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Review Article

Diagnosis And Treatment of Alzheimer's Disease Using Artificial Intelligence

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ABSTRACT

The identification, diagnosis, and treatment of Alzheimer's disease (AD), a neurodegenerative illness marked by memory loss and cognitive decline, are being completely transformed by artificial intelligence (AI). Artificial intelligence (AI)-powered services use natural language processing, deep learning models, and machine learning algorithms to analyse huge data sets from genomics, neuroimaging, and electronic medical records. By capturing minute biomarkers in speech patterns, cerebrospinal fluid, and brain scans that may anticipate clinical symptoms, these technologies allow for early detection. By detecting molecular interactions and refining clinical trial designs, AI additionally improves drug discovery and substantially decreases down on the time and price of developing new drugs. Further, real-time symptom monitoring and customized treatment regimens are provided by AI-powered cognitive and behavioural evaluation tools, which improves patient outcomes.

INTRODUCTION

The degenerative neurological condition known as AD is typified by a decrease in basic brain oscillations or a slowing of background oscillations[1].The primary cause of dementia is a rapid decline in cognitive function. In 2010, an estimated 35.6 million people worldwide had dementia. This figure is anticipated to nearly double every 20 years, reaching 65.7 million in 2030 and 115.4 million by 2050. In 2010, 58% of people with dementia lived in poor or middle-income countries. This figure is expected to increase to 63% by 2030 and 71% by 2050[2]. For patients and their families, an early diagnosis of AD can improve quality of life. Moreover, it could aid researchers in creating appropriate remedies.

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Additionally, the development of a plan for early AD detection is needed because to the significant economic impact that AD has on society[3].The most severe effects of AD are seen in oral ability, memory, and prolonged movement. As Alzheimer's disease (AD) progresses, the central nervous system (CNS) components involved in memory and reasoning are first distorted, followed by neuronal loss in the remaining brain, which ultimately leads to suicide. Individuals with AD usually show a steady decline in these kinds of skills due to the neurological side effects that are now incurable[4]. It is commonly accepted that MCI is a stage that lies in between AD and Healthy Ageing (HA), also known as Healthy Control (HC). MCI is the term used to describe people who have more cognitive decline than is normal for their age and numerous Alzheimer's disease symptoms, but not enough to meet the disease's diagnostic criteria[5]. Reducing (and ideally improving) cognitive decline and preserving independent functioning are the fundamental objectives of treatment for individuals with AD. Pharmacological therapeutic options (associated to the symptomology) include improving behavioral manifestations and focusing on modulating the damaged brain circuitries through a wide range of molecular targets. Other non-pharmacological methods include non-invasive brain stimulation (NIBS) and psychotherapy. In terms of the consolidation and reconsolidation processes, NIBS, a novel method, has shown encouraging results in restoring brain activity[6]. Precision medicine, which incorporates AI tools, is a new approach to disease prevention and treatment that integrates multimodal information with aspects including genetics, physiology, lifestyle, and pollution. This study includes a summary of the key ideas of AI application in AD research, with a focus on ML and DL models. With the exception of the intricate technical details, the structure will be separated into two sections:

(1) Implemented algorithms and their foundations, and

(2) Data-driven applications.

Each section's subjects will be chosen based on the scientific research published in the recent five years, which identifies the characteristics that were most frequently applied to AD[7]. The increase of amyloid beta peptide (Aβ), which can be precisely identified in CSF samples from AD patients, is one of the unique biomarkers of AD that define the disease. A recent cross-sectional study also looked into how Ab and tau interact in early AD and how that affects cognitive impairment[8].The study used CSF markers and discovered that, in the early stages of AD, tau levels were highly correlated with cognitive and memory performance, with the association being reliant on Ab. A recent suggestive study demonstrated how evaluating CSF molecules may help differentiate AD patients from those who do not have the disease. According to their research, the Ab42 to Ab40 ratio had the best discriminating power and could be useful in clinical settings. The application of CSF-based techniques for the early detection of AD is therefore the subject of a vast quantity of literature[9].

Methodologies:

Accurately determining whether a mild cognitive impairment (MCI) patient will convert to AD (MCI converter, MCI-C) or not (MCI non-converter, MCI-NC) during early diagnosis is necessary because not all MCI patients will develop AD. A doctor uses one of two methods to diagnose Alzheimer's disease: positron emission tomography (PET) or magnetic resonance imaging (MRI). In computer vision, machine learning and deep learning are particularly effective when it comes to extracting information from high-dimensional data[10]. Machine learning and deep learning methods for early classification of normal cognitive (NC) and Alzheimer's disease (AD)[11].

1.)Typical models for machine learning:

A) A logistic regression: The category of supervised machine learning algorithms is called logistic regression. This approach comes in handy when we need to make binary predictions (true or false). The logistic regression equation is as follows: A = 1/(1 + $e \wedge (-(b0+b1 \cdot x+b2 \cdot x \wedge 2))$ 1 where 'e' is Euler's number, which is 2.71828, b0, b1, and b2 are the model's coefficients, bo is the intercept, and 'b1' and 'b2' are the slope of the liner and quadratic components of the predictor variable 'x'. These coefficients are computed using a technique known as the estimation of maximum likelihood using the training data.

B) A support vector machine: In the field of image classification, SVM is a popular quick classification approach. Problems involving multiclass classification can be handled with SVM. A hyperplane that divides the potential outputs is produced by the SVM classifier: W^T represents the transposed value of the weight vector, a vector of coefficient that establishes the direction of the chosen boundary in the domain of features, and $WT \cdot X-b=0$, 2. The SVM is trained using an optimization approach that determines the weight vector 'W'. In the feature space, a data point is represented by the feature vector "X." The decision boundary's location in the feature space is determined by the bias factor, "b"[12].

C) Random Forest: Using the dataset's target value, Random Forest is utilized to forecast the result. Its foundation is an algorithm for supervised machine learning: $f=1 \quad B \cdot \sum b-1 \rightarrow B f b (x')$ 3, where 'b' is the forest's density of decision trees. The scaling factor 1/B averages the predictions of all the decision trees, and fb(x') is the bth decision tree's prediction on the input feature vector x'.

2.)Deep learning models were employed:

A) Artificial Neural Networks: The MRI dataset's underlying relationships and information can be extracted using a neural network, which is a collection of algorithms. It functions similarly to the human brain. The neural network consists of layers of neurons that are interconnected called perceptrons. Based on the specifications and particular architecture, these perceptual neurons are mathematical equations that categorize data taken from the magnetic resonance imaging dataset[13].

B) CNNs, or Convolutional Neural Networks: Features are taken from a convolutional network's output when two images that are displayed in a matrix forzm are added up to produce a new matrix. A CNN carries out two procedures: feature extraction and classification. CNN's primary benefit is its capacity to find out and generalize features from a huge data set.

C) Recurrent Neural Network-RNN: Alzheimer's illness is effectively predicted using RNN. RNN is employed to forecast the coming years health of AD patients. It also forecasts whether or not a patient with MCI will develop AD based on clinical data entered into the network at various time stamps[14].It has been demonstrated that AI technology, particularly machine learning algorithms, is effective for analysing enormous amounts of data from complex systems with many dimensions. Nowadays, genetic data-based studies of AD diagnosis and prognosis, genetic variation analysis, the expression of gene profiles, gene-gene associations in Alzheimer's disease, and genetic examinations of Alzheimer's disease through a knowledge base have all made use of machine learning[15].

Diagnosis:

1)Early Detection:

Timely interventions, customized medications, and improved patient care are all possible with an early AD diagnosis, which may delay the disease's course and improve the general quality of life for those who are impacted. Since early detection has a direct impact on treatment outcomes and people's overall quality of life, it is crucial to emphasize its importance in the framework of Alzheimer's dementia. Although earlier studies have advanced our knowledge of Alzheimer's disease, the complexity and diversity of symptoms make it difficult for traditional diagnostic techniques to reliably detect the illness in its early stages. This shortcoming has spurred research into cutting-edge AI-based strategies that could offer more accurate and sensitive early detection techniques. Artificial intelligence employs computers and technology to replicate the cognitive capabilities of the human mind in problem-solving and decision-making. It's crucial to keep in mind that AI algorithms usually gain knowledge from data and improve over time, enabling robots to do tasks more accurately and effectively. Among the uses of AI include speech recognition, image recognition, and language translation. The emergence of AI as a game-changing instrument in the medical field together with developments in ML and DL, the exponential increase in processing capacity opened up new avenues for the analysis of intricate medical data, such as biomarker profiles and neuroimaging images. AI can more precisely diagnose patients based on their symptoms of illness and vital signs and is very good at identifying subtle abnormalities in scans. AI is also utilized for patient classification, medical record management, tracking, and preservation[16].

2)Neuroimaging Applications:

The analysis of MRI, PET, and CT images for the diagnosis of Alzheimer's disease (AD) benefits greatly from artificial intelligence (AI), which increases efficiency and accuracy. AI opens us countless potential for AD diagnosis in the future by helping to analyze and interpret enormous volumes of brain imaging data[17].Recent research have shown the efficacy of AI in integrating multimodal neuroimaging data, including MRI and PET, to detect Alzheimer's disease in both early and late stages of mild cognitive impairment[18]. Curiously, some research has looked into cutting-edge methods to improve AI's ability to diagnose AD. For example, a multimodal fusion-based method that used a neural network that had been trained (VGG16) and separate wavelet transforms and transfer learning obtained good accuracy in detecting AD using MRI and PET data. Another study suggested integrating subject phenotypic and picture data using graph neural networks, showing better results for AD diagnosis[19]. In summary, AI has demonstrated significant promise in the analysis of CT, PET, and MRI data for the diagnosis of AD. Improved diagnostic precision, more effective radiography data analysis, decreased physician burnout, and precision medicine developments are some of AI's primary benefits. But issues like mistrust in the medical community, data scarcity, and generalization must be addressed[20].

3)Biomarker Discovery:

The work presents a novel plasmonic infrared sensor paired with artificial intelligence (AI) that can identify protein biomarkers linked to neurodegenerative illnesses like Alzheimer's. This sensor detects misfolded proteins using sophisticated immunoassay methods, allowing multiplexed detection and improving diagnostic precision, which may greatly enhance Alzheimer's disease early diagnosis and monitoring. Its capacity to examine intricate biological materials, such cerebrospinal fluid, makes it a potentially useful instrument for therapeutic settings, with the goal of improving our knowledge and treatment of neurodegenerative diseases[21]. Finding biomarkers using AI is becoming more and more crucial in the detection of the Alzheimer's disease (AD). The capacity of AI to improve the precision and effectiveness of AD detection utilizing a variety of biomarkers has been shown in numerous research. AI in conjunction with ocular biomarkers has demonstrated potential in the early detection of AD. AI combined with ocular biomarkers via multimodal imaging has been shown in studies to increase the accuracy of diagnosing AD patients. This could be used as a screening tool to identify early AD in older individuals before symptoms appear[22].Furthermore, a hybrid approach that uses several features taken from the foveal avascular zone (FAZ) and combines AI-based segmentation and machine learning (ML) classification has demonstrated better diagnostic performance for AD. With an AUC of 72.2±4.2%, this method outperformed the current single-feature criteria by more than 13%[23].It's interesting to note that although the number of AD biomarkers is constantly increasing, it's not always evident how useful and distinct they are. Only a small number of 27 AD biomarkers were shown to be highly predictive of clinical outcomes in a machine learning study that evaluated their associations. Amyloid PET status was found to be best predicted by CSF indicators[24]. This emphasizes how crucial it is to look at several biomarkers at once in order to comprehend the pathobiological changes associated with AD and choose which biomarkers are best for clinical treatment and research. To sum up, AI-based discovery of biomarker is improving the diagnostic process of AD by increasing detection accuracy, making it possible to use new biomarkers like ocular markers, and assisting in the identification of the best predictive biomarkers out of the numerous ones that are now accessible. AI-driven methods could result in better early detection and monitoring of AD as this field of study develops, which could enhance patient outcomes and aid in the creation of novel treatments[25].

Treatment:

1)Approaches for Developing ML (machine learning) Models in AD Research:

By evaluating data and carrying out tasks in a logical order, a computer may mimic human learning and reasoning processes. This is known as artificial intelligence (AI) and machine learning (ML). To put it simply, during these procedures, we are able to identify certain traits that are unique to the new elements and those that are comparable to those of previously known elements. We then name or label the information so that it can be easily recognized. It is anticipated that when a more complex system is used, the computer will be able to analyze vast amounts of data quickly, solve complicated issues, or follow patterns to produce logical conclusions with a lower error rate[26]. In order to overcome these constraints, good preprocessing techniques are required, where data normalization and missing value management are essential. These algorithms adhere to the ideas of logic, discrimination, and probability theories since they are always founded on mathematical and statistical principles. One of the factors that needs to be taken into consideration is the potential for overfitting, a statistical phenomenon in which the model incorporates noise as a component that adversely affects the result since it can contribute features that are not a part of the underlying distribution. This occurs when there are too many variables or features on show and not enough subjects[27].The quality of the data that is "fed" into the computer is one of the main limitations of artificial intelligence (AI). As with any scientific procedure, the conclusion regarding the underlying disease process may be harmed by the modification of the data to be examined, when traits are adapted to achieve a certain goal. As a result, the scientist or data analyst typically introduces biases, which compromises the results by assuming incorrect things. The suggested preparation to "clean" the data and exclude some outliers could introduce an exclusion bias into the final findings[28].

2)The Role of AI in AD Monitoring:

Although non-invasive procedures have the ability to forecast AD in its early stages, there are a number of computational issues with the data they produce that must be resolved. When it comes to noise, volume, dimensionality, and heterogeneity, the data produced by such processes can be incredibly complicated[29].Similarly, omics (genomics, transcriptomics, and proteomics) measures with an extremely high number of samples and features are frequently included in blood screening data[30].Because of its intricacy, it is difficult to examine and understand using conventional statistical techniques. Because AI and deep learning (DL) algorithms are well-suited to manage such massive and complicated datasets, their application has grown in popularity in recent years[31]. Predictive models that can help with the early detection and treatment of AD can be produced by AI and DL (deep learning) approaches, which can find patterns and relationships in data. These methods can also be used to create individual risk profiles according to each person's particular mix of risk variables. The accuracy of AI and DL models rises in tandem with the quantity of available data. All of these non-invasive technologies (imaging, blood-based, bio-sensors, wearable devices, etc.) allow the collection of large and complex datasets that can be used to identify Sensors of early AD detection, which leads to models that are more thorough and accurate in their identification and characterization[32].

3)Monitoring:

A variety of tools and systems known as assistive technologies help people with Alzheimer's with everyday tasks, communication, and safety[33].Voice-activated assistants, digital calendars, and reminders are examples of electronic memory aides that assist people with Alzheimer's in organizing their daily schedules and appointments. In order to guarantee dependability, the study also emphasizes the need for additional software and device improvement. Their studies' small sample sizes aid in generalizability, but there is a noticeable study void in the context of users' homes. Future research using reliable tools that specifically take into account the various requirements of people with dementia is encouraged by the review. Beyond help efficacy, attention should be paid to results including better everyday functioning, higher quality of life, and stronger social ties[34].Voice output systems, symbol-based communication tools, and visual assistance can help people with Alzheimer's stay in touch. The study highlights the encouraging viability and advantages of mHealth apps in improving dementia and AD community care, despite the paucity of studies in this area[35]. Real-time location tracking of Alzheimer's patients is made possible by GPS tracking devices, which detect people with the disease who might wander and get lost. This improves their safety and allows for quick retrieval of a GPS module and a WiFi modem/router. The technology is available through web and mobile applications for Android and iOS. It estimates the patient's position using a Kalman filter, which is essential for moves outside. The study demonstrates the prototype's effectiveness and presents a viable way to improve patients' quality of life while assisting caregivers with their duties[36].Sensors and smart home technology are used by ambient assisted living (AAL) systems to help people with Alzheimer's disease live their lives safely and with reminders. Concurrent validity was demonstrated by AAL reports, which revealed important changes, some of which the clinical nurse was unaware of. By addressing the particular difficulties faced by Alzheimer's patients, the study highlights AAL's ability to provide clinically relevant information throughout time, promoting aging in place and assisting in healthcare service decision-making[37,38].The effects of a two-month VR cognitive stimulation program on people with mild-to-moderate dementia caused by AD are examined. VR technology enables people with Alzheimer's disease to experience realistic and interactive worlds that improve cognitive stimulation, memory, and relaxation. The VR intervention, which consisted of ten sessions spread over two months, was intended to mimic everyday activities. Preliminary results from baseline and follow-up neuropsychological tests that focus on memory, attention, and executive functions show that the experimental group's general cognitive function significantly improved. The observed considerable effect size in global cognition highlights the importance of VR-based cognitive stimulation in maintaining cognitive function in the context of AD and points to its potential efficacy for older persons with dementia[39,40].

4)Use of artificial intelligence applications in medical treatment recommendation:

Only a few number of computer-based decision support system techniques have been used in the last 20 years. "OncoDoc," which was created for patients with breast cancer, is an early example. Using a rule-based engine, this computer-based decision support system applies various medical criteria, patient similarity, and data and decisions from prior instances to provide patients with breast cancer with several therapy recommendations[41].The difficulty is in simplifying difficult (human) jobs so that machine language can comprehend them while still addressing the complexity of the issue. Furthermore, two major issues are data privacy and the portrayal of data, which is primarily personal. Consequently, one of the main areas of research is the best way to use datasets. Additionally, efforts are undertaken to artificially expand the databases or automatically generate missing data. In order to improve performance, current AI research also aims to integrate machine-readable expert knowledge, such as clinical studies or medical guidelines. Last but not least, one of the biggest obstacles is explainability, which is essential for any clinical application to guarantee accountability and confidence. [42,43].

5)Artificial intelligence development:

Since "convolutional neural networks" (CNNs) may be applied to both image and time series analysis, they have received a lot of attention in recent years. CNNs are frequently used to assess medical images, including pathological classification of skin tissues, malignant tumors, and other disorders that are detectable to the naked eye. High accuracy and quick analysis are the main reasons these networks can score highly. Nevertheless, it makes sense to experiment with different approaches in addition to CNNs, particularly when dealing with time series. For instance, time series were intended to be used with "long short-term memories" (LSTMs). Another technique is called "Transformer," and it was initially created for text processing[44]. Long-term series can be handled by them without compromising accuracy. Additionally, by employing the attention that may be utilized to produce a type of heat map for the time series to highlight essential portions, transformers also offer limited explainability without requiring extra work. Additionally, AI techniques can be used to process texts or tables. The "encoding" process is a crucial component for this. Since an AI cannot comprehend language, the texts must be encoded or embedded. Words must be mapped in a high-dimensional space for an AI to process them, therefore models must be trained to generate outputs that are appropriate for technical jargon [45]

6)Privacy and data security:

In this setting, neural networks retain information about the data and learn from training datasets. Sensitive information can be obtained by reconstructing training data. In order to safeguard the models from outside attempts for data extraction, prevention is also necessary. Understanding attack techniques and how they affect the models is crucial. The membership attack is a popular attack technique that uses focused queries to try and acquire information about training data from the model. Together with this, the dataset may be rebuilt, and a custom model can be trained. Using a model reconstruction like this [46]. By asking specific questions to the private model, an attempt is made to train a model of one's own that replicates the original. There are numerous other ways to steal private data from AI techniques. There are ways to reverse this, thus classical anonymization can only stop it to a certain degree. To defend against such attacks, a variety of techniques are available. Among the most well-known is "homomorphic encryption," where the data and model are encrypted so that only the parties involved may access them [47]. This allows a model to be protected without sacrificing performance. Unfortunately, because to the high added processing cost, this strategy is not yet applicable to bigger networks. One way to get around this is to only encrypt the model after it has been trained, which would safeguard it after training but not throughout the training process. One popular substitute is "Differential Privacy" [48]. Here, the network's optimizers and data are already altered during training to ensure that the final model safeguards the private information. During training, "noise" is added, and the level of noise determines security. Although practically any network architecture can be used with this approach, the models' accuracy is reduced. Another possibility is to use an artificially dispersed learning model[49].In particular, data from many universities can be combined using distributed processing to produce datasets big enough to train neural networks; however, sharing entails additional security considerations. The gradients used for optimization are rounded during training. The model is updated in the second phase by averaging the calculated gradients of these models. The model is less vulnerable to attacks thanks to the average data information that is generated. Differential privacy models can be used in conjunction with the technique. Generative techniques generate synthetic data. Sensitive data is used by a protected generative model to create synthetic data that an attacker cannot tell apart from the actual data. Differential privacy is used to train the generative models, which are typically variational autoencoders (VAEs) or generative adversarial networks (GANs). A model can utilize the generated data without any safeguards [50].

Limitations:

We must be conscious of the present issues and limitations of AI. The "black box," which refers to the issue of AI judgments not being able to be explained, is a significant issue[51].

For a clinical deployment, an AI's ability to defend its choice is practically required. Known as "white boxes," there are already a few promising AI applications that forecast therapy response and can support their choices[52].

Lastly, we must take into account the enormous financial outlay and related risk required to create and apply AI in international healthcare systems [53].

Future Directions of Ai Used in Alzheimer Disease:

In image-based diagnosis, disease recognition, and risk management, AI techniques are gradually displaying efficiency. To achieve their full potential, an array of practical and technical solutions are still needed. This chapter presents the application of artificial intelligence (AI) strategies for the detection of AD and associated states employing several structural imaging techniques. Further, AI methods are being investigated for the recognition of AD, which causes serious health issues. Several studies have used AI algorithms across different image data. When it came to the comparison between AI algorithms, CNNs excelled standard machine learning methods on the basis of AD detection accuracy. In conclusion, these studies are an initial phase with some acknowledged challenges. which include the demand for data harmonization, procedure standardization, practical application of these theoretical models, generalizability of the conclusions, and multidisciplinary team integration.

1.Early Detection and Diagnosis: The application of AI models, particularly deep learning algorithms, for Alzheimer's early diagnosis is growing. Before clinical symptoms manifest, these models can detect indications of neurodegeneration by analyzing brain imaging data (such as MRI and PET scans) and other biomarkers. Future research will concentrate on enhancing these models' accuracy in order to identify Alzheimer's earlier and facilitate early intervention.

2.Predictive Models for Disease Progression:AI can assist in forecasting how Alzheimer's disease will develop and in customizing treatments for each patient according to their distinct biomarkers and cognitive scores. Personalized forecasts of the disease's course could be provided by machine learning models that integrate genetic information, imaging, and clinical records. This would help medical professionals make better treatment decisions.

3.Drug Development and Discovery: By evaluating huge datasets from molecular biology and clinical trials, artificial intelligence is significantly contributing to drug discovery. Machine learning algorithms can find new treatment targets and expedite the development process by predicting which drug candidates may be effective in treating Alzheimer's. This can be used in conjunction with conventional experimental drug testing.

4.Cognitive and Behavioral Monitoring: Wearable technology and smartphone apps driven by artificial intelligence are being created to track real-time behavioral and cognitive changes in Alzheimer's patients. These gadgets use sensors to monitor speech, sleep patterns, and physical activity in order to identify behavioral or cognitive problems early on. Their capacity to continually monitor a patient's state will be improved in the future, providing clinicians and caregivers with useful data.

5.Integration with Neuroinformatics: AI may eventually be integrated with neuroinformatics systems, which store enormous volumes of multi-modal data (such as genetic information, clinical records, and brain imaging). This might make it possible for scientists and medical professionals to develop more thorough models of Alzheimer's disease and uncover fresh information about its pathophysiology.

6. Ethical and Regulatory Considerations: Privacy, data security, and the ethical implications of AI in healthcare will need to be addressed as AI systems become more prevalent in Alzheimer's care. For AI tools to become widely used in clinical practice, it will be essential to make sure they are transparent, understandable, and ethically sound.

CONCLUSION:

AI has a revolutionary role in Alzheimer's disease, providing tools for continuing patient care, medication development, individualized treatment, and early diagnosis. To guarantee its efficient usage, however, issues with data privacy, algorithm transparency, and healthcare integration must be resolved. AI technologies and medical professionals will probably work together to provide more accurate, fast, and accessible therapies for Alzheimer's patients in the future. AI may be essential to both the search for a cure and the improvement of outcomes for people with Alzheimer's disease, provided that it continues to advance and ethical issues are taken into account.AI has the potential to completely transform the diagnosis, management, and treatment of Alzheimer's disease. To fully reap the benefits of AI in the fight against Alzheimer's disease, however, further research, ethical supervision, and cooperation between patients, clinicians, and technologists will be necessary.

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