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Image Classification Detection Technology in the Diagnosis of Alzheimer's Disease

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Abstract. Alzheimer's disease (AD) is a primary brain degenerative disease that occurs in the elderly and pre - elderly. This disease will produce irreversible brain structural and molecular changes, leading to progressive cognitive and behavioral disorders. The disease has the characteristics of strong concealment and difficult early diagnosis, which also leads to a very difficult diagnosis. Therefore, with the rise of deep learning, researchers began to use image classification detection technology to assist in the diagnosis of Alzheimer's disease. This paper summarizes the application of image classification and detection technology in the diagnosis of Alzheimer's disease from three parts: the application of the single convolutional neural network method in diagnosis, the application of the attention mechanism and the convolutional neural network fusion method in diagnosis, and the application of the fusion model method in diagnosis. At the same time, this paper also makes a comparative analysis of the mainstream related databases, including data scale, queue diversity, data mode, research scenarios, and acquisition methods. The research in this paper not only provides the basis for researchers to select models and data, but also promotes the integration of image technology and Alzheimer's disease diagnosis.

Keywords: Alzheimer's disease, deep learning, computer-aided diagnosis

1. Introduction

Alzheimer's disease (AD) is a primary degenerative brain disorder that occurs in old age and pre-old age. It refers to a persistent disorder of higher neural function activities, that is, disorders in memory, thinking, analysis and judgment, visual space recognition, emotion, and other aspects without consciousness disorders. The characteristic pathological changes are cerebral cortical atrophy with β-amyloid deposition, neurofibrillary tangles, a reduction in the number of memory neurons, and senile plaque formation. There are no specific treatments to reverse the progression of the disease. The characteristic pathological changes are cerebral cortical atrophy with β-amyloid deposition, neurofibrillary tangles, a reduction in the number of memory neurons, and senile plaque formation. At present, there are no specific drugs for treating or reversing the progression of the disease, which leads to the fact that Alzheimer's disease will have a huge impact on people's lives. Moreover, the onset of Alzheimer's disease is insidious and hard to detect. Its symptoms overlap with those of normal aging and are difficult to distinguish. This makes it difficult to diagnose Alzheimer's disease in its early stages. However, with the rise of deep learning, its powerful feature extraction and

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classification recognition capabilities have been significantly enhanced. Moreover, thanks to the upgrade of hardware conditions, it has become possible for deep learning to diagnose Alzheimer's disease. This has led an increasing number of computer scientists and neurologists to focus on this interdisciplinary field, using various deep learning algorithms to classify AD-related images to assist in the diagnosis of Alzheimer's disease. Traditional methods for analyzing images usually rely on manual screening of features, which is not only time-consuming but also difficult to capture subtle pathological changes, which are often key clues for the early diagnosis of Alzheimer's disease. However, deep learning can learn hidden, high-dimensional pathological features from massive image data through multi-level nonlinear transformations, thereby enabling the diagnosis of Alzheimer's disease.

Therefore, this article summarizes and expounds the methods applied in the image classification technology of deep learning in the diagnosis of Alzheimer's disease. The text will be elaborated from the following perspectives. The first is to introduce some basic information about Alzheimer's disease. Then it introduces how to use image classification technology to combine with the diagnosis of Alzheimer's disease, which is divided into three parts: the diagnosis method based on the single convolutional neural network method, the diagnosis method based on the fusion of the attention mechanism and the convolutional neural network, and the diagnosis method based on the fusion model. Then the data sets are described and compared. Finally, the significance of this paper is summarized and introduced.

2. Alzheimer's disease basic information

At present, mainstream research on the causes of Alzheimer's disease holds that it is the result of multiple factors working together. It is usually caused by genetics, excessive exposure to environmental pollutants, and an unhealthy lifestyle [1], and is also related to factors such as diabetes, cerebrovascular diseases, head injuries, and stress [2]. The symptoms of Alzheimer's disease can be characterized by severe progressive cognitive impairment affecting multiple domains, or neurobehavioral symptoms that are severe enough to cause a significant functional impact on daily life [3]. Cognitive dysfunction is the core symptom, mainly memory decline, accompanied by language disorder, visual-spatial ability decline, executive dysfunction, and other phenomena. At the same time, mental and behavioral symptoms may also occur. Usually, there will be changes in personality. Abnormal emotions may occur, such as anxiety, depression, irritability, or loss of interest in things. There may also be abnormal behaviors such as hallucinations, delusions, repetitive actions, and wandering at night. Alzheimer's disease has an impact on individuals, families, and society. For individuals, the life of patients will gradually become completely dependent on others from independent life, and accompanied by some complications such as pneumonia and fractures caused by mobility problems. For the patient's family, it requires a large amount of human and material resources for a long time, and increases economic pressure. It will also cause a certain degree of anxiety and depression, and other psychological problems for the family members. At the same time, it imposes a huge burden on the social pension and medical care systems. The influencing factors of Alzheimer's disease can be divided into controllable factors and uncontrollable factors. The controllable factors include cardiovascular diseases such as hypertension and hyperlipidemia, and unhealthy lifestyles such as lack of exercise and smoking, as well as insufficient cognitive stimulation and chronic lack of social and mental activities. Uncontrollable factors include age, genetics, and gender.

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3. Diagnostic methods for Alzheimer's disease based on the computer perspective

3.1. Diagnostic method based on the single convolutional neural network

With the continuous development of deep learning, convolutional networks (CNNs) have been created by people. A convolutional neural network learns the characteristics of data through images, and then realizes the diagnosis of Alzheimer's disease. The core of convolutional neural network design is "local perception" and "weight sharing". The core features of the convolutional neural network enable the convolutional neural network to extract features of images and learn key features. A convolutional neural network is widely used in the diagnosis of Alzheimer's disease because of its excellent image processing advantages. Junxu Liu et al. used a deeply separable convolutional neural network model to replace the traditional convolutional neural network to detect Alzheimer's disease. The deeply separable convolutional neural network greatly reduces the parameters and calculation cost of the neural network, which makes this model suitable for embedding into mobile devices. The detection of their model on the OASIS dataset was very successful [4]. Lisa Anita De Santi et al. proposed a 3DCNN technology and used dynamic 3D 18F-FDG PET images for training. This research first uses four feature extraction blocks to extract features, and extracts simple to complex features from the input image layer by layer. Each feature extraction block uses 2 layers of a 3D convolution layer first, then uses the maximum pooling layer, and finally uses the batch normalization layer. After feature extraction of four blocks, the global average pooling operation and L2 regularization enhancement are used. Finally, input two fully connected layers, each layer uses ReLU as the activation function, and each layer is followed by a Dropout to reduce overfitting. Finally, through the Softmax output layer, the features are converted into the probability of each category for classification, which is used to diagnose the clinical stage of Alzheimer's disease [5]. Zhang Anhang and Guan Junlin designed a three-branch convolutional neural network structure. The convolutional neural network design of each branch is different, and the convolutional neural network of each branch uses optimization techniques such as dropout and residual connection. This model has good accuracy in the classification application of Alzheimer's disease, and has higher research and application value than traditional techniques [6].

3.2. Diagnostic methods based on attention mechanism

On the basis of a convolutional neural network, many researchers are not satisfied with the structure of a pure convolutional neural network, so they introduce an attention mechanism. An attention mechanism is an algorithm framework that simulates human selective attention. An attention mechanism can filter out the key content from a large number of features and give it higher weight, and weaken the non-key features. The attention mechanism makes the training of the model pay more attention to the key features, and can learn the key points of the image faster and better. Adding an attention mechanism to a convolutional neural network can improve the accuracy of the model and better diagnose Alzheimer's disease. Sunjunnan et al. Combined the attention module of SimAM with two kinds of convolutional neural networks, namely, 3D convolutional neural network and dense connected network. A new algorithm named 3D-SAMDennet is proposed. This algorithm can well distinguish patients with Alzheimer's disease from normal people, and can also well distinguish patients with mild cognitive impairment from normal people [7]. Sun Haoran proposed two methods for the intelligent diagnosis of Alzheimer's disease, one of which is a classification model combining channel attention with dense connected networks. This model first uses the two-dimensional image information entropy slice screening algorithm, which can more accurately and

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effectively select the lesion-related slices with more key information, and then improve the quality of the experimental data set. Then the processed data set is trained in the classification model of channel attention combined with a dense connected network. Finally, this method proposed by Sun Haoran can be used for coarse-grained classification of Alzheimer's patients and normal people [8]. Liu Zirui showed that a 2D-VMD-MTV super-resolution algorithm was designed to process MRI images of Alzheimer's disease. This super-resolution algorithm not only improves the resolution of the image, but also increases the number of features. Then the processed MRI images were put into the improved residual attention network model designed by him. This model uses residual connection to solve the gradient disappearance problem, and embeds the attention module in the convolution feature extraction process to allocate the weight of the convolution-generated feature map. It provides strong support for the diagnosis of early Alzheimer's disease [9].

3.3. Diagnostic methods based on fusion models

In order to further improve the accuracy and reliability of the model in the diagnosis of Alzheimer's disease, researchers have taken the fusion model as a breakthrough point. The fusion model method no longer uses a single model, but integrates the advantages of different models together. The characteristic of the fusion model enables it to better and comprehensively capture the pathological features related to Alzheimer's disease, thereby providing more accurate support for the diagnosis of Alzheimer's disease. The characteristic of the fusion model enables it to better and comprehensively capture the pathological features related to Alzheimer's disease, thereby providing more accurate support for the diagnosis of Alzheimer's disease. In Yang Xie's research on the diagnosis of Alzheimer's disease based on deep learning, a fusion model was proposed by combining an improved V-Net with Swin Transformer in series. Integrating the advantages of two different models, V-Net and Swin Transformer. The improved V-Net can be used as a segmentation model to accurately extract key regions from images and input high-quality features into the Swin Transformer model. Afterwards, the Swin Transformer model's ability to capture local and global features is utilized to improve classification accuracy. This improved fusion model of V-Net and Swin Transformer achieves high-precision classification [10]. Jade Xiaoqing Wang et al. proposed a method called IGnet. This method adds gene sequencing data on the basis of magnetic resonance imaging (MRI) image data, forming multimodal data. According to the multimodal data, they combined the advantages of 3D CNN and Transformer encoder to form a new fusion model. 3D CNN is used to process 3D MRI image data and extract spatial features of the brain structure. A transformer encoder is used to process gene sequence data and capture the base dependency in gene sequences. Finally, different types of data processed by these two models were integrated and output, achieving a high accuracy classification of Alzheimer's disease [11].

4. Dataset comparison

During the years of research on Alzheimer's disease by neuroscientists and computer scientists. With the continuous improvement of imaging technology and the continuous accumulation of clinical data, a large amount of data has been recorded and made into public or semi-public data sets for people to use and study. These data provide key data for the application of deep learning technology in the diagnosis of Alzheimer's disease, especially image data, which records the differences between patients and normal people in detail. This study focuses on image data sets commonly used in Alzheimer's disease research. Through comparison, the data scale, queue diversity, data mode, research scenario, and openness of different data sets are analyzed.

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The first data set is the Alzheimer's Disease Neuroimaging Initiative (ADNI), which is one of the most widely used data sets at present. The data scale of ADNI is large, with more than 2000 participants in total. The cohort of ADNI covers the normal group (CN), mild cognitive impairment (MCI), and multiple disease stages of AD patients. The data contained in ADNI include long-term follow-up data, some of which have been followed up for up to 10 years. These data can clearly reflect the image changes of Alzheimer's disease from the early stage to the late stage. In terms of data mode, ADNI has very comprehensive data. ADNI not only contains structural MRI (T1 weighted), functional MRI (fMRI), PET, and other rich image data. Cerebrospinal fluid biomarkers, blood markers, APOE genotypes, and detailed clinical cognitive scores were also included. ADNI, a rich multimodal data set, is particularly suitable for biomarker discovery, drug clinical trials, and multimodal fusion research. However, the ADNI data set is not directly disclosed and needs to be applied to the ADNI official website.

The second data set is Open Access Serial Imaging Research (OASIS). The number of participants in OASIS is not as large as that in ADNI. OASIS included 416 transverse T1-weighted MRIs and 150 longitudinal follow-up data. The cohort covers healthy people aged 18-96 and patients with Alzheimer's disease, and has a cross-age characteristic. Such cross-age characteristics make the OASIS dataset have unique advantages in exploring the relationship between age-related brain structural changes and early pathological changes in AD. In terms of data mode, although OASIS has a single data mode, the data is highly standardized. Such highly standardized features can make the OASIS dataset better applied to image processing. Compared with the application of ADNI, OASIS is more convenient to obtain. The data in OASIS is completely open and can be downloaded directly. The last is Australian Imaging, Biomarker and Lifestyle Research (AIBL). AIBL includes 1100 participants. The data were followed up for more than 4.5 years, and some participants provided 3 years of imaging and clinical data. The queue feature of AIBL also covers NC, MCI, and AD. However, the AIBL sample comes from the Australian center, with low ethnic diversity. In terms of data mode, AIBL includes not only T1-weighted MRI, PIB-PET (amyloid imaging), Florbetapir-PET, and other image data, but also biomarkers such as blood samples, APOE genotype, cerebrospinal fluid (partial subset), and lifestyle data such as diet, exercise, smoking, and other questionnaire information. Most of them have been applied to multimodal classification, research on the relationship between biomarkers and lifestyle. AIBL can only be accessed after an application.

The comparison of ADNI, OASIS, and AIBL datasets is shown in Table 1.

Table 1. Comparison of data sets

Dimension	ADNI	OASIS	AIBL
Data Scale	Maximum (over 2000 cases), follow-up at multiple time points	Moderate (416 cases cross section+150 cases longitudinal)	Moderate (1100 cases baseline + long-term follow-up)
Cohort Diversity	Covering all stages of CN, MCI, and ad, Global Multi-Center	Cross-age, focusing on health and early AD	Comply with the ADNI standard, including lifestyle data
Data Modalities	Most comprehensive (MRI, PET, cerebrospinal fluid, gene)	Mainly structural MRI, with limited clinical data	MRI, PET, Blood markers, and lifestyle questionnaire
Research Scenarios	Drug testing, multimodal biomarker research	Image algorithm development and basic mechanism research	Multimodal classification, biomarker, Lifestyle Association
Openness	Application required, high degree of data standardization	Completely open, suitable for rapid validation of models	Application required, support cross-queue analysis

5. Conclusion

This research focuses on the application of image classification detection technology in the diagnosis of Alzheimer's disease. This research systematically examines the research methods and data support in this field. The specific research is carried out from two aspects. On the one hand, there is the diversity of diagnostic methods and technological evolution of Alzheimer's disease from the perspective of computers. The diagnosis methods based on single convolutional neural network (such as depth separable CNN, 3D CNN, and multi branch CNN), the diagnosis methods based on attention mechanism and convolutional neural network fusion (such as the combination of SimAM and 3D CNN, channel attention and dense connection network fusion), and the diagnosis methods based on fusion models (such as V-Net and Swin Transformer series, 3D CNN and Transformer encoder integration of image and gene data) are introduced in turn. On the other hand, the data sets commonly used in the study of Alzheimer's disease (ADNI, OASIS, AIBL) are compared and analyzed. This paper analyzes the data scale, queue diversity, data mode, research scenario, and openness of different data sets, and reveals the characteristics and application scope of different data sets. In conclusion, this paper combines and analyzes the deep learning model used in the diagnosis of Alzheimer's disease and the main data set. It not only provides researchers with the basis for model selection and data selection, but also promotes the integration of image technology in deep learning and Alzheimer's disease diagnosis technology.

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