Designing an IoT Network for the Diagnosis of Alzheimer's Disease Using OSTIS

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***Abstract*—The report is devoted to the development of the Internet of Things for the diagnosis of Alzheimer's disease (AD) using OSTIS technology. The structure of the ontology for describing the elements of AD disease is given. The article considers the construction of an IT diagnostic network of BA, which uses the semantic capabilities of the OSTIS platform for processing and analyzing medical data. The elements of describing the knowledge base, solvers and user interfaces using a component-based design approach are presented.**

***Keywords*—IoT network, Alzheimer's disease, user interface, IT diagnosis, ostis**

I. Introduction

In the contemporary era, marked by the advent of information technology, the progression of technological and scientific theories has led to the digitization and informatization of traditional medicine [1]. Smart hospitals, relying on an environment founded upon information and communication technologies, especially those optimized and automated by the Internet of Things (IoT) [2], have enhanced the efficiency and reliability of IT systems. IT diagnostics refers to the process of using information technology (IT) tools for diagnosing, analyzing, and solving technical issues. In the medical field, it involves the use of information technology, such as artificial intelligence, machine learning, and data analysis, to aid in medical diagnosis. This technology has the potential to improve the quality and safety of healthcare services [3]. Given that each disease requires a complex medical process, the IoT infrastructure must adhere to the medical rules and steps involved in the diagnostic process to meet the requirements of healthcare providers [4].

An IT network for intelligent detection of Alzheimer's disease can be defined as a comprehensive information technology system that integrates the collection, processing, pattern recognition, and interactive user interfaces of medical health data. This data may involve a variety of multimodal data, such as human behavior data, brain imaging data, or sound audio data, etc., providing support in the process of identifying and predicting signs of Alzheimer's disease, with system tasks that can be broken down into:

1) System Analysis and Simulation Task: The intelligent detection system for Alzheimer's disease analyzes data from diverse sources to build IT network, aiming to identify characteristics unique to Alzheimer's patients.
2) Prediction Task: By using information extracted from features, it effectively distinguishes between Alzheimer's patients and healthy control groups, achieving early detection or prediction of disease progression
3) Management Task: Management of patient data in the Alzheimer's detection system involves ensuring the privacy and security of the data while providing necessary data to doctors and researchers to support the decision-making process

The purpose of this paper is to introduce an approach that integrates IT diagnostic networks with OSTIS technology. The objective of this work is to enhance data interpretation capabilities and apply the principles of intelligent disease detection. Through a highly structured and semantic approach, this method aims to improve information processing, knowledge representation, and intelligent decision-making capabilities, enabling the model to be seamlessly optimized and utilized across various scenarios.

II. The ontology

OSTIS (Open Semantic Technology for Intelligent Systems) is closely related to ontology as a framework

aimed at developing and implementing intelligent systems.The use of semantic technologies and ontology advocated by it finds application in IoT networks.
The ontology of the knowledge base of the intelligent Alzheimer's detection system can be subdivided into:

1) Theoretical concepts of Alzheimer's recognition

2) Applications of Alzheimer's recognition theory

To achieve interoperability between intelligent systems, it is necessary to develop an ontology for the theoretical concepts of Alzheimer's recognition. This ontology will cover the framework and basic theoretical foundation of Alzheimer's recognition, defining a hierarchical system 243 to build the foundation for IT networks for Alzheimer's recognition, enabling these knowledge to be efficiently shared, understood, and utilized in IT networks.

Alzheimer's Recognition Theory Concept Ontology

:= [A collection of theoretical concepts of Alzheimer's recognition.]
:= [Instances of theoretical objects in the subject area of "Alzheimer's recognition" include key concepts and their relationships.]
⊂ Ontology
∋ Specialized Terminology Categories for Alzheimer's Disease
∋ Data Form Categories for Alzheimer's Disease
∋ Feature Extraction Categories for Alzheimer's Disease
∋ Diagnostic Method Categories for Alzheimer's Disease

Specialized Terminology Categories for Alzheimer's Disease

:= [Describes specialized terminology related to Alzheimer's, from the domain perspective, including corresponding medical terms and technical synonyms, defining the basic concepts, symptoms, and progression stages of the disease.]
:= [The pathological phenomenon existing in the human brain in the form of a neurodegenerative disease, whose origins can be genetic, environmental factors, or an interaction of both. At a given time point, the pathological state is determined through clinical assessment and biomarker testing, characterized by cognitive dysfunction, memory decline, executive function impairment, and language difficulties. Specialized terminology for Alzheimer's not only describes the clinical manifestations and neuropathological features but also includes concepts related to disease diagnosis and recognition process.]
∋ Disease Process

The disease process, referring to the entire process of disease development and its impact on an individual's health status, starting from its initial factors, including the mechanisms of disease onset, development stages, symptoms produced, and the final outcome (recovery, persistence, or deterioration). To describe and understand the disease process and its manifestations in different contexts, here is a hierarchical structure description of subcategories classified by different dimensions or properties for the disease [5].

Classified disease-relevant process by properties

⇒ *subdividing*∗ :

- disease-relevant process by Frequency

:= [The frequency or commonness of the disease process.
⇒ includes*:
  - commonly frequent disease-relevant process
  - frequent disease-relevant process
  - occasional disease-relevant process
  - very frequent disease-relevant process

- disease-relevant process by pathogenic intensity

:= [The intensity or severity of the disease process's impact on individual health.
⇒ includes*:
  - highly impacting disease-relevant process
  - lowly impacting disease-relevant process
  - mildly impacting disease-relevant process

- disease-relevant process by specificity

:= [The degree of association of the disease process with specific diseases, conditions or factors.]
⇒ includes*:
  - Alzheimer Disease disease-relevant process
  - Alzheimer Disease type disease-relevant process
  - individual disease-relevant process
  - life disease-relevant process
  - lifestyle disease-relevant process
  - neurodegenerative disease disease-relevant process
  - pathogenic disease-relevant process

In this way, the disease process is organized into different subcategories, each defined by a shared set of properties. Based on this structure, the following subcategory "identified disease-relevant process" supplements specific content and examples, including processes that have been confirmed in disease research to have a specific impact or role.

Identified disease-relevant process

⇒ includes*:

- environmental disease-relevant process
- gene-related disease-relevant process
- molecular disease-relevant process
- other disease-relevant process
- pathological disease-relevant process
- physiological disease-relevant process

III. IT diagnostics network structure

When adopting IT diagnostics for the intelligent identification of neurological diseases, it is necessary to construct an IoT network structure tailored to the specific neurological condition. Based on the analysis, Alzheimer's disease is characterized by long-term progression and gradual worsening, affecting various aspects of an individual's cognitive functions, motor skills, and daily living abilities. It typically requires long-term management and treatment, and there is currently no possibility of complete cure through short-term treatment, making early stage identification and intervention particularly important.

Utilizing acoustic features for the automated detection of Alzheimer's disease is a promising research area. Broadly speaking, the application of IoT networks in IT diagnostics can be divided into three key steps: collection, processing, and analysis of sensor data. To achieve automation in detection tasks, we are developing an IoT network:

1) Sensor data collection: When users enter the client interaction page, the main page displays the required steps and instructions. Participants respond or describe based on the given questions or images, and the system collects and saves their voice data, which is then uploaded to a test library for assessment. The data can be stored locally, uploaded to the cloud, or decentralized.

2) Sensor data processing: Data processing can occur locally or on cloud servers, mainly involving data cleaning, extracting acoustic features, or preprocessing voice data.

3) Sensor data analysis: The extracted data features are sent to a previously trained model prediction agent, where machine learning algorithms deployed in the model provide analysis results. These data are then sent to servers for storage and also serve as a training set to improve the model's accuracy.

The client application displays the likelihood of a participant having Alzheimer's disease on the screen. The doctor's mobile application, on every device that has the app installed, shows real-time patient monitoring information from sensors in the cloud database. The detection results for participants are sent based on the user's registration information. The overall structure of the proposed framework is shown in Fig. 1, illustrating the network's basic structure, which consists of datasets, model prediction agents, participant data, the IoT platform, and mobile applications.

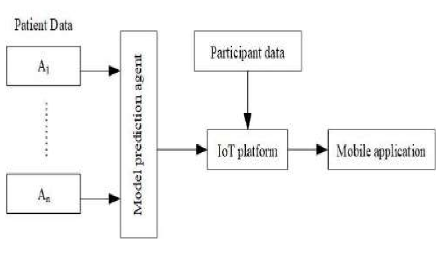

Figure 1: Overall structure of the proposed network

IV. Distinguishing Voice Characteristics of Alzheimer's Patients

Taking the application of IoT technology and voice analysis for the diagnosis of neurological diseases as an example, the human ear is incapable of perceiving variations in sound and voice rhythm. However, advancements in technology enable automatic voice analysis to identify and extract acoustic and temporal parameters [6], making voice analysis of Alzheimer's patients a focal point of scholarly research. Clinically, these patients exhibit symptoms of unclear speech characterized by slowness, fluctuation, monotony, trembling, hesitation, weakness, inability to control over-breathing, loss of voice, low melody levels, and slower rhythms [7]. In semantic tasks, patients with Alzheimer's disease also perform poorly, often confusing names or unable to accurately name objects [8]. Non-verbal indicators predictive of dementia include the continuity of speech, the duration and proportion of silent segments, pitch (periodicity) related parameters. Useful linguistic markers require automatic voice recognition for assessment, including the richness of speech and the proportion of different parts of speech [9].

Based on the aforementioned voice characteristics of Alzheimer's patients, research in [10] has demonstrated the feasibility of using machine learning methods to distinguish between the voice transcripts of Alzheimer's patients and healthy individuals by analyzing the semantic information in patients' natural language expressions. By converting voice data into text and analyzing these texts with a Random Forest classifier, researchers were able to identify specific language features associated with Alzheimer's disease.

V. Proposed approach

In the development of an IT network for Alzheimer's disease diagnosis using OSTIS, the core components involve the development of a problem solver, knowledge base, and user interface. This is due to the OSTIS system architecture, which integrates a semantic model