TOWARDS CEREBRAL PALSY DIAGNOSIS: AN-ONTOLOGY BASED APPROACH

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ABSTRACT

Cerebral Palsy (CP) is one of the most complicated disabilities which is a permanent motor disorder causing mental and physical disabilities. Different reports published by different health organizations asked for researches on CP disability in order to improve diagnosis. Globally, there are different researches conducted to improve CP diagnosis, but most of those studies do not diagnose CP in children's early ages, which limit the treatment impact. This paper report on a research conducted to develop an ontology-based approach to diagnose children with CP in early ages. In this paper, Ontology was used to represent CP domain. Then, a set of manually built rules have been optimized through a knowledge-based survey to be used in CP diagnosis. The proposed approach improves CP diagnosis and by consequence positively reflects physical therapy treatment. The proposed approach was evaluated by a real dataset consisted of 70 pre-diagnosed cases, where 84% correctly diagnosed.

KEYWORD

Cerebral Palsy Diagnosis, ontology, knowledge-based survey.

1. INTRODUCTION

Cerebral Palsy is of the most complicated disabilities that defined as a primary disorder of posture and movement, however approximately 45% of children with CP also have an intellectual impairment [1]. It is a severe disability that caused by an abnormal or disruption in brain development. In 2015, World Health Organization WHO published a factsheet shows that over one billion people over the world; about means about 15% of the world's population; has some form of disability. WHO recommended the need to develop normative tools including guidelines to strengthen health care for disabled people [2]. Cerebral Palsy Center of Palestinian Avenir for Childhood Foundation asked for more researches on cerebral palsy disability in Gaza Strip in order to improve diagnosis and treatment. Such studies will be positively reflected on the outputs of physical therapy treatment.

In the recent years, the basic technologies and techniques that have been used in disability and diseases diagnosis are Expert Systems (ES), Case-Based Reasoning (CBR), and Ontology. Expert Systems is used to support learning and decision support in diseases diagnoses [3][4], which behave like expert human based on system knowledge and rules. Recently, different techniques and systems developed to diagnose diseases such CardioOWL Ontology-Driven ES [3], and OBESTDD Ontology-Based ES [4]. Case-Based Reasoning (CBR) is another effective technology in diseases diagnoses which benefits from previous problems and solutions to generate solution for the new cases. For example, HESS which is ontology supported CBR system for cognitive diagnosis applied on HIV/AIDS detection [5], and SNOMED CT ontology based encoding methodology for Diabetes diagnosis [6]. Ontology works as an important tool for modeling the knowledge in different health care services areas such as disability and diseases

diagnosis. This technology allows implementation several kinds of interoperability and inference processes between different types of systems [7]. After a deep literature study and an empirical study [12] of CP diagnosis, we found that ontology-based approach could serve as a better solution for CP diagnosis.

This paper present an ontology based approach to diagnose CP disability. This paper is divided into six sections where section 2 reviews the related work, section 3 illustrates the research methodology, section 4 discusses the research results, and section 5 concludes the paper.

2. RELATED WORK

Different studies have been conducted in diseases and disability diagnosis field, where the aim is to improve health care services and support decision making [8]. The base of the most previous studies in this field can be classified into CBR, ES, and Ontology based techniques. In this section, the popular techniques that used in diagnosis and treatment field has been reviewed.

In the recent years, Different assessment and diagnosis techniques have been developed to diagnose Cerebral Palsy disability. Velasco, M. A. et. al. in 2014 developed a system called ENLAZA to analyze the presence of positive and negative head signs in people with Cerebral Palsy [9]. Positive motor sings means that the patient can control the head/motor motion, where the negative signs mean the patient unable to control the head motion. The objective of their study was to develop a computerized technique to assess motor signs for people with CP by measuring and analysing on patient task performance and control of posture. To reach this, they followed reaching task methodology. They developed analysis system with interface (GUI) contains points and a courser controlled by a ring (IMU) put on the patient head. The patient move the courser from point to point using his/her head and eyes. Then the system analyses the motion to identify patient impairment and task performance. From our point of view, ENLAZA is effective for young children who are not mentally affected. Also, the tool cannot differentiate between CP and other physical disabilities that affect neck and shoulders.

In 2016, a research study aimed to identify the best age for diagnosis children with CP disability has been conducted [10]. The research methodology was to diagnosis newborn children then does a follow up till school age the get a final diagnosis. They found that 2 years old seems a reliable time to diagnose cerebral palsy severe enough to cause disability, but not to diagnose milder cases. The search results correspond to our vision of the best age for diagnosis and the need to include different levels of diagnosis bases

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In 2017, a Mini-MACS system has been developed, which is a development of the Manual Ability Classification System for children younger than 4 years of age with signs of cerebral palsy [11]. They used the child's functional abilities to move objects using hands in order to confirm CP diagnosis. The developed system success to describe the children manual abilities, but it would not be reliable for all types CP.

In the same line, Robles-Bykbaev presented an ontology-based expert system to generate general intervention guidelines for children with disabilities and communication disorders [14]. The system includes several intelligent ICT tools such as robotic assessment, mobile application and web environment. They represented the domain knowledge using ontology. The ontology entities have been identified manually by domain experts from patient's profiles, rehabilitation activities

and therapy plans. The researchers use GUI to enable the users to query and manage the clinical information in order to diagnose and to generate therapy plans for communication disorders.
Based on the the previous literature review, Case-Based Reasoning will not be effective because the limitation of available electronic health records in health care centers and in CP disability each child has different pattern of physical and mental disability based on the affected area in human brain. Expert systems are a good solution, but there is a need to combine it with the ontology in order to improve effectiveness and accuracy of the proposed approach.

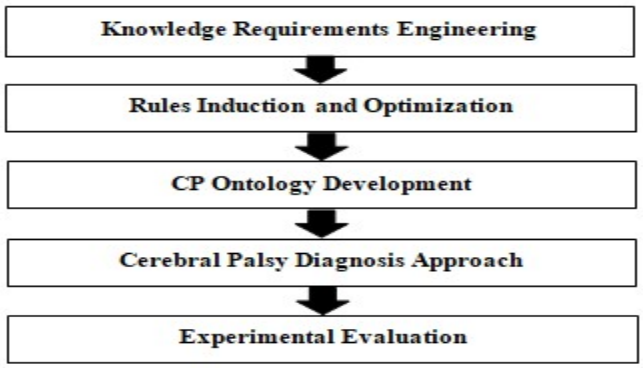
The previous studies provide effective techniques for diagnosing Cerebral Palsy. But in Gaza strip, according to the domain experts, the need is to use symptoms and reflexes assessment in the simplest way to provide the initial diagnosis in primary health care centers. Also, we found that ontology is an effective technology to represent disability domain for decision support or diagnosis purposes.

The developed techniques provide diagnoses based on specific factors such as child age, specific symptom like muscle tone, or child birth weight. However, there are set of symptoms that help to diagnose CP in early ages in general, and each symptom is important in diagnosis and for the proposed treatment. Also, some types of CP cannot be diagnosed based on specific indicators like weight or head motor only. So, our proposed system can benefit from the advantages of expert systems and ontology to provide provisional diagnosis of CP for children from 1 day to 3 years using symptoms and reflexes.

3. RESEARCH METHODOLOGY

In order to build effective approach for CP diagnosis, a set of activities to build the proposed ontology and the diagnosis rules have been identified. Those activities are implemented in five steps which are Knowledge Requirements Engineering, Rules Induction and Optimization, CP Ontology Development, Cerebral Palsy Diagnosis Approach, and Experimental Evaluation, as shown in Figure 1.

Figure 1. Research methodology.



In Knowledge Requirements Engineering step, four activities were used. These activities are requirement gathering and elicitation, requirement analysis, requirement validation, and requirement management. The outputs of this step are a set of functional and non-functional requirements, and the structure of the proposed system, see Figure 2.

There are a set of symptoms and reflexes that indicate CP disability in early ages, but each symptom has different weight if connected with child age. Based on that, a knowledge based

survey was conducted. The survey targeted 50 participants who have related education and experience to disability domain. The aim of the survey was to optimize a set of manual built rules through a set of 52 symptoms that weighted using the knowledge based survey.

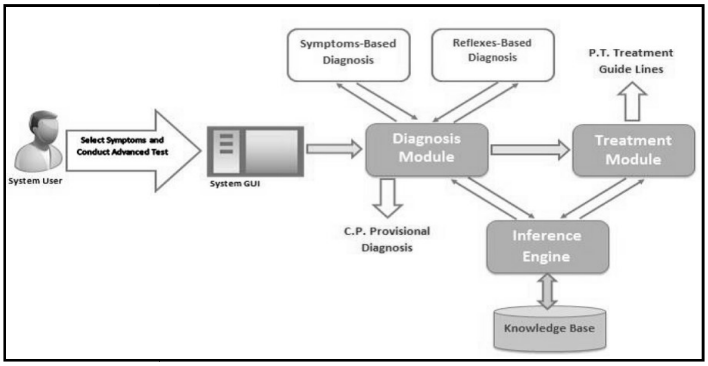


Figure 2. CP Ontology system structure.

The first two steps are previously presented and published in [12].

3.1 CP ONTOLOGY DEVELOPMENT

In order to develop the proposed ontology, we followed Noy and McGuinness, "Ontology Development 101: A Guide to Creating Your First Ontology" [13]. More than 170 important terms found in CP related documents. Out of those terms, 54 classes were identified. These classes included Child, Symptom, Reflex, Physical Therapy Treatment, Disability, Body Parts and Diagnosis. In addition to 19 object properties and 24 data properties (See Table 1).

Table 1. A sample of object properties in CP Ontology with domain and range.

Object Property	**Domain**	**Range**
Appears_On	Symptom	Child
Affects	Symptom	Body Part
Treats	Physical Therapy Treatment	Symptom
Has_Symptom	Child	Symptom
Indicates	Symptom	Disability
Has_Initial_Diagnosis	Child	Diagnosis

In this research study, Protégé platform was used to construct CP Ontology. The identified classes, properties, and annotations constructed in addition to 143 instances representing all ontology concepts (See Figure 3).

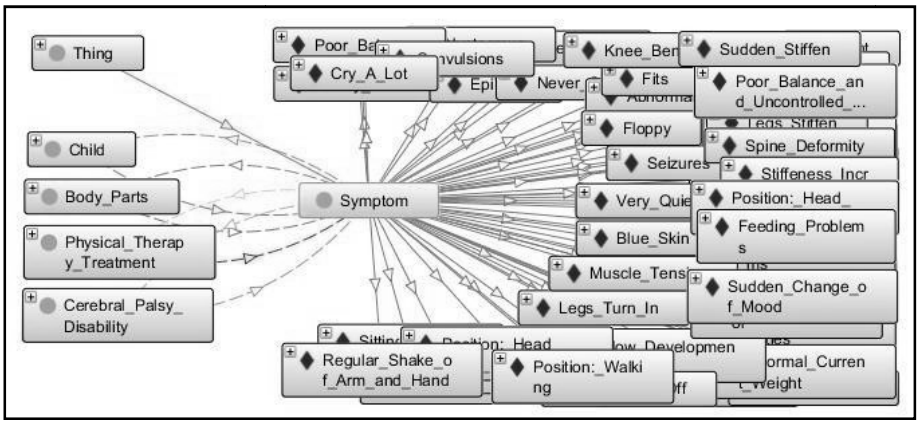


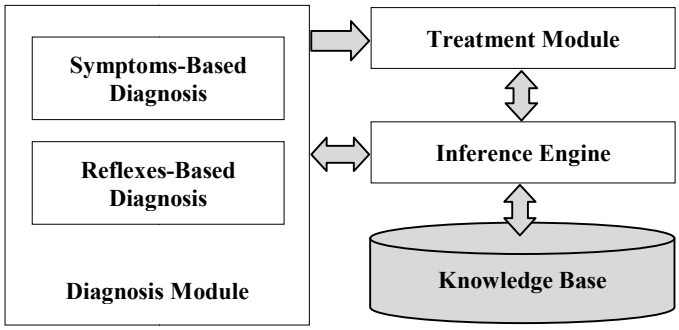
Figure 3. Instances of Symptom class in CP ontology.

3.2 CEREBRAL PALSY DIAGNOSIS APPROACH

In order to diagnose Cerebral Palsy disability for the children whose ages are between one month and three years, twelve steps were identified to get the final diagnosis, which are:

Step 1, Child personal information filled by the user.
Step 2, System activates diagnosis interface with the symptoms that indicate CP.
Step 3, User marks the symptoms that the child has.
Step 4, System run Pellet reasoner over the ontology file.
Step 5, System retrieves the weights of the marked symptoms from Ontology file.
Step 6, System calculates Symptoms-Based Score.
Step 7, Based on the calculated score, system gives a recommendation.
Step 8, if the Symptoms-Based Score is lower than 40%, then the system recommend Reflexes-Based Diagnosis.
Step 9, User identifies the results of Reflexes Assessment.
Step 10, System calculates Reflexes-Based Score.
Step 11, System calculates Final Score.
Step 12, System stores and display Final Diagnosis Results and Treatment Plan.

Figure 4. CP ontology system structure.



To realize the above steps, the system mainly constructed with three modules which are Diagnosis Module, Treatment Module and Inference Engine as shown in Figure 4. Diagnosis Module constructed to implement symptoms and reflexes diagnosis through a set of rules.

Treatment Module generates the physical therapy plan according to the symptoms and reflexes assessment.

3.3 EXPERIMENTAL EVALUATION

This section shows the evaluation results of the developed CP diagnosis approach by diagnosing a test set of 70 records for real CP and Non-CP cases that are previously diagnosed in Cerebral Palsy Center of Palestine Avenir for Childhood Foundation. Each record contained 55 attributes. Some of them are personal data such as Name, Gender, Age, and Mother Age. Most of the other attributes are medical data such as Speech Problems, Pregnancy, Delivery, Birth Weight, Breast Feeding, Hospitalization, Truma, Fits, Vocalization, Head Support, Sitting, crawling, standing, walking, Abnormal Features, Gait, and Parachute. The testing data set contained 47 Cerebral Palsy cases, 19 cases that probably have CP, and 4 cases have other disabilities (Non-CP cases).
As shown in Table 2, 43 children with Cerebral Palsy disability out of 47 have been correctly diagnosed. For the children who probably has Cerebral Palsy disability, 13 children out of 19 had matched diagnosis results, and 6 out of 19 have unmatched results.

From the table, 4 cases in the test dataset have been previously diagnosed as Has Uncertain Disabilities. Our approach gave matched diagnosis results to 3 of them.

Table 2. Evaluation results of CP diagnosis approach.

Diagnosis Category	# of cases in test dataset	Evaluation Results	
		Matched	Not Matched
Cerebral Palsy	47	43	4
Probably have Cerebral Palsy	19	13	6
Uncertain (Other disabilities)	4	3	1
Total	70	59	11

Our approach correctly diagnosed 59 cases out of 70 cases in the test dataset. Using Recall, 84% of cases have been correctly diagnosed by CP Ontology application.

$$\text{Recall} = \frac{Number\ of\ cases\ that\ correctly\ diagnosed\ by\ the\ application}{Number\ of\ diagnosed\ cases} = \frac{59}{70} = 0.84$$

4. DISCUSSION

Referring to Table 2, there were 47 cases in the test dataset previously diagnosed as CP cases. Our approach gave the same diagnosis to 43 cases out of them, which means that the developed approach correctly diagnosed 91.4% of CP cases. According to the domain expert, however CP disability domain is a complex domain; this study provided a useful approach for diagnosing CP disability with minimum resources, which useful and helpful in Gaza Strip where there is a lack of diagnosis tools. The developed prototype of the proposed approach is usable, and the accuracy of CP Ontology-based approach (84% of test dataset has been correctly diagnosed) make this approach work as a domain expert in disability diagnosis field, as he said. Building on the results of the research and the ontology approach illustrates that the developed approach could be a key element in CP diagnosis and even for other diseases diagnosis and treatment.

5. CONCLUSION

In this research study, an ontology-based approach for Cerebral Palsy diagnosis has been developed. The developed CP Ontology system consists of two main components which are knowledge base and approach. The diagnosis approach contained the system interfaces, diagnosis module, physical therapy module, and inference engine. CP Ontology-based diagnosis approach was evaluated through a test dataset contained 70 cases of children who are previously diagnosed. The results showed that 59 cases out of 70 had matched diagnosis. At the end of the research study, we reached our research objectives, where the proposed approach is correct, provide acceptable accuracy.

REFERENCES

[1] Yin Foo, R., Guppy, M., & Johnston, L. M. (2013). Intelligence assessments for children with cerebral palsy: a systematic review. Developmental Medicine & Child Neurology, 55(10), 911-918.

[2] World Health Organization. (2015, December). Disability and Health Fact sheet No. 352. Retrieved from http://www.who.int/mediacentre/factsheets/fs352/en/.

[3] Al-Hamadani, B. (2014, October). CardioOWL: An ontology-driven expert system for diagnosing coronary artery diseases. In Open Systems (ICOS), 2014 IEEE Conference on (pp. 128-132). IEEE.

[4] Rawte, V., & Roy, B. (2015, January). OBESTDD: Ontology Based Expert System for Thyroid Disease Diagnosis. In Nascent Technologies in the Engineering Field (ICNTE), 2015 International Conference on (pp. 1-6). IEEE.

[5] Sharma, S. Y., Roy, D. P., & Chakraborty, B. (2015, March). Health Services Support System (HESS): An Ontology supported CBR system for cognitive diagnosis applied on HIV/AIDS detection. In Computing for Sustainable Global Development (INDIACom), 2015 2nd International Conference on (pp. 284-290). IEEE.

[6] El-Sappagh, S., Elmogy, M., Riad, A. M., Zaghloul, H., & Badria, F. (2014, December). A proposed SNOMED CT ontology-based encoding methodology for diabetes diagnosis case-base. In Computer Engineering & Systems (ICCES), 2014 9th International Conference on (pp. 184-191). IEEE.

[7] Galán-Mena, J., Ávila, G., Pauta-Pintado, J., Lima-Juma, D., Robles-Bykbaev, V., & Quisi-Peralta, D. (2016, June). An intelligent system based on ontologies and ICT tools to support the diagnosis and intervention of children with autism. In Biennial Congress of Argentina (ARGENCON), 2016 IEEE (pp. 1-5). IEEE.

[8] Nahar, J., Imam, T., Tickle, K. S., & Chen, Y. P. P. (2013). Computational intelligence for heart disease diagnosis: A medical knowledge driven approach. Expert Systems with Applications, 40(1), 96-104.

[9] Velasco, M. A., Raya, R., Ceres, R., Clemotte, A., Bedia, A. R., Franco, T. G., & Rocon, E. (2014). Positive and Negative Motor Signs of Head Motion in Cerebral Palsy: Assessment of Impairment and Task Performance.

[10] Korzeniewski, S. J., Feldman, J. F., Lorenz, J. M., Pinto-Martin, J. A., Whitaker, A. H., & Paneth, N. (2016). Persistence of Cerebral Palsy Diagnosis Assessment of a Low-Birth-Weight Cohort at Ages 2, 6, and 9 Years. Journal of child neurology, 31(4), 461-467.

[11] Eliasson, A. C., Ullenhag, A., Wahlström, U., & KrumlindeSundholm, L. (2016). Mini MACS: development of the Manual Ability Classification System for children younger than 4 years of age with signs of cerebral palsy. Developmental Medicine & Child Neurology.

[12] W. F. A. Sarraj and M. S. Zurob, "Towards Rules Induction Optimization for Cerebral Palsy Diagnosis: An Empirical Study," 2017 International Conference on Promising Electronic Technologies (ICPET), Deir El-Balah, 2017, pp. 135-140. doi: 10.1109/ICPET.2017.31.

[13] Noy, N. F., & McGuinness, D. L. (2001). Ontology development 101: A guide to creating your first ontology.

[14] Robles-Bykbaev, V. E., Guamán-Murillo, W., Quisi-Peralta, D., López-Nores, M., Pazos-Arias, J. J., & García-Duque, J. (2016, October). An ontology-based expert system to generate therapy plans for children with disabilities and communication disorders. In Ecuador Technical Chapters Meeting (ETCM), IEEE (Vol. 1, pp. 1-6). IEEE.

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