INTELLIGENT SEMANTIC BASED FRAMEWORK FOR PERSONALIZED REHABILITATION TO CHILDREN WITH CEREBRAL PALSY

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ABSTRACT

Cerebral palsy (CP) is one of the most common developmental disorders. Technological development has allowed the transformation of the healthcare sector to provide more preventive services. This research proposes our intelligent decision support system" KineCP" that aims to assist a recommendation system based on Hybrid model and an intelligent system in which we proposed an ontology and we applied different SWRL rules to extract the inference and recommend solutions. These rules will be inferred for suggesting appropriate recommendations to the patient. The Framework could be used to help Children with Cerebral Palsy for personalized rehabilitation. The main idea is to help those children who attack CP to practice different home exercises under the supervision of parents.

KEYWORDS

Recommendation System, Intelligent System, Ontology, SWRL Rule, Cerebral Palsy, Personalized Rehabilitation

1. INTRODUCTION

The overall prevalence of cerebral palsy (CP) has remained at 1.96 per 1000 live births in recent years (Alabdulqader 2022), despite improvements in the survival rate of low-birth-weight infants. CP is the largest diagnostic group in pediatric rehabilitation. Children with CP feel limited in their social participation, independence, and self-efficacy because they are limited in their ability to perform daily activities. It is important to detect CP early so that treatment can begin as soon as possible and be as effective as possible. Therefore, developing Artificial Intelligence (AI) methods to detect cerebral palsy could significantly improve children's lives. Recent developments have shown encouraging results for cerebral palsy diagnostic purposes. In addition, AI combined with imaging technology can measure large data sets from video footage. It also makes it easier for medical professionals to share their insights into CP-related spontaneous movements and help them diagnose patients. In recent years, Expert Systems (ES) (Algehyne 2022), Case-Based Reasoning (CBR) (Huo 2022), and Ontology have become the basic techniques used to diagnose disorders. Ontology is an important tool for modeling knowledge in various areas of medicine, including diagnosis of disability and illness. This technology allows you to implement different types of interoperability and inference processes between different types of systems.

In this paper, we explore the technologies used in disability and disease symptoms, we study some examples that use intelligent frameworks, their strengths, and weaknesses. Then, based on these weaknesses, we propose several ontological models that support a coherent design of the data set related to rehabilitation. Finally, we present an implementation of our research where we highlight how the data can be recommended to patients and provide the necessary SWRL rules to describe the formal process of the intelligent framework.

2. RELATED WORK

This section discusses the research works related to intelligent framework and to Cerebral palsy. It also discusses papers describing intelligent chatbots used in medicine.

2.1 Representative Approaches based on Intelligent Framework for Healthcare

AI techniques can support healthcare professionals in a wide range of tasks. For theses, Sermet et al. proposed the creation of an informatory assistant for COVID-19 (chatbot) based on the Centers for Disease Control and Prevention (CDC) data in order to demonstrate the framework's usage (Sermet 2021). Essa et al. Proposed an efficient IFHDS approach using encryption algorithms in a distributed aspect among different cloud platforms to improves the performance of processing health data (Essa 2019). El-Sappagh et al. asserted two mature reasoning techniques (ontology&fuzzy logic) in a novel aspect to propose a Fuzzy Decision Support System for Diabetes Diagnosis (El-Sappagh 2018).

2.2 Representative Approaches to Examine Children with Cerebral Palsy

Cerebral Palsy (CP) is a neuro developmental confusion that envelop multiple neurological disorders that appear in minority or early childhood and persist through the lifespan of the individual (Pham 2021). CP is caused by abnormal brain development or damage to the developing brain and affects the ability of a person to control muscles. Symptoms of CP vary from person to person (Cooney 2021). People with severe CP may need to use special equipment to walk, may not be able to walk at all, and may require lifelong care. People with mild CP, on the other hand, may walk a little clumsy, but may not require special assistance. The exact symptoms can change over a person's life, but CP does not worsen over time.

Vengatesh et al. proposed to construct a computer vision-based communication system to monitor the kids (Vengatesh 2020). The intelligent agent based on computer vision is created to be built with the help of an OpenCV python library using a programming language and classifiers to recognize the image. It senses the movement of the youngsters through addressing the children's needs, pain, and emotions capturing the expressions on the face, body language, and through the webcam, the children's sign language is captured. However, we observe there are few emotions to be recognized in the current system, and the system's accuracy is minimal. Gong and Wu proposed an application of human-computer interaction technology in the field of cerebral palsy rehabilitation which is a is a robot auxiliary system that is needed as the output feedback system to feedback the recognition results and realize the interaction between human and robot(Gong 2021). Bionic robot hand is a kind of robot system which can make a variety of gestures with the same motion characteristics as human hand. It mainly realizes the control purpose through the internal control chip. Although, the robot assisted cerebral palsy rehabilitation training system based on action interaction, five kinds of limb actions are designed as action training schemes by applying action recognition, and the recognition results are fed back by the bionic robot hand system. Another approach proposed by Berdina et al. was to use a robot-assisted complexes with biofeedback for locomotor training of the upper and/or lower limbs that promote verticalization and the formation of direct motor stereotypies is now used in the rehabilitation of individuals with CP (Berdina 2017). The robot provides a transparent assistance by utilizing a low inertia motor and an impedance reduction control algorithm. This makes it possible to minimize discomfort by preventing unexpected resistance to the spontaneous movement of a patient with incomplete paraplegia. We observe for this system an absence of attention to the ontogenetic brain maturation principle and the development of the motor skills, and the gradual extinction of the primitive reflexes in children, very expensive.

So, we can result that the medical sector, and especially the physical and physiotherapy sector that deals with children affected by cerebral palsy, uses artificial intelligence in its various solutions to improve their health and help them to heal. In addition, semantic web technologies are presented as a method of data analysis that automates the creation of analytical models. These technologies consist of using machine learning models to search medical data and discover information to improve health outcomes and patient experiences. But none of these approaches uses Ontologies for data description and inferences. Besides all these environments do not use more than two of the three systems (intelligent system, recommendation system and personalization system). Based on their limitations and the above synthetic, we propose to build our solution for designing an intelligent framework for CP.

2.3 Research Example for Medical Chatbot

In the table below, we focus our study on some papers, that designed medical chatbot as an important system and especially we are interested in the technology used.

Table 1. Different technologies for medical chatbot

Approaches	Technologies
Chatbot for medical treatment using NLTK Lib	Natural Language Toolkit (NLTK)
Intelligent healthbot for transforming healthcare	Natural Language Processing (NLP), ML
Conception and realization of a chatbotsystem to support psychological and medical procedures	Support Vector Machine (SVM)
A personalized medical assistant chatbot: MediBot	Recurrent Neural Network (RNN), NLP
Automated medical chatbot	NLP and Classification

3. INTELLIGENT CP SYSTEM ARCHITECTURE

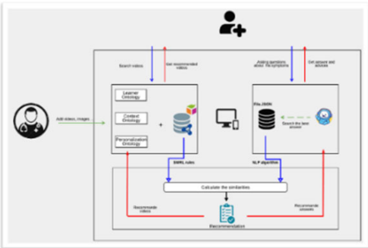

Figure 1. Proposed functional for intelligent kinecp

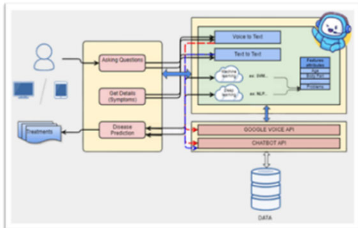

Figure 2. Hierachy of KineCP chatbot functionalities

Our CP intelligent Framework needs the services of an Apache Web server (figure 1). To do this, the client sends a SOAP request to the server in the form of an HTTPs message. The web service interprets the contents of the request and ensures that the service performs an action: Our system is composed of 3 ontologies which are: Learner ontology (contains the required knowledge about the user's preferences.), Context ontology (describe the structure of our system) and finally the Personalization ontology (present the concepts constituting medicine physical). A filter is performed via the ontologies and the representative nature of the concepts. It allows users to select the concepts presented in the ontologies and have a representativeness above a certain level. Thus, it allows the structural index to be built by associating the page in question with the ontologies concepts it contains. To obtain inference rules within the semantic web, we have used SWRL rules which are editing using the SWRLTab features. It ensures the processing of knowledge in the ontology supporting the command. The system uses a recommendation system by calculating the similarity of keywords in the data. After execution, the web service formulates a response and sends it back to the client, again using SOAP and HTTPs. The response is interpreted and the information is passed to the software where it is processed. To summarize, our system is composed of 4 main layers:

- **Presentation Layer:** provides information to users (patient and/or systems) and handles patient requests.
- **Application layer:** is responsible for executing system tasks, including authorization control.
- **Domain layer:** is accountable for mapping the problem domain.
- **Infrastructure layer:** is responsible for the technical issues supporting the other layers (i.e. messaging…)

This Framework (figure 2) helps users submit their health complaints and questions. The real purpose of the chatbot is to help people by giving them advice on how to live healthy. The way the system works is as follows:

- **Asking Questions and getting details:** It is possible to ask some health care questions and get more details about symptoms.
- **Interactive mode:** Questions are related text-to-text. It is also related to voice-to-text and text-to-voice conversations. For example, children who cannot write and send text, they can send a vocal message.
- **Google API and Chatbot API:** Using Google APIs for voice-to-text and text-to-voice conversions. The Chatbot API sends requests to chatbots, receives corresponding responses, and references those responses.
- **Disease Prediction:** Depending on the disease symptoms, the NLP algorithm can predict a disease.

4. HYBRID RECOMMENDATION ALGORITHM FOR INTELLIGENT KINECP FRAMEWORK

Matrix factorization allows the system to represent its data structure in a more concise and relevant way, in order to achieve much more competitive processing times and storage space savings. Moreover, it is used to generate an output in the form of recommendations. The scalar product of the patient matrix and the item matrix can produce a rating matrix, while the patient matrix has the form k(patient)*f(feature) and the item matrix has the form j(item)*f(feature). From patient's and item's matrices, features of the videos can be its spasticity, treatment, etc. After obtaining the best factors to approximate the ratings we have, we then perform dot product of the factor matrices to fill in the missing entries in the rating matrix. These filled in ratings are then used to provide recommendations to the users.

```
Algorithm1: Matrix factorization for recommendation
Input: R: rating matrix, P: |U|*k (user features matrix), Q:|D|*k (item features matrix), k: latent   features, step: iteration, α: learning rate, β: regularization parameter
Output: P, Q
Begin
For (step=0, step<=STEP, step++)
    For (i=0, i<=long(R), i++)
        For (j=0, j<=long(R[i]), j++)
            If R[i][j] > 0
                eij = R[i][j] – P[i]Q[j]
            end if
            For (k=0, k<=K, k++) # calculate gradient with α and β parameter
                P[i][k] = P[i][k] + α * (2 * eij *  Q[k][j] – β * P[i][k])
                Q[k][j] = Q[k][j] + α * (2 * eij *  P[i][K] – β * Q[k][j])
     eR = P*Q
     e=0

     For (i=0, i<=long(R), i++)
         For (j=0, j<=long(R[i]), j++)
             If R[i][j] > 0
                 e = e + (R[i][j])^(P[i]Q[j])
             End if
             For (k=0, k<=K, k++)
                 e = e + (β/2) * (P[i][k])^2 + (Q[k][j])^2
     If e<0.001 # 0.001: local minimum
       Exit
     End if
   Return P, Q
End
```

Cosine similarity is used to measure similarities between two vectors, regardless of their size. It is most used in information retrieval, image recognition, text similarity, bioinformatics, and recommender systems.

$$\text{Similarity} = cos(\theta) = \frac{A \cdot B}{\|A\|\|B\|} = \frac{\sum_{i=1}^{n} A_i B_i}{\sqrt{\sum_{i=1}^{n} A_i^{21}} \cdot \sqrt{\sum_{i=1}^{n} B_i^2}}$$

An advantage of the cosine similarity is that it preserves the sparsity of the data matrix. It gives the similarity of two n-dimensional vectors, P and Q, by determining the cosine of their angle. This score is frequently used in text mining. If we consider the cosine function, its value at 0 degrees is 1 and -1 at 80 degrees. This means that for two overlapping vectors, the value of the cosine will be maximum and minimum for two exactly opposite vectors. The spatial.distance.cosinus(o) function in the scipy module calculates the distance instead of the cosine similarity, but to achieve this, we can subtract the distance value from 1.

```
Algorithm2: Calculating the similarity using CosineSimilarity
Input: P, Q, R, K
Output: MatrixSimilarity
Begin
For (i=0, i<=long(R), i++)
        For (k=0, k<=K, k++)
          MatrixSimilarity[i][k] = SimilarityCosine(i, k)
        End for
End for
For (k=0, k<=K, k++)
     For (j=0, j<=long(R[k]), j++)
          MatrixSimilarity[k][j] = SimilarityCosine(k, j)
        End for
End for
Return (1 − spatial.distance.cosinus((P[i][k]), (Q[k][j])
End
```

5. FRAMEWORK ONTOLOGICAL MODELS

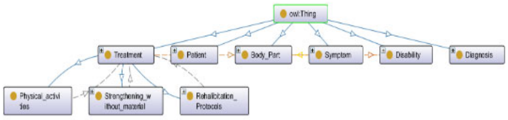

Figure 3. OntoGraph of the personalization model

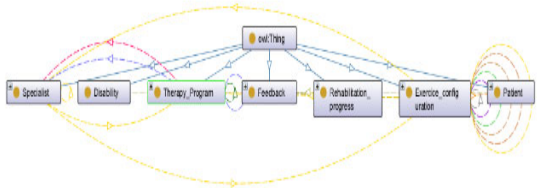

Figure 4. OntoGraph of the learner model

We started with the idea of building an ontology representing only the concepts constituting medicine physical. The figure 3 shows the different classes implemented in our system and individuals for each class. We take an example the class 'treatment' and its individuals which are medical care given to a patient for a spasticity to deal.

We propose a learner ontology that contains the required knowledge about the user's preferences (figure 4). It is created from the learner's data, typically collected by intelligent tutoring systems through interactions between the learner and the learner's tutoring system. We have seen that the proposed OWL is about generally 6 terms which are: disability, exercise configuration, patient, rehabilitation progress, specialist, and therapy program. Those terms represent a model to describe health domains for personalization the patient. Thus, it indicates a patient behavior.

6. SWRL RULES FOR THE INTELLIGENT CP FRAMEWORK

SWRL allows the application of production and inference rules within the Semantic Web. The proposed rule takes the form of an implication between an antecedent (body) and a consequent (head) (Zhai 2018).

SWRL rules provide a mechanism for discovering a lifestyle pattern. The rule R1 classifies a child(patient) according to its treatment: If a child attends symptom, then he must have treatment.

- **R1:** Child(?c) V Symptom(?s) V Attend(?c, ?s) → Treatment(?c)

The next step consisted of to introduce in the ontology an object property called has disability and classifying a person's degree of illness, as it's shown in R2, if a patient has a special disability, then he must has exercise training refer to his disability.

- **R2:** Patient(?p) V has disability(?p, Disability) → Exercise training(?p))

The next rule defines a type of strengthening without material (planks) and it presents a type of treatment.

- **R3:** Strengthening without material(?s) V is a(?s, ?t) V Treatment(?t) → Planks(?s)

7. INTELLIGENT FRAMEWORK DEVELOPMENT

Figure 5 presents the patient's chatbot interface where he can contact it in any time by taping "send" and he will receive a message at the same time. It shows a dialog between a chatbot and a patient in our platform. The patient asks about a solution for his problem and the chatbot gives him the right exercises that he must practice. These questions are in form of data.json where we have used nltk (Natural Language Toolkit) to mesure the similarity by applying stemming.

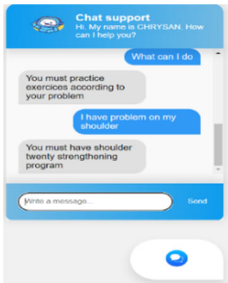

Figure 5. Interface of chatbot

8. CONCLUSION AND FUTURE WORK

This research aims to help children with CP by providing them a platform that contains different exercise videos to select the adapted one to their profile and handicap. It puts also a medical chatbot to be in contact with them and provides answer their questions. As a future work, we aim to develop further our solution to be better adapted to various learners' contexts, enhance our platform to be, also, a mobile application and the chatbot by adding the phase voice-to-voice and edit the data for further personalization of the rehabilitation.

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