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Diagnosis System of Mycoplasma Pneumonia based on Multimodal Hypergraph Neural Network

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Abstract

Since September last year, there has been an epidemic trend of mycoplasma pneumonia in China, which is in urgent need of effective and rapid diagnosis. To solve this public health problem, a multimodal visual hypergraph neural network diagnosis system for mycoplasma pneumonia is proposed. Firstly, a cooperative relationship was established with the Affiliated Hospital of North China University of Science and Technology to collect the lung CT and biochemical data of patients, and then the collected data was denoised and enhanced by VEVE-GAN technology. Finally, based on multi-modal data, a visual hypergraph neural network was built, which aims to learn the high-level interaction between various biological and clinical factors leading to mycoplasma pneumonia, so as to achieve accurate diagnosis of mycoplasma pneumonia.

Keywords

Multimodal Vision; VAE-GAN; Hypergraph Neural Network.

1. Introduction

In this project, variational autoencoder was used to generate adversarial network for the preprocessing of lung CT images and biochemical data. Considering the diversity and complexity of data, this technology realizes accurate feature extraction and representation learning of data through deep learning algorithm. Through this method, not only can the underlying characteristics and internal structure of the data be captured and retained while reducing the data dimension, but also the ability to generate models to produce additional data samples, thus significantly enhancing the diversity and integrity of the data set, and effectively addressing the challenge of data scarcity or imbalance. Further, at the end of the preprocessing process, the reconstruction error of the model is used to identify and correct data outliers or errors, so as to improve the quality of the data set and the accuracy of the analysis. Not only the pre-processing of lung CT images and biochemical data was systematically optimized, but also a more accurate and reliable data was constructed for pneumonia diagnosis and related studies based on these data.

The project also considered the patient's biochemical markers, such as white blood cell count and C-reactive protein (CRP), which directly reflect the patient's body inflammation status. These biochemical indicators are integrated into the neural network model, allowing for a deeper analysis of the patient's overall health. By fusing the visual features of lung CT with the numerical features of biochemical indicators, a comprehensive feature representation including imaging and biochemical

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characteristics was constructed. This multimodal fusion method provides comprehensive and accurate decision support for the diagnosis of mycoplasma pneumonia.

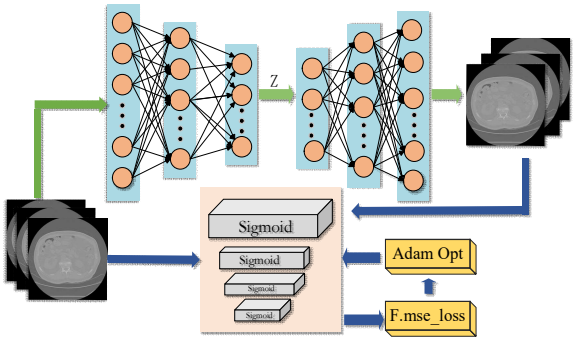

Figure 1. Flowchart of VESPA-GAN

2. Research Technology Route

Multi-modal data refers to the data of two or more different forms of representation or source channels. This project intends to build a new type of intelligent diagnosis system for pneumonia through the joint embedding of two different modal data of lung CT and biochemical indicators during the treatment of mycoplasma pneumonia, so as to provide help for the rapid diagnosis of actual mycoplasma pneumonia. Specific data forms are as follows: (1) Medical diagnosis provides an important visual basis. In this study, CT image data of pneumonia patients were collected as structured data such as mmHg) BP, white blood cell count, neutrophil, lymphocyte, erythrocyte sedimentation rate, etc. (2) In the treatment and diagnosis of mycoplasma pneumonia, the acquisition of CT images is usually an indispensable part, which provides an important visual basis for medical diagnosis. In this study, CT image data of patients with pneumonia were collected as the image data source of this study.

A hypergraph is a generalization and extension of a traditional graph (a graph with only two nodes per edge). In a hypergraph, an edge can contain any number of vertices. Therefore, a hyperedge is a simple closed curve containing all vertices in the hyperedge. Compared with traditional graphs, hypergraphs have the ability to describe complex relationships of multiple high orders. It studies how to fine-tune hypergraph structures and dynamically learn higher-order relationships. It can be regarded as finding the best hypergraph structure in the hypergraph space, as shown in Figure 3.

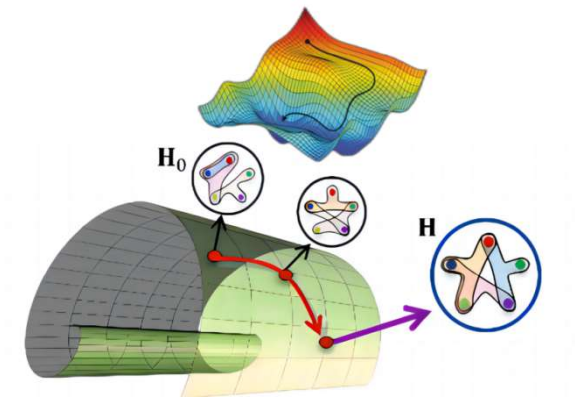

Figure 2. Hypergraph construction

The development of deep learning in computer vision has led to advances in models such as convolutional neural networks (CNNS) and vision transformers (Vits), which represent images as

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regular grids of pixels or sequences of patches. Drawing on ViT's strategy of dividing images into small patches, visual graph neural networks (ViG) treat each patch as a node and establish connections with neighboring nodes to form an adaptable graph structure. However, these methods still have limitations in the efficiency of processing complex connections in images.

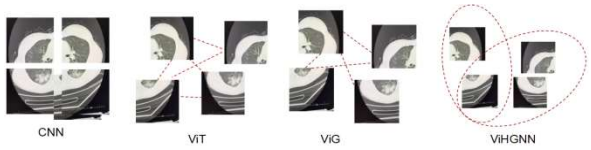

Figure 3. Visual capture

The software design architecture of the pneumonia intelligent diagnosis system covers front end, service layer, application layer, data layer and support layer, aiming to achieve high availability, scalability and security. The front-end includes WEB, mobile applications, and third-party apis; the service layer handles REST and JSON requests; the application layer includes internal and external services; the data layer includes message queues, caches, databases, and monitoring systems; and the support layer provides infrastructure support. The overall design provides reliable technical support for intelligent diagnosis of pneumonia.

Intelligent pneumonia diagnosis platform interface integrates multiple data to support immediate clinical decision making. Key features include a diagnostic dashboard that displays real-time statistics and trend data on pneumonia; It also provides patient data visualization tools, such as chest X-rays and CT scans, to help doctors quickly acquire and analyze the affected lung area. The platform also contains statistical and analytical tools to support in-depth analysis of health trends and disease predictions, which provides healthcare professionals with powerful data support for pneumonia treatment and management.

3. Specific Goal

(1) Data preprocessing

Develop and implement a data preprocessing strategy based on variational autoencoder and generative adversarial network to optimize data consistency and accuracy of lung CT images and biochemical indicators. This will cover data normalization processing, feature extraction and representation learning, and outlier detection and correction.

(2) The establishment of hypergraph model

Using hypergraph theory, a complex model is constructed to describe and analyze multivariate and higher-order relationships between lung CT images and biochemical data. This includes the definition of nodes, the construction of hyperedges, and the synthesis of interactions between multiple data sources.

(3) Implementation of multi-modal visual hypergraph neural network

By integrating hypergraph theory and deep neural network, an efficient multi-modal vision hypergraph neural network model is created to improve the accuracy and efficiency of pneumonia diagnosis. The model will focus on early diagnosis of pneumonia and prediction of severity using CT imaging and blood biomarker data.

(4) The establishment of intelligent diagnosis systemBy integrating hyper

Combining the existing diagnostic tools and data platform, a complete intelligent diagnosis system for children with mycoplasma pneumonia was established. The system can quickly and accurately provide the analysis of pathogenic pathogens and the prediction of the development trend of pneumonia.

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4. Goal Meaning

The traditional diagnosis of pneumonia often has misdiagnosis and missed diagnosis in the face of complex diseases. By using multi-modal visual hypergraph neural network and integrating lung CT images with blood biomarkers, we can significantly improve the diagnostic accuracy and efficiency, and thus improve the quality of clinical diagnosis. This technique is particularly critical in the accurate diagnosis of mycoplasma pneumoniae pneumonia (MPP), especially in the face of the problem of resistance due to the widespread use of macrolide antibiotics. The growth of drug resistance has made macrolide resistant Mycoplasma pneumoniae (MRMP) a global public health threat. By improving diagnostic accuracy, we can accurately identify MPP cases that require antibiotics, rationally guide medication, avoid unnecessary antibiotic use, and slow down the development of resistance. This is not only an effective strategy to address the challenge of antibiotic resistance, but also a significant improvement in global public health.

In the clinical diagnosis of mycoplasma pneumonia (MPP) in children, a comprehensive method of laboratory microbiology, serology and imaging is often used. AD hoc MP cultures are often considered the "gold standard" for diagnosis. However, MP culture requires specific environmental conditions and a long growth cycle of mycoplasma, making it impractical for clinical use. Although the MP rapid test suite supports rapid qualitative diagnosis, its sensitivity and specificity are limited, with a positive detection rate of approximately 60%. The use of intelligent diagnostic systems can quickly provide doctors with critical information to help accurately assess the condition, thereby improving the speed and accuracy of diagnosis.

In the current global public health context, especially in the face of challenges such as the COVID-19 pandemic, the need for diagnosis and treatment of lung diseases is even more prominent and critical. Mycoplasma pneumonia is a widespread infectious pneumonia in children and adults, and the timeliness and accuracy of its detection are very important for the effectiveness of treatment and disease control. This project focuses on improving the detection of mycoplasma pneumonia, which not only overcomes the slow detection of current diagnostic methods, but also significantly improves the timeliness and accuracy of treatment.

5. Feasibility

In recent years, the frequent global outbreaks of COVID-19 and other respiratory diseases have seriously threatened the life safety and health of people around the world. China has increased investment and resource allocation for the prevention and control of pneumonia and similar infectious diseases to ensure national health and public health safety. Given this background, this study demonstrates its social value and practical importance in response to the specific needs of epidemic prevention and control. As a key supplement and optimization to the existing medical prevention and treatment system, this study can not only improve the rapid response ability and treatment efficiency of the epidemic by developing targeted technologies and implementing specific strategies, but also contribute to the effective allocation and utilization of medical resources, thus enhancing the overall function of the national public health emergency management system. It shows its key role and feasibility in public health crisis response and management.

6. Analysis of Research Status at Home and Abroad

Since the 1990s, hypergraph theory has made remarkable progress in the world. In China, Professor Li Dong has developed a hypergraph-based social network link prediction that can fully capture all types of objects in the network and the pairs or higher-order relationships between these objects[1]. In addition, Professor Sun Ziyou of Jinan University has conducted a pioneering study on disease prediction model based on hypergraph neural network[2]. At the international level, Mulas Raffaella of the Institute of Life Sciences at the University of Southampton, UK, has applied hypergraph models to conduct in-depth studies of genetic expression networks in organisms [3].

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In addition, Prof. Filatovas Ernestas of Vilnius University in Lithuania has proposed a set of improvements to implement quantum blockchain protocols based on hypergraphs, reducing the resources and operations required and increasing noise tolerance [4]. Since the early 2000s, multimodal theory has shown wide application prospects in both academia and industry. In Finland, Professor Le Ngu Nguyen and his team at the University of Oulu carried out pioneering research on multimodal indoor human monitoring systems [5]. The technology they developed comprehensively analyzes user and environmental data through multiple sensor inputs such as cameras, radio equipment and inertial measurement units, greatly improving the accuracy and reliability of indoor monitoring. In the United States, Professor Elazer Edelman and his team at the Massachusetts Institute of Technology have carried out pioneering research on multimodal genotype-phenotype dynamic mapping [6]. Professor Yue Minlu and Professor Jiang Guiyan of Peking University used multimodal ultrasound to dynamically evaluate the efficacy of neoadjuvant chemotherapy for breast cancer[7].

Professor Shao Wenwen of Jiangsu University developed the application of visual hypergraph neural network in the visual system of crop disease recognition. Through dynamic hypergraph reconstruction layer, the hypergraph structure is dynamically updated for each layer, and local and overall correlation is extracted to improve the fusion effect of the two modes, so as to obtain better classification effect [8]. Professor Song Yanpeng of Beijing University of Posts and Telecommunications proposed a user multi-behavior self-supervised recommendation algorithm model based on attention mechanism. This model is based on the network structure of hypergraph, integrates hypergraph attention and self-supervised learning, and makes the model pay attention to the beneficial behavioral semantic information in the hyperedge [9]. Internationally, Professor Jose Perez Cano of the Political University of Catalonia in Barcelona, Spain, has used visual hypergraph neural networks to explore in depth the classification of nuclei in lung tissue, which can increase the field of view with low computational requirements [10]. Across the globe, multiple research teams are using artificial intelligence to conduct intelligent diagnostic research for pneumonia. In the United States, Pranav Rajpurkar's team at Stanford University developed an intelligent diagnostic system known as CheXNeXt, which detects and diagnoses pneumonia by analyzing X-ray images through deep learning models, and the technical level has been equivalent to that of radiologists [11] Professor Jia Nan of Inner Mongolia University of Science and Technology and his team developed a COVID-19 intelligent diagnosis system based on deep learning, which can well assist doctors in the diagnosis of COVID-19 based on chest X-ray and improve the diagnosis accuracy and efficiency [12]. Yadav Sapna of India has developed an AI tool that can diagnose lung abnormalities caused by infectious diseases such as COVID-19, pneumonia, or tuberculosis [13].

7. Conclusion

The method adopted by the research project is to establish an intelligent diagnosis system for pneumonia through multi-modal data fusion, hypergraph learning and other algorithms on the diagnosis of pneumonia based on the existing research results of the instructor and professional knowledge in the medical field.

Table 1. Effect of privacy parameters on the model

Privacy parameters	Accuracy (%)	Privacy risk
0.3	78.5	Lower
0.6	81.2	Moderate
0.9	83.8	Moderately high
1.2	85.5	High
1.5	87.0	Higher

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