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THE INTERNET OF THINGS NETWORK FOR THE DIAGNOSIS OF HUMAN LUNG DISEASE BY VOICE ANALYSIS

Abstract
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INTRODUCTION

Diagnosis of human lung diseases through breath sound analysis is an emerging research field that uses acoustic features and pathological information in breath sounds to assist in the diagnosis of lung diseases. The main steps of this technology include breath sound acquisition, feature extraction, and model classification. In this project, the analysis of breath sound changes is used to diagnose a variety of lung diseases, including asthma, chronic obstructive pulmonary disease (COPD), and lung cancer. This project uses machine learning and neural network algorithms to analyze and diagnose patients' breath sounds to analyze breath sound samples and determine the relationship with specific lung diseases.

The aim of this work is sound data collection, sound feature extraction and extracted sound data analysis for the sound diagnosis system. The focus is on solving key technical problems such as sound feature extraction and analysis. At present, this technology is being developed and improved, and is expected to become a fast and non-invasive method for diagnosing lung diseases, providing better medical services for patients.

To achieve this goal, the following tasks were solved in the paper:

1 Establish a respiratory sound database containing a variety of lung diseases, collect patients' respiratory sound samples, compare, classify and record them, and provide basic data for subsequent research and analysis.

2 Extract the MFCC (Mel-frequency cepstral coefficient) features of respiratory sound data for subsequent model training and lung disease prediction.

3 Use deep learning and convolutional neural networks to train the preprocessed respiratory sound data to generate a model that can predict lung diseases and improve the accuracy and generalization of diagnosis.

4 Establish a lung disease diagnosis system based on the Internet of Things, collect and transmit patients' respiratory sound data in real time, and use the trained model for analysis and diagnosis, provide doctors and patients with health status feedback and warnings, and improve the diagnosis and treatment effects.

In general, the research in this paper aims to improve the diagnosis level and treatment effect of lung diseases by establishing a respiratory sound database, feature extraction, deep learning model training, and develop a lung disease diagnosis system based on the Internet of Things.

GENRAL DESCRIPTION OF WORK

Relevance of the subject

The work corresponds to paragraph 1 « *Digital information and communication and interdisciplinary technologies, production based on them* » of the State Program of innovative development of the Republic of Belarus for 2021–2025. The work was carried out in the educational institution Belarusian State University of Informatics and Radioelectronics.

The aim and tasks of the work

Human breath sounds play an important role in the diagnosis of lung diseases. Different pathological characteristics of lung diseases have different breath sound characteristics. These lung diseases can be effectively identified and diagnosed through auscultation, but this requires a professional. It should only be performed by an experienced doctor. However, in some areas with limited medical conditions, the lack of professional doctors and medical resources prevents many patients with lung diseases from receiving effective treatment. In order to solve this problem, an intelligent system for automatically diagnosing lung diseases is needed to alleviate the pressure of insufficient medical resources in some areas. With the development of IoT and artificial intelligence technology in the medical field, with the help of the IoT network, an IoT platform based on deep learning and neural networks can be built to build breath sound data by recording and classifying the breath sounds of patients with lung diseases. These breath sound data are then used to train deep neural network models to accurately diagnose lung diseases.

To achieve this aim, the following tasks were solved in the dissertation:

1 Establish a breath sound database of different lung diseases. In order to deeply understand and diagnose lung diseases, it is necessary to establish a breath sound database containing a variety of different lung diseases. This database will collect breath sound samples from patients and compare these samples. Classify and record for subsequent research and analysis. Through this database, a large amount of breath sound data can be accumulated, providing valuable resources for the research and diagnosis of lung diseases.

2 Extract MFCC (Mel Cepstrum Coefficient) features corresponding to different lung diseases. For the preprocessed breath sound data, use MFCC to extract features. MFCC is a feature representation method commonly used in speech and audio processing, which can effectively capture the spectral characteristics of sound. By applying the MFCC algorithm to breath sound data, it can be converted into a set of representative feature vectors for subsequent model training and lung disease prediction.

3 Use deep learning and neural network tools CNN (Convolutional Neural Network) to train the preprocessed breath sound data and generate a model that can predict lung diseases. After obtaining the preprocessed MFCC features, use the convolutional neural network to train the breath sound data. Conduct training. By associating the extracted MFCC features with corresponding lung disease labels, a model capable of predicting lung diseases based on breath sound features is trained. This model will have high accuracy and generalization capabilities and can be used to predict and diagnose different lung diseases.

4 Establish an Internet of Things network to diagnose lung diseases and develop a corresponding disease diagnosis system. In order to achieve rapid diagnosis and remote monitoring of lung diseases, it is necessary to establish an Internet of Things network and develop a corresponding disease diagnosis system. By connecting the patient's breath sound collection device to the Internet, the system can collect and transmit the patient's breath sound data in real time. These data can be analyzed and diagnosed through previously trained lung disease prediction models, thereby providing timely health status feedback and early warning to doctors and patients. Such IoT networks and disease diagnosis systems will greatly improve the diagnostic accuracy and treatment effect of lung diseases, while providing patients with convenient and reliable medical services.

Personal contribution of the author

The content of the paper reflects the individual contributions of the authors. It includes organizing and classifying data sets, using models, conducting experiments, processing and analysing results, and formulating conclusions.

Testing and implementation of results

The main provisions and results of the dissertation work were reported and discussed at: International scientific and technical seminar "Technologies of information transmission and processing" (Minsk, April, 2024) and 60th scientific conference of graduate students, undergraduates and students (Minsk, March, 2024).

Author’s publications

According to the results of the research presented in the dissertation, 4 author’s works was published, including: 4 articles and abstracts in conference proceedings.

Structure and size of the work

The dissertation work consists of introduction, general description of the work, four chapters with conclusions for each chapter, conclusion, bibliography.

The total volume of the thesis work is 102 pages, including 90 pages of text, 40 figures, 3 tables, a list of bibliographic sources used, and a list of author's publications on the topic of the thesis.

Plagiarism

An examination of the dissertation «*The Internet of Things Network for the Diagnosis of Human Lung Disease by Voice Analysis*» by He Tao was carried out for the correctness of the use of borrowed materials using the network resource «Antiplagiat» (access address: https://antiplagiat.ru) in the online mode 22.05.2024. As a result of the verification, the correctness of the use of borrowed materials was established (the originality of the thesis is 81.27 %)

SUMMARY OF WORK

In chapter 1, an in-depth understanding of how the human respiratory system works under normal conditions is necessary to better understand lung sounds and lung diseases.

In the process of characterization and extraction of respiratory sound signal analysis and extraction, time domain analysis, frequency domain analysis, cepstrum analysis, linear prediction analysis and other methods are endless, such as the respiratory sound signal of different extraction methods shown in Figure 1.

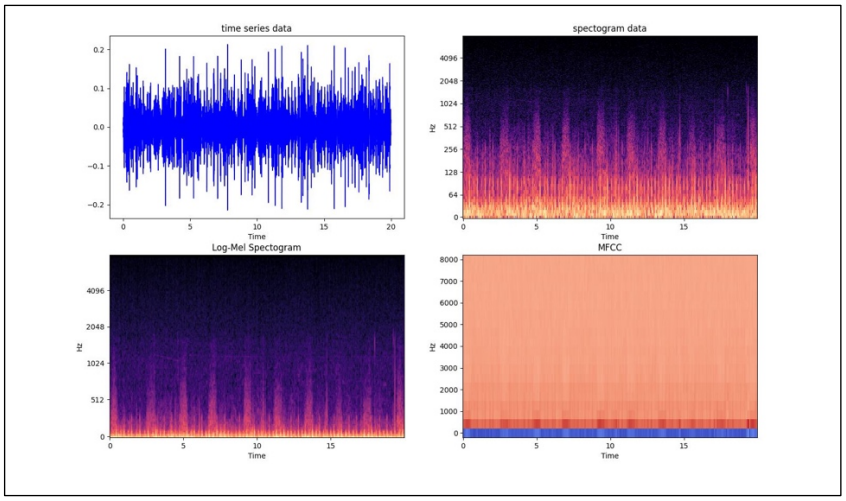

Figure 1 – Sound visualization

The chapter 2 provides several methods and IT tools for recognizing diseases through speech. And the IoMT for diagnosing lung diseases through breath sounds is a broad research area that covers many important aspects. The design process of

the IoT network application for diagnosing lung diseases through sound is as follows, and the model diagram as shown in Figure 2.

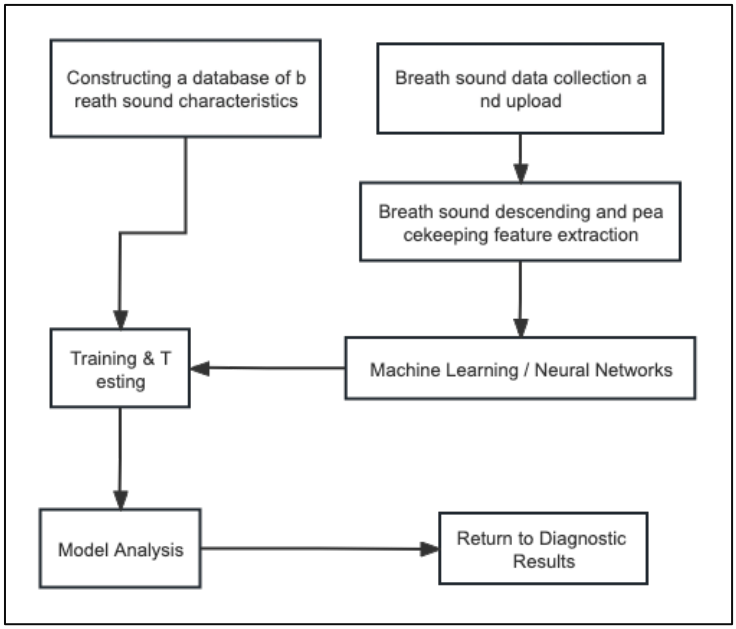

Figure 2 – Technical model design for diagnosis of lung diseases by sound

The application of CNN and VGG neural network models plays a great role in the training of diagnostic disease models, making the trained models more accurate. In addition, Internet of Medical Things (IoMT) plays an important role in the diagnosis of lung diseases. And extract the MFCC (Mel Cepstrum Coefficient) features of breath sound files corresponding to different lung diseases, as shown in Figure 3.

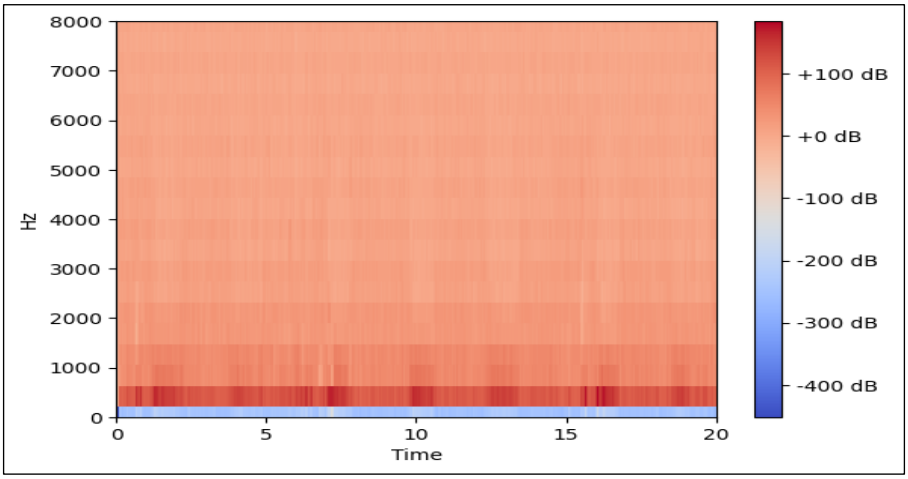

Figure 3 – Breathing sound MFCC spectrum sample

Chapter 3 details how to use deep learning methods to recognize breath sound audio and classify lung diseases, and describes the overall framework and details of the model in this article. This model mainly uses a deep learning algorithm based on VGGish and combined with CNN. In order to initially apply the trained model, this article developed the breath sound classification Android service function based on deep learning. The main purpose of this chapter is to introduce the system framework and content of Android services in detail.

CONCLUSION

Contributions and innovations of this thesis

With the development of IoT and artificial intelligence technology in the medical field, IoT networks can be used to build a platform based on deep learning and neural networks. The platform builds a breath sound data set by recording and classifying the breath sounds of patients with lung diseases, and uses these data to train a deep neural network model to achieve the purpose of accurately diagnosing lung diseases. The main contributions and innovations of the whole paper can be summarized as follows:

1 Building an integrated IoT system can improve the diagnostic efficiency of lung diseases. The system includes components such as wearable sensor devices, cloud data centers, and medical management platforms [1–A].

2 In order to initially apply the trained model, an Android-based APP service function was developed, which allows users to upload respiratory sound audio data to the backend server for diagnosis and returns the diagnosis results [2–A].

3 This experiment uses the ICBHI respiratory sound dataset for training. First, the respiratory sound features are extracted and optimized. After denoising, the MFCC spectrogram is used to image the respiratory sound, and the convolutional neural network (CNN) model is used [3–A].

4 Using Grad-CAM technology, the key areas of the model are superimposed on the original image in the form of class activation maps, which helps to further analyze the key image features that affect the diagnosis and optimize and improve the diagnostic model [4–A].

Further research work

In order to improve the accuracy, comprehensiveness and convenience of lung disease diagnosis through breath sounds, the following issues need to be further studied:

1 Expand the data set. The current respiratory sound data set may not be large enough, and the data set can be further expanded, including collecting data from more types of lung disease patients and healthy individuals.

2 Deepen feature extraction and optimization. Respiratory sound feature extraction is a key step in establishing a diagnostic model, and the respiratory sound feature extraction and optimization methods can be further studied and improved.

3 Optimize mobile applications. The Android-based APP service functions can be further optimized to improve user experience and data upload efficiency. Encryption, permission control and other measures can be taken to protect users' personal data and privacy security.

LIST OF AUTHOR'S PUBLICATIONS

1–A Vishnyakou, U. A. Structure and components of internet of things network for it patient diagnostics / U. A. Vishnyakou, H. Tao, Z. Yian, W. Haoran // Технологии передачи и обработки информации: материалы Международного научно-технического семинара, Минск, март-апрель 2023 г. / Белорусский государственный университет информатики и радиоэлектроники; редкол.: В. Ю. Цветков [и др.]. – Минск, 2023. – С. 61–64.

2–А Вишняков, В. А. ИТ-диагностика заболеваний легких с помощью голосового анализа в сети интернет вещей / В. А. Вишняков, Х.Тэо / Современные средства связи : материалы XXVIII Международной научно-технической конференции, Минск, 26-27 октября 2023 г. / Белорусская государственная академия связи ; редкол.: А.О. Зеневич [и др.]. – Минск, 2023. – С. 36–37.

3–А Вишняков, В. А. Сверточная нейронная сеть для ИТ-диагностики легких = Convolutional neural network for IT lung diagnostics / В. А. Вишняков, Т. Хэ // Системный анализ и прикладная информатика. – 2024. – № 1. – С. 59-64.

4–А Tao, H. Crad-Cam visualization model for lung disease diagnosis / H. Tao // 60-я научная конференция аспирантов, магистрантов и студентов, Минск, 11-15 марта 2024 года / Белорусский государственный университет информатики и радиоэлектроники; – Минск, 2024.