallow, and move may deteriorate as the disease progresses [3]. Recent estimates put the number of people impacted by AD at over 6.5 million. With 2.41 million ranging from 75 to 84 years old and 2.31 million from 85 and up, the majority of those living with AD are 65 and up. The disease must be detected in its early stages for a proper diagnosis because, alas, no conclusive test exists to detect AD. Machine learning and other AI-based technologies may identify the sickness[4].
In order to diagnose Alzheimer's disease, a number of markers must be present. One of these is magnetic resonance imaging (MRI), genetic testing, and clinical & biological materials [5]. The initial data utilised for Alzheimer's disease detection is biomarkers. Since there is no conclusive proof as to which biomarker is the most dependable, it is crucial to choose the correct one [6]. The diagnostic value of biomarkers is enhanced by the ability to automatically extract spatial characteristics, such as cortical CT measurements, brain volume, and brain surface area, through processing that incorporates both handcrafted as well as deep learning techniques [7].

In addition to a smaller cerebral cortex and enlarged ventricles, Alzheimer's disease causes a significant shrinkage in the hippocampal area of the brain, which is significantly smaller than in a healthy person. Memory, planning, reasoning, and judgement are all carried out by these areas [8]. The severity of alterations in various brain regions is influenced by the phases of illness progression. The biomarker of volume loss in the hippocampal area and cerebral cortex, as well as enlargement of the ventricles, can be seen by Magnetic Resonance Imaging (MRI) [9]. For precise diagnosis and stage classification of AD, deep learning-based algorithms employ 2D T1-weighted MRI. Figure 1 displays a sample of brain MRI pictures. Figure 2 shows the MRI of the brain in a coronal view.

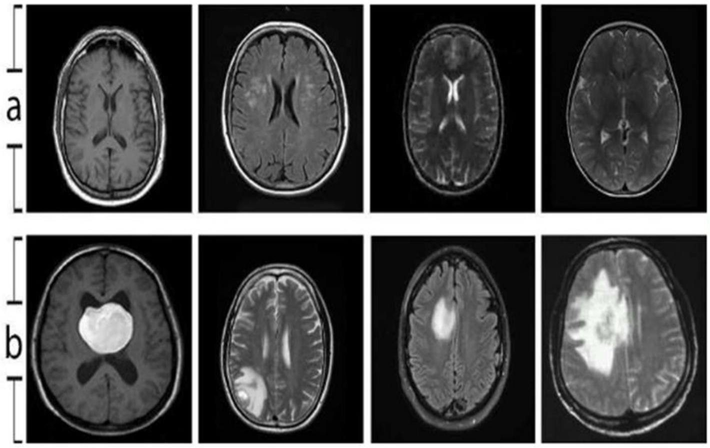

Fig. 1. Brain MRI pictures from the Dataset: (a) healthy brains (b) Tumours.

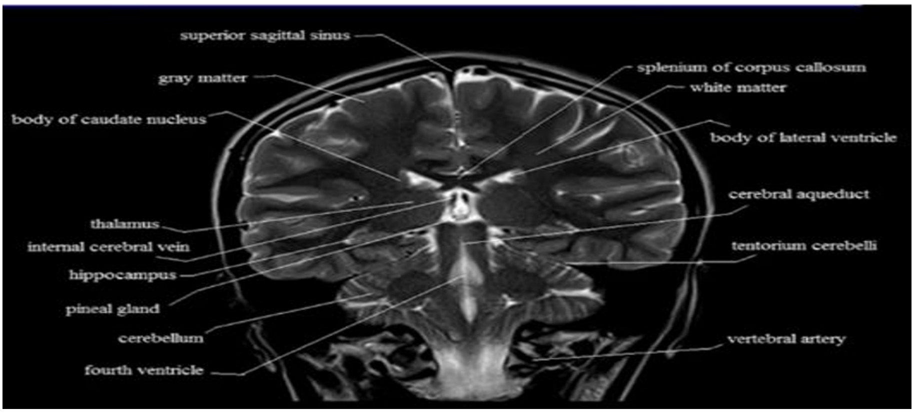

Fig. 2. Coronal View of Brain MRI

A lot of recent work in ML and CV has pushed towards deep learning and neural networks. Thanks to its high-quality and proven network structure, deep learning [10] has become popular as a representational learning method that enables machines to read various representations from raw data. The primary objective of this study is to classify Alzheimer's disease phases using machine learning and deep learning techniques applied to the Kaggle database. In addition, finding the most distinctive feature for every phase of Alzheimer's disease in the Kaggle dataset is a sub-objective of this study.

2 Literature Survey

Any disruption to the neurological system, which regulates all of the body's senses, decision-making, and reflexes (both big and small), could lead to illness. The harm or destruction of nerve cells & their links to the brain [11] produces disorders like dementia, which affect people in various ways and cause distinct symptoms. The National Institute of neuroscience and stroke reports that the most common type of dementia, Alzheimer's disease, impacts human cognition, memory, and behaviour by attacking brain cells including neurotransmitters [12]. The majority of dementia cases were first believed to be caused by Alzheimer's disease around the turn of the millennium [13].

Progressive loss of cognitive function characterises Alzheimer's disease, an irreversible brain illness. An estimated 10.5% of adults aged 65 and over will develop Alzheimer's disease during their lifetimes [14]. Between 1990 and 2016, the number of individuals affected with Alzheimer's disease more than tripled, based on a study that carefully evaluated the burden of the condition [15]. A great load has been placed on healthcare practitioners worldwide as a result of the ongoing hard work of investigators to discover an efficient therapy for this condition. In addition, it has far-reaching, detrimental effects on patients' social behaviours, which in turn affect their professional lives, families, and communities in various ways (physical, psychological, social, and economic).

Additionally, AD detection makes use of the Ensembles method and an ANN-based approach. When contrasted with the Gradient Boosting & Polling Classifier, the ANN attains a sustainable level of accuracy [16]. The goal of an integrated deep learning approach that incorporates MRI and the Long Short-Term Memory algorithm is to differentiate between cognitively normal and MCI patients in order to aid in early diagnosis and treatment [17]. For early detection, the multimodality technique uses wavelet transform-based multiple mediums [18]. By combining MRI with cross-sectional biomarkers, a hybrid deep-learning framework can investigate the impact of early AD diagnosis [19]. A 3D convolutional neural network (CNN) and a BRNN (unidirectional recurrent neural network) make up this architecture. This study explored different types of artificial neural networks (ANNs) to identify and forecast Alzheimer's disease (AD) using brain imaging of people with moderate cognitive impairment (MCI) [20]. After careful consideration of all relevant factors, the most appropriate articles were selected. Other approaches are available as well. Such as convolutional neural networks (NNs) and modified convolutional neural networks (CNNs) for EEG data classification into Alzheimer's disease and healthy controls (HCs) [21]. Disease progression includes multiple subtypes and stages, beginning with cognitive normal (CN). One binary class or class can detect AD with a high degree of accuracy, especially when comparing AD to CN, AD to MCI, or CN to MCI [22]. Nevertheless, there is room for improvement in multi-class identification, particularly when dealing with up to four classes, and in MCI subclasses. It is still not good enough to use binary & multiple-class identification for the many kinds of MCI. Consequently, a plethora of research methodologies have been implemented in an effort to unearth the most suitable process for identifying these phases. On top of that, certain pipelines have proven to be fairly accurate in identifying AD across various categories.

Deep learning allows for more robust and detailed feature representation; it is a subfield of machine learning. According to [24], auto encoders were able to attain a 92% success rate in the binary stage of Alzheimer's disease when characteristics were integrated from PET and MRI images (see to [23] for details). To identify atropy patterns in specific brain MRI regions, they recommended structural modelling and independent component analysis. It was also thought that each part of an MRI scan would cover significant regions of cognitive functioning, therefore capturing sequential chunks from these scans would be another possible solution. [25] achieved a new benchmark in three areas by using Dense Net and combined approaches to deconvolute all 3D MRI scans. Research using VGG16 structures learned over a sequence of MRI scans shows promising progress towards phased accuracy [26].

3 Methodology

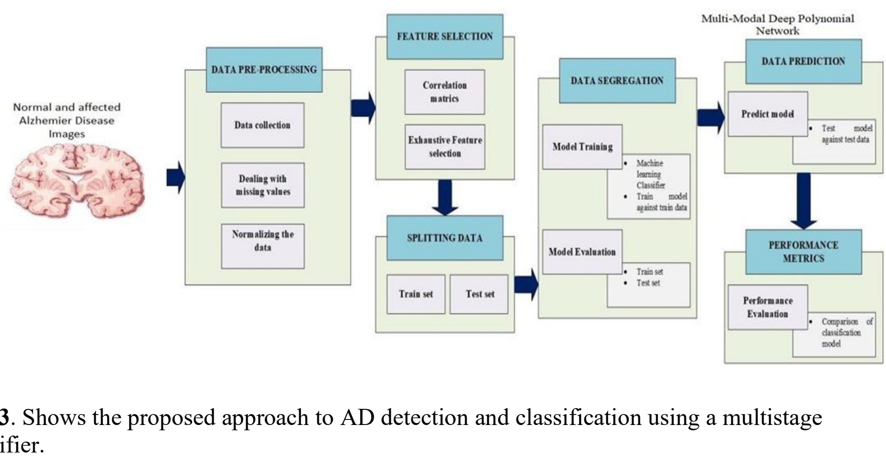

Fig. 3. Shows the proposed approach to AD detection and classification using a multistage classifier.

The Multi-Modal Deep Polygon Networks (MMDPN) is a groundbreaking deep learning method that is introduced in this section. Several methods and techniques were used to develop this methodology, including image normalisation, disease classification, feature selection, and imaging pre processing. We precisely determine the prevalence of disease and the level of affection by classifying and evaluating the input sequence based on these criteria and accordingly to the procedures outlined above. In the results section, we can see the evidence of accuracy achieved by applying the proposed method, MMDPN. The following breakdown shows the opinion of all operations that were briefly addressed. Findings from this application permit early AD detection using the samples it collects and the information it offers regarding classification. These requirements are presented in the next Section dataset overview. Applying the rules of biomedical computational biology to the dataset's images in line with the procedures yields synopses, which are then cross-validated against randomly selected samples of the trained data to evaluate the model's performance. Even if the suggested approach requires more fine-tuning in relation to level of precision and prediction criteria, the appropriately accurate model suggests that the reasoning is correct when pulled from standard learning frameworks. To ensure the validity of the reasoning for early Alzheimer's disease detection and the availability of the necessary visual data and procedural representations, the MMDPN technique provides the highest reliability ratio in a trial result at the first level.

3.1 Image Preprocessing

When dealing with digital or medical photos, the most crucial step is image pre-processing, which includes not only acquiring the images but also choosing the right image or dataset to work with, as well as any necessary practise or further testing? The pre-processing picture is changed in respect to the picture data using the "handles" object. Using the image modify function, the input image that was collected can be stretched to meet a specific standard. To achieve excellent precision in subsequent processing, the most important part of pre-processing is adjusting the image size. This is because it is necessary to convert the image and tests input into a preset format and structure. Simply pass the correct input image and any extra parameters, like image size, to the image-resize function, and it will do the trick. After a thorough analysis, the picture obtained is fine-tuned to achieve the highest possible prediction accuracy. The disparity amplification function is then used to enhance the changed image.

3.2 Image Normalization

When images are analysed, normalization changes the range of contrasts in the pictures. Photos with luminance-related needless removal have been included as samples. Swapping the terms "normalization" with "contrast stretch" or "frequency dispersion stretching" isn't uncommon. Its foundation is a linear framework, and its availability has been steadily rising across other basic data processing domains, including digital calculations. An essential first step is data normalization, which guarantees that all input variables have similar distributions. This improves resolution speed while training the system. Such information's likelihood would curve like a zero-cantered stochastic curve. In order to improve image quality in many applications, it is common practice to apply a technique known as "normalization" on images or other data in order to bring them closer to a certain or typical perceptual region. It is common practice to maintain a high contrast ratio for images, signals, or collections of information in order to forestall mental diversions and exhaustion.

3.3. Future Selection and Classification with Prediction:

Feature extraction is a technique for building prediction models with fewer component parameters. Reduce the computational complexity and cost of simulation to improve the efficiency of the procedure. Instead of simply feeding the image data into the deep-learning technique with all of the features, feature selection for disease classification would often choose a set of attributes before feeding the data to the categorization algorithm. In biomedical imaging research, the number of variables per person can be rather high; this phenomenon is referred to as multidimensional limitations. To reduce the amount of features in images of higher dimensional space, an optimum learning-based features extraction method is used. Consequently, the essential parts are preserved while the unnecessary ones are removed. Using a cluster-based dimension domain for each pattern occurrence, principal component analysis generates additional traits as a proportionate synthesis of the basic qualities and matrices. The main parts are the adjusted k-representation and the removal of volatility by means of the maximum variation of each machine. When considering all of the parameters indicated, the first ingredient protects the highest degree of volatility, while the subsequent elements protect a lower level of variability importance. The new learning method, Multi-Modal Deep Probabilistic Network, is essentially a hybrid of the two algorithms mentioned earlier; it focuses solely on classification. The Early Lung Cancer Action Project (ELCAP):

4 ADNI Data Set

In order to conduct this investigation, researchers consulted the ADNI database (adni.loni.usc.edu), which contains information about Alzheimer's disease neuroimaging. The ADNI began in 2004 as a joint venture between the government and business sector. The major objective of ADNI has been to verify the feasibility of combining clinical and neuropsychological evaluation with serial magnetic resonance imaging (MRI), PET (positron emission tomography), and other biological markers in order to track the development of mild cognitive impairment (MCI) and early-stage Alzheimer's disease (AD). The ADNI was established in 2003 by a consortium of six non-governmental organisations (NGOs) including the NIA, NIBIB, the FDA, and private pharmaceutical companies. It can be accessed online at adni.loni.ucla.edu. Each of the three levels of ADNI—ADNI 1, ADNI GO, and ADNI 2—has its own unique set of objectives and cognitive benchmarks. This dataset includes the following stages: typical control (NC), major memory concern (SMC), early moderate cognitive impairment (EMCI), moderate cognitively impairments (MCI), late mild cognitively impair (LMCI), & Alzheimer's disease (AD). This study examined the amounts of the ADNI MCI, NC, & AD data sets.

5 Results and Evaluation:

This section discusses the Multi-Modal Deep Probabilistic Network (MMDPN), a novel approach that is crucial for the correct diagnosis of Alzheimer's disease. It is based on the concept of deep learning. To put the strategy into action, we use MATLAB, a robust digital image processing tool that provides a standard package that meets all of the requirements. When the datasets used for training and testing are processed in a 70:15:15 ratio, cross-validation of the results is carried out using more conventional learning and categorization logics like as the Support Vector Machine (SVM) and Random Forest (RF) methods, leading to highly accurate findings. When training the different images, three conditions were considered: There are four stages of dementia: mild, moderate, non-dementia, & extremely mild. Some example training images are shown in Fig 5.1A,B,C)

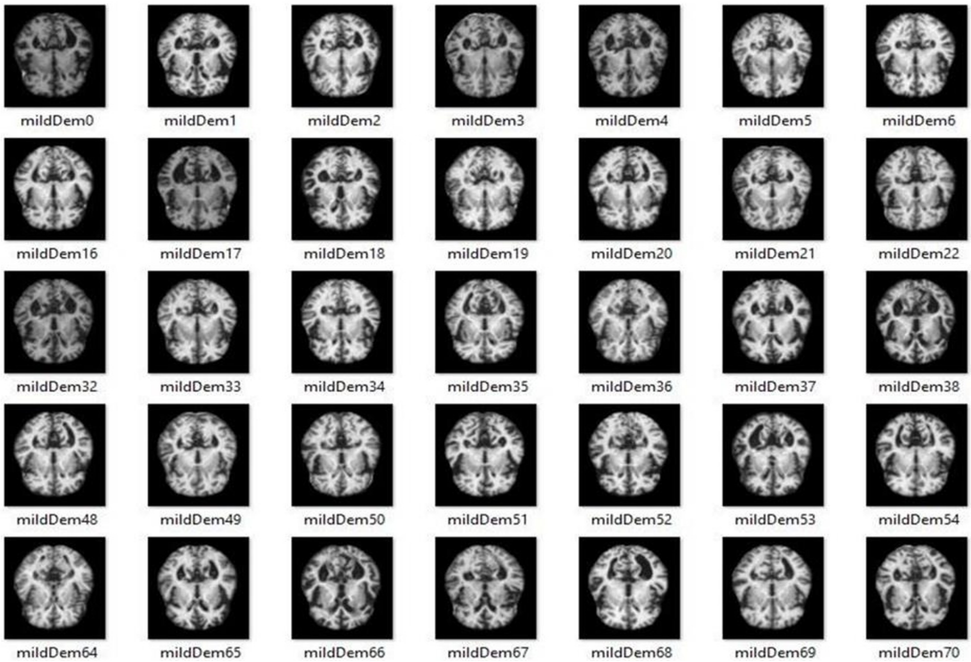

Fig. 4. Sample Mild demented Image

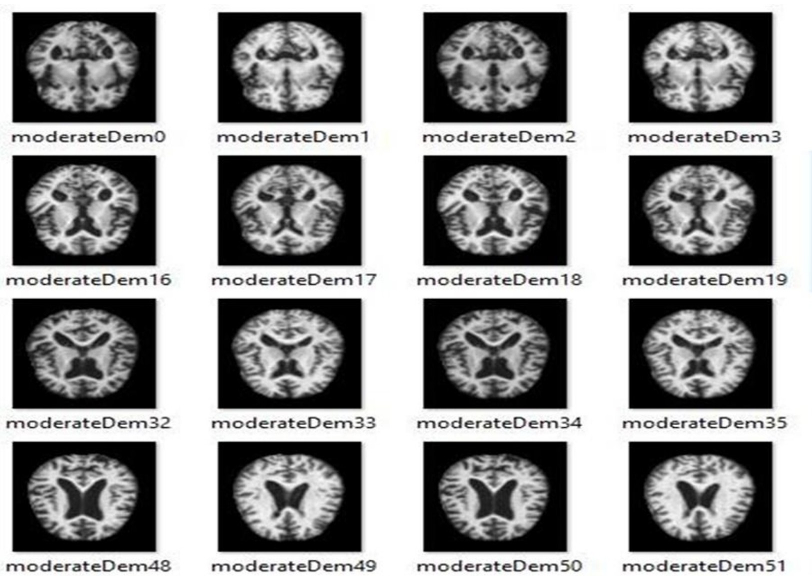

Fig. 5. Sample Moderate demented Image

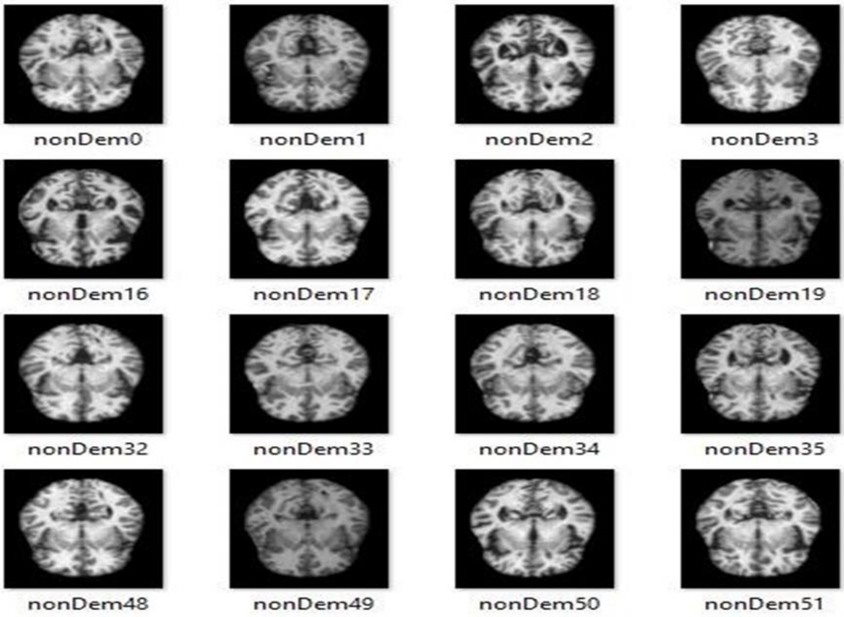

Fig. 6. Sample Non- demented Image

With respect to prediction accuracy, the suggested technique, MMDPN, outperforms the traditional classifiers that were previously covered. In Figure5, you can see the picture query that needs processing.

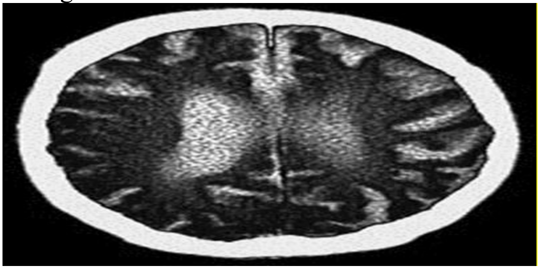

Fig. 7. Query Image Input

Fig. 8. Pre-Processed Image

The performance validation includes both the structural diffusion and various forms of attacks to prove finite robustness of proposed system with advance cipher key expansion phase.

Figure 6 shows the pre-processed image utilizing the selected image processing approach; it shows both the contrast-enhanced and structured viewpoints of the image. Figure 7 shows the results of an evaluation of a picture normalization operation that used an amalgamation of clumping techniques and the feature selection strategy to determine which image processing methods were the most effective. This condition emphasizes the affected area by minimizing its surrounding area using the image reduction approach. The capacity to comprehend the Region-of-Interest (RoI) visual perspective is illustrated in figure 8, which is essential for validating an Alzheimer's diagnosis. In essence, the proposed image processing method's normalization notion is applied to this in relation to the features that were collected. In Figure 9, we can see the correlation matrix that utilized all of the attributes.

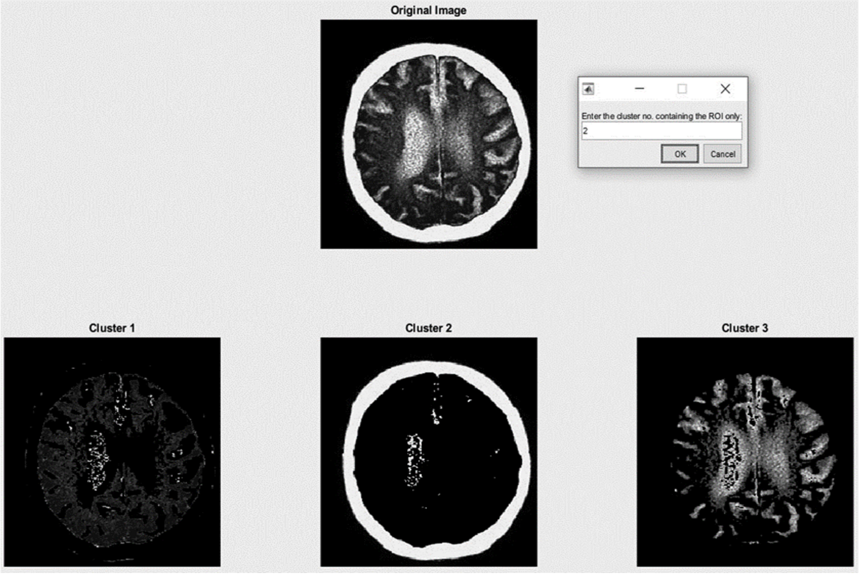

Fig. 9. Image Normalization Process

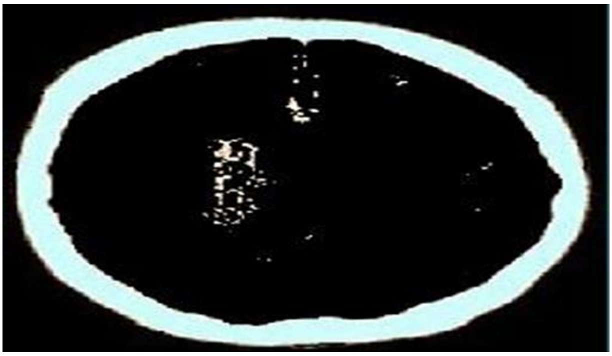

Fig. 10. Region of Interest

 https://doi.org/10.1051/matecconf/202439201119

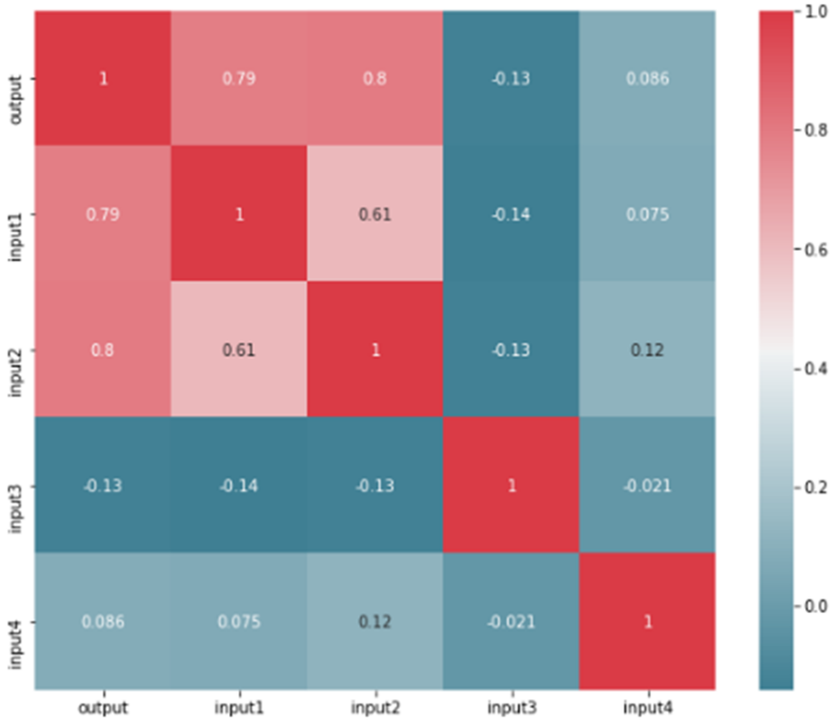

Fig. 11. Correlation Matrix for Features Selection

Figure 9 shows the accuracy percentage of the suggested method, which is called MMDPN since it has been tested using popular algorithms for learning like SVM as well as RF. Two more algorithms, Random Forest (RF) and conventional Support Vector Machine (SVM), have significantly higher accuracy ratios [21, 22]. The output of MMDPN has a level of accuracy of 97.6%. You can see it graphically and in great detail in picture 10.

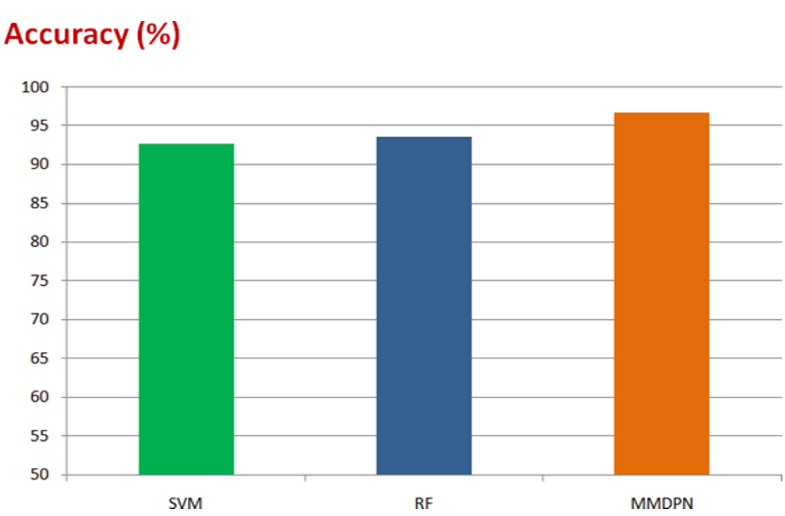

Fig. 12. Accuracy Estimation and Comparison

6 Conclusion

In order to prevent a horrible death scenario and keep people's life respectable, this work offers a critical method for detecting Alzheimer's disease in its earliest stages. In order to aid physicians in providing better patient care and early Alzheimer's disease diagnosis, this work created the Multi-Modal Deep Neural Network, a novel deep learning approach. Using the suggested MMDPN approach's intelligent processing capabilities to arrive at a diagnosis is crucial. Fig. 4, the resulting section figure, provides a comprehensive view of contrast enhancement and clearly divides the condition. Figure 7 is a section diagram that shows how the suggested MMDPN method compares to other popular learning algorithms, such as SVM and RF. The traditional SVM algorithm achieves 92.65% accuracy, the RF approach reaches 93.6%, and the MMDPN technique reaches 96.7%. That is, since the proposed scheme is comprehensive enough to reliably predict the onset of Alzheimer's disease.

References

1. Caine, D. Posterior Cortical Atrophy: A Review of the Literature. *Neurocase (*2004), *10*, 382–385.
2. Albert, A.L.W.M.L.; Feldman, R.G. The 'subcortical dementia' of progressive supranuclear palsy. *J. Neurol. Neurosurg. Psychiatry (*1974), *37*, 121–130.
3. Dr.L.Venkateswara Reddy and Dr.D.Venkatesh,"Enhanced Detection of retinopathy affected blood vessels using deep convolutional neural networks", International Journal of Advanced Science and Technology, Vol. **29**, No. 7s, pp. 917-927, (2020).
4. Soares, H.D.; Potter, W.Z.; Pickering, E.; Kuhn, M.; Immermann, F.W.; Shera, D.M.; Ferm, M.; Dean, R.A.; Simon, A.J.; Swenson, F.; et al. Plasma biomarkers associated with the apolipoprotein E genotype and Alzheimer disease. *Arch. Neurol. (*2012), *69*, 1310–1317
5. Dr.D.Venkatesh and Dr.L.Venkateswara Reddy "Advanced feature Selection Methodology for Cancer Datasets to Improve Accuracy of Classification", , International Journal of Advanced Science and Technology, Vol. **29**, No. 7s, pp.906-916, (2020).
6. Goenka, S.T. Deep learning for Alzheimer prediction using brain biomarkers. Artif. Intell. Rev. (2021), 54, 4827–4871.
7. Dr.L. Venkateswara Reddy et al., "Cardiac Arrhythmia detection using dual tree wavelet transform and Convolutional Neural Network", Soft Computing, Vol. **26,** pp:3561–3571, March, (2022). (SCI), https://doi.org/10.1007/s00500-021-06653-w.(SCI).
8. A.Farooq, S. Anwar, M. Awais and S. Rehman (2017) A deep CNN based multi-class classification of Alzheimer's disease using MRI, IEEE International Conference on Imaging Systems and Techniques (IST), pp. 1-6,
9. Dr. L. Venkateswara Reddy et al., "Secure Data Storage and retrieval system using hybridization of orthogonal knowledge swarm optimization and oblique cryptography algorithm in cloud "Applied Nanoscience, SCI, December, (2021).
10. F. Liu and C. Shen. (2014) Learning deep convolutional features for mri based alzheimer's disease classification".arXiv:1404.3366
11. Dr. Ratna Raja Kumar Jambi , Dr L Venkateswara Reddy And Dr. Mrs. Suvarna Ranjeet, "Traffic Prediction Using Deep Learning And Ai", Journal of Harbin Institute of Technology, Vol. **54** Issue. 6 (2022), ISSN: 0367-6234
12. Duff, C. Dementia: Assessment, Management and Support for People Living with Dementia and their Carers. (accessed on 29 November 2021).

13. Ambrose, C.T. Alzheimer's Disease: The Great Morbidity of the 21st Century. Am. Sci. (2013), 100, 194.
14. Livingston, G.; Huntley, J.; Sommerlad, A.; Ames, D.; Ballard, C.; Banerjee, S.; Brayne, C.; Burns, A.; Cohen-Mansfield, J.; Cooper, C.; et al. Dementia prevention, intervention, and care: (2020) report of the Lancet Commission. Lancet (2020), 396, 413–446.
15. Nichols, E.; Szoeke, C.E.; Vollset, S.E.; Abbasi, N.; Abd-Allah, F.; Abdela, J.; Aichour, M.T.E.; Akinyemi, R.O.; Alahdab, F.; Asgedom, S.W.; et al. Global, regional, and national burden of Alzheimer's disease and other dementias, (1990–2016): A systematic analysis for the Global Burden of Disease Study 2016. Lancet Neurol. (2019), 18, 88–106.
16. Venkateswara Reddy, L., et al. "Bio-Inspired Firefly Algorithm for Polygonal Approximation on Various Shapes." *Intelligent Computing and Applications: Proceedings of ICDIC 2020*. Singapore: Springer Nature Singapore, (2022). 95-107.
17. Balaji, P.; Chaurasia, M.A.; Bilfaqih, S.M.; Muniasamy, A.; Alsid, L.E.G. Hybridized Deep Learning Approach for Detecting Alzheimer's Disease. Biomedicines (2023), 11, 149.
18. Goel, T.; Sharma, R.; Tanveer, M.; Suganthan, P.N.; Maji, K.; Pilli, R. Multimodal Neuroimaging based Alzheimer's Disease Diagnosis using Evolutionary RVFL Classifier. IEEE J. Biomed. Health Inform. (2023).
19. Rahim, N.; El-Sappagh, S.; Ali, S.; Muhammad, K.; Ser, J.D.; Abuhmed, T. Prediction of Alzheimer's progression based on multimodal Deep-Learning-based fusion and visual Explainability of time-series data. Inf. Fusion 2023, 92, 363–388.
20. A.K. Damodaram , Dr. L. Venkateswara Reddy , M. Giri , and N. Manikandan "A Study On 'LPWAN' Technologies For A Drone Assisted Smart Energy Meter System In 5g-smart City Iot-cloud Environment", , Journal of Applied Science and Engineering, Vol. **26,** No 8, Page 1197-1205., pp.11971205, (2022)