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Mobile IT-diagnostic system for Alzheimer's disease recognition

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Abstract
The article presents the structure of an IoT-based mobile system for the IT-diagnosis of Alzheimer's Disease (AD), including mobile applications, server management, algorithms development, and data protection. The authors conducted analytical and predictive work on the mobile diagnosis of Alzheimer's disease based on decoded text-based speech data from patients using machine learning algorithms and a neural network. The data used in the article was taken from the Address 2020 Challenge kit, which contains speech data from patients with Alzheimer's disease and healthy people. The system combines the technologies of IoT, machine learning and blockchain, supporting early detection of AD and its continuous monitoring. The mobile application module performs voice data recording patients, preprocessing, and predictive analysis by contacting the server via requests. The data management and preprocessing module structures the input data by converting the raw voice data into JSON format for server-side analysis via the Flask backend, with additional integration of the EMQX broker for real-time data distribution. In the algorithms and analysis module (on the server), text features are highlighted and classification algorithms are used to obtain probabilistic predictions for patients with Alzheimer's disease. Users receive diagnostic feedback in real time through the results visualization module, which can transmit diagnostic results to medical professionals. The system's security and privacy module uses IPFS-based decentralized storage and blockchain-driven access control to ensure data integrity and support authorized data retrieval.

I. INTRODUCTION

Alzheimer's disease (AD) is an almost incurable disease that affects the brain of older people, making their lives uncomfortable and subsequently difficult [1]. Early diagnosis makes it possible to prolong the life of such patients, as it allows timely recognition of this progressive disease and improves the quality of life of patients and loved ones caring for patients. Common screening tools include the Mini-Mental State Examination (MMSE) and the Montreal Cognitive Assessment (MoCA). Well-known diagnostic methods such as magnetic resonance imaging and neuropsychological examination are fraught with difficulties, they are not only expensive and time-consuming, but also require visits to specialized medical institutions that may not be accessible to residents in remote areas. But with the development of mobile technologies and Internet of Things, a good information base has emerged to solve these problems [2]. The use of smartphones with their powerful computing capabilities, large internal and external memory, and built-in sensors in integration with local or cloud servers creates the basis for building efficient, scalable mobile systems for continuous patient health monitoring, IT-diagnostics, and IT-therapy. Mobile applications can provide real-time data collection and analysis, providing information about the physical and mental health of patients. To do this, you can use the patient's sound information, extract speech patterns and other markers from it [3].

THE CONCEPT OF RECOGNITION OF AD

[4]. Machine learning, neural network, and Internet of Things were used to identify patients with AD. The classifier, which is part of the IT -diagnostic system, was trained based on the data set of patients with already diagnosed AD,

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and later it was used for the examined patients to divide them into healthy participants and those with Alzheimer's disease. The patients entered a voice description of the picture, which was converted into text. Then the natural language text processing method TfidfVectorizer was used [5]. The system uses a classifier trained on the basis of random forests. The GridSearchCV cross-validation algorithm was used to select the best hyper parameters from the patient's speech.The data for the study was taken from the ADReSS 2020 challenge set [6]. This dataset consists of two parts, a training and a test, and contains 1955 speech fragments from 78 non-patient participants and 2122 speech segments from 78 participants with AD.

For each speech information, the recordings were acoustically amplified using a fixed noise level. The experiment used only a training dataset containing information from 54 patients with AD and 54 participants in the control group. At the same time, the subject's narrative speech was identified using the task of describing a picture from the Boston study [7]. According to the procedure, the interviewer showed the participants a picture and asked them to describe it. The available data contained complete improved and normalized audio blocks. In the experiment, only the decrypted text corresponding to the complete augmented audio recording was used. The decrypted text was provided with a set of data that was annotated using the chat encoding system [8].

For an effective and comprehensive assessment of the proposed model, three resampling methods were applied: K-Fold cross-sampling (K-Fold CV), LOSO CV cross-validation, and Bootstrap Sampling. The expanded recognition algorithm for patients with AD included steps.

1. The transformation of the subject's speech data into text for the process of their preliminary processing. Speech features were extracted from voice data, and semantic features were extracted from text data.

2. Three types of features were extracted: temporal (average, minimum, maximum, and meridian time of utterance of a sentence), demographic (gender, age), and semantic (transcripts transmitted to TfidfVectorizer after extracting objects).

3. The using TfidfVectorizer is an open source method for processing text in natural language [9], the central part of which is the TF–IDF (Term frequency – the inverse frequency of the document) algorithm, a common weighting method for information retrieval and data mining. TfidfVectorizer uses the inverse domain frequency (IDF) and term frequency (TF) of words to calculate their corresponding values of the inverse domain frequency (TF-IDF).

4. Input of all the features into a pre-trained neural network (random forest classifier) for their recognition, which determines with probability whether the tested participant has or does not have Alzheimer's disease.

II. AD RECOGNITION RESULTS [4]

During the research, at each iteration of the bootstrap sample, one model was created, which was tested based on the test data from this sample. The accuracy was obtained for 5 samples, the final result of the accuracy is their average value. The result for comparison was obtained using the LDA (Latent Dirichlet allocation) classifier with linguistic features during LOSO cross-validation for the AD classification task (77%) [6]. The best author's recognition result was obtained using the Random forest classifier and K-fold cross-sampling, which amounted to 87.6%.

An effective mobile IT-diagnostic system for patients with AD includes five main modules: mobile applications, data management and preprocessing, a server, visualization of results and reporting, security and confidentiality. The mobile application module functions as the main interface, providing user interaction, performing data collection and predictive analysis to detect Alzheimer's disease. The module is implemented with a user-friendly interface and performs three main functions: voice recording, speech-to-text conversion, and predictive analysis. This module used the "OkHttpClient" function for HTTP communication, ensuring reliable data transfer between the mobile application and the server. The POST request function transmits the preprocessed data in JSON format to the server (`http://192.168.100.14:5000/predict `). After successful server processing, the response is analyzed to extract the prediction results.

III. THE DIAGNOSTIC PROCESS

The studied patients perform the data collection process by recording their voice using the Record Voice function. The received sounds of the patient's speech serve as initial data for subsequent preprocessing and predictive analysis, recording the cognitive and linguistic features of the patient's voice that indicate Alzheimer's disease. After recording the audio of the patient's voice, the Speech to Text function is performed, which performs preliminary data processing, converting speech into text format. This step is an important preprocessing step where linguistic characteristics are extracted from text data. The Predict function uploads the preprocessed patient data to a local server using an HTTP POST request. The server, which includes a trained neural network, processes the input data and generates a

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probabilistic forecast regarding the patient's Alzheimer's disease. The data management and preprocessing module is a component of the Alzheimer's disease diagnosis system in an IT system (based on the Internet of Things). It provides data processing through integrated dual functionality: client-side preprocessing and server-side analysis. The module starts by collecting speech data from diagnosed patients on a client device (smartphone). The received speech data, saved as .csv format files, is preprocessed on the client side. To ensure efficient and structured communication, the mobile client sends preprocessed data to the internal server via an HTTP POST request. On the server, the Flask platform is a component for data processing. After receiving the processed data in JSON format, the server converts it into a structured Pandas frame. This processed data is then transferred to a trained classifier (based on a neural network) for analysis and diagnosis. The prediction results generated by the server are formatted into a JSON object and sent back to the client via an HTTP response. The described real-time feedback loop allows you to display the results directly in the client interface, providing ease of use for both practitioners and patients. To expand the system's capabilities, the module can integrate an EMQX broker (an MQTT broker that can subscribe to a stream of events from an external source) to distribute data [9].

The structure of the Internet of Things network used for IT-diagnostics of AD is shown in Figure 1. The algorithms and analysis module on the server, which provides diagnostic capabilities of the system, is designed to classify participants in both AD patients and healthy people based on their speech transcription data. For each participant, the speech texts are combined into one line and formed into a Pandas data frame. A column with markers has been added to distinguish the participants of the control group from patients with AD. The transcription data is converted into numerical characteristics using the TFIDF vectorizer, which calculates the values that are the inverse of the frequency of use of term in the document [4].

The classifier using the ML random forest algorithm is the main component for solving the classification problem. Its effectiveness depends on the total size of the dataset. For small neural network datasets, it may take more training iterations to achieve convergence. The results visualization and reporting module provides real-time feedback to users, which allows the system to monitor and follow up. The module allows healthcare professionals to remotely access patient data and prescribe and adjust a treatment plan. Users can view the results of their IT diagnostics through the smartphone app. The results can be transmitted via the MQTT protocol to authorized parties such as clinics or healthcare providers.

IV. DATA SECURITY

The security and privacy module, which is a component of the IoT system for IT diagnostics, is designed to ensure compliance with the requirements of the legislation on medical data (HIPAA and GDPR). This module uses encryption and decentralized storage mechanisms to protect confidential medical data of patients with AD. The module includes a private Ethereum blockchain network and a decentralized IPFS database.

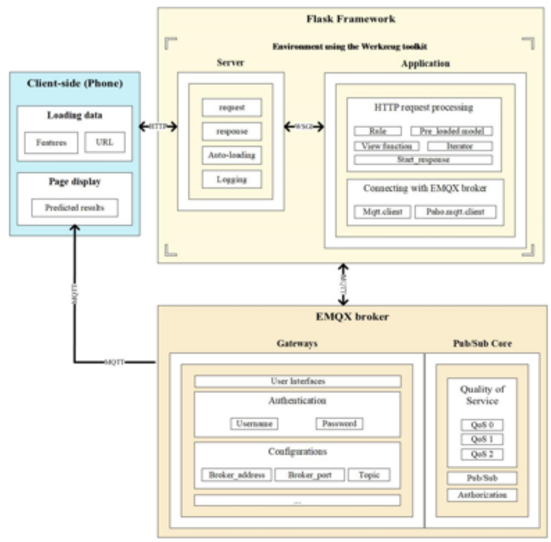

Fig. 1. The structure of IoT network for the diagnosis of Alzheimer's disease

The smart contract is designed to provide a secure structure for storing and exchanging medical information, and its composition is as follows. 1. Data Structures: store the hash value of medical records, the owner's address, and the record's availability status. Manage access rights to medical records for specific individuals (doctors, researchers); 2. Comparisons of data hashes with corresponding medical records, data hashes and individual addresses with their access rights; 3. Events for registration of medical records, granting, revocation and verification of access permissions. The integration of IPFS with the Ethereum blockchain technology supports big data storage, offering a secure, efficient solution suitable for patient data management [10].

The module workflow proceeds as follows: when user A initiates a data publication request, the relevant information is uploaded to IPFS for cryptographic hashing, the generated unique hash value is then recorded on the blockchain. Authorized users (e.g., user B or C) can submit access requests through a smart contract, which automatically ex-

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ecute predefined permission control protocols. The system issues access credentials to validated requests, if a request is determined to be unauthorized by the system, it is then automatically rejected through contract-enforced procedures. All patient records are encrypted before upload and are distributed across IPFS nodes via shared storage. Each dataset's blockchain-anchored hash value serves as its tamper-proof unique identifier. The module can be complemented with additional features such as using prediction results to determine if a carer is required and to develop an appropriate care plan.

V. CONCLUSION

The IT-diagnostic system for the recognition of Alzheimer's disease is presented using the publicly available dataset (Address 2020 Challenge kit), which contains speech data from patients with Alzheimer's disease and healthy people. The system includes the trained neural network (classifier) based on a subset of data from patients with detected AD. This classifier is later used to diagnose other patients. The results showed that the experimental accuracy was 87.6%, exceeding the baseline level obtained in [6], which means that the experiments yielded promising results. An integrated approach used in the development of a mobile IT diagnostic system for the diagnosis of Alzheimer's disease is described: the creation of mobile applications, server management, the development of a classifier and ensuring the security of medical patient data.

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