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الجامعة الإسلامية بغزة  
عمادة البحث العلمي والدراسات العليا  
كلية تكنولوجيا المعلومات  
ماجستير تكنولوجيا المعلومات

## An Ontology-Based Approach for Cerebral Palsy Diagnosis and Physical Therapy in Gaza Strip

اقتران يعتمد على الانتولوجيا لتشخيص الشلل الدماغي والعلاج  
الفيزيائي في قطاع غزة

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## إقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

### **An Ontology-Based Approach for Cerebral Diagnosis and Physical Therapy in Gaza Strip**

#### **اقتران يعتمد على الانتولوجيا لتشخيص الشلل الدماغي والعلاج الفيزيائي في قطاع غزة**

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## نتيجة الحكم على أطروحة ماجستير

بناءً على موافقة عمادة البحث العلمي والدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحث/ محمد سلمان جبيل زعرب لنيل درجة الماجستير في كلية تكنولوجيا المعلومات برنامج تكنولوجيا المعلومات وموضوعها:

### اقتران يعتمد على الانتولوجي لتشخيص الشلل الدماغي والعلاج الفيزيائي في قطاع غزة An Ontology - Based Approach for Cerebral Palsy Diagnosis and Physical Therapy in Gaza Strip

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والله ولي التوفيق،،،

عميد البحث العلمي والدراسات العليا

.....  
أ.د. مازن اسماعيل هنية



## Abstract

World Health Organization (WHO) published a factsheet in 2015 shows that over one billion people have disabilities around the world. This means 15% of world population has some forms of disability. Most of these disabilities are physical disabilities. Cerebral Palsy (CP) is one of the most complicated disabilities which is a permanent motor disorder that appears in early age and cause mental and physical disabilities. In Gaza Strip, 2.6% of population has some forms of disability. The children under 18 years with CP disability represent 3.1% of disability population in Gaza Strip.

Based on domain experts, there is very little studies targeted disability domain in Gaza Strip especially Cerebral Palsy. In addition, different reports published by governmental and non-governmental organizations such as Cerebral Palsy Center of Palestinian Avenir for Childhood Foundation ask for more focus on cerebral palsy disability in Gaza Strip in order to improve diagnosis and treatment basing on the available resources in Gaza Strip.

Globally, there are different studies conducted to improve and assist CP diagnosis and physical therapy treatment, most of those studies do not provide diagnosis techniques for the children in their early ages. This means that the impact and the effectiveness of physical therapy treatment may be lost because of the delay in diagnosis. So, the real need is to find an approach that diagnoses CP in early ages.

In this research, we proposed an ontology based approach to diagnose children with CP in early ages, generate physical therapy planning, and assist in knowledge sharing. We used ontology to build and represent CP disability domain. Then, a set of rules has been manually built in collaboration with a domain expert. The rules have been optimized through a set of symptoms that have been weighted through a knowledge-based survey in order to be used in CP diagnosis. The proposed approach improves CP diagnosis and by cosequence positively reflects physical therapy treatment. The proposed approach was evaluated by a real dataset consisted of 70 pre-diagnosed cases, where our approach correctly diagnosed 84% of those cases.

**Key Words:** Cerebral Palsy Disability, CP Diagnosis, Ontology, semantic web, Knowledge extracting.

## المخلص

نشرت منظمة الصحة العالمية ورقة حقائق حول الإعاقة لعام 2015 بينت أن أكثر من بليون شخص حول العالم لديهم إعاقات. هذا يعني أن 15% من سكان العالم يعانون من أحد أشكال الإعاقات، ومعظم هذه الإعاقات هي إعاقات جسدية. إعاقة الشلل الدماغي هي إحدى الإعاقات المعقدة والتي هي قصور في الحركة تظهر في مراحل العمر الأولى بسبب قصور عقلي وجسدي لدى المعاق المصاب بها. في قطاع غزة 2.6 من السكان يعانون من أحد أشكال الإعاقة. يمثل الأطفال دون سن 18 سنة والمصابون بإعاقة الشلل الدماغي نسبة 1.3% من مجمل المعاقين في قطاع غزة.

بناء على الخبراء في مجال الإعاقة، يوجد عدد قليل ومحدود من الدراسات العلمية والأبحاث استهدفت مجال الإعاقة وخصوصاً الشلل الدماغي. بالإضافة لذلك، نشرت منظمات حكومية وغير حكومية كمركز الشلل الدماغي التابع لمؤسسة فلسطين المستقبل لأطفال الشلل الدماغي عدة تقارير طالبت فيها بمزيد من الأبحاث والدراسات في مجال إعاقة الشلل الدماغي بهدف تحسين خدمة تشخيص إعاقة الشلل الدماغي وخدمة العلاج الطبيعي بناءً على الموارد المتوفرة في قطاع غزة.

على الرغم من توافر عدد من الأبحاث والدراسات السابقة حول العالم والتي هدفت لتحسين خدمة تشخيص الإعاقة والعلاج الطبيعي، إلا أن معظم تلك الدراسات لم يوفر التشخيص المبكر للشلل الدماغي. هذا يعني أن فعالية ونجاعة العلاج الطبيعي سوف تتأثر بسبب التأخر في تشخيص هذه الإعاقة. لذلك، فإننا نجد أن الاحتياج الحقيقي هو توفير طريقة للتشخيص المبكر للشلل الدماغي.

في هذا البحث العلمي، نحن ندرس بناء اقتراح مبني على الانتولوجيا لتشخيص إعاقة الشلل الدماغي وتحسين العلاج الطبيعي المقدم للمعاقين خلال المراحل العمرية الأولى وبناء خطط علاجية مساعدة لخدمة العلاج الطبيعي والمساهمة في تسهيل مشاركة المعرفة. لقد استخدمنا الانتولوجيا لتمثيل وتوصيف مجال إعاقة الشلل الدماغي، ومن ثم قام خبير في هذا المجال بوضع عدد من القواعد يدويا والتي قمنا بتحسينها من خلال دمجها بمجموعة من الأعراض المصاحبة لإعاقة الشلل الدماغي والتي تم وضع أوزان لها من خلال استبيان مبني على المعرفة بهدف تحسين قدرة هذه القواعد على تشخيص إعاقة الشلل الدماغي. هذه الطريقة سوف توفر تشخيص مبكر للشلل الدماغي والذي سوف ينعكس تلقائياً بالإيجاب على خدمة العلاج الطبيعي. تم تقييم الطريقة من خلال قاعدة بيانات تحتوي على 70 حالة حقيقية تم تشخيصها مسبقاً من قبل خبراء، حيث أن طريقتنا نجحت بتشخيص 84% من تلك الحالات بطريقة صحيحة.

**الكلمات المفتاحية للبحث:** الشلل الدماغي، تشخيص الشلل الدماغي، الانتولوجي، الويب الدلالي، استخراج المعرفة.

## **Dedication**

*I would like to didicate my work to my mother and father who always support me and push me forwarded. I didicate this work and the effort to my kids who had been left playing alone with minimum care from my side during 4 years of study.*

*I would like to didicate this research to the families who have children with CP disability and looking for better life style for their beloved disabled children.*

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*Mohammad Salman Zurob  
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## List of Abbreviations

<b>API</b>	Application Programming Interface
<b>CBR</b>	Case-Based Reasoning
<b>CP</b>	Cerebral Palsy
<b>DL</b>	Description Logic
<b>DoB</b>	Date of Birth
<b>ES</b>	Expert System
<b>GUI</b>	Graphical User Interface
<b>IDD</b>	Intellectual Developmental Disability
<b>IMU</b>	Inertial Measurement Unit
<b>MR</b>	Mental Retardation
<b>OWL</b>	Web Ontology Language
<b>PRCS</b>	Palestinian Red Crescent Society
<b>PT</b>	Physical Therapy
<b>RDF</b>	Resource Description Framework
<b>RDFS</b>	Resource Description Framework Schema
<b>SPARQL</b>	Simple Protocol And RDF Query Language
<b>SWRL</b>	Semantic Web Rule Language
<b>URI</b>	Uniform Resource Identifier
<b>WHO</b>	World Health Organization
<b>XML</b>	Extensible Markup Language

# Chapter 1

## Introduction

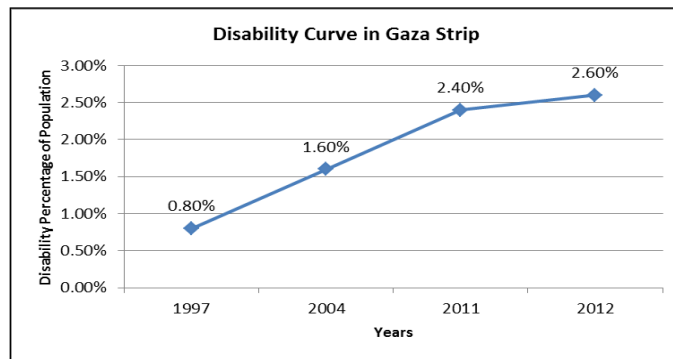
# Chapter 1

## Introduction

### 1.1 Cerebral Palsy Disability and Ontology

Cerebral Palsy (CP) is defined as a primary disorder of posture and movement, however approximately 45% of children with CP also have an intellectual impairment (Yin Foo et al., 2013). Cerebral Palsy is one of the most severe disabilities that caused by an abnormal or disruption in brain development. In most CP cases the exact factor is unknown, but there are many factors that affect human brain development such as mutations in genes, maternal infections that affect the developing fetus, fetal stroke and a disruption of blood supply to the developing brain, infant infections that cause inflammation in or around the brain, traumatic head injury to a child in his/her first years from a motor vehicle accident or fall, and lack of oxygen to the brain (asphyxia) related to difficult delivery (Mayo Clinic Staff, 2007). These factors assist in causing damage in the part of the human brain that controls movement, balance, and posture (Rosenbaum et al., 2007). Most of the problems caused CP occurs during pregnancy like exposure to methylmercury, during child birth like difficult delivery, or after birth during the first years of the child life like head trauma.

World Health Organization (WHO) published a factsheet in 2015 related to disability and health mentioned that over a billion people, about 15% of the world's population, have some form of disability, and recommended the need to develop normative tools including guidelines to strengthen health care (World Health Organization, 2015). In the United States there are 0.5 million infants have CP disability, where in Europe the patients with CP are higher (Velasco et al., 2014).



**Figure (1.1):** Disability in general percentage of population curve in Gaza Strip (Palestinian Center Bureau of Statistics, 2017)

For Gaza Strip, there are very little studies and researches conducted in disability domain, but there are different statistical reports published by governmental and non-governmental organizations show some facts about CP in Gaza Strip (See Figure 1).

Based on The Palestinian Central Bureau of statistics, the percent of disabled people in Palestine (West Bank and Gaza Strip) were 1.7% of population in 1997; it was 1.6% in Gaza Strip and 1.7% in West Bank; But, these percentage increased year by year to be 2.7% of Palestinian population in 2012. Where, it was 2.4% in Gaza Strip and 2.9 in West Bank.



From these statistics, we find that the number of disabled people increased, however the siege that established over Gaza Strip since 2007 limited the improvement of health care services in general and disability rehabilitation in specific. For Cerebral Palsy, there was no presence in previous statistics data for Gaza Strip except the statistical report conducted in 2012 and published in 2013. This report mentioned that 39,877 disabled persons in Gaza Strip which mean 2.6% of population. The Cerebral Palsy disabled people with ages 18+ years represented 1.4% of disability population, and people with ages less than 18 years represented 3.1%.

It is clear now the Cerebral Palsy Disability increased and the children who are less than 18 years old represent 3.1% of disability population in Gaza Strip. In addition, there is a very little statistical research and studies targeted CP in Gaza Strip. So, there is a high need to focus on this problem by conducting researches that may help CP disability service providers to improve the quality of diagnosis and physical therapy treatment.

There are different technical technologies and strategies proposed and developed to assist in solving disability domain problems or to improve the care services such as Human-Robot Interaction Strategy which developed to improve the locomotion treatment for children with CP (Cifuentes et al., 2016), User-Friendly and Interactive Data Collection System which is a database system with graphical user interface (GUI) for data collection for children with CP, and ENLAZA which is a system developed to provide CP assessment of impairment and task performance.

In the recent years, there were a focus on specific computer technologies in developing new strategies and techniques to diagnose diseases or improving health care services like Ontology, Expert Systems (ES), Case-Based Reasoning (CBR), and Intelligent Systems.

Ontologies still work as an important tool for modeling the knowledge in different health care areas. This technology is useful because it allows implementing several kinds of interoperability and inference processes between different types of systems (Galán-Mena et al., 2016). Also, it is a way of presenting the domain objects and the relation between these objects in a specific domain such as disability (Al-Hamadani, 2014).

Expert System is used to support learning and decision support in diseases diagnoses (Al-Hamadani, 2014; Rawte & Roy, 2015), 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 (Al-Hamadani, 2014), and OBESTDD Ontology-Based ES (Rawte & Roy, 2015).

Case Based Reasoning CBR is another effective technology in diseases diagnoses which benefits from previous problems and solutions to generate solution for new cases. For example, HESS which is ontology supported CBR system for cognitive diagnosis applied on HIV/AIDS detection (Sharma et al., 2015), and SNOMED CT ontology based encoding methodology for Diabetes diagnosis (El-Sappagh et al., 2014).

In this research, the goal is to develop an ontology-based approach to diagnose Cerebral Palsy disability using domain knowledge and rules. In addition, to generate professional physical therapy work-plans using previous expertise experience in physical therapy.

## 1.2 Statement of the Problem

Cerebral Palsy (CP) is one of the most severe disabilities which affect locomotion and brain's performance. In the recent years, the number of children with cerebral palsy in Gaza Strip increased based on the Palestinian Central Bureau of statistics. Locally, Dr. Mahmoud Douleh, the medical director of Cerebral Palsy Center in Palestine Avner for Childhood Foundation, published a report called “Cerebral Palsy in Gaza, Facts and Future” in 2013. In that report, he asked for more studies in Cerebral Palsy disability in Gaza Strip. Internationally, in 2015, 4 researchers from Canada (Two of them have PhD degrees in physical therapy and rehabilitation) published a research results regarding age at referral of children for initial diagnosis of cerebral palsy and rehabilitation showing that half of children with cerebral palsy do not have a complicated birth history, so referral for diagnosis and management are often delayed. So, they asked for new strategies to optimize prompt referral by primary care providers (Hubermann et al., 2016).

Locally, in spite of the accepted number of available diagnosis and therapy service providers for cerebral palsy including governmental and non-governmental organizations, based on our observation and review, the used diagnosis tools are still general, expensive, manually conducted, and have a very limited knowledge sharing between domain expertise and fresh physiotherapists.

So, there is a need to improve and optimize CP disability diagnosis and physical therapy services quality for the children in their early ages. In addition, improve the knowledge sharing especially tacit knowledge between experts' and beginner physiotherapists, and conduct researches focus on disability domain in Gaza Strip.

## 1.3 Objectives

### 1.3.1 Main Objectives

The main objective of the research is to develop an otology-based approach for diagnosing Cerebral Palsy disability in children's early ages, providing professional and trusted physical therapy support work-plan for each child based on his/her need, and improving knowledge sharing.

### 1.3.2 Specific Objectives

The specific objectives for the proposed solution are:

- Conduct deep review and literature study.
- Identify symptoms of Cerebral Palsy for children in early ages.
- Build the domain knowledge including previous CP problems, solutions, and results.
- Design and build a database to store patient's personal and medical information, and domain knowledge.
- Design and build ontology that describe and represent domain knowledge.
- Create rules to infer the diagnosis of Cerebral Palsy based on the symptoms.
- Build the GUI of the system.
- Evaluate the proposed approach.

## 1.4 Importance of the Project

There are many governmental and nongovernmental organizations provide diagnosis and rehabilitation services for disabled people like Hospitals, Palestinian Red Crescent Society (PRCS), and non-governmental organizations (NGOs). But, all of these institutions still use old, expensive, manual, and general techniques like Portage County and MRI to diagnose disability and have very limited knowledge sharing in diagnosis and physical therapy fields. So, there is a need to focus on children with CP and work to improve the quality of care services provided to the children with Cerebral Palsy like diagnosis and physical therapy services. Also, assist in improving knowledge sharing in CP disability domain and integrate parents in physical therapy treatment process.

The proposed approach will help doctors, physiotherapists, and service providers to diagnose children with CP in children early ages, generate professional and trusted physical therapy support work-plans, and transform expertise's tacit knowledge into explicit knowledge which will assist in transferring experience from expertise physiotherapists to fresh physiotherapists.

Diagnose CP in early ages and use effective physical therapy support work-plans will work together to improve the daily life of children with CP and their family's life by reducing the impact of CP on patient's locomotion and brain performance.

## 1.5 Scope and Limitations of the Research

### Scope of the Research

In this research project, we will develop an approach to diagnose children with cerebral palsy in the early ages (From one day old to 3 years old), generate professional and trusted physical therapy work-plans based on previous experience captured from domain expertise (Physiotherapists), and assist in knowledge sharing between expertise physiotherapist and fresh physiotherapists. The approach will diagnose children with CP whose ages lies between one day to 3 years old based on symptoms that caused by CP.

### Limitations of the Research

The proposed approach has some limitations which are:

- It will not diagnose children over three years old.
- Diagnosis will not take in consideration medical checks like MRI, where diagnosis will consider symptoms of CP that appears on the child.
- In addition, the number of CP cases that will be provided by Palestinian Future Society for Children with CP will be 70 real pre-diagnosed cases, and this limited number may affect system testing results.

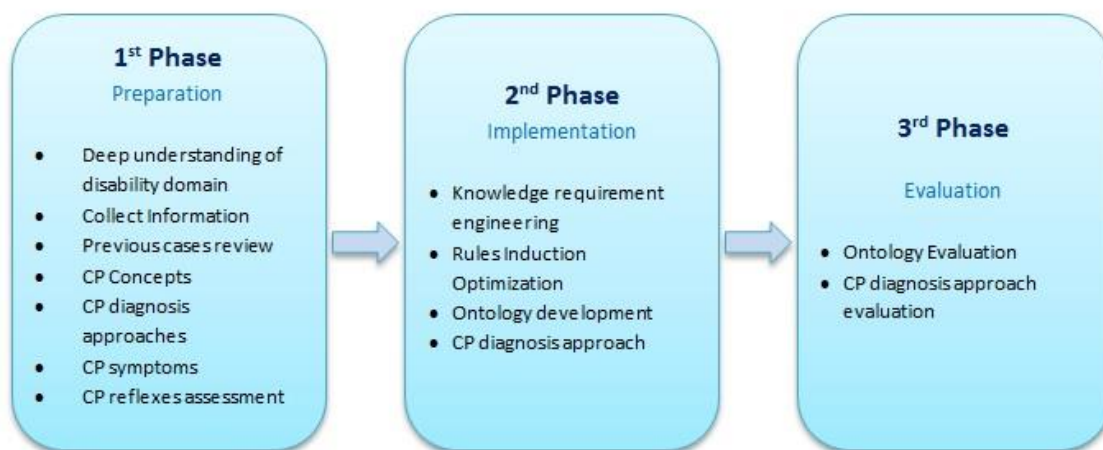
Also, the approach will not provide other types of treatments required to CP disability such as:

- Community rehabilitation.
- Occupational therapy.
- Speech therapy.
- Medical treatment.

But, as a future work, the approach may be extended to be able to provide speech therapy, occupational therapy, and identify the interaction between CP treatment's medicines with flash diseases medicines like flu disease.

## 1.6 Research Methodology

Our research study for developing an ontology-based approach for CP diagnosis and physical therapy support planning will be accomplished in three phases. In 1<sup>st</sup> Phase, previous CP disabled children's information and diagnosis documentations will be collected to identify CP concepts, relations, and disability symptoms in early ages. In 2<sup>nd</sup> Phase, the approach will be developed including ontology, rules, and knowledge base (See Figure 2). In 3<sup>rd</sup> Phase, the proposed approach will be applied and evaluated to check system functionality in Cerebral Palsy Center of Palestinian Avenir for Childhood Foundation as a case study. The following statements show more details about each phase.



**Figure (1.2):** Research Methodology

### 1.6.1 Phase One: Prepare previous CP disabled children records and diagnosis to discover symptoms

Many electronic health records and patients files contain personal and medical data and information about cerebral palsy disability. Some of these data is useless in CP diagnosis and physical therapy and some of them are useful. So, only the useful data should be identified, extracted, processed, and used in an ontology that that will be designed and built to easily store and retrieve knowledge.

In this phase, a set of documents that are used to describe cerebral palsy disability and other disabilities, a set diagnosis templates that are used in cerebral palsy disability diagnosis and a set of medical files of disabled children with CP will be studied carefully in order to identify basic concepts, relations, and symptoms of cerebral palsy disability in children early ages. This will be implemented in three steps. First step, collect medical documents of previous CP cases whose ages less than 18 years. Second step, use knowledge extracting techniques to analyse and identify physical and mental symptoms that cerebral palsy is cause. Third step, check results of step two with a domain expert.

## 1.6.2 Phase Two: Building the proposed approach

This is the implementation phase, where the proposed approach components will be built. In this phase, there are six main components will be developed or used which will work together to achieve the approach functionality. These components are system graphical user interface, system application, diagnosis rules, OWL API, ontology or knowledge base, and reasoner.

### 1.6.1.1 System Graphical User Interface

This component will represent the intermediate between system users and system components. Because the users of the proposed approach may not be professionals in computer application, we will design the interface to be as simple as the user can easily use and understand. So, we will use a simple desing with minimum interfaces components such as buttons, tables, and check boxes.

### 1.6.1.2 System Ontology

The Ontology or Knowledge Base Component will be built using Protégé Framework to define and describe CP disability domain including classes, properties, attributes, and relations between domain entities.

The main classes of the proposed ontology initially will be *Child*, *Symptom*, *physical therapy support activity*, *Disability*, and *budy Parts*. Some of ontology properties between those classes will be *Has\_Symptom* (Domain: Child, Range: Symptom, Cardinality min = 1), *Treated\_By* (Domain: Symptom, Domain: Physical therapy treatment), *Has\_Age* (Domain: Child, Range: Literal, Cardinality =1), *Has\_Diagnosis* (Domain: Symptom, Range: Diagnosis, MaxCardinality =3, MinCardinality = 1), and *affects* (Domain: Symptom, Range: Body Part).

Also, there are some properties initially identified because of its importance in diagnosis and physically treat children with CP like *Child* (*Name, Weight, skills*), *Mother* (*Name, Age, diseases*), and *Incident* (*Date, Type, result*).

### 1.6.1.3 System Reasoner

The System Reasoner will be Pellet Reasoner. It will be used to infer the logical relation between system entities and domain concepts. We will use Pellect Reasoner because we will use OWL2 to build domain ontology.

### 1.6.1.4 System Rules

System Rules will be built manually by a domain expert, then it will be integrated with a set of symptoms that appear on the children with CP. The discovered symptoms from phase one will be weighted by a group of experienced people through a knowledge-based survey. Some of rules are initially identified. For example:

- If *child* Has\_Symptom *Floppy* and Has\_Symptom *Continues\_Stiffen*, then The *Child* has *CP Disability*.

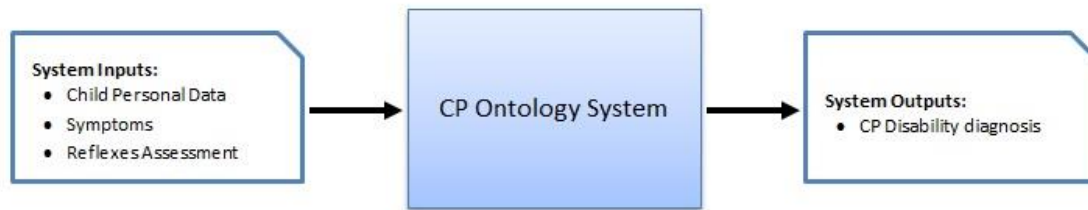
- If *child* Has\_Age “From 6 months to 12 months” and Has\_Symptom *Sitting\_Problems* and Has\_Symptom *Standing\_Problems* and Has\_Symptoms *Runny\_Saliva* and Has\_Symptom *Convulsions*, then *Child* has *CP Disability*.

Now, we can collect information about the child and his/her mother related to incidents, infections, and life skills he/she has or has not yet. This information will be used together in diagnosing CP using rules.

### 1.6.1.5 Cerebral Palsy Ontology Application (CP Ontology Application)

CP Ontology Application will be built using Java in order to connect and use other components through java code and OWL API. The application will be presented by a set of classes and frames that will be used for different purposes. The application will mainly connect graphical user interface with system components such as Reasoner, knowledge base, and rules. In addition to that, it will provide the ability to store and retrieve knowledge including previous CP cases information from knowledge base, display symptoms, display physical therapy support activities, and display diagnosis results. Moreover, this part of system will be responsible for adapting physical therapy work plans to each case based on symptoms that each child has and store new physical therapy treatments in the knowledge database.

CP Ontology application will be used to transform expert’s experience (Tacit Knowledge) into explicit knowledge by enabling the experienced physiotherapists or doctors to add physical therapy treatments and connect it with symptoms of CP in order to be used later in physical therapy treatment plans. The generated plan will be retrieved as a unit or will be built from basic units based on symptom that the child has. In addition, these generated plans will be improved to be fit with case needs.



**Figure (1.3):** CP Ontology System inputs and outputs

These six components will cooperate to process the user’s inputs to provide the system output as Figure 1.3 shows.

### 1.6.1.6 OWL API

OWL API is a Java API and inference implementation for creating, manipulating, and serializing OWL ontologies (GitHub, 2007). We will use OWL API to access ontology file in order to extract and store knowledge.

## 1.6.2 Phase Three: System Evaluation

We will evaluate our proposed approach by testing system functionality. The System Functionality testing will be conducted to ensure that the whole system (six Components) work together correctly to achieve the research objectives. We will use Domain Expert Review to test system functionality. Domain Expert Review will be used to ensure that the system diagnose CP cases correctly, generate support physical therapy plan and enable user to create new treatment activity for specific physical problem.

## 1.7 Thesis Structure

The thesis consists of seven chapters organized around the objectives of the research

**Chapter 1** (Introduction): Gives a short introduction on the diagnosing Cerebral Palsy disability, ontology, and the thesis problem and objectives.

**Chapter 2** (Theoretical and Technical Foundation): Describes the theoretical and technical foundation needed for the thesis work, Cerebral Palsy, disability, diagnosis of disability, symptoms, physical therapy, ontology concepts, and web application.

**Chapter 3** (Related Work): Presents related works on ontology and knowledge retrieval, disability diagnosis based on ontology, ontology and decision support.

**Chapter 4** (Knowledge Requirement Engineering): presents conceptual and logical design, in addition to rules induction and optimization.

**Chapter 5** (CP Diagnosis Ontology Development): describes the development of the CP disability ontology with the knowledge base and its evaluation.

**Chapter 6** (CP Diagnosis Ontology Approach): presents the ontology based approach realized as a web application for diagnosing CP disability.

**Chapter 7** (Experimental Evaluation and Discussion): presents an evaluation of CP Diagnosis Ontology system by conduct a number of experiments on the system.

**Chapter 8** (Conclusions and Recommendations): presents the conclusions and the possible future work.

## 1.8 Summery

In this chapter we introduced the thesis by descrbing Cerebral Palsy (CP) disability and ontology. Where, CP is one of the most complicated disabilities because most of the factors that causing CP are unknown. In Gaza Strip, number of children has CP disability increased in the recent years, but the quality of the care services not meets this increase. Around the world, there are different techniques used to diagnose CP but they use tools that are not available in Gaza Strip. Our research study proposed approach for diagnosing CP disability through its symptoms. The proposed approach will improve CP diagnosis process and improve quality of

physical therapy treatment by integrating parents in treatment plan. This will reflected positively on child daily life.

Research methodology divided into three steps. First step is to collect and analyse a set of documents that describing cerebral palsy disability in addition to review personal and medical records of children with CP in order to identify concepts of disability domain. Second step is describing the approach and components of the proposed system which include six components work together to provide system functionality. Third step is about the system evaluation, where the proposed system will be evaluated by a domain expert who will review results to ensure correctness of diagnosis and physical therapy support planning.



# **Chapter 2**

## **Theoretical and Technical**

### **Foundations**

## Chapter 2

### Theoretical and Technical Foundations

In this chapter, we presenting the fundamental concepts and technical knowledge that represent the basis for conducting and understanding of the thesis work. The basic information of disability and CP disability have been presented, In addition to, basic information about semantic web, ontology, ontology languages such as RDF, RDFS, OWL, querying, and reasoning.

#### 2.1 Disability

Disability is an impairment that may be cognitive, developmental, intellectual, mental, physical, sensory, or some combination of these and that substantially affects a person's life activities (Mackelprang & Salsgiver, 2016). A disability may be present from birth or occur during a person's lifetime.

Disability is an umbrella term, covering impairments, activity limitations, and participation restrictions. Impairment means a problem in body function or structure; an activity limitation is a difficulty encountered by an individual in performing a task or action; while a participation restriction is a problem experienced by an individual in involvement in life situations. Disability is not just a health problem. It is *a complex phenomenon, reflecting the interaction between features of a person's body and features of the society in which he or she lives* (World Health Organization, 2017).

There are different definitions for disability. The definition of disability improved year by year to include not only physical and mental disability but also included social barriers. Dan Goodley in his book *Disability Studies: An interdisciplinary Introduction*, Second Edition defined disability as, *the loss or limitation of opportunities to take part in the normal life on the community on an equal level with others due to physical or social barriers* (Goodley, 2016).

##### 2.1.1 Normal Development

Normal human's abilities start development since birth. This includes mental and motor abilities. All innate normal motor function, such as sitting, walking, jumping, running, reaching, and speaking, is a complex combination of individual motor skills that allow development of these activities of daily living.

Some other activities, such as playing a piano, dancing, gymnastics, and driving a car, require much more learning and practice to remain proficient. These motor activities all include volitional motor control, motor planning, balance and coordination, muscle tone, and sensory feedback of the motion.

As babies mature from infancy to 1 year of age, neurologic maturity develops rapidly from proximal to distal. To demonstrate, children first gain head control, then develop the

ability to weight bear on the arms, followed by trunk control and the ability to sit, then develop the ability to stand (Table 3.1). This progressive distal migration of maturation includes all the parameters of the motor skills (Miller, 2007).

**Table (2.1):** Normal development milestones

<b>Cross motor skills</b>	<b>Mean age of development</b>	<b>Abnormal if not present by:</b>
<b>Lifts head when prone</b>	1 Month	3 Months
<b>Supports chest in prone position</b>	3 Months	4 Months
<b>Rolls prone to supine</b>	4 Months	6 Months
<b>Sits independently when placed</b>	6 Months	9 Months
<b>Pulls to stand, cruises</b>	9 Months	12 Months
<b>Walks independently</b>	12 Months	18 Months
<b>Walks up stair steps</b>	18 Months	24 Months
<b>Kicks a ball</b>	24 Months	30 Months
<b>Jumps with both feet off the floor</b>	30 Months	36 Months
<b>Hops on one foot with holding on</b>	36 Months	42 Months

**Source:** Miller, F. (Ed.). (2007). *Physical therapy of cerebral palsy*. Springer Science & Business Media.

### 2.1.2 Physical Disability

Physical disability is a limitation on person's physical functioning, mobility, dexterity or stamina. Disability in mobility can be a congenital or acquired problem, or a consequence of disease. People who have a broken skeletal structure also fall into this category (Wikipedia, 2017).

### 2.1.3 Mental Disability

Mental disability is a concept that refers to different types of disabilities in its wide definition such as developmental disability, disabilities affecting intellectual abilities, intellectual disability, learning disability, mental disorder and Neurodevelopmental disorder.

Developmental disability: chronic condition that is due to mental impairments, often detected early in a child's development (Wikipedia, 2017).

Disabilities affecting intellectual abilities: a broad concept encompassing various intellectual or cognitive deficits (Wikipedia, 2017).

Intellectual disability: aka intellectual developmental disability (IDD), general learning disability, or mental retardation (MR), a generalized neurodevelopmental disorder characterized by significantly impaired intellectual and adaptive functioning (Wikipedia, 2017).

Learning disability: a classification that includes several areas of functioning in which a person has difficulty learning in a typical manner (Wikipedia, 2017).

Mental disorder (also called mental illness or psychiatric disorder): *a diagnosis of a behavioral or mental pattern that can cause suffering or a poor ability to function in ordinary life* (Wikipedia, 2017).

Neurodevelopmental disorder: *impairments of the growth and development of the brain or central nervous system* (Wikipedia, 2017).

#### **2.1.4 Cerebral Palsy Disability (CP)**

Cerebral means "concerning the brain" and palsy means paralysis or the inability to move. Cerebral Palsy (CP) *is a kind of paralysis that results from damage to the brain. The modern definition of CP is, a persistent but not unchanging disorder of movement and posture due to a non-progressive disorder of the immature brain* (that is, under about 2 years of age) (Hinchcliffe, 2007).

#### **2.1.5 Disability Symptoms**

Disability symptoms are tiredness, slowness, and pain doing daily tasks made difficult by health (Verbrugge & Sevak, 2004).

In general, each disease has a set of symptoms that appears and can be seen on the human body referring to the disease itself such as change in skin color, blood, body temperature, and headache. For disability, there are different symptoms caused by different types of disability including mental and physical disabilities. Some of disabilities share different symptoms with each others but in most cases there are at least one symptom can differentiate between each two disabilities. For example, cerebral palsy and brain atrophy share a set of symptoms such as seizures and speech difficulties but they differ in head lag where brain atrophy cause small head lag to the children.

### **2.2 CP Disability Diagnosis and Physical Therapy Treatment**

There are different techniques developed to diagnose CP disability. Some of these techniques used muscle tone (Ouellet & Jevremovic, 2016), where they measure knee pain during muscle exercise, and others used child weight as an indicator for cerebral palsy disability (Korzeniewski et al., 2016). For physical therapy treatment, children learn some new skills by receiving training or when they see other doing it such as playing and dancing. The same occurs with children who have disability in general and who has CP disability for specific. For children with CP, the disability will not disappear, but its effects will be reduced by medical and physical treatment in addition to rehabilitation. Most important factor for successful treatment is to diagnose CP early and to provide an effective physical therapy treatment based on the child needs (Hadders-Algra, 2014).

#### **2.2.1 CP Disability Diagnosis and Assessment**

Early diagnosis especially before 2 year old and good assessment of a child with CP is the key factor for effective treatment. Each child with CP is different, and the therapist who

treating the child must be able to find the underlying causes of his or her inability to function normally before the treatment to make it effective. There are different types of CP. These types can be described under two main headings which are the part of the body affected and the quality of the child's postural tone (Hinchcliffe, 2007). Based on the effects of brain's damage on child body there are three patterns which are hemiplegia, diplegia, and quadriplegia. A child whose body is totally affected is described as having quadriplegia, one whose lower limbs are mostly affected is described as having diplegia, and one whose upper and lower limbs in one side are affected described as having hemiplegia (Hinchcliffe, 2007).

### **2.2.2 CP Physical Therapy Treatment**

The goal of physical therapy treatment is to improve gross motor functions such as crawling, walking, running, jumping, and joint range of motion. In early childhood, the treatment's focus shifts during the early childhood from working on activities such as self feeding and removing clothes to fine motor skills such as using scissors and early writing skills. In middle childhood, the main focus will be over fine motor skills development, especially writing, self dressing, and toilet training, if it has not occurred yet (Miller, 2007).

## **2.3 Semantic Web and Ontology**

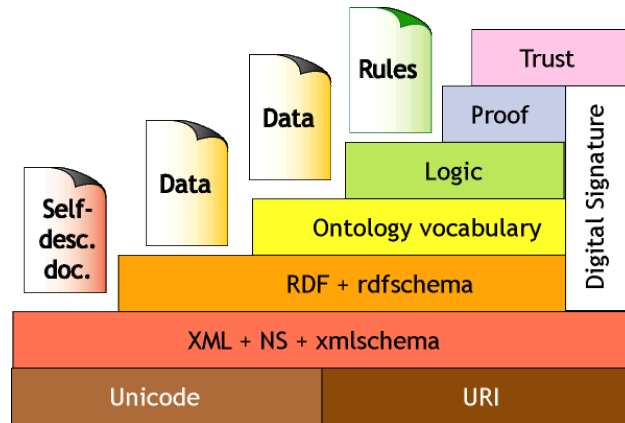
In this section we will give basic information about semantic web, ontology, ontology languages and tools, and how it can be built.

### **2.3.1 Semantic Web**

The word Semantic is related to the word syntax which means how to say something. Semantic means the meaning behind what you said. Therefore, the Semantic Web can be understood as "The Web of meanings". The main goal of semantic web is to make the web more understandable and accessible by human and machine.

The Semantic Web is *an extension of the current Web in which information is given well-defined meaning, better enabling computers and people to work in cooperation* (Yu, 2011).

Berners Lee proposed the semantic structure as the semantic web which contains seven layers. These layers are Unicode and URI, XML, RDF, Ontology, Logic, Proof and Trust.



**Figure (2.1):** A layered approach to the semantic web (Antoniou et al., 2012).

### 2.3.2 Ontology

Ontology formally defines a common set of terms that are used to describe and represent a specific domain. Ontology defines the terms that used to describe and represent an area of knowledge (Yu, 2011).

Ontology is a domain specific, which used to describe specific area of knowledge such as disability, diseases, education and medicine. Ontology contains terms and relations among these terms. The terms in the domain often called concepts or classes. Also, there is another level of relationships expressed by using a special group of terms which called *Properties*. The property term describe various features and attributes of the concepts, and they can also be used to associate different classes together. Therefore, the relationships among classes are not only super class or sub-class relationships, but also relationships expressed in terms of properties (Antoniou et al., 2012).

Now, by having well defined concepts and relationships between these concepts for specific domain, ontology can describe this domain in way that will be understandable and readable by human and machine.

There are many benefits for using ontology; some of them are (Yu, 2011):

- It provides a common and shared understanding/definition about certain key concepts in the domain.
- It offers the terms one can use when creating RDF documents in the domain.
- It provides a way to reuse domain knowledge.
- It makes the domain assumptions explicit.
- Together with ontology description languages (such as RDFS and OWL, which we will learn in the next chapter), it provides a way to encode knowledge and semantics such that the machine can understand.
- It makes automatic large-scale machine processing become possible.

### 2.3.2.1 Constructing Ontology

Building ontology is not easy task, which need time and effort in addition to domain expertise. There are steps for building ontology. Noy and McGuinness built a guide for building our first ontology (Noy & McGuinness, 2001). We will follow their guide that contains eight steps which are:

#### 1. Determine Domain and Scope of Ontology

In this research study, constructing CP ontology itself is not our goal. Where, it is a model for describing CP disability domain in order to diagnose CP disability. The developed ontology will be used to define a set of concepts and relations among these concepts in order to be used by other program. In this step there are basic questions should be answered (Noy N. F. and MCGuinness D. L., 2001, Ch. 7, P 195), which are:

- What is the domain that the ontology will cover?
- For what we are going to use the ontology?
- For what types of questions should the ontology provide answers?
- Who will use and maintain the ontology?

#### 2. Consider reuse

Semantic web provide effective solutions for different problems through ontology description for problem domain. Ontology used to represent different domains for different purposes. For example, in health care domain, there are different ontologies developed for diagnosis and treatment purposes. Most of these ontologies already constructed, tested, and available to be reused (Noy N. F. and MCGuinness D. L., 2001, Ch. 7, P 195). So, we should not start from scratch.

#### 3. Enumerate terms

The first step in the real developing of ontology is to build a list of terms, including nouns and verbs, which expected to appear in the ontology. Nouns are typically forms the classes and verbs forms the properties of the proposed ontology. These lists of terms or annotations initially built manually (Erdmann et al., 2000), but now there are different knowledge engineering tools can be used for enumerating domain terms such as laddering and grid analysis tools (Antoniou et al., 2012). M Erdman in 2012 developed automatic annotation tool for web content and digital libraries annotation called Pundit (Grassi et al., 2012).

#### 4. Define taxonomy

After defining domain terms, we have to build the taxonomic hierarchy of these terms. In step 3, we enumerate the terms that describe the domain in order to identify ontology classes. These classes cannot provide useful information without respecting semantics primitives such as `rdfs:subClassOf` (Noy N. F. and MCGuinness D. L., 2001, Ch. 7, P 196). This hierarchy can be built on top-down or bottom-up fashion.

## 5. Define properties

In step 3, we enumerate the terms that describe the domain in order to identify ontology classes. These classes cannot provide useful information without the properties that describe relation between these classes. It makes sense to attach general properties to the super classes because subclasses will inherit these properties, also we need to define domain and range immediately for each property (Noy N. F. and MCGuinness D. L., 2001, Ch. 7, P 196).

## 6. Define facets

In this step we enrich the properties that we previously defined in step 5 with facets that manage and control values on both sides of the defined property such as cardinality, required value and relational characteristics.

- *Cardinality*: Specify for as many properties as possible whether they are allowed or required to have a certain number of different values (Noy N. F. and MCGuinness D. L., 2001, Ch. 7, P 196). For example, a case may occur “at least one value”, this means this property is required.
- *Required Value*: Classes are defined by virtue of a certain property’s having particular values, and such required values can be specified in OWL, using owl:hasValue. Sometimes the requirements are less stringent: a property is required to have some values from a given class (Noy N. F. and MCGuinness D. L., 2001, Ch. 7, P 197).

## 7. Define instances

We use ontology to organize sets of instances for the proposed domain. The number of instances must be larger than the number of classes in the ontology. Because of the large number of instances, adding these instances to the ontology does not do manually.

## 8. Check for anomalies

After building ontology and defining instances, it is important to check the built ontology for internal inconsistencies. For example, inconsistencies may be in incompatible domain and range definitions for transitive, symmetric, or inverse properties.

### 2.3.2.2 Ontology Evaluation

There is no one ontology for one domain which means there are may be different ontology describing the same area in a knowledge domain. So, there is a high need to find the best suit ontology based on predefined criteria. Also, developers who constructing ontologies need some way to evaluate the constructed ontologies.

Based on kind and purpose of ontology, there are different approaches can be followed to evaluate ontology (Brank et al., 2005). There are four main categories of ontology evaluation approaches which are comparing the ontology with a golden standard (Maedche & Staab, 2002), use ontology for an application and then evaluate the results (Porzel &



Malaka, 2004), compare a set of document from domain with ontology to check if the ontology cover the domain or not (Brewster et al., 2004) and evaluate the ontology by a human by check how well the constructed ontology meet a predefined criteria and standards (Lozano & Gómez-Pérez, 2004).

From the above, we found there is no one best evaluation approach. So, the choice of selecting evaluation approach should be based on the purpose of evaluation.

### 2.3.2.3 Ontology Tools

There are many tools, applications and languages can be used for building ontologies, use ontology and implement queries over the constructed ontologies. Here under some tools that can be used for the mentioned purposes

- **RDF:**

RDF is a universal language that lets users describe resources using their own vocabularies. RDF does not make assumptions about any particular application domain, nor does it define the semantics of any domain. In order to specify these semantics, a developer or user of RDF needs to define what those vocabularies mean in terms of a set of basic domain independent structures defined by RDF Schema (Antoniou et al., 2012).

- **Web Ontology Language (OWL2):**

OWL describes the structure of a domain in terms of classes, properties, individual and restrictions. Its constructors of classes and properties have rigorous formal foundation based on Description Logic and there exists decidable reasoning algorithms when OWL is used under some restrictions. Individuals represent objects in the domain, maybe members of one or more classes. Properties describe the relationships between individuals, link two individuals. Classes, also known as sets members of classes, share some properties or characteristics.

OWL is a computational logic-based language such that knowledge expressed in OWL can be exploited by computer programs, e.g., to verify the consistency of that knowledge or to make implicit knowledge explicit. OWL documents, known as ontologies, can be published in the World Wide Web and may refer to or be referred from other OWL ontologies. OWL is part of the W3C's Semantic Web technology stack, which includes RDF, RDFS, SPARQL (OWL Working Group, 2012).

- **Protégé:**

Protégé is an open source application built to be used as ontology editor and knowledge management system (Stanford University, 2016). It can be used to build simple and complex ontology which works as framework for building intelegent systems. It has a graphical user interface to build ontologies. Ontology devlopers' can use the

constructed ontology using Protégé to be integrated with rule system in purpose of extracting knowledge.

- **Discriptive Logic (DL) Query:**

Description logic is a formal language for knowledge representation. It is used in artificial intelligence to describe and reason about the relevant concepts of an application domain. It is providing a logical formalism for ontologies and the Semantic Web, where the Web Ontology Language (OWL) and its profile is based on DLs (Wikipedia, 2017).

- **Semantic Web Rule Language (SWRL):**

SWRL is a proposed Semantic Web language combining OWL DL with function-free Horn logic, and it is written in Unary/Binary Datalog RuleML. Thus it allows Horn-like rules to be combined with OWL DL ontologies (Antoniou et al., 2012). A rule in SWRL has the form  $B_1, \dots, B_n \rightarrow A_1, \dots, A_m$ . If the head of the rule has more than one atom, then the rule can be transformed into equivalent set of rules.

- **SPARQL Query:**

It is a querying language used to select and extract particular part of knowledge that expressed by ontology. SPARQL is especially designed for RDF language, and need software to execute the query over specific ontology or set on ontologies.

- **Jena:**

Jena is a semantic web framework for java. It is providing a programmatic environment RDF, RDFS, OWL and SPARQL. It also includes a rule based inference engine (Yu, 2011).

- **OWL API:**

The OWL API is a Java API and reference implementation for creating, manipulating and serialising OWL Ontologies (GitHub, 2007). OWL API provides a set of methods that enable us to access, read and write from OWL files. In addition, it allows us to run reasoner over OWL file through java platform such as NetBeans and E-Clips in order to extract asserted and inferred properties.

## 2.4 Summary

In this chapter, we showed basic theoretical and technical foundations of disability and semantic web which will be used to develop our proposed approach. Disability have different definitions, but recently it's definition cover mental, physical and social disabilities. Cerebral palsy is one of most complicated disabilities which appear after a brain damage or brain abnormal development. So, CP appears directly after child birth or after an accident. CP will not completely treated but its impact may be reduced if the child diagnosed in

his/her early ages and if received effective and high quality treatment. Semantic web is a good technology and effective in diseases diagnosis based on previous studies. We explained the 8 steps for developing ontology and different queries languages that can be used to implement queries over ontology files such as SPARQL and DL queries.

# Chapter 3

## Literature Review

## Chapter 3

### Literature Review

Comparing to many years ago, now adays most of medical complex operations like surgery and diagnosis are conducted through computer systems (Lund et al., 2014). These systems provide high efficiency and accuracy. That's because the error rate in trusted applications is minimum and the performance of these systems increased by time where these systems designed to learn from its experience.

There are different studies have been conducted in diseases and disability diagnosis field (Nahar et al., 2013). The purpose of such studies is to improve health care services, give more accurate results, reduce diagnosis cost, and manage knowledge. Most of previous studies in this field can be classified in general into Case-based Reasoning (CBR) techniques, Expert Systems (ES) based techniques, and ontology based techniques. In this chapter, we review the most popular techniques and methods that used in diagnosis and treatment field.

#### 3.1 Case Based Reasoning (CBR) methodology for diagnosis purposes

Case Based Reasoning CBR is one of best methodologies that used in combination with other methodologies such as artificial intelligence and ontology for problems solving and learning such as diseases diagnosis and treatment support systems in medical fields (Sharma et al., 2015). Case-Based Reasoning means reasoning from experiences (previous cases) in order to solve new problems and explain anomalous situations (Salem & Voskoglou 2013).

There are many researchers conducted based on CBR in diseases diagnosis field. Most of these studies developed effective techniques for diseases diagnosis and treatment. In 2009, a research study, conducted by Lin, employed classification and regression tree (CART) and case-based reasoning (CBR) techniques to structure an intelligent diagnosis model aiming to provide a comprehensive analytic framework to raise the accuracy of liver disease diagnosis (Lin, 2009). Regarding Diabetes diagnosis, a research study conducted in 2014, developed an encoding methodology for clinical data using systemized nomenclature of medicine medical terms SNOMED CT where a case study for diabetes diagnosis data set tested (El-Sappagh et al., 2014). They found that their methodology of using CBR and ontology is suitable for coding any datasets in medical domains. HESS is ontology supported CBR system for cognitive diagnosis of HIV and AIDS (Sharma et al., 2015).

RespiDiag is a decision support system for the diagnosis of serious respiratory disease caused by tobacco named the chronic obstructive pulmonary disease. The system is based on case-based reasoning principles and gathers the experience of experts of the pneumology department of Dorban Hospital in Algeria (Guessoum et al., 2014).

These case based reasoning techniques provide effective and useful solutions for diagnosing different type of diseases including disability. But, to develop such solution you need to have the right and pure corner stone which is a set of the previous cases or training examples (Sutanto et al., 2014). Where, most of electronic health records contain a huge amount of personal and medical data and need effort to be prepared. In addition, the system performance depends on the size of training examples, and these systems will lose its usefulness when a new case submitted but not matched with previous cases. So, CBR is effective approach for rich and complex domains in which there are many ways to generalize a case (Chattopadhyay et al., 2013).

For CP disability diagnosis, there are different reasons prevent using CBR to diagnose children with CP disability in Gaza Strip. Where, each child with CP has different mental and physical disorders based on the affected area in brain. Moreover, there are no electrical records available in health care center contains detailed health data and most of available data are in paper documents, which need huge time to be converted into electrical records. But, we found that we can benefit from experts experience in disability domain by extracting their experience with previous problems in specific domain in order to use it for solving new problems or cases.

### **3.2 Expert Systems methodology for diagnosis and treatment purposes**

Experts system is a computer system designed to solve complex problems based on reasoning where expert system behaves like a human in solving these problems. In recent years, the use of expert systems increased and witnesses a fast growing. This grow increased because expert systems reduce the required time to diagnose specific diseases, reduce diagnosis cost, minimize error rate in diagnosis that physicians made, and minimize cost of laboratory tests (Al-Hamadani, 2014).

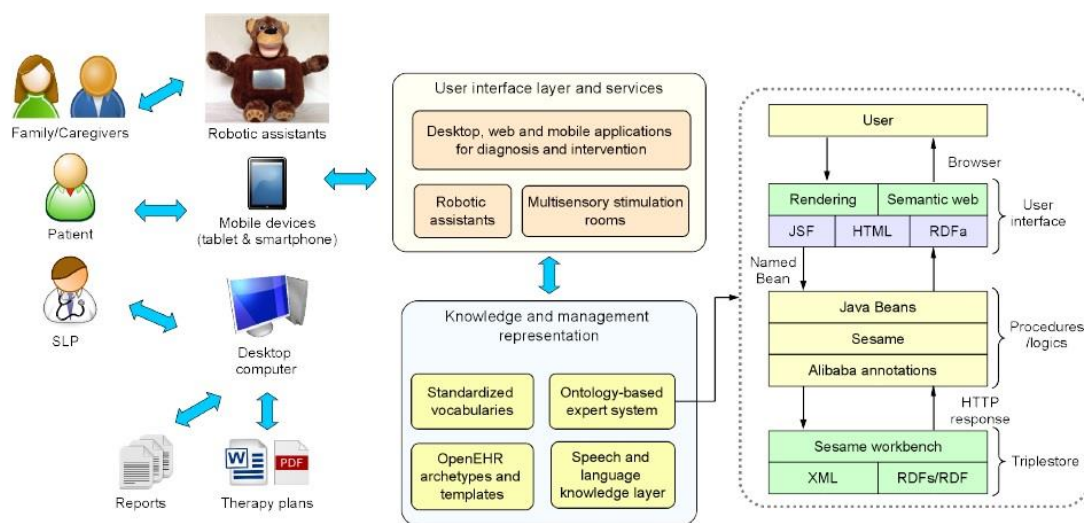
Recently, several studies proposed an expert system based techniques using ICT or ontologies to improve the effectiveness of diagnosis assessment and diseases treatment. Jorge Galan-Mena developed an expert system based on ontologies and ICT tools to support diagnosis and intervention of children with Autism (Galán-Mena et al., 2016). Their system success to handle the domain knowledge of Autism by define domain and build rules, and keep in mind the needs of each patient.

In 2015, Rawte V. et. al. developed OBESTDD system. OBESTDD is an ontology based expert system for Thyroid disease diagnosis (Rawte & Roy, 2015). The main objective of developing OBESTDD is to use expert system and ontology to build an effective system to diagnose thyroid disease which help people who lives far from clinics to diagnose the disease for free especially in India. They used Expert Systems technology as interactive tool that use knowledge and rules to solve difficult decision problems. Also, they built an ontology that describes domain knowledge and contains three main classes which are Category, Diagnosis, and symptoms. The system has been tested through hospitals sample

that involved 4739 patients have thyroid function test, where higher prevalence of hypothyroidism was observed. This means the system success to correctly diagnose thyroid disease.

In 2014, Al Hamadani developed a system called CardioOWL which is an ontology based expert system for diagnosing coronary artery diseases (Al-Hamadani, 2014). The objectives of the proposed system is building CardioOWL ontology based expert system to help the general practitioners (GPs) to diagnose the all types of cardio diseases and give recommendation of medicine and required operations. Researcher used ontology to describe and represent the knowledge domain, and SWRL rules to deduce the suitable medicine and the required operations for the patient. The researcher follows METHNOLOGY methodology which does not specify only the stages but also depicted the depth of some of these stages. CardioOWL system has been tested by defining 10 instances and the system ran by different three general practitioners to ensure the generality of the designed system. The correct results obtained by the system after implementing all the instances were 100% correct, and system average precision was 0.872 and recall was 0.831.

In the same line, Robles-Bykbaev et al. present an ontology-based expert system to generate general intervention guidelines for children with disabilities and communication disorders. The system includes several intelligent ICT tools such as robotic asisement, mobile application and web environment (See Figure 3.1). They represented the domain knowledge using ontology. The ontology entities have been identified manually by doman 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 (Robles-Bykbaev et al., 2016).



**Figure (3.1):** Architecture of the ontology-based ES that generate therapy plans for communication disorders. (Robles-Bykbaev et al., 2016)

In this part, we found expert systems are effective in diseases diagnosis and treatment domain, avoid the problem of learning examples or previous cases, knowledge base can be extended and updates, can process a huge amount of information and rules, reduce required time to diagnose diseases, and one expert system can include experiences of many domain experts. In addition, it is easy to be combined and implemented with a knowledge base represented through ontology. For example, Robles-Bykbaev et al. presented ontology-based ES to generate therapy plans for communication disorders.

But, the main problem is the domain knowledge, where, the developers need always to refer to a domain expert for support, however domain expertise have high value and difficult to reach. Also, expert system based solutions face another challenge which is to define the rules and ontologies; however this problem solved by referring to domain expert, the solution is still challenge.

### **3.3 Ontology methodology to describe domains for decision support purposes**

Ontology is a formal naming and definition of types, properties, and interrelationship of the entities that exist in a particular domain (Taleb, 2016). Ontologies used widely to support different techniques such as Case Based Reasoning (Sharma et al., 2015; El-Sappagh et al., 2014), Expert Systems (Al-Hamadani, 2014; Rawte & Roy, 2015; Galán-Mena et al., 2016), Semantic Search (Anusha & Sathiyamoorthy, 2016), and Data integration (Daraio et al., 2016). In health field, it is widely used to define health domain and support diseases diagnosis like Cancer Disease diagnosis (Taleb, 2016), Tuberculosis Disease diagnosis (Pandiyan et al., 2016), and many other diseases.

In 2014, Y Kassahun et. al. developed an ontology-based classification approach which aims at developing a fully automatic classifier of epileptic types and their localization using ictal symptoms and machine learning methods (Kassahun et al., 2014). They presented the achieved results by using two machine learning methods. First method was an ontology-based classification which can directly incorporate human knowledge. The second method was a genetics-based data mining algorithm that extracts the domain knowledge from medical data in its implicit form. The developed approach tested on a clinical dataset of 129 patients. Where, the performance of the methods is measured against the performance of seven clinicians. The results showed that the approach perform at the level of experienced clinicians, when both the methods and the clinicians use the same information.

In 2014, F. Alamu et. al. develop a semantic ontology for Malaria disease using Protege OWL software (Alamu et al., 2014). The objective of the research was to develop an ontology model that is completely devoted to the malaria parasite along with the establishment of a semantic website that enables a less cumbersome mode of access to relevant information gathered on malaria. The methodology of the research study was



gathering adequate and correct information on malaria from recognized bodies, developing an ontology model from the information given, and providing a means of remote or online access for individuals or groups that require information that is well represented. System performance evaluation results showed that the developed ontology-based system is a user friendly, has enough summarized information, and recommended to be used as reference for malaria disease management.

From my point of view, I found that ontology is a good methodology to define and describe specific domain's knowledge base. It helps to give a semantic to domain concepts which will be human and machine readable and support efficient reasoning. In addition to that, we found that ontology worked effectively with different methodologies such as case-based reasoning and expert systems, and widely used in diseases diagnosis and treatment, that's because it is provide a semantic representation of domain concepts which enable systems to develop new facts from the exesting ones.

### 3.4 Cerebral Palsy Diagnosis

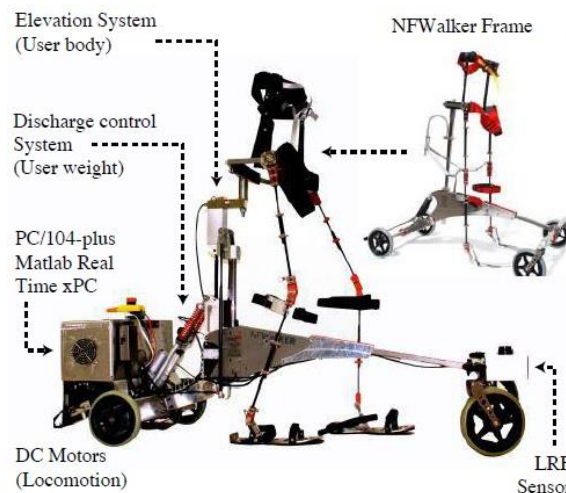
Cerebral palsy is an umbrella term used to describe a group of clinically defined developmental disorders of movement and posture that cause activity limitation, are attributed to nonprogressive disturbances occurring in the developing fetal or infant brain, and are often accompanied by disturbances of sensation, perception, cognition, and communication (Baxter et al., 2007).

Researchers in the recent years developed different assessment and diagnosis techniques to diagnose Cerebral Palsy disability in early ages. Some previous studies diagnosed Children with CP in early ages based on child weight (Korzeniewski et al., 2016), diagnose CP for 9 years old children (Ouellet & Jevremovic, 2016), and children younger than 4 years (Eliasson et al., 2016).

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 (Velasco et al., 2014). In their research, 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 this paper is to develop a computerized technique to assess motor signs for people with CP by measuring and analyzing on patient task performance and control of posture. To reach this, they followed reaching task methodology. Where, they developed analysis system with interface (GUI) contains points and a course 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. The system tested by 11 participants, classified into two groups' first group consisted of 3 controlled persons, and the second group consisted of 8 CP patients. The test results show high task performance in the controlled group, and median in the CP patients group.

Cifuentes, C. A. et. al., in 2016, developed Human-Robot Interaction Strategy for Overground Rehabilitation in Patients with Cerebral Palsy (Cifuentes et al., 2016). The main objective of the proposed strategy is to present a Human-Robot interaction strategy for

robotic-based over ground rehabilitation as novel therapy for CP rehabilitation. This approach will enable the use of a robotic platform through which the child can start experiencing autonomous locomotion in a rehabilitation environment. To reach their study objective, the researchers developed a new strategy implemented on a new robotic platform named CPWalker which used to improve the locomotion treatment for children with CP. Their methodology was to modify an existing robotic system. They tested their modified robotic system by using the CPWalker by two CP patients. After 60 seconds patients presented more homogeneous gait patterns until the end of the experiments. Also, their velocity was increased over the time.



**Figure (3.2):** CPWalker platform. (Cifuentes et al., 2016)

Korzeniewski, S. J. et. al., in 2016, conducted a research study called Persistence of Cerebral Palsy Diagnosis: Assessment of a Low-Birth-Weight Cohort at Ages 2, 6, and 9 Years (Korzeniewski et al., 2016). Study objective was to identify the best age for diagnosis children with cerebral palsy disability. The research methodology was to diagnosis newborn children then does a follow up till school age the get a final diagnosis. They found 4 out of 10 children have no longer CP disability, and 6 out of 10 still have the same diagnosis. Also, they found that 2 years seems a reliable time to diagnose cerebral palsy severe enough to cause disability, but not to diagnose milder cases.

Eliasson, A. C., in 2017, developed a Mini-MACS system which is a development of the Manual Ability Classification System for children younger than 4 years of age with signs of cerebral palsy (Eliasson et al., 2016). The main objectives of the research study it to develop a Mini-Manual Ability Classification System (Mini-MACS) and to evaluate the extent to which its ratings are valid and reliable when children younger than 4 years are rated by their parents and therapists. The development process involved a pilot project, consensus discussions within an expert group, and the creation of a test version of the Mini-MACS. A sample of 61 children with signs of cerebral palsy aged 12 to 51 months was classified by one parent and two occupational therapists across a total of 64 assessments. Agreement between the parents' and therapists' ratings was evaluated using the intraclass correlation coefficient (ICC) and the percentage of agreement. Most parents and therapists found the

descriptions in the Mini-MACS suitable and easy to understand. Which mean, the Mini-MACS seems applicable for children from 1 to 4 years of age.

Ellouze A. S. et al. in 2014 reused OpenEHR archtypes for the expression of Cerebral Palsy electronic health records. The problem was that a hospital in Tunisia, that providing health care to children with Cerebral Palsy disability, has different doctors who provide different services to the same child but without proper sharing of the information. So, the solution is an information system that represent CP disability domain, as they said. To reach that, they proposed to cover all concepts related to CP through reuse of OpenEHR archtypes in order to use it in developing the proposed information system. At the end of their research they reused a set of archtypes with a set of concepts that manually extracted from therapy documents to represent CP domain. The results of this study encourage us to follow the same approach for reusing archtypes in open repositories. In addition, we can reuse some of the concepts identified in this work with some adaptation.

From my point of view, I found these researches provide effective techniques for diagnosing cerebral palsy and for improving physical therapy treatment. In addition to that, they got good results that can help researchers in future solutions for CP diagnosis. From the literature review, we found that symptoms do not have the same weight for indicating CP, the improvement of physical therapy treatment comes from including home in treatment process, child birth weight can be used as indicator for CP disability, and year 2 is the best age to diagnose children with spasticity not mild children.

But, these techniques developed for specific cases like child age and works based on only one symptom like muscle tone (Ouellet & Jevremovic, 2016) or child weight (Korzeniewski et al., 2016). However, there are a set of symptoms that helps to diagnose CP for children in early ages in general. Also, some types of CP cannot be diagnosed based on specific indicators like weight or head motor in early ages. So, I think our proposed system can benefit from these studies (Korzeniewski et al., 2016; Ouellet & Jevremovic, 2016; Eliasson et al., 2016), expert systems advantages and ontology advantages to provide provisional diagnosis of CP for children from 1 day to 3 years.

Based on the the previous literature review, we found that Case-Based Reasoning will not be effective because the limitation of a available electronic health records in Gaza health care centers. Expert systems is a good solution, but we need to combine it with ontology in order to improve effectiveness and accuracy of the proposed approach because ontology will enable us to use reasoning over the knowledge base.

Expert systems will enable us to avoid the need for training examples by using a set of rules for cerebral palsy diagnosis, but it will not be effective for developing physical therapy treatment plan for each case based on its need. Ontology is a good technology for describing domains through a set of concepts and relations between these concepts, also it will enable us to discover and inferred relations. So, we found that the combination between expert systems

technology and ontology will give us the opportunity to develop effective approach CP diagnosis and physical therapy treatment.

Also, we found that there are different tools used to evaluate the developed diagnoses techniques and approaches. Those tools were effective and useful, so we will use some of them in the evaluation part of our work. In addition, we found that ontology is an effective technology to define and describe disability domain for decision support or diagnosis purposes, ES is effective when we have clear symptoms, and CBR will be useful in rich and complex domain. However, CP symptoms are defined but overlap with other type's disabilities symptoms. So, we find that it is better to use ontology to describe CP domain knowledge.

### 3.5 Summary

In this chapter, we presented a number of previous studies in Case-Based Reasoning, Expert Systems, and Ontology methodologies regarding decision support in disease and disability diagnosis and treatment. Also, we presented a set of studies that developed techniques for CP diagnosis or conducted assessment studies regarding CP disability.

From our review, we found that based on the available resources in Gaza Strip we have to benefit from the results of previous studies to design a new ontology-based approach to diagnose CP disability. We found that:

- The early diagnosis of CP disability will increase the effectiveness of physical therapy treatment and will reduce the disability impact on the child and parents daily life.
- Abnormal or disruption of brain development causes Cerebral Palsy (CP) disability.
- Brain damage causes a set of physical and mental disorders called symptoms that are appear on the children with CP disability.
- We can use symptoms as indicators of CP disability.
- Famous types of CP disability, such as Spastic Cerebral Palsy, can be recognized through the symptoms.
- Other types of CP disability, such as Mild Cerebral Palsy, can be recognized through additional assessments like reflexes assessment.
- We should connect symptoms and reflexes with child age in order to indicate abnormal symptoms and reflexes.
- Each symptom has different indication weight to Cerebral Palsy disability.
- According to the limitation of available resources including electronic health records, and based on the need to extract new facts from the existing ones, an ontology-based approach will be more effective than CBR and ES in CP disability diagnosis.
- We can use some of motor signs that mentioned in the previous studies to indicate some forms of CP disability such as head support sign.

# **Chapter 4**

## **Knowledge Requirement Engineering of CPOno and Rules Induction**

## Chapter 4

### Knowledge Requirement Engineering of CP Ontology and Rules Induction

In this chapter we will present the knowledge requirement engineering of our proposed approach for cerebral palsy disability diagnosis using ontology. We will also present rules induction optimization process. This part of our work has been submitted as a paper titled “Towards Rules Induction Optimization for Cerebral Palsy Diagnosis: An Empirical Study” to the International Conference on Promising Electronic Technologies 2017. It is accepted and will be published in IEEE. This chapter is divided into two main parts, first part showing the main steps for knowledge requirement engineering and the second part show the process of inducing diagnosis rules through knowledge based survey.

#### 4.1 Knowledge Requirement Engineering of CP Ontology

Requirement engineering activities are varying widely depending on the type of system being developed, people involved, and organization itself. In our study we found that there are four activities will be usefull for CP Ontology requirement engineering which are requirement gathering and elicitation, requirement analysis, requirement validation, and requirement management.

##### 4.1.1 Requirments Gathering and Elicitation

In recent years, different reports have been published by governmental and non-governmental organization showing the need for improving health care services especially in disability domain. Regarding cerebral palsy disability, Dr. Mahmoud Douleh, the medical director of Cerebral Palsy Center in Palestine Avner for Childhood Foundation, published a report called “Cerebral Palsy in Gaza, Facts and Future” in 2013. In that report, he asked for more studies in Cerebral Palsy disability domain in Gaza Strip.

So, we conducted a deep review in disability and cerebral palsy disability domain to get more understanding of the problem and the needs. Then, in October 2016, we conducted different interviews with Dr. Mahmoud and his team in order to identify the needs, then to transform it into a research goal and objectives.

We found that they are using a paper documenting and diagnosing template prepared inside Cerebral Palsy Center. The template used by the doctor to provisionally diagnose new cases, and later for follow up purposes by the team. At the end of this phase, we successfully identified a set of functional and non-functional requirments that can be achieved by a specific system or approach, which are:

➤ **Functional Requirements:**

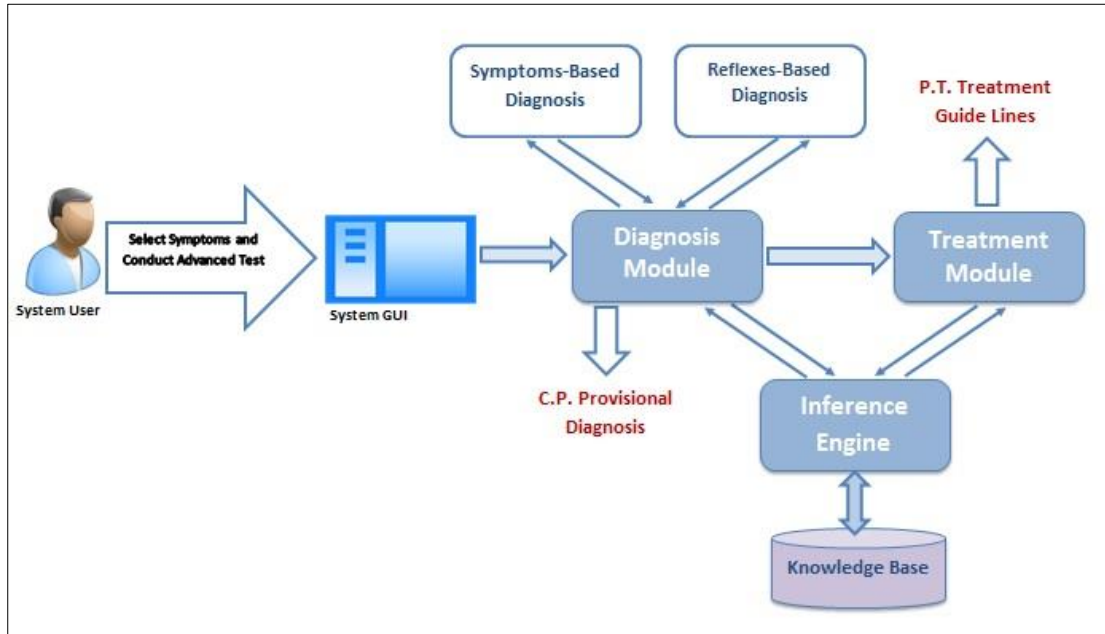
- The system enables the specialist to add symptoms that the child has in order to diagnose CP disability.
- The system enables the specialist to get cerebral palsy diagnosis based on weights of submitted symptoms.
- If initial diagnosis is “Probably Have C.P.” then the system will recommend advance diagnosis test, else, if initial diagnosis is “Definitely Have C.P.” then initial diagnosis will be the final provisional diagnosis.
- The system enables the specialist to get type of cerebral palsy based on submitted symptoms.
- The system enables the specialist to generate a manual of guidelines for the child caregivers in order to support physical therapy treatment based on the symptoms that the child has.
- The system enables the specialist to display basic information of cerebral palsy and cerebral palsy sub-types.
- The system enables the specialist to display basic information of each symptom.
- The system enables the specialist to display basic information of each physical therapy treatment.
- In order to share knowledge, the system enables the specialist to add physical therapy treatment to treat specific symptom.

#### ➤ *Non-Functional Requirement*

- **Usability:** System have five main interfaces which are main interface, diagnosis interface, physical therapy support guidelines interface, about C.P. interface, and add treatment interface. These interfaces designed to be simple and easy to be used by non-professional users like doctors and physiotherapists.
- **Effectiveness:** However the traditional ways of cerebral palsy disability diagnosis take too much time because most of these ways done based on paper documents and diagnosis templates, the proposed system provides good quality performance comparing to effort provided to diagnose cerebral palsy disability. Where the user just select the symptoms that the child have in order to diagnose C.P. disability.
- **Extensibility:** CP Ontology system has been designed and developed to easily extend with new features, where based on the future need different functions can be added to the knowledge base and the the interfaces.

#### 4.1.2 Requirements Analysis

We found that the functions of the proposed system are clear and already meet the needs of the primary health care providers who provide diagnosis and physical therapy treatment for children with cerebral palsy. The structure of the proposed system will have three main modules as Figure 4.1 shows. These modules named; *Diagnosis Module*, *Treatment Module*, and *Inference Engine Module*.



**Figure (4.1): CP Ontology System Structure**

In order to diagnose new case, system user will identify symptoms that the child has to the Diagnosis Module. System Module will use Inference Engine Module to read weights of symptoms and then submit them to Symptoms-Based Diagnosis component in order to conduct initial diagnosis based on symptoms. Then, if initial diagnosis is “Probably Have C.P.” then Diagnosis Module will recommend advanced testing to the user through Advanced Testing-Based Diagnosis component. In such scenario, the user will conduct tests and submit results. Then the Diagnosis Module will show diagnosis result.

After making diagnosis, if the child has C.P. disability, then user can prepare physical therapy support treatment plan based on the symptoms and advanced testing results through Treatment Module that refers to Inference Engine Module to get treatments that match symptoms and testing results.

### 4.1.3 Requirements Validation

Based on a systematic manual analysis for requirements conducted with domain experts including doctors and physiotherapists we found that the identified requirements are supporting the needs of health care providers of cerebral palsy disability, compatible, can be verified, and can be implemented through new computer technologies such as expert systems and ontology.

### 4.1.4 Requirements Management

System requirements may be changed during requirement engineering process and development process. In our research study, we start diagnosing cerebral palsy disability firstly based on symptoms, but after developing and testing CP Ontology system we found that some cases did not diagnosed correctly by the system. So, we added new function



called “Advanced Testing-Based Diagnosis” which follows Symptoms-Based diagnosis when diagnosis result is “Probably Have C.P.”.

## 4.2 Symptoms Weighting and Rules Induction

The aim of this section is to weight symptoms and identify reflexes that indicate brain damage that cause cerebral palsy disability. Symptoms and reflexes will be compined with a set of rules that describe the relation between cerebral plasy from one side, and symptoms, reflexes and child age in the other side. These rules will be used to diagnos cerebral palsy and to identify its sub-type.

To weight symptoms, we need initially to list all the symptoms that may appear on children with CP whoes ages are from one day to three years old. Here, we prefeere to conduct a deep review for a set of books and previous studies inorder to list cerebral palsy symptoms manually, in additional to that use diagnosing document that prepared in Cerebral Palsy Center of Palestine Avenir for Childhood Foundation. Then, review the built list with a domain expert to ensure its completeness.

In previous studies there are different techniques and methods developed to extract rules from datasets or from knowledge base. Some of these techniques are decision Tree and neural networks. Decision tree methods are effective in extracting rules from existing big dataset, but in cerebral palsy disability domain in Gaza Strip, we have no computerized big dataset of children with CP to extract rules using rule induction methods. However decision tree produce a simple and easy to be understood model, the calculations can get very complex particularly if many values are uncertain and/or if many outcomes are linked. In addition, in some domain decision tree can grow huge, where become hard to understand and become less accurate.

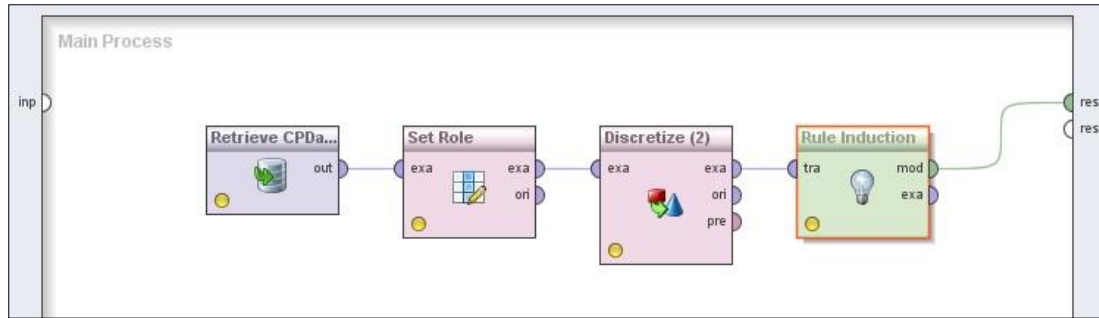
Neural networks offer a number of advantages, including requiring less formal statistical training, ability to implicitly detect complex nonlinear relationships between dependent and independent variables, ability to detect all possible interactions between predictor variables, and the availability of multiple training algorithms (Tu, 1996). But, neural networks need greater computational burden, proneness to overfitting, and the empirical nature of model development.

### 4.2.1 Rule Induction through Data Mining Approach

Information can be analysed in different ways in order to extract useful and novel knowledge and information. One of the ways is classification of information in order to classify new data based onto predefined set of classes. Classification is effective in decision making tasks (Datta & Saha, 2016). It is also enable us to pridect about future behavior of the same datatype. Which mean, in disability diagnosis domain we can use datamining to build classification rules to be used then to classify new cases such as cerebral plasy.

To induce rules, we initially used data mining to extract rules from personal and health records of children with cerebral palsy. We used rapid miner application to extract a set of

rules using Rule Induction operator which is an operator provided by Rapid Miner for rule extraction as figure 4.2 shows.



**Figure (4.2):** Rule induction process using Rapid Miner.

In the rule induction process, there are four components which are necessary to generate rules using Rule Induction operator. The first component is *Dataset* which contained 50 records collected using online survey. The second component is *Set Role Operator* which is used to change the role of one or more attributes. The third operator is *Discretize by Entropy* which is used to convert the selected attributes into nominal attributes where Rule Induction Operator can process it. The fourth component is *Rule Induction operator* which used to build rules from the relationship between attributes in dataset.

But, unfortunately we collected very small amount of data which was 70 records. That data was low quality and did not provide meaningful results as figure 4.3 shows. So we have to use another tool for rules induction which will be Knowledge-Based Survey.

```

RuleModel

if Child age when you saw him/her = 12 Months to 36 Months - شهر حتى 36 شهر - 12من and Uncontrolled movements = Null then
if Mental Age = 3 Months to 6 Months - شهور حتى 6 شهور - 3من and Speaking difficulties = Null then Cerebral Palsy (9 / 1 / 0 / 0 / 0)
if Shoulder and head press back = Yes then Spastic CP (0 / 3 / 0 / 0 / 0)
if Slow Development = Null and Never Cry = Yes then Cerebral Palsy (5 / 1 / 0 / 0 / 0)
if Uncontrolled movements = Yes then Athetosis CP (0 / 0 / 6 / 0 / 0)
if Never Cry = Yes then Spastic CP (0 / 3 / 0 / 0 / 0)
if Abnormal gait = Yes then Ataxic CP (0 / 0 / 0 / 4 / 0)
if Mental Age = 9 Months to 12 Months - شهور حتى 12 شهر - 9من then Cerebral Palsy (2 / 0 / 0 / 0 / 0)
if Runny saliva = Yes then Spastic CP (0 / 2 / 0 / 0 / 0)
else Not Cpecified (0 / 0 / 0 / 0 / 0)

correct: 44 out of 50 training examples.
    
```

**Figure (4.3):** Extracted rules from real dataset for children with CP

#### 4.2.2 Rule Induction through Knowledge-based Survey

There are different methodologies developed and used in order to survey knowledge. One of them is questionnaire methodology. Mainly, there are three types of questionnaire which are Open-Ended Question, Partially Categorized Questions, and Closed Questions (Denscombe, 2014). In our research, the objective of knowledge-based survey is to weight specific and pre-defined set of symptoms that are indicating cerebral palsy disability in order to optimize diagnosis rules. These symptoms will be weighted by a group of domain

experienced people who have experience with cerebral palsy disability. Thus, we will use closed questions in the questionnaire.

We set our own methodology for conducting questionnaire, which contains five steps. This methodology will be fit to extract tacit knowledge from specialists who have past experience with CP disabilities. The steps that we will follow are: Identification of CP Symptoms, Questions and Choices Identification, Survey Design, Targeted Group Selection, and Survey Implementation and Results Collection.

➤ **Step 1: Identification of CP Symptoms**

Manually, we collected a set of symptoms that indicate Cerebral Palsy disability from a set of documents and diagnosis forms. We identified 52 symptoms that appear on children with CP. The identified symptoms collected from a set of books, papers, and evaluation manuals such as the form that the Palestinian Avenir for Childhood Foundation uses for CP diagnosis in Cerebral Palsy Center. These symptoms have been evaluated by a domain expert<sup>1</sup>, and it is represent the primary and secondary symptoms that may appear on children with CP disability as the domain expert declared.

➤ **Step 2: Questions and Choices Identification**

In our proposed knowledge-based survey we identified 8 questions for the questionnaire. These questions are distributed into three categories: Survey Respondents, Symptoms and Child Age, and Initial Diagnosis. First category contains three questions about survey respondents in order to ensure their eligibility to answer our knowledge-based survey based on their working experience, education background, and specialization (See Table 4.1). The second category contains four questions, three of them are about the child age including age, motor age and mental age (See Table 4.2). The fourth question in this category is about symptoms that the child may have (See Table 4.3). The third category contains one question about survey respondent's opinion in the diagnosis as Table 4.3 shows. In this question, responders give their opinion in diagnosing sub-type of CP based on the selected symptoms.

**Table (4.1):** Questions 1 to 3 in survey about respondents

<b>Question 1</b>	<b>Education degree you have - الدرجة العلمية الحاصل عليها</b>
<b>Choice 1</b>	Diploma Degree - دبلوم
<b>Choice 2</b>	Bachelor Degree - بكالوريوس
<b>Choice 3</b>	Master Degree - ماجستير
<b>Choice 4</b>	Phd Degree - دكتوراه
<b>Question 2</b>	<b>Specialization - التخصص</b>
<b>Choice 1</b>	Human Medicine - طب بشري
<b>Choice 2</b>	Physiotherapy - علاج طبيعي
<b>Choice 3</b>	Community Based Rehabilitation - تأهيل مجتمعي

<sup>1</sup> The domain expert is the doctor who responsible for disability diagnosis in Cerebral Palsy Center of Palestinian Avenir for Childhood Foundation

<b>Choice 4</b>	Occupational Therapy - علاج وظيفي
<b>Question 3</b>	Experience in years - سنوات الخبرة
<b>Choice 1</b>	From 1 Year to 3 Years - من 1 سنة الى 3 سنوات
<b>Choice 2</b>	From 4 Years to 6 Years - من 3 سنة الى 6 سنة
<b>Choice 3</b>	From 7 Years and plus - من 7 سنوات وأكثر

In our survey, the choices have been set for each question based on the required information from these questions. So, each question has different number of choices and different answers in most cases. These choices have been identified based on a set of pre-defined restrictions in order to collect the information from its right resources and to reach the exact objective of conducting survey which is previously declared. In first group which is about survey respondents, we set four education degrees for Education level question starting from Diploma to PhD. The second question has four choices which are four specializations that deal with people with disability.

**Table (4.2):** Questions 4 to 6 in survey about child age

<b>Question 4</b>	<b>Child age - عمر الطفل</b>
<b>Choice 1</b>	1 Day to 6 Months - من 1 يوم حتى 6 شهور
<b>Choice 2</b>	6 Months to 12 Months - من 6 شهور حتى 12 شهر
<b>Choice 3</b>	12 Months to 36 Months - من 12 شهر حتى 36 شهر
<b>Question 5</b>	<b>Motor Age - العمر الحركي</b>
<b>Choice 1</b>	1 Day to 3 Months - من 1 يوم حتى 3 شهور
<b>Choice 2</b>	3 Months to 6 Months - من 3 شهور حتى 6 شهور
<b>Choice 3</b>	6 Months to 9 Months - من 6 شهور حتى 9 شهور
<b>Choice 4</b>	9 Months to 12 Months - من 9 شهور حتى 12 شهر
<b>Question 6</b>	<b>Mental Age - العمر العقلي</b>
<b>Choice 1</b>	1 Day to 3 Months - من 1 يوم حتى 3 شهور
<b>Choice 2</b>	3 Months to 6 Months - من 3 شهور حتى 6 شهور
<b>Choice 3</b>	6 Months to 9 Months - من 6 شهور حتى 9 شهور
<b>Choice 4</b>	9 Months to 12 Months - من 9 شهور حتى 12 شهر

In the second group, there are four questions about child age, motor age, mental age, and symptoms. Child age question have three choices which identified based on the ages that the original research cover which is from 1 day to 34 months. This period divided into three sub-periods based on normal development of the child. The last question in this group is about the symptoms that CP may cause. This question is multiple-choice and has 52 answers, where the survey respondents can select more than one choice.

**Table (4.3):** Question 7 in survey about CP symptoms

Question 7	Which of the following symptoms appears on a child whose age specified previously in Q4 أي من هذه الأعراض تظهر على الطفل خلال الفترة العمرية المحددة سابقاً في البند رقم 4
Choice 1	Floppy/Limp
Choice 2	Can not hold up his/her head
Choice 3	Do not use one hand
Choice 4	Do not use both hands
Choice 5	Abnormal Reflexes
Choice 6	Muscle tension
Choice 7	Not respond
Choice 8	Poor balance
Choice 9	Uncontrolled movements
Choice 10	Head twist to one side
Choice 11	Arm stiffen straight out
Choice 12	Legs stiffen
Choice 13	Arm stiffen bent
Choice 14	Fist grip thumb
Choice 15	Shoulder and head press back
Choice 16	Legs turn in
Choice 17	Knee bent
Choice 18	Legs separated
Choice 19	Squint
Choice 20	Spine deformity
Choice 21	Slow Development
Choice 22	Abnormal birth weight
Choice 23	Sudden Change of Mood
Choice 24	Speaking difficulties
Choice 25	Cry A lot
Choice 26	Never Smile
Choice 27	Head and shoulder stiffen forward
Choice 28	Head press back and arms stiffen straight
Choice 29	While standing, legs stiffen or cross like scissors
Choice 30	While walking, knees pulled together and bent
Choice 31	Crawling problems
Choice 32	Sitting problems
Choice 33	Standing problems
Choice 34	Walking problems
Choice 35	Regular shake of arm and hand
Choice 36	Abnormal gait
Choice 37	Irregular steps while walking
Choice 38	Sudden stiffen
Choice 39	Continuous stiffen in whole body
Choice 40	Epilepsy
Choice 41	Convulsions
Choice 42	Fits
Choice 43	Blue Skin after birth
Choice 44	Not breath right away during birth
Choice 45	Nystagmus
Choice 46	Abnormal shape of skull

<b>Choice 47</b>	Feeding Problems
<b>Choice 48</b>	Abnormal current weight
<b>Choice 49</b>	Restless Behavior
<b>Choice 50</b>	Runny saliva
<b>Choice 51</b>	Never Cry
<b>Choice 52</b>	Very Quiet (Passive)

Question 8 asking the respondent about his initial diagnosis based on the symptoms that selected in question 7 by identifying sub-type of CP disability. So, this question has four choices which include cerebral palsy sub-types and cerebral palsy disability itself as Table 4.4 shows.

**Table (4.4):** Question 7 in survey about initial diagnosis

Question 8	Your initial diagnosis for this case based on selected symptoms in Q 7
	تشخيصك الأولي لهذه الحالة بناء على الأعراض التي تم تحديدها في البند رقم 8
<b>Choice 1</b>	Cerebral Palsy
<b>Choice 2</b>	Spastic Cerebral Palsy
<b>Choice 3</b>	Ataxic Cerebral Palsy
<b>Choice 4</b>	Athetosis Cerebral Palsy

### ➤ Step 3: Survey Design

Our survey designed to be easy to be understood and appears in one page. So, we designed it on SurveyMonkey website in order to facilitate publishing and access. The survey did not include large questions, charts, or figures. The questions were short and simple.

All the questions are designed to enable respondents to select one choice through dropdown lists or radio buttons except question seven. Where, it is designed to enable respondents to select more than one choice through check boxes. This is because of the possibility of the appearance of several symptoms on the child at the same time.

### ➤ Step 4: Targeted Group Selection

Based on the objective of the proposed knowledge-based survey, we identified specific group of people to be the survey respondents. This group contains specialists who have educational degree, have experience with CP, and related educational background. Education background included human medicine, physiotherapy, community rehabilitation, and occupational therapy. As the survey will target 50 participants who are fitly educated, specialists, and with long period of working experience in CP domain, we trust that their responses will be with lowest bias.

### ➤ Step 5: Survey Implementation and Results Collection

We create online survey to easily share it with targeted group who distributed in different location in Gaza Strip. We shared a website link<sup>2</sup> for the survey with 50 specialists through a private communication channels to avoid collecting responds from not targeted people. After one week of starting survey, we collected 50 responses which is good number of responses because we are talking about professionals where the correctness rate is very high.

### 4.3 Knowledge-Based Survey Results

Our analysis will be conducted based on the three categories of questions (Respondents information, child age and symptoms, and diagnosis).

Based on responses analysis as shown in Figure 4.4, 12% of responders have diploma, 84% have bachelor degree, and 4% have master degree.

Answer Choices	Responses	
Diploma Degree - دبلوم	12.00%	6
Bachelor Degree - بكالوريوس	84.00%	42
Master Degree - ماجستير	4.00%	2
Phd Degree - دكتوراه	0.00%	0
Total		50

**Figure (4.4):** Respondents Education degree collected results

Most of responders were physiotherapists where they represent 70% of total responses. Also, 16% of knowledge-based survey responders are specialized in Community Based Rehabilitation, 12% of them are Occupational therapists, and 2% are doctors as Figure 4.5 shows.

Answer Choices	Responses	
Human Medicine - طب بشري	2.00%	1
Physiotherapy - علاج طبيعي	70.00%	35
Community Based Rehabilitation - تأهيل مجتمعي	16.00%	8
Occupational Therapy - علاج وظيفي	12.00%	6
Total		50

**Figure (4.5):** Resbondents specialization collected results

Respondents experience was very haigh where 48% of them have experience between three years and six years, 26% have more than six years of experience, and 26% of them have experience between one year and three years as Figure 4.6 shows.

Most of respondents' education background is physiotherapy, where their responses represent 70% of total responses. The experience of survey respondents meets the knowledge-based survey requirements, where 48% of respondents have 3 to 6 years of experience and 26% have more than 7 years of experience. As CP domain is rarely has experts with high qualification such as PhD degree in Gaza Strip, we took the most experienced specialists based

<sup>2</sup> <https://www.surveymonkey.com/r/FWDLCMQ>

on their work experience, education background, and specialization. So, from the previous statistics we found that the required experience, education background and education degree meet knowledge-based survey requirements.

Answer Choices	Responses	
From 1 Year to 3 Years - من 1 سنة الى 3 سنوات	26.00%	13
From 4 Years to 6 Years - من 3 سنة الى 6 سنة	48.00%	24
From 7 Years and plus - من 7 سنوات وأكثر	26.00%	13
Total		50

**Figure (4.6):** Respondents years of experience

48% of responders think that cerebral palsy symptoms often appear on the children whoes ages are between 12 months and 36 months as Figure 4.7 shows. 32% of them think it appears on the children whoes ages are between 6 months and 12 months. 12% of them think that it is appear on the children whoes ages are between 1 day and 6 months. These results match a previous research's results aimed to indicate age at referral of children for initial diagnosis of cerebral palsy and rehabilitation (Hubermann et al., 2016).

Answer Choices	Responses	
1 Day to 6 Months - من 1 يوم حتى 6 شهور	12.00%	6
6 Months to 12 Months - من 6 شهور حتى 12 شهر	32.00%	16
12 Months to 36 Months - من 12 شهر حتى 36 شهر	48.00%	24
Other - غير ذلك	8.00%	4
Total		50

**Figure (4.7)** Children collected ages in knowledge-based survey

For motor and mental ages, most of responders think that the children with CP disability often have delay in their motor age and mental age as Figure 4.8 and Figure 4.9 show. But, the delay in mental age will be bigger than delay in motor age, where 40% of them think the children with CP mentally look like children whose ages are between 1 day and 3 months, however 28% of them think that the motor age of the children with CP look like children whose ages are between 1 day and 3 months.

Answer Choices	Responses	
1 Day to 3 Months - من 1 يوم حتى 3 شهور	28.00%	14
3 Months to 6 Months - من 3 شهور حتى 6 شهور	24.00%	12
6 Months to 9 Months - من 6 شهور حتى 9 شهور	28.00%	14
9 Months to 12 Months - من 9 شهور حتى 12 شهر	16.00%	8
Other - غير ذلك	4.00%	2
Total		50

**Figure (4.8):** Children collected motor ages in knowledge-based survey



Answer Choices	Responses
1 Day to 3 Months - من 1 يوم حتى 3 شهور	40.00% 20
3 Months to 6 Months - من 3 شهور حتى 6 شهور	24.00% 12
6 Months to 9 Months - من 6 شهور حتى 9 شهور	14.00% 7
9 Months to 12 Months - من 9 شهور حتى 12 شهر	14.00% 7
Other - غير ذلك	8.00% 4
Total	50

**Figure (4.9):** Children collected mental ages in knowledge-based survey

The collected results from question 7 show that symptoms indication of cerebral palsy disability differs from symptom to another as Table 4.5 shows. For example, 56% of responders think that “Runny saliva - سيلان اللعاب” and “Poor balance - مشكلة في التوازن” are strong indicators to cerebral palsy disability. But, only 2% of them think “Abnormal shape of skull - شكل غير طبيعي للججمة” and “Never Cry - لا يبكي مطلقاً” are indicators for cerebral palsy disability.

**Table (4.5):** Numbers of symptoms selection in knowledge-based survey

Question 7 Choices in Knowledge-based Survey (Symptoms)	% of Responses	# of Responses
Floppy/Limp - ارتخاء	38.00%	19
Can not hold up his/her head - ضعف عضلات الرقبة	30.00%	15
Do not use one hand - لا يستخدم احدى يديه	8.00%	4
Do not use both hands - لا يستخدم كلتا يديه	24.00%	12
Abnormal Reflexes - ردود فعل غير طبيعية	34.00%	17
Muscle tension - شد في العضلات	44.00%	22
Not respond - لا يستجيب	40.00%	20
Poor balance - مشكلة في التوازن	56.00%	28
Uncontrolled movements - حركات لا ارادية	24.00%	12
Head twist to one side - الرأس متجه الى جانب واحد	16.00%	8
Arm stiffen straight out - الذراع متصلبة بشكل مستقيم	14.00%	7
Legs stiffen - الأقدام متصلبة	36.00%	18
Arm stiffen bent - اليد متصلبة ومنحنية	12.00%	6
Fist grip thumb - القبضة مغلقة على الابهام	28.00%	14
Shoulder and head press back - الكتفان والرأس للخلف	20.00%	10
Legs turn in - الأقدام ملتفة للداخل	24.00%	12
Knee bent - الركبة منحنية	10.00%	5
Legs separated - الساقان متباعدان	12.00%	6
Head and shoulder stiffen forward - الرأس والكتفين مشدودين للأمام	6.00%	3
Head press back and arms stiffen straight - الرأس للخلف والذراعين مستقيمة	14.00%	7
While standing, legs stiffen or cross like scissors - أثناء الوقوف تتصلب الأقدام وتتقاطع كالمقص	8.00%	4
While walking, knees pulled together and bent - أثناء المشي تلتصق الركبتين وتنحنيان	10.00%	5
Crawling problems - مشاكل في الحبو	40.00%	20
Sitting problems - مشاكل في الجلوس	44.00%	22
Standing problems - مشاكل في الوقوف	48.00%	24
Walking problems - مشاكل في المشي	42.00%	21
Regular shake of arm and hand - اهتزاز منتظم لكف اليد أو لليد كاملة	4.00%	2
Abnormal gait - مشية غير طبيعية	24.00%	12
Irregular steps while walking - خطوات مترنحة وغير منتظمة أثناء المشي	18.00%	9
Sudden stiffen - مفاجئ في العضلات تصلب	14.00%	7
Continuous stiffen in whole body - تصلب مستمر في كل الجسم	18.00%	9

Epilepsy - نوبات صرع	12.00%	6
Convulsions – تشنجات	42.00%	21
Fits – نوبات	4.00%	2
Blue Skin after birth - أزرقاق في الجلد عند الولادة	14.00%	7
Not breath right away during birth - عاني من ضيق تنفس أثناء الولادة	18.00%	9
Squint - حول في العينين	30.00%	15
Nystagmus - تذبذب المقلتين	4.00%	2
Spine deformity - تشوه العمود الفقري	10.00%	5
Abnormal shape of skull - شكل غير طبيعي للججمة	2.00%	1
Slow Development - تطور بطيء	38.00%	19
Feeding Problems - مشاكل التغذية	48.00%	24
Abnormal birth weight - وزن غير طبيعي عند الميلاد	4.00%	2
Abnormal current weight - وزن حالي غير طبيعي	24.00%	12
Sudden Change of Mood - تغيير مفاجئ في المزاج	8.00%	4
Restless Behavior - لا يهدأ	4.00%	2
Speaking difficulties - مشاكل في النطق	34.00%	17
Runny saliva - سيلان اللعاب	56.00%	28
Cry Alot - كثير البكاء	26.00%	13
Never Cry - لا يبكي مطلقاً	2.00%	1
Never Smile - لا يضحك مطلقاً	2.00%	1
Very Quiet (Passive) - هادئ جداً وكأنه غير موجود	8.00%	4

Also, the results show that “Feeding Problems - مشاكل التغذية”, “Convulsions – تشنجات”, “Standing problems - مشاكل في الوقوف”, and “Sitting problems - مشاكل في الجلوس” are strong indicators to cerebral palsy disability.

Answer Choices	Responses	
Cerebral Palsy	44.00%	22
Spastic Cerebral Palsy	34.00%	17
Ataxic Cerebral Palsy	16.00%	8
Athetosis Cerebral Palsy	6.00%	3
Total		50

**Figure (4.10):** Collected results for CP sub-types

From question 8, we found that Spastic Cerebral Palsy have the majeroty of sub-types of CP Disability as Figure 4.10 shows. Where, 44% of responders identified symptoms indicate Cerebral Palsy in general, 34% of them identified symptoms indicate Spastic Cerebral Palsy, 16% of them identified symptoms indicate Ataxic Cerebral Palsy, and 6% of them identified symptoms indicate Athetosis Cerebral Palsy.

#### 4.4 Results Analysis and Discussion

As we mentioned in section 4.2.2 in step 5, there is 50 domain experts have been responded to the knowledge-based survey. In this part we will analyse the collected data from four different points of views.

First point of view, the domain experts who responded to our survey have the required experience, education level, and specialization to provide correct and usefull information.

Where, 84% of them have bachelor degree, 70% of them are Physiotherapists, and 48% of them have working experience with disabled children between 3 years and 6 years.

Second point of view, the best age at referral children for initial diagnosis of cerebral palsy disability and rehabilitation is after one year old based on the collected results. Where, 24 respondents out of 50 (48% of responses) think CP symptoms appear on the children whoes ages are between 1 year and 3 years as Figure 4.6 shows.

This result matches a research result conducted in Canada in 2015. The objective of that study was to describe current practices in the age at referral for diagnosis of cerebral palsy and factors that influence earlier referral (Hubermann et al., 2016). They found that the subset of children hospitalized in the neonatal intensive care unit was referred to a neurologist for diagnosis earlier than the subset not originally in a neonatal intensive care unit. They found also, the majority of children were referred to a neurologist for diagnosis by other medical specialists (78.6%) at a mean age of 14.6 months, whereas a primary care provider referred the remaining cases (21.4%) at a mean age of 28 months. So, from both cases, we found that referral of children for initial diagnosis of cerebral palsy done after 14.6 months at least, which match our findings.

Third point of view, symptoms have different numbers of selections as Table 4.5 shows. This mean, based on experience of survey responders, symptoms-based indication of cerebral palsy disability strongly connected to the symptom itself, so each symptom should have appropriate weight based on its indication to cerebral palsy and other disabilities. For example, only one responder think that the symptom “Never Smile - لا يضحك مطلقاً” is an indication to cerebral palsy, however 19 responders think that the symptom “Slow Development - تطور بطيء” is an indicator to cerebral palsy disability. In addition, we found that the delay in mental development is bigger than delay in motor development, where 64% of responses think that the children with CP have motor age between 1 day and 6 months, and 52% of responses think that the children with CP have mental age between 1 day and 6 months. From this analysis we find that we have to include mental and motor development problems in our proposed approach to get more accuracy.

Fourth point of view, the results of question 8 show that most of symptoms are indicators to cerebral palsy disability in general where 44% of responders identified sets of symptoms indicate CP in general. Moreover, 34% of responders identified sets of symptoms that indicate Spastic CP which mean that it is easier for them to recognize children with Spastic CP, 16% of them identified symptoms that indicate Ataxic CP, and only 6% of them identified symptoms that indicate Athetosis CP. This means it is easier for them to recognize children with Spastic CP than recognizing other sub-types of CP like mild children. These results match results of different previous researches. For example, Ouellet J. et. al. in 2016 conducted a research case study for diagnosing 9-years old children with cerebral palsy disability. They found that most of milder forms of disabilities are diagnosed after years (Ouellet & Jevremovic, 2016), and

asking for more attention to the importance of maintaining a high level of suspicion for milder forms of diseases that can go unnoticed for years.

For our proposed approach, we find some important findings that should be reflected on the proposed system. We find that

- Symptoms based diagnosis can be effective for diagnosing not mild forms of cerebral palsy disabilities.
- Advance testing should be included in our proposed approach to diagnose mild forms of cerebral palsy disability.
- Motor and mental symptoms should be included in diagnosis attributes.
- The real need is to optimize and to improve techniques for diagnosing cerebral palsy disabilities that used by primary care providers to recognize CP as early as possible which positively reflected on treatment's impact.

#### 4.5 Symptoms Weighting

We weighted each symptom based on the number of times that the symptom had been selected by responders in knowledge-based survey. Where, symptom weight equals the number of times that the symptom selected (*Symptom selection times*) divided by the total number of selections (*Total selections*) multiply by 100 to get the percentage of the weight as equation 4.1 shows.

$$\text{Symptom Weight} = \frac{\text{Symptom selection times}}{\text{Total selections}} * 100 \quad (4.1)$$

The total number of selection is 575. So, weights of symptoms are calculated based on the above equation as Table 4.6 shows.

**Table (4.6):** Calculated weights of symptoms

Answer Choices	% of Responses	# of Responses	Weight
Floppy/Limp – ارتخاء	38.00%	19	3.30
Can not hold up his/her head - ضعف عضلات الرقبة	30.00%	15	2.61
Do not use one hand - لا يستخدم احدى يديه	8.00%	4	0.70
Do not use both hands - لا يستخدم كلتا يديه	24.00%	12	2.09
Abnormal Reflexes - ردود فعل غير طبيعية	34.00%	17	2.96
Muscle tension - شد في العضلات	44.00%	22	3.83
Not respond - لا يستجيب	40.00%	20	3.48
Poor balance - مشكلة في التوازن	56.00%	28	4.87
Uncontrolled movements - حركات لا ارادية	24.00%	12	2.09
Head twist to one side - الرأس متجه الى جانب واحد	16.00%	8	1.39
Arm stiffen straight out - الذراع متصلبة بشكل مستقيم	14.00%	7	1.22
Legs stiffen - الأقدام متصلبة	36.00%	18	3.13
Arm stiffen bent - اليد متصلبة ومنحنية	12.00%	6	1.04
Fist grip thumb - القبضة مغلقة على الايهام	28.00%	14	2.43
Shoulder and head press back - الكتفان والرأس للخلف	20.00%	10	1.74
Legs turn in - الأقدام ملتفة للداخل	24.00%	12	2.09

Knee bent - الركبة منحنية -	10.00%	5	0.87
Legs separated - الساقان متباعداً	12.00%	6	1.04
Head and shoulder stiffen forward - الرأس والكتفين مشدودين للأمام	6.00%	3	0.52
Head press back and arms stiffen straight - الرأس للخلف والذراعين مستقيمة	14.00%	7	1.22
While standing, legs stiffen or cross like scissors - أثناء الوقوف تتصلب الأقدام وتتقاطع كالمقص	8.00%	4	0.70
While walking, knees pulled together and bent - أثناء المشي تلتصق الركبتين وتحنينان	10.00%	5	0.87
Crawling problems - مشاكل في الحبو	40.00%	20	3.48
Sitting problems - مشاكل في الجلوس	44.00%	22	3.83
Standing problems - مشاكل في الوقوف	48.00%	24	4.17
Walking problems - مشاكل في المشي	42.00%	21	3.65
Regular shake of arm and hand - اهتزاز منتظم لكف اليد أو لليد كاملة	4.00%	2	0.35
Abnormal gait - مشية غير طبيعية	24.00%	12	2.09
Irregular steps while walking - خطوات مترنحة وغير منتظمة أثناء المشي	18.00%	9	1.57
Sudden stiffen - مفاجئ في العضلات تصلب	14.00%	7	1.22
Continuous stiffen in whole body - تصلب مستمر في كل الجسم	18.00%	9	1.57
Epilepsy - نوبات صرع	12.00%	6	1.04
Convulsions - تشنجات	42.00%	21	3.65
Fits - نوبات	4.00%	2	0.35
Blue Skin after birth - أزرقاق في الجلد عند الولادة	14.00%	7	1.22
Not breath right away during birth - عاني من ضيق تنفس أثناء الولادة	18.00%	9	1.57
Squint - حول في العينين	30.00%	15	2.61
Nystagmus - تذبذب المقلتين	4.00%	2	0.35
Spine deformity - تشوه العمود الفقري	10.00%	5	0.87
Abnormal shape of skull - شكل غير طبيعي للجمجمة	2.00%	1	0.17
Slow Development - تطور بطيء	38.00%	19	3.30
Feeding Problems - مشاكل التغذية	48.00%	24	4.17
Abnormal birth weight - وزن غير طبيعي عند الميلاد	4.00%	2	0.35
Abnormal current weight - وزن حالي غير طبيعي	24.00%	12	2.09
Sudden Change of Mood - تغيير مفاجئ في المزاج	8.00%	4	0.70
Restless Behavior - لا يهدأ	4.00%	2	0.35
Speaking difficulties - مشاكل في النطق	34.00%	17	2.96
Runny saliva - سيلان اللعاب	56.00%	28	4.87
Cry Alot - كثير البكاء	26.00%	13	2.26
Never Cry - لا يبكي مطلقاً	2.00%	1	0.17
Never Smile - لا يضحك مطلقاً	2.00%	1	0.17
Very Quiet (Passive) - هادئ جداً وكأنه غير موجود	8.00%	4	0.70

From Table 4.6 we find that the weights of symptoms are varying. Where, symptoms that are strongly indicate cerebral palsy have high weight, for example the weight of “Runny saliva - سيلان اللعاب” symptom is 4.87 which is high comparing to other weights, however other symptoms like “Fits - نوبات” has weight 0.35 which is low because it has less indication to cerebral palsy disability.

## 4.6 Rules Induction

The aim of this section is to define a set of rules that describe relationship between cerebral palsy diagnosis, cerebral palsy symptoms, child age, and reflexes. These rules will be used to diagnose cerebral palsy and to identify its sub-type.

We followed two approaches in order to extract these rules. The first approach implemented through data mining classification techniques which failed to reach high quality rules from disabled children's medical data, and the second approach implemented through knowledge-based survey which provided better results.

Logically and based on the facts we reached in section 4.7, we will conduct the diagnosis process in two levels. First level will be symptoms-based diagnosis which will give two initial diagnoses which are *Probably Has Cerebral Palsy* and *Definitely Has Cerebral Palsy*. Second level will be reflexes-based diagnosis which will be conducted if the initial diagnosis is *Probably Has Cerebral Palsy*. In addition, each level will include a set of steps as the following sub-sections shows.

In this research study, we find that the best way to induce rules is Manual Rules Induction based on weighted symptoms. The proposed rules will define relationship between symptoms and child age, between symptoms and CP sub-type, between initial diagnosis that resulted from symptoms-based diagnosis and second level of diagnosis which is reflexes-based diagnosis, and to recognise mild CP cases then recommend diagnosis level.

The process of inducing rules will be distributed to the steps of two levels of diagnosis. Where, in each step we will induce the required rules to get the objective of the step.

### 4.6.1 Symptoms-Based Diagnosis

Based on knowledge-based survey that we previously conducted, we found that there are different symptoms appear on the children whose ages are between one day and three yaers. These symptoms are differe in its appearance. Where, some of them appear in all age groups such as Ranny Slavia, Continous Stiffness, and convulsions. Some other symptoms appear on the children who are elder than one year such as walking problems, abnormal gait, and abnormal child weight. This means that the weights of some symptoms change based on child age. So, weights of some symptoms will be optimized based on its relationship with child age.

#### Step 1: Symptoms Weight Optimization

Normal children abilities are developed since birth. This development includes mental and motor abilities. All normal motor functions such as sitting, walking, jumping, running, reaching, and speaking, is a complex combination of individual motor skills that allow development of these activities of daily living. These motor activities all include volitional motor control, motor planning, balance and coordination, muscle tone, and sensory feedback of the motion.

As babies mature from infancy to 1 year of age, neurologic maturity develops rapidly from proximal to distal. To demonstrate, children first gain head control, then develop the ability to weight bear on the arms, followed by trunk control and the ability to sit, then develop the ability to stand (See Table 2.1 in Chapter 2, Page 12). This progressive distal migration of maturation includes all the parameters of the motor skills (Miller, 2007).

Based on the knowledge-based surevy that we conducted, we found that there are some abnormal developments appear on the children with cerebral palsy disability in specific periods of ages. Where, the child becomes unable to perform some functions like his/her siblings. These inabilities may be for specific period of child's age which will be an indicator for Delay in development, or it will stay forever to be disability indicator. So, in order to differentiate between normal development, delay in development, and disability we have to use a set of rules to identify the relationship between symptom/inability weight and child's age. The below 5 rules identify the relationship between child's age and weights of some symptoms that may indicate CP disability in specific periods of life.

**Rule 1:** If child Age is greater than 6 months and child Unable to Roll, then Rolling\_Reflexes\_Result equals negative, else Rolling\_Reflexes\_Result equals positive.

**Rule 2:** If child Age is greater than 12 months and child Unable to Crawl, then Crawling\_Problems weight equals 10.44 (weight of Crawling\_Problems\*3), else if child Age is greater than 9 months and child Unable to Crawl, then Crawling\_Problems has weight equals 6.96 (weight of Crawling\_Problems\*2), else if child Age is greater than 6 months and child Unable to Crawl, then Crawling\_Problems has weight equals 3.48 (weight of Crawling\_Problems\*1), else Crawling\_Problems has weight equals 0 (weight of Crawling\_Problems\*0).

**Rule 3:** If child Age is greater than 16 months and child Unable to Sit, then Sitting\_Problems weight equals 11.49 (weight of Sitting\_Problems\*3), else if child Age is greater than 12 months and child Unable to Sit, then Sitting\_Problems has weight equals 7.66 (weight of Sitting\_Problems\*2), else if child Age is greater than 9 months and child Unable to Sit, then Sitting\_Problems has weight equals 3.83 (weight of Sitting\_Problems\*1), else Sitting\_Problems has weight equals 0 (weight of Sitting\_Problems\*0).

**Rule 4:** If child Age is greater than 24 months and child Unable to Stand, then Standing\_Problems weight equals 12.51 (Weight of Standing\_Problems\*3), else if child Age is greater than 16 months and child Unable to Stand, then Standing\_Problems has weight equals 8.34 (Weight of Standing\_Problems\*2), else if child Age is greater than 12 months and child Unable to Stand, then

Standing\_Problems has weight equals 4.17 (Weight of Standing\_Problems\*1), else Standing\_Problems has weight equals 0 (Weight of Standing\_Problems\*0).

**Rule 5:** If child Age is greater than 36 months and child Unable to Walk, then Walking\_Problems weight equals 10.95 (Weight of Walking\_Problems\*3), else if child Age is greater than 24 months and child Unable to Walk, then Walking\_Problems has weight equals 7.30 (Weight of Walking\_Problems\*2), else if child Age is greater than 18 months and child Unable to Walk, then Walking\_Problems has weight equals 3.65 (Weight of Walking\_Problems\*1), else Walking\_Problems has weight equals 0 (Weight of Walking\_Problems\*0).

Also, Cerebral Atrophy disability may share some symptoms with Cerebral Palsy, but it causes a group of language disorders which called aphasias. The below rule indicate Cerebral Atrophy as uncertain disability.

**Rule 6:** If child has symptom *aphasias* then *Initial Diagnosis* is *Uncertain Disability*.

## Step 2: Calculate Symptoms-Based Total Score

Based on the above table (Table 4.6), the initial diagnosis will be calculated according the below equation (4.2). The initial diagnosis will equal the summation of symptoms' weights that the child have.

$$Symptoms\_Based\ Score = \sum_{i=1}^n Weight\_of\_Symptom_i \quad (4.2)$$

Where:

$i$  is the current symptom,

$n$  is the number of symptoms that are appear on the child.

The following two examples show two real cases approached Cerebral Palsy Center of Palestine Avenir for Childhood Foundation to be diagnosed. Their data is real and collected by the primary care providers in Cerebral Palsy Center. Those two cases have been initially diagnosed. Where, case 1 has been diagnosed as a cerebral palsy case, and case 2 diagnosed as not a cerebral palsy case.

### Case 1

Age Information	
Child age - عمر الطفل	12 Months to 36 Months - من 12 شهر حتى 36 شهر
Motor Age - العمر الحركي	9 Months to 12 Months - من 9 شهور حتى 12 شهر
Mental Age - العمر العقلي	6 Months to 9 Months - من 6 شهور حتى 9 شهور
Symptoms Appear on the child	



Symptom	Weight (Based on Table 4.6)
Abnormal Reflexes - ردود فعل غير طبيعية	2.96
Poor balance - مشكلة في التوازن	4.87
Legs stiffen - الأقدام متصلبة	3.13
Fist grip thumb - القبضة مغلقة على الإبهام	2.43
Head press back and arms stiffen straight - الرأس للخلف والذراعين مستقيمة	1.22
While standing, legs stiffen or cross like scissors - أثناء الوقوف تتصلب الأقدام وتتقاطع كالمقص	0.7
Standing problems - مشاكل في الوقوف	4.17
Walking problems - مشاكل في المشي	3.65
Abnormal gait - مشية غير طبيعية	2.09
Irregular steps while walking - خطوات مترنحة وغير منتظمة أثناء المشي	1.57
Convulsions - تشنجات	3.65
Squint - حول في العينين	2.61
Abnormal birth weight - وزن غير طبيعي عند الميلاد	0.35
Runny saliva - سيلان اللعاب	4.87
<b>Provisional Diagnosis</b>	
Probably Has Cerebral Palsy	

Based on equation 4.2 the symptom-based score for the child whose information mentioned in Case 1 will be

$$\begin{aligned}
 \text{Symptoms-Based Score} &= \\
 &2.96+4.87+3.13+2.43+1.22+0.7+4.17+3.65+2.09+1.57+3.65+2.61+0.35+4.87 \\
 &= 38.27
 \end{aligned}$$

According to the calculated score for this case based on symptoms that the child has, the initial diagnosis is “Probably Has Cerebral Palsy”.

## Case 2

Age Information	
Child age - عمر الطفل	12 Months to 36 Months - من 12 شهر حتى 36 شهر
Motor Age - العمر الحركي	6 Months to 9 Months - من 6 شهور حتى 9 شهور
Mental Age - العمر العقلي	3 Months to 6 Months - من 3 شهور حتى 6 شهور
Symptoms Appear on the child	
Symptom	Weight (Based on Table 4.6)
Do not use both hands - لا يستخدم كلتا يديه	2.9
Abnormal Reflexes - ردود فعل غير طبيعية	2.96
Not respond - لا يستجيب	3.48
Poor balance - مشكلة في التوازن	4.87
Standing problems - مشاكل في الوقوف	4.17
Walking problems - مشاكل في المشي	3.65
Abnormal gait - مشية غير طبيعية	2.09
Sudden stiffen - مفاجئ في العضلات تصلب	1.22

Convulsions – تشنجات	3.65
Blue Skin after birth - أزرقاق في الجلد عند الولادة	1.22
Not breath right away during birth- عاني من ضيق تنفس أثناء الولادة	1.57
Slow Development - تطور بطيء	3.3
Feeding Problems - مشاكل التغذية	4.17
Abnormal current weight - وزن حالي غير طبيعي	2.09
Sudden Change of Mood - تغير مفاجئ في المزاج	0.7
Speaking difficulties - مشاكل في النطق	2.96
Runny saliva - سيلان اللعاب	4.87
Very Quiet (Passive) - هادئ جداً وكأنه غير موجود	0.7
<b>Provisional Diagnosis</b>	
Definitely Has Cerebral Palsy	

Based on equation 4.2 the symptom-based score for the child whose information mentioned in Case 2 will be

$$\begin{aligned}
 \text{Symptoms-Based Score} = & \\
 & 2.9+2.96+3.48+4.87+4.17+3.65+2.09+1.22+3.65+1.22+1.57+3.3+4.17+2.09+0.7+2.96+ \\
 & 4.87+0.7 \\
 & = 50.57
 \end{aligned}$$

According to the calculated score for this case based on symptoms that the child has, the initial diagnosis is “Definitely Has Cerebral Palsy”.

### Step 3: Give Symptoms-Based Initial Diagnosis

Based on the domain expert review, the initial diagnosis will be reached through two simple rules which are:

**Rule 7:** if the child has Symptoms-Based Score less than 20, the Initial Diagnosis will be “Uncertain Disability”. Otherwise,

**Rule 8:** if the child has Symptoms-Based Score less than 40, the Initial Diagnosis will be “Probably Has Cerebral Palsy”. Otherwise,

**Rule 9:** if the child has Symptoms-Based Score greater than or equals 40, the Initial Diagnosis will be “Definitely Has Cerebral Palsy”.

The range (less than 20) in rule 7 has been specified based on summation of symptoms’ weights that indicate disability in general. Rule 8 range (less than 40 and greater than 20) has been specified based on the summation of symptoms’ weights that indicate CP disability. Rule 9 range (greater than 40) has been specified based on the summation of symptoms’ weights that indicate sub-types of CP disability.

For Case 1 that mentioned in Step 1, the calculated symptoms-based total score is 38.27 which is less than 40. So, the initial diagnosis is “Probably Has Cerebral Palsy”. For Case 1 that mentioned in Step 1 also, the calculated symptoms-based total score is 50.57 which is greater than 40. So, the initial diagnosis is “Definitely Has Cerebral Palsy”.

#### Step 4: Recommendation

Based on the results of Step 2, the proposed system will give a recommendation. The aim of this recommendation is to minimize diagnosis time and to give more accurate results. The below rule will be followed to implement the objective of this step

**Rule 10:** if Initial Diagnosis equals “Definitely Has Cerebral Palsy”, then the recommendation equals “Go for Treatment”. Otherwise

**Rule 11:** if Initial Diagnosis equals “Probably Has Cerebral Palsy”, then the recommendation equals “Go to Reflexes-Based Diagnosis”.

**Rule 12:** if Initial Diagnosis equals “Uncertain Disability”, then the recommendation equals “Go to Reflexes-Based Diagnosis”.

As seen in *Rule 11* and *Rule 12* the action is similar in both cases (*Go to Reflexes-Based Diagnosis*). This because the need for a next level of assessment in such cases.

#### 4.6.2 Reflexes-Based Diagnosis

Some patterns of cerebral palsy disability are not easily recognised such as mild cases and cases that do not have a lot of seen symptoms that indicate CP disability. In such cases, there is a need to conduct reflexes-based diagnosis. The aim of reflexes exercises is to test the child ability to do some functions and to test how the child responds to some actions. There are different reflexes can be checked, but in our research we will use the main reflexes. Edelman C. L. et. al. in 2013 identified a set of assessment reflexes for infants from 1 day to 9 months in order to diagnose CP.

**Table (4.7): Assessment Infant Reflexes**

No.	Reflex	Description	Appearance/Disappearance
1	Rooting	Touching baby’s cheek causes head to turn toward the side touched.	Present in utero at 24 weeks; disappears 3–4 months; may persist in sleep 9–12 months.
2	Sucking	Touching lips or placing something in baby’s mouth causes baby to draw liquid into mouth by creating vacuum with lips, cheeks, and tongue.	Present in utero at 28 weeks; persists through early childhood, especially during sleep.

3	Moro	Making a loud noise or changing baby's position causes baby to extend both arms outward with fingers spread, then bring them together in a tense, quivery embrace	Present at 28 weeks of gestation; disappears at 4–7 months
4	Plamar Grasp	Placing object or finger in baby's palm causes his or her fingers to close tightly around object.	Present at 32 weeks of gestation; disappears at 3–4 months, replaced by voluntary grasp at 4–5 months
5	Plantar Grasp	Placing object or finger beneath toes causes curling of toes around object.	Present at 32 weeks of gestation; disappears at 9–12 months
6	Tonic Neck or Fencing	Postural reflex is seen when infant lies on back with head turned to one side; arm and leg on the side toward which he or she is looking are extended while opposite limbs are flexed.	Present at birth; disappears at approximately 4 months
7	Landau	Suspending infant in horizontal, prone position and flexing head against trunk causes legs to flex against trunk.	Appears at approximately 3 months; disappears at approximately 12–24 months
8	Parachute	Sudden thrusting of infant downward from horizontal position causes hands and fingers to extend forward and spread as if to protect self from a fall.	Appears at approximately 7–9 months; persists indefinitely
9	Bite	Touching gums, teeth, or tongue causes baby to open and close mouth.	Disappears at 3–5 months when biting is voluntary, but seen throughout adult years in comatose person
10	Stepping, Walking and Dancing	Holding baby upright with feet touching flat surface causes legs to prance up and down as if baby were walking or dancing.	Present at birth; disappears at approximately 2–4 months; with daily practice of reflex, infant may walk alone at 10 months
11	Babkin	Pressure applied to palm causes baby to open mouth, close eyes.	Present at birth; disappears in 2 or 4 months

12	Swimming	Placing baby horizontally, supporting him or her under abdomen, causes baby to make crawling motions with his or her arms and legs while lifting head from surface as if he or she were swimming.	Present after 3 or 4 days; disappears at approximately 4 months; may persist with practice
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**Source:** Edelman, C. L., Mandel, C. L., & Kudzma, E. C. (2013). *Health Promotion throughout the Life Span-E-Book, 8<sup>th</sup> Edition, Chapter 9, Table 9.3.* Elsevier Health Sciences.

Table 4.8 shows ten reflexes that taken from Ruth Beckmann Murray assesement infant reflexes table. These 12 reflexes will be used to indicate Cerebral Palsy disapility in our research. So, Reflexes-based diagnosis will be conducted in three steps which presented below.

### Step 1: Age-Based Testing Reflexes Identification

The first step in Reflexes-based diagnosis is to identify the assessment reflexes that are fit to the child age. Reflexes are usualy tested during the early childhood. So, reflexes assesement is better to be conducted for children whose ages are between one day and 12 months (Edelman et al., 2013).

**Table (4.8):** Age groups reflexes

Age Group	Assesement Reflexes
1 Day to 6 Months	Rooting, Sucking, Moro, Palmar grasp, Plantar grasp, Tonick neck or fencing, Landau, Bite, Babkin, Swimming, Stepping, Walking, and Dancing.
6 Months to 12 Months	Moro, Palmar grasp, Plantar grasp, Landau, Swimming, and Parachute.

Table 4.9 shows age groups and the reflexes for each age group. Where, first year of child life has been divided into two age groups similar to symptoms-based diagnosis age groups. First age group is from 1 day to 6 months, and second age group is from 6 months to 12 months. Based on the mentioned information in the table, two rules have been sit to identify assesement reflexes based on child age.

**Rule 13:** If child age is greater than one day and less than 6 months, then reflexes assesement include Rooting, Sucking, Moro, Palmar grasp, Plantar grasp, Tonick neck or fencing, Landau, Bite, Babkin, Swimming, Stepping, Walking, and Dancing.

**Rule 14:** If child age is greater than one day and less than 6 months, then reflexes assesement include Moro, Palmar grasp, Plantar grasp, Landau, Swimming, and Parachute.

### Step 2: Get Reflex-Based Score

Based on the domain expert, total score of symptoms based diagnosis and score of reflexes based diagnosis will be equal. So, total score of reflexes will be 100, where it will be divided onto reflexes in each age group.

**Table (4.9):** Reflexes scores for children from 1 day to 6 months

No.	Reflex	Score
1	Rooting	10
2	Sucking	10
3	Moro	10
4	Palmar grasp	10
5	Plantar grasp	10
6	Tonick neck or fencing	10
7	Landau	10
8	Bite	10
9	Babkin	10
10	Swimming	5
11	Stepping, Walking, and Dancing	5

**Table (4.10):** Reflexes scores for children from 6 months to 12 months

No.	Reflex	Score
1	Moro	20
2	Palmar grasp	10
3	Plantar grasp	10
4	Landau	20
5	Swimming	20
6	Parachute	20

It is clear now that we have the scores for each reflex in each age group as Tables 4.10 and 4.11 shows.

### Step 3: Calculate Total Score

Total score of reflexes based diagnosis will be calculated the summation of scores of reflexes that have negative result as equation 4.3 shows.

$$\text{Reflexes - Based Score} = \sum_{i=1}^n \text{Reflex\_Score}_i. \quad \forall \text{ reflex has Negative result} \quad (4.3)$$

### 4.6.3 Final Diagnosis

Final diagnosis will be identified based on the final score that resulted from diagnosis process. This final score will be calculated through equation 4.4

$$\text{Final Score} = (\text{Symptoms based score} + \text{Reflexes based score})/2 \quad (4.4)$$

Then, according to the calculated score, we identify the final diagnosis of cerebral palsy disability based on the below rule

**Rule 15:** If Final Score is greater than 60, then Final Diagnosis is Definitely Has Cerebral Palsy. Else, If Final Score is greater than 40 and less than 60, then Final Diagnosis is Probably Has Cerebral Palsy. Else, If Final Score is less than 20, then Final Diagnosis is Uncertain Disability.

#### 4.7 Consequences and Recommendation

At the end of this study, we have some consequences and recommendations based on the experience that we gain during the research regarding ontology and cerebral palsy disability. These recommendations and consequences are as follow

- We can say that researches in disabilities domain in Gaza Strip are very limited and most of facts about disability in general and cerebral palsy for specific are passive in research domain.
- There is a high need to conduct more and deep researches in disability domain especially in diagnosis and treatment fields in order to improve quality of knowledge sharing and health care.
- The real need in this domain as a first step regarding the compination between disability health care services and computer systems is to improve information systems inside local institutions and national NGOs that provide such services to the disabled children.
- We found that Ontology is ausful tool for describing concepts of cerebral palsy disability and relations between them in order to diagnose and improve treatment of cerebral palsy disability.
- Cerebral Palsy is one of most complicated disabilities because it has no specific causes and share part of its symptoms with other disabilities like brain atrophy.
- The improvement of health care services for disabled people firstly comes from improving diagnosis in early childhood.
- We can use symptoms and reflexes assesments in order to recognize cerebral palsy disability.
- Knowledge based survey is a useful tool for surveying tacit knowledge.
- Data mining techniques are not useful for inducing rules from poor quality health records.

#### 4.8 Summery

In this chapter we presented functional and non-functional requirements of the proposed approach. Mainly, the proposed approach will diagnose cerebral palsy disability based on symptoms and reflexes that indicate Cerebral Palsy. In addition to that, the proposed approach will facilitate knowledge sharing between system users and will provide physical therapy planning. We found that Knowledge based survey is a good tool for extracting tacit knowledge and to support rules induction in such domain. Finaly, we were unable to induce rules through

data mining classification techniques because of poor quality of available electronic health records in local health care organizations. So, we induce rules manually through domain expert.

This part of thesis has been submitted as a paper titled “Towards Rules Induction Optimization for Cerebral Palsy Diagnosis: An Empirical Study” to the International Conference for Promising Electronic Technologies 2017. Our paper has been accepted and will be published in IEEE.



# Chapter 5

## CP Ontology Development

## Chapter 5

### CP Ontology Development

In this chapter, we present the steps that we had followed to develop CP Disability ontology to be used then as a knowledge base by another application. Those applications can use it in order to diagnose CP disability and building physical therapy work plans. We are present a concrete steps on developing the ontology and realizing it in a specific development environment (Protégé). Also, we will overview the evaluation of the developed CP ontology.

#### 5.1 Conceptual and Logical Design

In order to develop the proposed ontology we followed the manual of steps for constructing new ontology. So we followed Noy and McGuinness, “Ontology Development 101: A Guide to Creating Your First Ontology” (Noy & McGuinness, 2001) to construct the proposed ontology manually. The main stages for constructing ontology are as follow

##### 5.1.1 Determining the Domain and Scope of the Ontology

In this research study, constructing CP ontology itself is not our goal. Where, it is a model for describing CP disability domain inorder to diagnose CP disability. The developed ontology will be used to define a set of concepts and relations among these concepts inorder to be used by other program. In this step there are basic questions should be answered (Noy N. F. and MCGuinness D. L., 2001, Ch. 7, P 195), which are:

- What is the domain that the ontology will cover?
- For what we are going to use the ontology?
- For what types of questions should the ontology provide answers?
- Who will use and maintain the ontology?

##### 5.1.2 Consider Reuse

Semantic web provide effective solutions for different problems through ontology description for problem domain. Ontology used to represent different domains for different purposes. For example, in health care domain, there are different ontologies developed for diagnosis and treatment purposes. Most of these ontologies already constructed, tested, and available to be reused (Noy N. F. and MCGuinness D. L., 2001, Ch. 7, P 195). So, we should not start from scratch.

##### 5.1.3 Enumerate Terms

The first step in the real developing of ontology is to build a list of terms, including nouns and verbs, which expected to appear in the ontology. Nouns are typically forms the classes and verbs forms the properties of the proposed ontology. These lists of terms or annotations initially built manually (Erdmann et al., 2000), but now there are different knowledge engineering tools can be used for enumerating domain terms such as laddering

and grid analysis tools (Antoniou et al., 2012). M Erdman in 2012 developed automatic annotation tool for web content and digital libraries annotation called Pundit (Grassi et al., 2012).

#### 5.1.4 Define taxonomy

After defining domain terms, we have to build the taxonomic hierarchy of these terms. In step 3, we enumerate the terms that describe the domain in order to identify ontology classes. These classes can not provide useful information without respecting semantics primitives such as `rdfs:subClassOf` (Noy N. F. and McGuinness D. L., 2001, Ch. 7, P 196). This hierarchy can be built on top-down or bottom-up fashion.

#### 5.1.5 Define Properties

In step 3, we enumerate the terms that describe the domain in order to identify ontology classes. These classes can not provide useful information without the properties that describe relation between these classes. It makes sense to attach general properties to the super classes because subclasses will inherit these properties, also we need to define domain and range immediately for each property (Noy N. F. and McGuinness D. L., 2001, Ch. 7, P 196).

#### 5.1.6 Define facets

In this step, we enrich the properties that we previously defined in step 5 with facets that manage and control values on both sides of the defined property such as cardinality, required value and relational characteristics.

- *Cardinality*: Specify for as many properties as possible whether they are allowed or required to have a certain number of different values (Noy N. F. and McGuinness D. L., 2001, Ch. 7, P 196). For example, a case may occur “at least one value”, this means this property is required.
- *Required Value*: Classes are defined by virtue of a certain property’s having particular values, and such required values can be specified in OWL, using `owl:hasValue`. Sometimes the requirements are less stringent: a property is required to have some values from a given class (Noy N. F. and McGuinness D. L., 2001, Ch. 7, P 197).

#### 5.1.7 Define Instances

We use ontology to organize sets of instances for the proposed domain. The number of instances must be larger than the number of classes in the ontology. Because of the large number of instances, adding these instances to the ontology does not do manually.

#### 5.1.8 Check for anomalies

After building ontology and defining instances, it is important to check the built ontology for internal inconsistencies. For example, inconsistencies may be in incompatible domain and range definitions for transitive, symmetric, or inverse properties.

## 5.2 CP Ontology Development

The proposed CP Ontology that we are working to develop has important roll in overall approach that will work to diagnose cerebral palsy disability. There are different approaches and systems have been developed to improve physical treatment or to assist and improve CP diagnosis quality. But, according to our review, there is no one system provides both; early diagnosis and physical treatment at the same time.

Our proposed ontology is related to health domain in general and disability domain in specific. The content of CP ontology have been collected from books and papers that are related to CP disability in addition to a paper documents used in Palestine Avenir for Childhood Fundation – Cerebral Palsy Center for CP diagnosis and follow up. Domain experts from Palestine Avenir for Childhood Fundation helped us in developing the ontology. They assist in identifying and confirming domain concepts, identifying and confirming domain relations and rules.

In order to build a real ontology we will use a platform for real ontology construction. From our point of view, Protégé is good application for this task. The result of using protégé application is a knowledge base file (CP Ontology File) that will be available as OWL file. But, constructing the ontology file is not our objective. So, the produced OWL file will be used as a knowledge base by another application, such as java applications, in order to develop a graphical user interfaces that will be used by end users. In addition to that, we need to implement some queries and run a set of rules to diagnose CP disability. So, we will use different query languages such as SPARQL and DL, in addition to SWRL.

We used Protégé because it is widely used application and has the ability to define domain classes, data properties, object properties, annotations, restrictions and execute DL and SPARQL queries. Also, it supports different languages like RDF and OWL. We followed the main nine steps to develop CP ontology which are

### Step 1: Determining the Domain and Scope of the Ontology

Developing ontology is not our goal itself. The proposed CP Ontology will provide a complete description of Cerebral Palsy Disability domain. This description will provide common understanding of the information structure among users and system agents. It will works as a knowledge base that will be used by another application. The whole system including application and ontology will be a computerized tool that will be used by physiotherapists, doctors and may be by parents to diagnosis CP disability and build guidelines to support physical therapy treatment.

Information retrieval from CP ontology is done through the language queries like DL queries and SPARQL queries. Through ontology all these information can be aggregated and can be published. The users and agents can use this aggregated information to answer user

queries. The developed ontology can be reused in the future for other purposes like building larger ontologies.

We can summarize the above information in the following four questions:

**1. What is the domain that the ontology will cover?**

The domain of the ontology is Cerebral Palsy disability diagnosis.

**2. For what we are going to use the ontology?**

CP Ontology will be used as a knowledge base of human body, cerebral palsy symptoms, treatments, and reflexes assessments. It will be used by a system to make diagnosis of cerebral palsy disability and to develop guidelines to support physical therapy treatment.

**3. For what types of questions should the ontology provide answers?**

It has to provide comprehensive answers to the questions that are related to cerebral palsy disability diagnosis and treatment, including

- What are the symptoms that indicate cerebral palsy disability?
- What are the symptoms that indicate sub-types of cerebral palsy disability?
- What are the body parts that have been affected by CP symptoms?
- What are the disabilities that a specific symptom may cause?
- What are the supportive guidelines that may improve physical therapy treatment for each child based on symptoms that he/she has?
- What is the physical therapy support treatment for a particular symptom?
- What are the reflexes that can indicate cerebral palsy disability?
- Based on child age, what are the reflexes that may indicate cerebral palsy disability for a particular child?
- What is the supportive physical therapy treatment that treats a particular symptom?
- What is the symptoms-based diagnosis for a specific child?
- What is the reflexes-based diagnosis for a specific child?
- What is the final diagnosis for a specific child?

**4. Who will use and maintain the ontology?**

CP Ontology will be used and maintained by the proposed cerebral palsy diagnosis approach as a knowledge base. Users such as doctors, physiotherapists, and primary health care providers also can use and maintain CP Ontology.

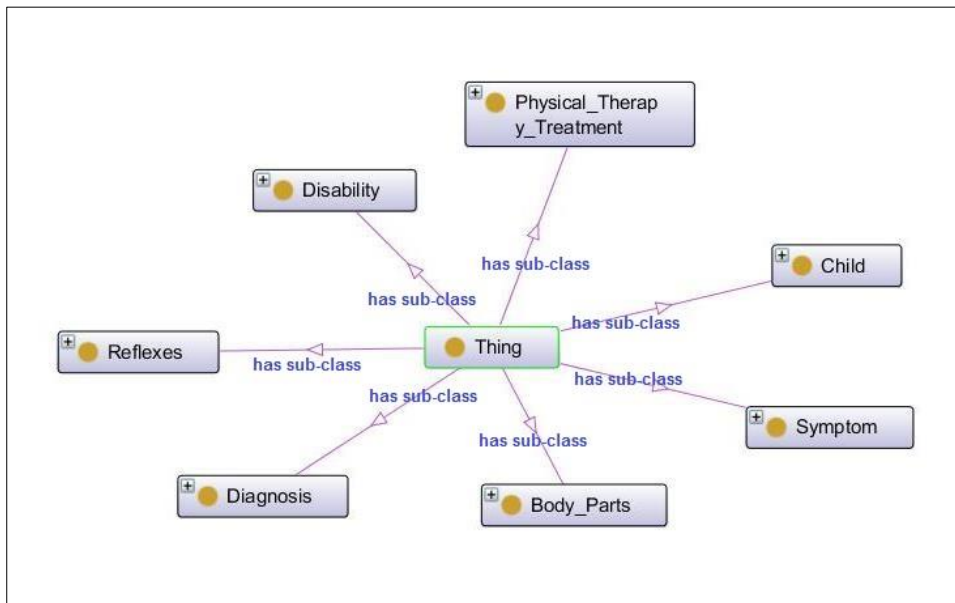
**Step 2: Reuse Existing Ontologies**

In this research, there are different parts included in the proposed ontology such as disability, cerebral palsy, symptoms, reflexes and human body. There are different ontologies developed to describe CP disability diagnosis domain or part of it. In our research we reused parts of previous ontology developed to describe human body with some modifications to adapt it to our purpose of the study (Nimmagadda et al., 2008). In addition, we reused cerebral

palsy diagnosis vocabularies that have been used by Hubermann L. et.al. in 2016 (Hubermann et al., 2016).

### Step 3: Overview of Ontology

Our ontology is developed to describe Cerebral Palsy Disability in order to diagnose it in its early stages, and to provide supportive guide lines for physical therapy treatment. We identified 54 classes, 19 object properties and 24 data properties. Figure 5.1 shows the main classes and the sub-class relation between them.



**Figure (5.1):** Main classes of CP Ontology

### Step 4: Enumerate the Important Terms in CP Ontology

In this step we identified the main terms in CP disability domain including terms of symptoms, diagnosis and physical therapy treatment. We found more than 170 important terms including nouns and verbs.

From this long list of terms, we identified the main terms that we want to talk about which is related to CP disability diagnosis and physical therapy treatment which are listed in Table 5.1.

**Table (5.1):** Main terms in CP Ontology

Sno.	Term	Description	Importance of term
1	Child	Person whose age is between 1 day and 3 years.	We need this term in the ontology to represent child that will be diagnosed based on the symptoms and reflexes.

2	Body_Parts	Parts of the human body	We need this term to represent the parts of human body that affected by CP symptoms and can not perform specific excercises.
3	Disability	Physical or mental inability to perform daily tasks.	We need this term in order to represent disabilities including cerebral palsy and its sub-types.
4	Symptom	Symptoms that indicate cerebral palsy	We need this term to describe the symptoms that may indicate cerebral palsy disability.
5	Reflexes	Child reflex to a specific action of exercise	We need this term to describe the reflexes that may indicate child ability to reflexes to specific action.
6	Diagnosis	The diagnosis of cerebral palsy disability.	We need this term to represent the cerebral palsy disability diagnosis.
7	Physical_Therapy_Treatment	Physical therapy treatment.	We need this term in order to represent the main physical therapy treatments that will be used to reduce disability physical impact.

These terms are connected to each others through relations. These relations are called properties in ontology domain. We used properties to descrip the nature of relationship between each two terms. The below points showing some of identified properties for the previous terms

- *Child* term has the following properties: *Has\_Assesement\_Reflexes*, *Has\_Diagnosis*, *Has\_Refleses\_Based\_Diagnosis*, *Has\_Symptom*, *Has\_Symptoms\_Based\_Diagnosis*, *Positively\_Reflexed\_To*, *Negatively\_Reflexed\_To*, *Age*, *Name*, *Gender*, *Birth\_Weight*, *Current\_Weight*, *Delivery\_Type*, and *DoB*.
- *Body\_Parts* term has the following properties: *Affected\_By*.
- *Disability* term has the following properties: *Has\_Severity\_Degree* and *Is\_Indicated\_Through*.
- *Symptom* term has the following properties: *Affects*, *Appears\_On*, *Indicate*, *Treated\_By*, *Has\_Score*, and *Produces*.
- *Reflexes* term has the following properties: *Indicate*, *Appearance\_Disappearance*, *Description*, *Has\_Result*, *Has\_Score*, and *Max\_Child\_Age*.
- *Diagnosis* term has no properties.
- *Physical\_Therapy\_Treatment* term has the following properties: *Improve\_Function\_Of*, *Treats*, *Description*, *Exercise\_Name*, *Photo*, and *Purpose*.

### Step 5: Define Classes and Class Hierarchy of CP Ontology

In step 4 we identified the main classes of CP Ontology from the list of important terms. The terms in Table 5.2 represent the sub classes of main classes in CP ontology and will become anchors in the class hierarchy.

**Table (5.2): Super and Sub classes of CP Ontology**

Sno.	Sub-Class	Description of Sub-Class	Super-Class
1	Infant	Is a child whose age between 1 day and 6 months	Child
2	Baby	Is a child whose age between 6 months and 12 months	Child
3	Young Child	Is a child whose age between 12 months and 36 months	Child
4	Probably_has_cerebral_palsy	It is represents the children whose diagnosis is probably have cerebral palsy disability	Diagnosis
5	Definitely_has_cerebral_palsy	It is represents the children whose diagnosis is definitely have cerebral palsy disability	Diagnosis
6	Has_uncertain_disability	It is represents the children whose disability diagnosis is uncertain disability	Diagnosis
7	Cerebral_Palsy_Disability	This subclass represents CP disability	Disability
8	Other_Disability	This subclass represents other disabilities.	Disability
9	Ataxic_CP	This represents the ataxic type of CP disability.	Cerebral_Palsy_Disability
10	Athetosis_CP	This represents the athetosis type of CP disability.	Cerebral_Palsy_Disability
11	Spastic_CP	This represents the spastic type of CP disability.	Cerebral_Palsy_Disability
12	Carrying_Positions	This represent the correct positions while carrying a child with CP.	Physical_therapy_treatment
13	Contractures	This represents the physical therapy treatments for muscles contractures.	Moving_About
14	Hand_Use	This subclass represents the activities that encourage the child to use hands.	Physical_therapy_treatment
15	Lying_and_Sleeping	This subclass represent the positions of sleeping for child with CP.	Physical_therapy_treatment
16	Moving_About	This subclass representing the activities to encourage the child to move forward.	Physical_therapy_treatment
17	Rolling_and_Twisting	This subclass represent rolling and twisting exercises to improve muscles tone.	Physical_therapy_treatment
18	Sitting	This represents the treatment activities to enable child to sit.	Physical_therapy_treatment
19	Standing	This represents the treatment activities to enable child to stand.	Physical_therapy_treatment
20	Other_treatment_referral	This sub-class represents referral to other treatments which is not related to physical therapy.	Physical_therapy_treatment



21	Joints	It is represents the human body joints	Body_parts
22	Lower_side	It is represents the lower side of human body	Body_parts
23	Muscles	It is represents the muscles of human body	Body_parts
24	Skin	It is represent human body skin	Body_parts
25	Upper_side	It is represents the upper side of human body	Body_parts
26	Extra_joints	It is represents bones extra joints like finger joints	Joints
27	Hips	It is represents hips of human body	Lower_side
28	Legs	It is represents human body legs	Lower_side
29	Hip	It is represents left or right hip of human body	Hips
30	Hip_joints	It represents joints of hip in human body	Hip
31	Leg	It is represents left or right leg of human body	Legs
32	Ankle	It is represents the ankle of the leg	Leg
33	Foot	It is represents the foot of the leg	Leg
34	Knee	It is represents the knee of the leg	Leg
35	Abdomen	It is represents the abdomen	Upper_side
36	Hands	It represents the hands	Upper_side
37	Head	It is represent the head of human body	Upper_side
38	Shoulders	It is represents the shoulders of the human body	Upper_side
39	Spine	It represents the spine of human body	Upper_side
40	Hand	It is represents left or right hand of human body	Hands
41	Elbow	It is represents left or right elbow of human body	Hand
42	Fist	It is represents fist of hand in human body	Hand
43	Brain	It is represent the brain	Head
44	Ears	It is represents the ears	Head
45	Eyes	It is represents the eyes	Head
46	Mouth	It is represents the mouth	Head
47	Nose	It is represents the nose	Head

In step 4 we identified the key terms of CP ontology. These terms must be organized in a taxonomic hierarchy. This means if B is a sub-class of A, then all instances of B must be instances of A. There are three possible ways to develop class hierarchy (Jinhu et al., 2010) which are top-down approach, bottom-up approach, and combination of both approaches.

#### Step 6: Define the Properties of Classes (Slots)

In ontology we use properties to describe the relationship between ontology objects. There are two types of properties which are object properties and data properties. Object properties define the relationship between two objects, and Data properties define the relationship between an object and a data type. For CP ontology, we identified 43 properties, 19 of them are object properties and 24 are data properties. Table 5.3 show the identified object and data properties with the domain and range of each property.

**Table (5.3):** CP ontology data and object properties

S.No.	Property Type	Property	Domain	Range
1	Object Property	Affected_By	Body_Part	Symptom
2		Affects	Symptom	Body_Part
3		Appears_On	Symptom	Child
4		Has_Assesment_Reflexes	Child	Reflex
5		Has_Diagnosis	Child	Diagnosis
6		Has_Reflex_Based_Diagnosis	Child	Diagnosis
7		Has_Severity_Degree	CP_Disability	Spastic_CP/Athetoided_CP/Ataxic_CP
8		Has_Symptom	child	Symptom
9		Has_Symptom_Based_Diagnosis	child	Diagnosis
10		Improve_Function_of	PT_Treatment	Body_Parts
11		Indicate	Reflex/Symptom	CP_Disability
12		Is_Type_of	Spastic_CP/Athetoided_CP/Ataxic_CP	CP_Disability
13		Is_Indicated_Through	CP_Disability	Reflex/Symptom
14		Is_part_of	Body_Parts	Child
15		Reflex_Assesment_Result	Child	Reflex
16		Negatively_Reflexed_to	Child	Reflex
17		Positively_Reflexed_to	Child	Reflex
18		Treated_By	Symptom	PT_Treatment
19		Treats	PT_Treatment	Symptom
20	Data Property	Name	Child	String
21		Gender	Child	Literal
22		DoB	Child	dateTime
23		Age	Child	Literal
24		Address	Child	String
25		Birth_Weight	Child	Real
26		Current_Weight	Child	Real
27		Delivery_Type	Child	Literal
28		Hight	Child	Real
29		Mental_Age	Child	Literal
30		Motor_Age	Child	Literal
31		Appearance_Disappearence	Reflex	String
32		Description	Reflex/PT_Treatment	String
33		Exersise_Name	PT_Treatment	String
34		Had_Head_Truma	Child	Literal
35		Has_Final_Score	Child	Int
36		Has_Reflexes_Based_Score	Child	Int
37		Has_result	Reflex	String
38		Has_Score	Reflex/Symptom	Int
39		Has_Symptoms_Based_Score	Child	Int
40		Max_Child_Age	Reflex	Real
41		Photo	PT_Treatment	String
42		Produces	Symptom	String
43		Purpose	PT_Treatment	String

Figure 5.2 shows some properties of CP Ontology, and Figure 5.3 shows the properties of the Symptom Class.

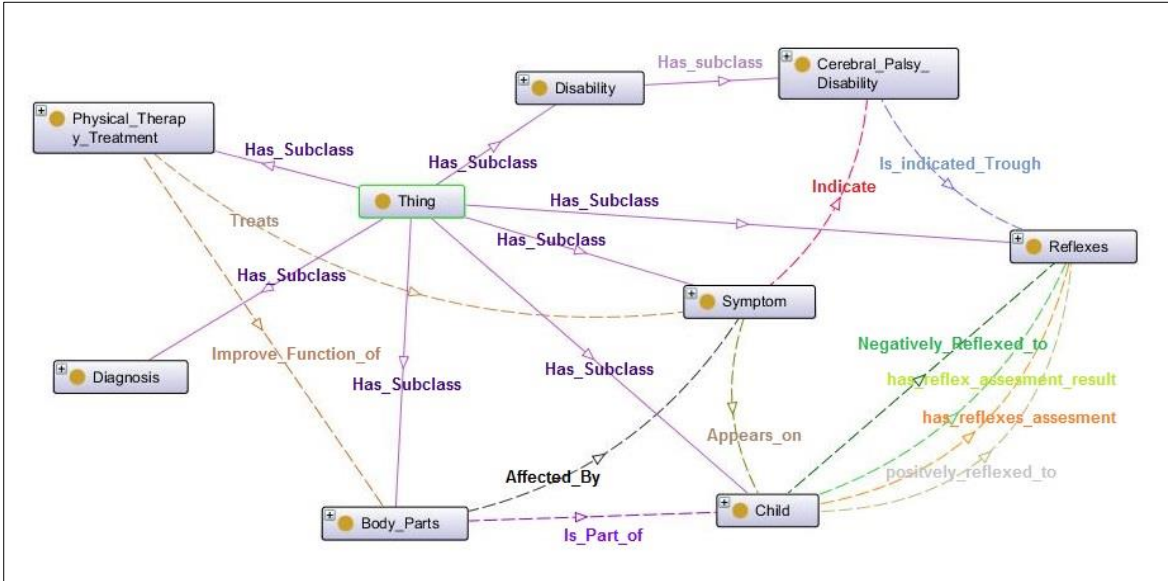


Figure (5.2): Some Properties of CP Ontology

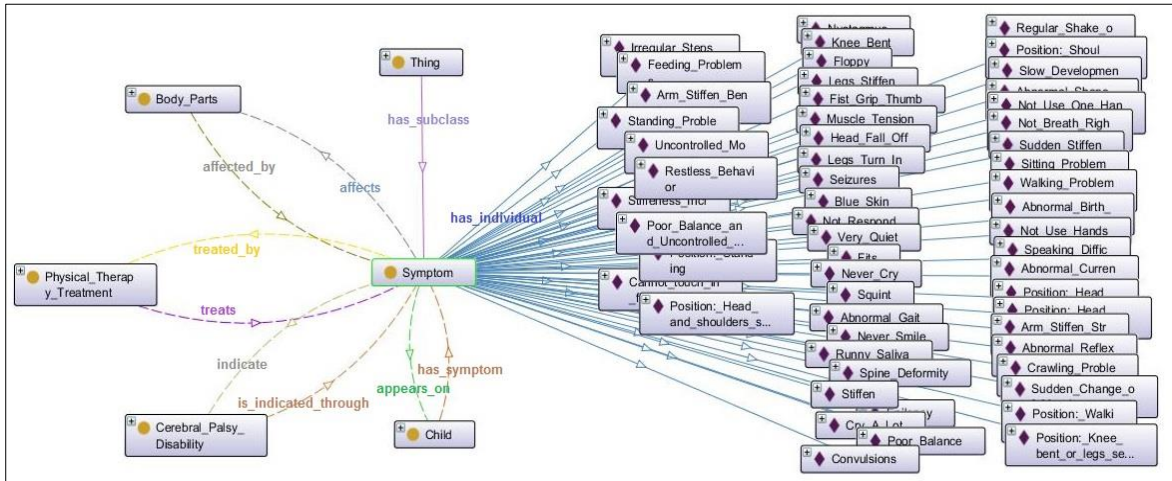


Figure (5.3): Properties of Symptom class

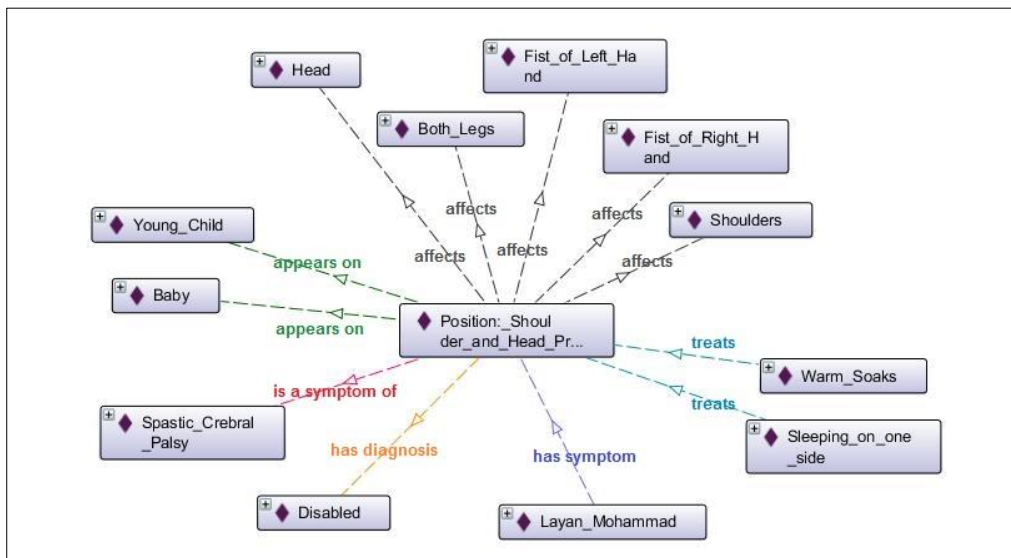
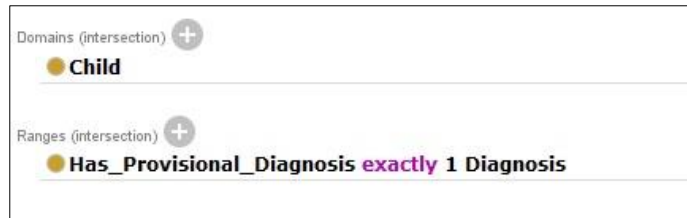


Figure (5.4) Properties of "Shoulder and Head Press Back" symptom

The following figure (Figure 5.4) shows an example of a symptom with its properties.

**Step 7: Define the Facets of the Slots**

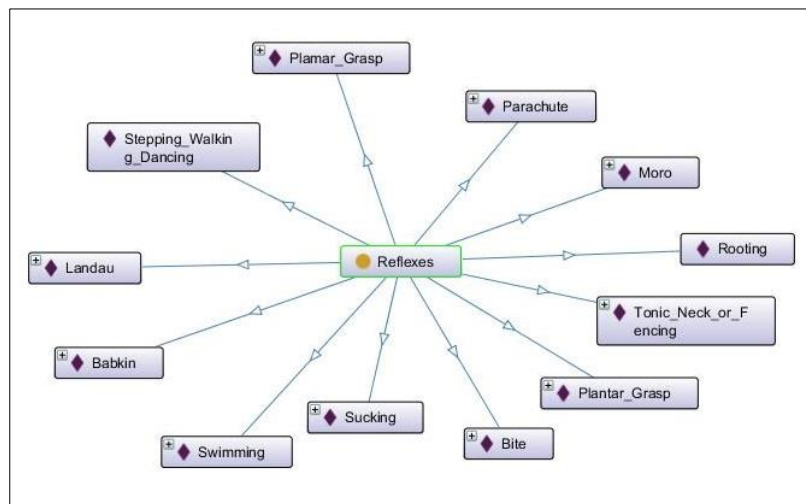
Slots have different facets that describe the value type, allowed values, the cardinality and other features of the values the Slots can take. In our ontology we mainly used cardinality to restrict values that the object can take. For example, Child has exactly one provisional diagnosis. See Figure 5.5



**Figure (5.5):** Cardinality of “Has Provisional Diagnosis” object

**Step 8: Create instances of CP Ontology**

To create the knowledge base of the proposed ontology we added the instances to the classes that we defined and built. We use ontology to organize sets of instances. Since the number of instances in CP ontology is large when compared to the number of classes. The creation of individuals allows for all the properties of the classes to be recorded. The information of individuals is taken from a number of relevant books, papers, and documents contain personal and health data of children with CP.

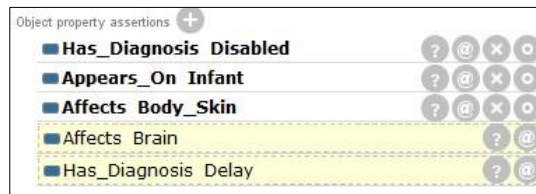


**Figure (5.6):** Instances of Reflexes class in CP Ontology

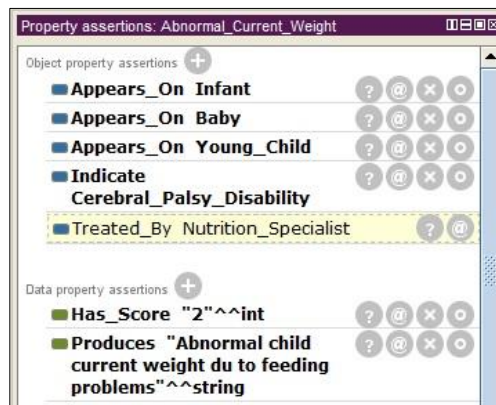
CP Ontology contains 143 instances that are representing all ontology concepts including body parts, children, Diagnosis, CP Disabilities types, Physical therapy treatment, reflexes and Symptoms. As an example, from Figure 5.6 there are 12 instances that connected to reflexes class.

### Step 9: Apply Ontology Reasoner

After creating the instances, we run an ontology reasoner (Pellet reasoner) on the ontology. This is necessary to identify new relations from existing ones. The reasoner is able to identify the different types of ontological relations such as transitive, symmetric, inverse and functional properties, and use them to add new facets. The figure below (Figure 5.7) shows the facts that defined by reasoners.



**Figure (5.7):** Pellet reasoner identified two additional facts



**Figure (5.8):** Pellet reasoners over Abnormal\_current\_weight symptom

Figure 5.8 shows that Pellet reasoner automatically added the object property Treated\_By to the object properties that have been manually added.



**Figure (5.9):** Pellet explanations for Abnormal\_Current\_Weight Treated\_By Nutrition\_Specialist

In figure 5.9 Pellet reasoners provide its explanation for adding Treated\_By property to the object properties of Abnormal\_Current\_Weight symptom, where Nutrition\_Specialist treats Abnormal\_Current\_Weight and Treated\_By is the inverse of Treats property, so Abnormal\_Current\_Weight is Treated\_By the Nutrition\_Specialist.

### 5.3 CP Ontology Implementation in Protégé OWL

Protégé is an open-source platform that provides a number of tools to construct domain models and knowledge-based applications with ontologies. Protégé can be customized to provide domain-friendly support for creating knowledge models and entering data (Stanford University, 2016). This section represents the development of CP Ontology using Protege platform.

#### 5.3.1 Classes and Sub-Classes

Classes are the building blocks of ontology. In CP Ontology we have seven main classes which are *Body\_Parts*, *Child*, *Diagnosis*, *Disability*, *Physical\_Therapy\_Treatment*, *Reflex* and *Symptom* as Figure 5.10 shows.



Figure (5.10): Main classes of CP Ontology

These seven classes have 47 subclasses as Figure 5.11 and Figure 5.12 show. Where, 27 of them are subclasses of Body Parts class, 3 of them are subclasses of Child class, 3 of them are subclasses of Diagnosis class, 5 of them are subclasses of Disability class and 9 of them are subclasses of Physical\_Therapy\_Treatment.

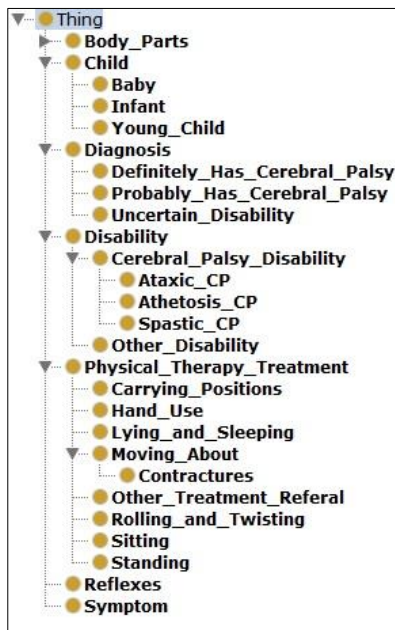


Figure (5.11): Suclases of CP Ontology

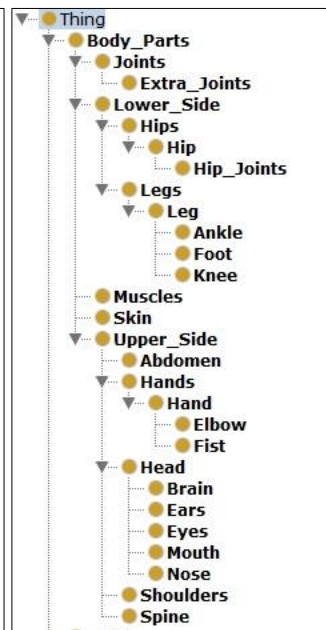


Figure (5.12): Subclasses of Body Parts Class

Figure 5.12 show the taxonomy of *Body\_Parts*. This class has a set of sub-classes such as *Joints*, *upper\_side*, *lower\_side*, *muscles*, *head*, *skin* and *shoulders*.

### 5.3.2 Propertise, Facets and Instances

We defined the properties, facets and instances in CP Ontology using Protégé platform. Where, we defined 143 instances, 19 object properties and 24 data properties in CP ontology as Figures 5.13 and 5.14 show. Most of CP Ontology instances are instances of *Symptom*, *Reflexes* and *Physical\_therapy\_Treatment* classes. Each instance has *Type*, *Annotations* and *Properties*.

The class *Child* has a set of instances, data properties and object properties. To document child medical and personal information we identified a set of data properties such as *Name*, *DoB*, *Address*, *Gender*, *Mental\_Age* and *Motor\_Age* as Figure 5.13 shows. We defined also a set of object properties to represent the relationship between Child class and other classes such as *has\_diagnosis*, *has\_reflexes\_based\_diagnosis*, *has\_symptoms\_based\_diagnosis*, and *has\_symptom* as Figure 5.14 shows.

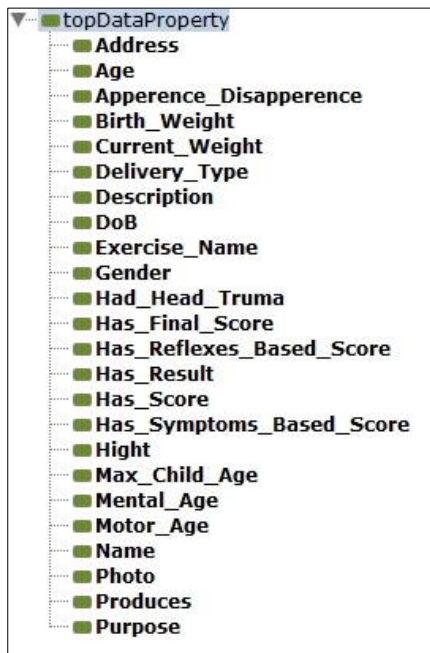


Figure (5.13): Ontology Data Properties

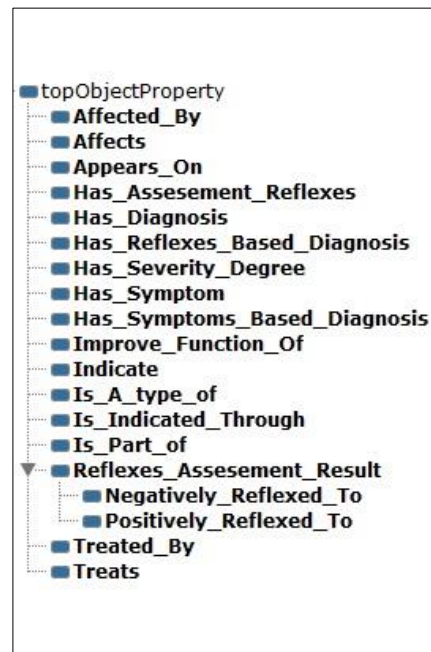


Figure (5.14): Ontology Object Properties

*Physical\_therapy\_treatment* class has 42 instances, two object properties and four data properties. Its object properties are *improve\_function\_of* and *treats*. The property *improve\_function\_of* has been designed to be used to identify body parts that the physical therapy treats. Its data properties are *Description*, *Exersise\_name*, *Photo* and *Purpose*.

The instance *Irregular\_steps\_while\_waliking* is an individual of *Symptom* class and has four object properties and two data properties as Figure 5.15 shows.

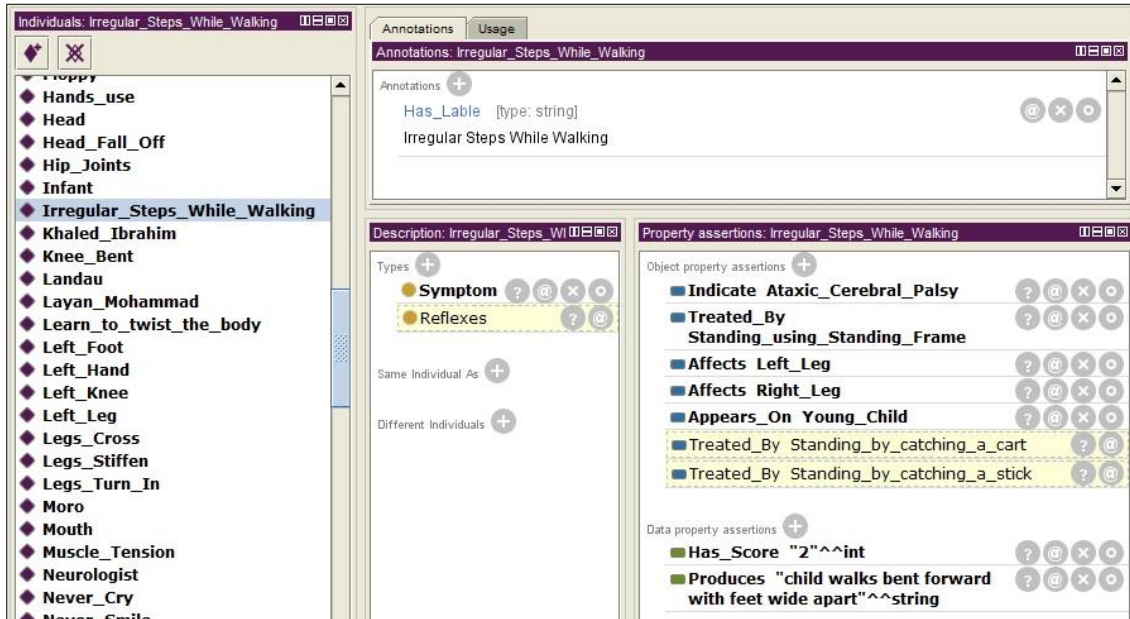


Figure (5.15): The instance Irregular\_steps\_while\_walking in CP Ontology

### 5.3.3 Run Reasoner

To ensure ontology consistency, we run Pellet reasoner on CP ontology. The reasoner extracts new facts among the given ones. Figure 5.16 show three object properties discovered by reasoner and have been added to the *Learn\_to\_twist\_the\_body*.

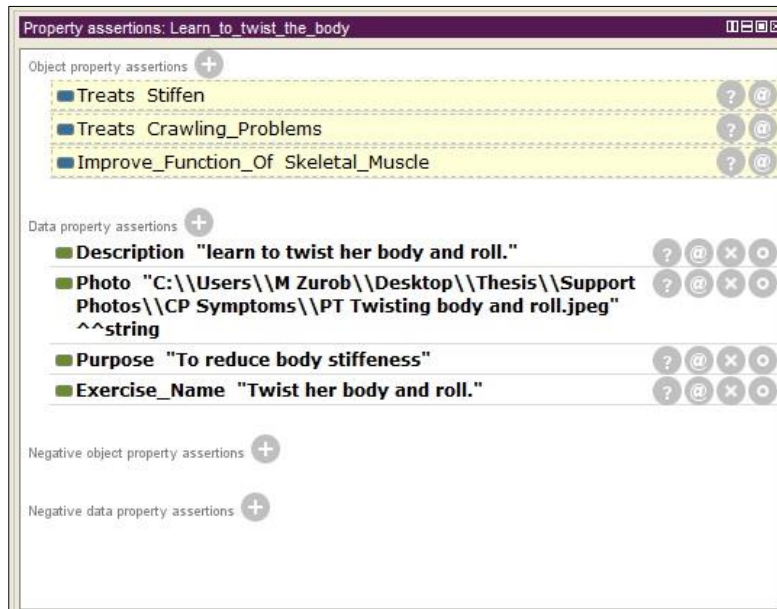


Figure (5.16): Object properties of “Learn\_to\_twist\_the\_body”

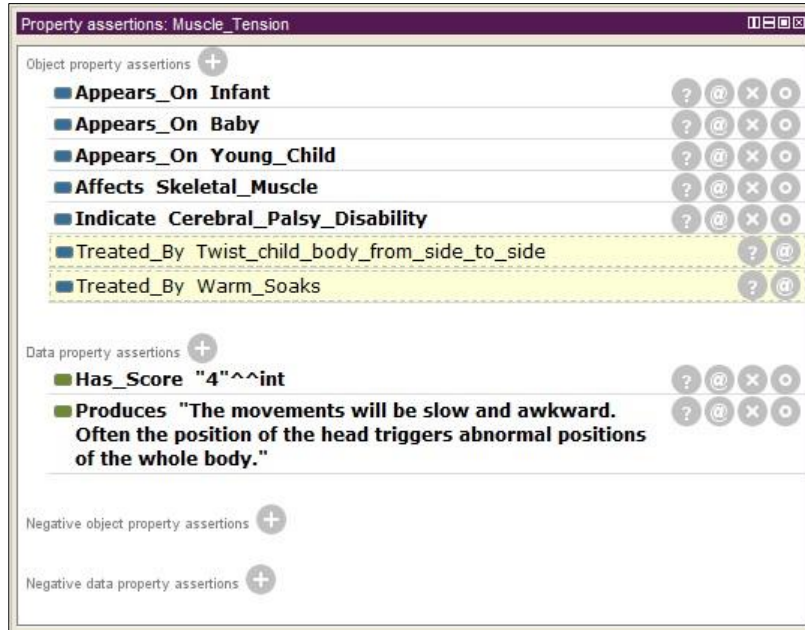
For the property *Learn\_to\_twist\_the\_body:Treats:Stiffen* reasoner used SameAs to add the new fact. Where, *Learn\_to\_twist\_the\_body* SameAs *Swinnign\_legs\_back\_and\_forth*, and *Swinnign\_legs\_back\_and\_forth* Treats *Stiffen*. Thus, the new fact is *Learn\_to\_twist\_the\_body:Treats:Stiffen* as figure 5.17 shows.





**Figure (5.17):** Reasoner explanation of *Learn\_to\_twist\_the\_body:Treats:Stiffen*

Figure 5.18 show that reasoner added new fact *Muscle\_tension:Treated\_by:Twist\_body\_from\_side\_to\_side* to the individual *Muscle\_tension*. Pellet reasoner explained this new fact using *SameAs* and *InverseOf*. Where, the physical therapy treatment “*Twist\_child\_body\_from\_side\_to\_side*” is *SameAs* “*Warm\_soaks*”, *Treated\_by* *InverseOf* *Treats*, and “*Warm\_soaks*” *Treats* “*Muscle\_tension*”. This implies *Muscle\_tension* is *Treated\_by* the physical therapy treatment *Twist\_body\_from\_side\_to\_side* as shown in figure 5.15.



**Figure (5.18):** Object properties of “Muscle\_tension”



**Figure (5.19):** Reasoner explanation of *Muscle\_tension:Treated\_by:Twist\_body\_from\_side\_to\_side*

### 5.3.4 Class Hierarchy in OWL Viz

When we used OWL Vis plugin in Protégé platform we got the class hierarchy of CP Ontology as shown in 5.20. In the figure we clearly see seven main classes where each class has asset of subclasses as mentioned in section 5.2.1.

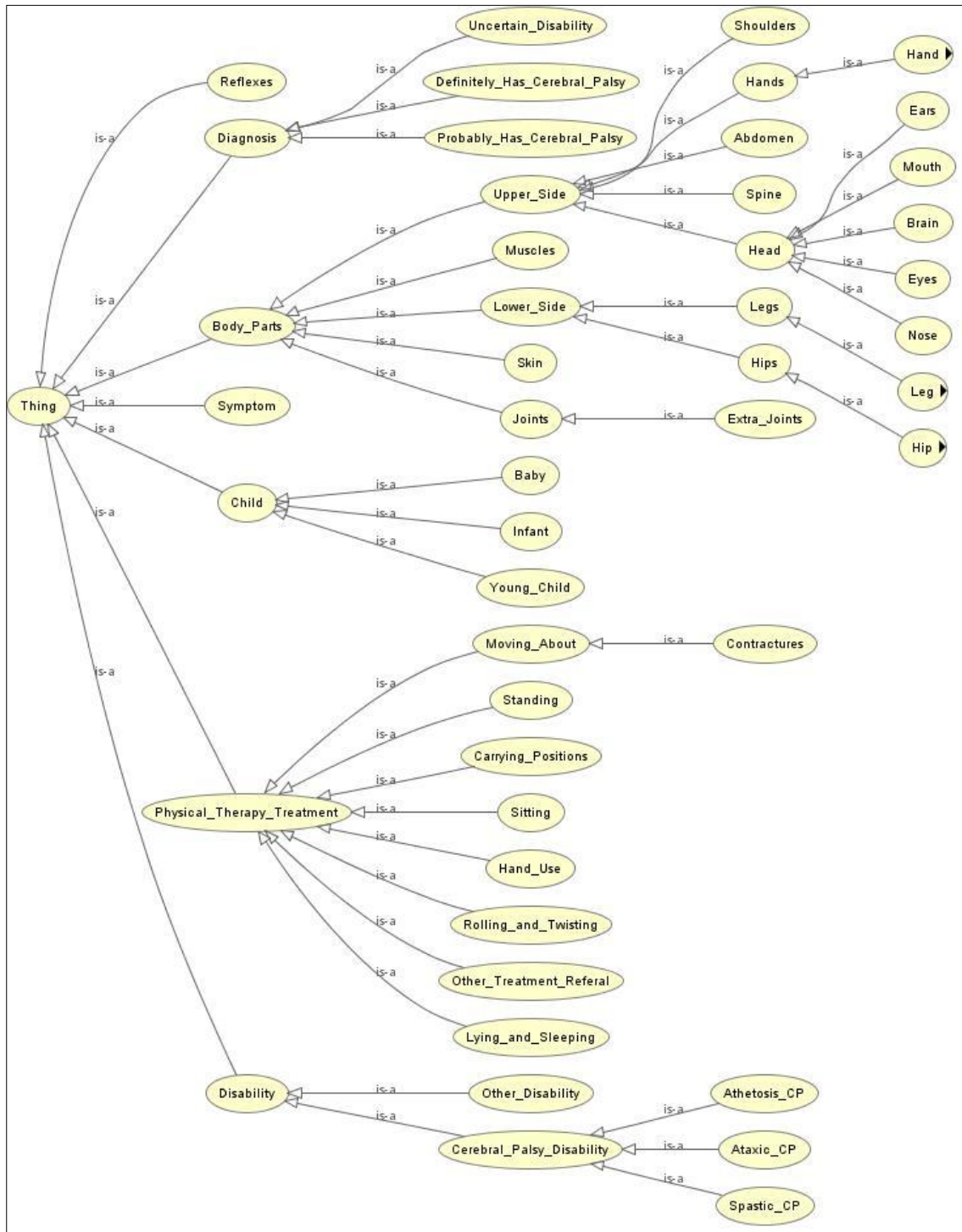


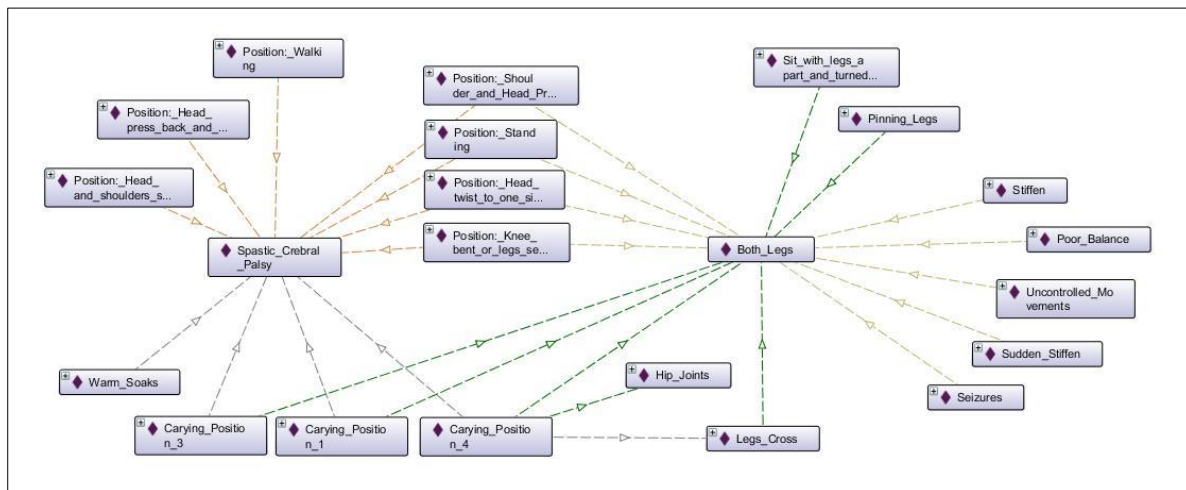
Figure (5.20): Asserted Model of CP Ontology

## 5.4 Evaluation of CP Ontology

In order to ensure the quality of CP Ontology, we evaluated it through Description Logic Queries (DL Queries) and SPARQL Query Language. These queries allow us to access ontology easily and to retrieve the stored knowledge.

### 5.4.1 Quality Evaluation through Spastic CP Disability Example

In order to evaluate the quality of CP Ontology we chose Spastic CP as an example to check if the ontology represent terms, properties and relations of this type of CP disability. Figure 5.21 shows the terms, properties, and relations of disease that are represented in the ontology using OntoGraph plugin in Protege. From the figure we find Spastic CP has 7 symptoms where each on of them affects body parts and treated by specific physical therapy treatment.



**Figure (5.21):** Ontology graph of Spastic Cerebral Palsy disability

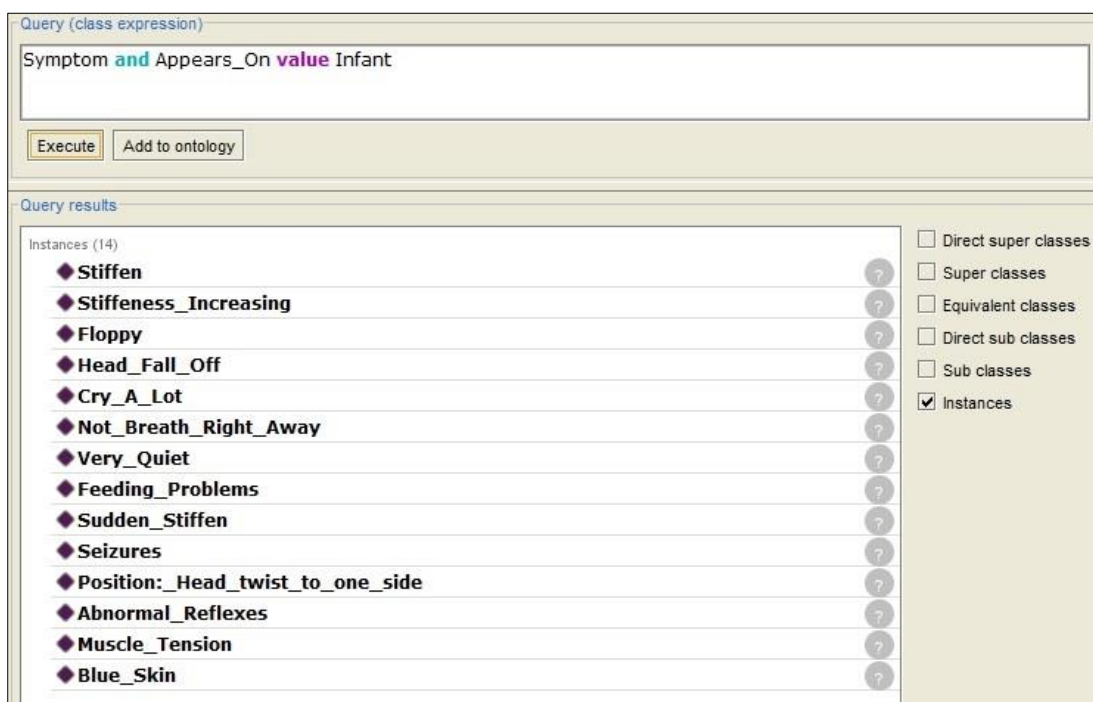
As an example, *Spastic\_Cerebral\_Palsy* has symptom *Shoulder\_and\_head\_press\_back* which affects *Both\_legs* and treated by three *Caring\_positions*.

### 5.4.2 Quality Evaluation through Ontology Querying

The examples below represent the main questions that may be asked to check the functionality of CP Ontology.

#### Example 1:

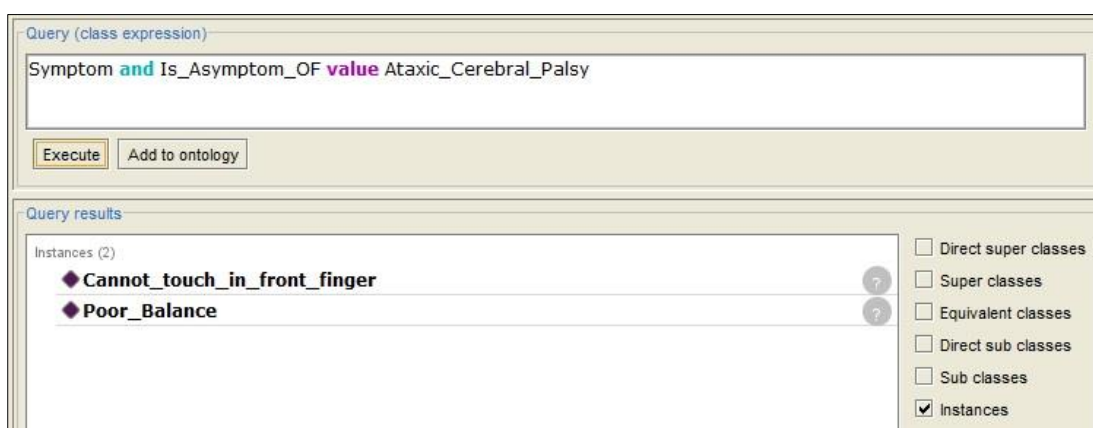
- ❖ What are the main symptoms of CP disability that affect Infants?
- ❖ DL Query to answer this question is: *Symptom and Appears\_On value Infant*
- ❖ The result of this query shown in Figure 5.22 which clearly shows the symptoms that may appear on the Infant who has CP Disability such as floppy, stiffen, head fall off, cry a lot, feeding problems, blue skin and seizures.



**Figure (5.22):** Results of DL Query to retrieve CP symptoms that appears on infants

**Example 2:**

- ❖ What are the symptoms that refer to Ataxic Cerebral Palsy?
- ❖ DL query to answer this question is: *Symptom and Is\_Asymptom\_OF value Ataxic\_Cerebral\_Palsy*
- ❖ The results of this query are shown in figure 5.23. Where the main symptoms of Ataxic CP are poor balance and if we asked the child to touch something in front of him/her then he/she will not do this from the first time unlike the normal child.



**Figure (5.23):** Results of DL query to show symptoms of Ataxic CP

**Example 3:**

- ❖ What are the physical therapy treatments that we need to treat specific symptom like Stiffen?
- ❖ DL query to answer this question is: *Physical\_Therapy\_Treatment and Treats value Stiffen*.

- ❖ The results of this query are shown in figure 5.24. The results matches to required physical therapy treatments that is used to treat stiffen based on references we used.



**Figure (5.24):** Results of DL query to show physical therapy treatments for stiffen child

#### Example 4:

- ❖ What are the symptoms that appear on each body part?
- ❖ SPARQL query to answer this question is:

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns<#
PREFIX owl: <http://www.w3.org/2002/07/owl<#
PREFIX xsd: <http://www.w3.org/2001/XMLSchema<#
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema<#
PREFIX uni: <http://www.semanticweb.org/mzurob/ontologies/2017/1/untitled-ontology-68#<

SELECT ?symptom ?bodyParts ?produces
WHERE {
    ?symptom uni:Affects ?bodyParts.
    ?symptom uni:Produces ?produces }

```

- ❖ Results of this question are shown in figure 4.19.

symptom	bodyParts	produces
Position:_Walking	Right_Foot	"Child try to walk in a stiff, awkward position, with the knees pulled together and bent
Position:_Walking	Left_Foot	"Child try to walk in a stiff, awkward position, with the knees pulled together and bent
Position:_Walking	Left_Knee	"Child try to walk in a stiff, awkward position, with the knees pulled together and bent
Position:_Walking	Right_Knee	"Child try to walk in a stiff, awkward position, with the knees pulled together and bent
Abnormal_Reflexes	Uncontrolled_Muscles	"They may last much longer the automatic body movements."@
Abnormal_Reflexes	Brain	"They may last much longer the automatic body movements."@
Not_Breath_Right_Away	Body_Skin	"Body skin will turn blue due to breathing problem which may cause brain damage."@
Not_Breath_Right_Away	Brain	"Body skin will turn blue due to breathing problem which may cause brain damage."@
Restless_Behavior	Skeletal_Muscle	"Sudden changes of mood."@
Restless_Behavior	Disabled	"Sudden changes of mood."@
Position:_Head_and_shoulders_stiffen_forward	Head	"The head and shoulders may stiffen forward"@
Position:_Head_and_shoulders_stiffen_forward	Shoulders	"The head and shoulders may stiffen forward"@
Floppy	Skeletal_Muscle	"Child hangs in upside down 'U' with little or no movement."@

**Figure (5.25):** Results of SPARQL query to show symptoms and affected body parts

## 5.5 Summary

In this chapter we explained the development and evaluation of CP ontology. Where, the steps of building ontology manually have been presented. We started with identifying ontology

domain and scope. Then we define ontology terms, classes, properties and facets. After that, we realized CP ontology using Protégé platform. Finally, a set of instances have been added to the ontology in order to enrich the knowledge base. The last part in this chapter was the ontology evaluation. Where, the realized ontology evaluated through DL and SPARQL queries. The results show that the ontology provided correct answers to the whole questions.

# Chapter 6

## CP Ontology Approach

## Chapter 6

### CPOnto Approach

In this chapter we present the realization of our proposed CP Ontology for CP diagnosis and physical therapy support treatment. The development of the approach consists of three phases which are system analysis, system structure and system design.

#### 6.1 System Analysis

In this section we will show a detailed description of the proposed CPOntology by explain the interaction between users and system, interaction between system components, and functional and nonfunctional requirements through a set of usecases.

##### 6.1.1 System Description

Our proposed system is developed through an approach for diagnosing cerebral palsy disability based on symptoms that appears on children who have CP disability and reflexes that indicate cerebral palsy disability. The system divided into two parts which are knowledge base and CP Ontology application.

##### 1. CP Ontology Knowledge Base

An ontology that contains the classes and subclasses, data properties and object properties, facets and instances that used to provide the information that will be used in Cerebral Palsy disability diagnosis.

##### 2. CP Ontology Application

CP Ontology application is a desktop application which interfaces that can be used by system users for different purposes related to cerebral palsy disability such as CP Diagnosis, explore information about Cerebral Palsy disability domain, sub-types of Cerebral Palsy disability, symptoms and reflexes that may indicate Cerebral Palsy disability, retrieve record of children who previously diagnosed by the system, and to add new physical therapy treatments.

##### 6.1.2 System Functions

The developed system provides a set of functions that is identified in cooperation with Cerebral Palsy Center of Palestinian Avenir for Childhood Foundation based on the basic needs of the primary health care centers for Cerebral Palsy diagnosis. We used Use Cases and actors to describe system functions as table 6.1 shows.



**Table (6.1): CP Ontology System Use Cases**

UseCase No.	Use Case Name	Actor
1.	CP disability diagnosis based on symptoms	Doctor or Physiotherapist
2.	Generate physical therapy treatment support manual	Doctor or Physiotherapist
3.	Diagnose sub-type of cerebral palsy that the child has based on symptoms	Doctor or Physiotherapist
4.	Conduct CP disability diagnosis based on reflexes assesement	Doctor or Physiotherapist
5.	Display basic information of cerebral palsy disability	Doctor or Physiotherapist
6.	Display basic information of symptoms that indicate Cerebral Palsy	Doctor or Physiotherapist
7.	Display basic information of reflexes that indicate Cerebral Palsy	Doctor or Physiotherapist
8.	Display basic information of physical therapy treatments	Doctor or Physiotherapist
9.	Display personal and diagnosis information for the children who previously diagnosed	Doctor or Physiotherapist
10.	Add new physical therapy treatment to treat specific symptom	Doctor or Physiotherapist

**Use Case number 1: CP disability diagnosis based on symptoms**

Actor	Doctor or Physiotherapist
Scenario	<ol style="list-style-type: none"> <li>1. User click on Diagnose CP Disability button in main window.</li> <li>2. System activate Child Personal Information window.</li> <li>3. User fills in child personal information.</li> <li>4. System activate symptoms based diagnosis window.</li> <li>5. User selects the symptoms that appear on the child.</li> <li>6. User click on Diagnoses button.</li> <li>7. System reads the selected symptoms of disability and then retrieves weight of each symptom from CPOno owl file (Knowledge base).</li> <li>8. System count symptoms based score.</li> <li>9. Based on the calculated score, system provides diagnosis or recommends reflexes assesement.</li> </ol>

**Use Case number 2: Generate physical therapy treatment support manual**

Actor	Doctor or Physiotherapist
Scenario	<ol style="list-style-type: none"> <li>1. After conducting symptoms based diagnosis, user click Generate Physical Therapy Manual button.</li> <li>2. System retrieve physical therapy treatments for each symptom.</li> <li>3. System disaply resulted plan.</li> </ol>

**Use Case number 3:** Diagnose sub-type of cerebral palsy that the child has based on symptoms

<b>Actor</b>	Doctor or Physiotherapist
<b>Scenario</b>	<ol style="list-style-type: none"><li>1. User click on Diagnose CP Disability button in main window.</li><li>2. System activate Child Personal Information window.</li><li>3. User fills in child personal information.</li><li>4. System activate symptoms based diagnosis window.</li><li>5. User selects the symptoms that appear on the child.</li><li>6. User click on Diagnoses button.</li><li>7. System reads the selected symptoms and compares it with symptoms that indicate sub-types of Cerebral Palsy disability which stored in CPontology owl file (Knowledge base).</li><li>8. System displays the sub-type of Cerebral Palsy disability.</li></ol>

**Use Case number 4:** Conduct CP disability diagnosis based on reflexes assesment

<b>Actor</b>	Doctor or Physiotherapist
<b>Scenario</b>	<ol style="list-style-type: none"><li>1. Based on symptoms-based score, system recommends reflexes assesment.</li><li>2. System activate reflexes assesment button.</li><li>3. User goes through reflexes based assesment by clicking the button.</li><li>4. System activates the reflexes based assesment window.</li><li>5. Based on child age, system activates the appropriate reflexes.</li><li>6. System calculates reflexes based score.</li><li>7. System calculates final score.</li><li>8. System display diagnosis summery through new window.</li></ol>

**Use Case number 5:** Display basic information of cerebral palsy disability

<b>Actor</b>	Doctor or Physiotherapist
<b>Scenario</b>	<ol style="list-style-type: none"><li>1. From main window, user clicks on Explore Information button.</li><li>2. System show information window.</li><li>3. User click on Cerebral Palsy Disability lable.</li><li>4. System retrieves basic information of Cerebral Palsy class including instannses.</li><li>5. System disaply results in the same window.</li></ol>

**Use Case number 6:** Display basic information of symptoms that indicate Cerebral Palsy

<b>Actor</b>	Doctor or Physiotherapist
<b>Scenario</b>	<ol style="list-style-type: none"><li>1. From Information window, user select specific symptom.</li><li>2. System retrieves annotations, data and object properties of the selected symptom from knowledge base.</li><li>3. System display reults.</li></ol>

**Use Case number 7:** Display basic information of reflexes that indicate Cerebral Palsy

<b>Actor</b>	Doctor or Physiotherapist
<b>Scenario</b>	<ol style="list-style-type: none"><li>1. From Information window, user select specific reflex.</li><li>2. System retrieves annotations, data and object properties of the selected reflex from knowledge base.</li><li>3. System display results.</li></ol>

**Use Case number 8:** Display basic information of physical therapy treatments

<b>Actor</b>	Doctor or Physiotherapist
<b>Scenario</b>	<ol style="list-style-type: none"><li>1. From Information window, user selects specific physical therapy treatment.</li><li>2. System retrieves annotations, data and object properties of the selected physical therapy treatment from knowledge base.</li><li>3. System display results.</li></ol>

**Use Case number 9:** Display personal and diagnosis information for the children who previously diagnosed

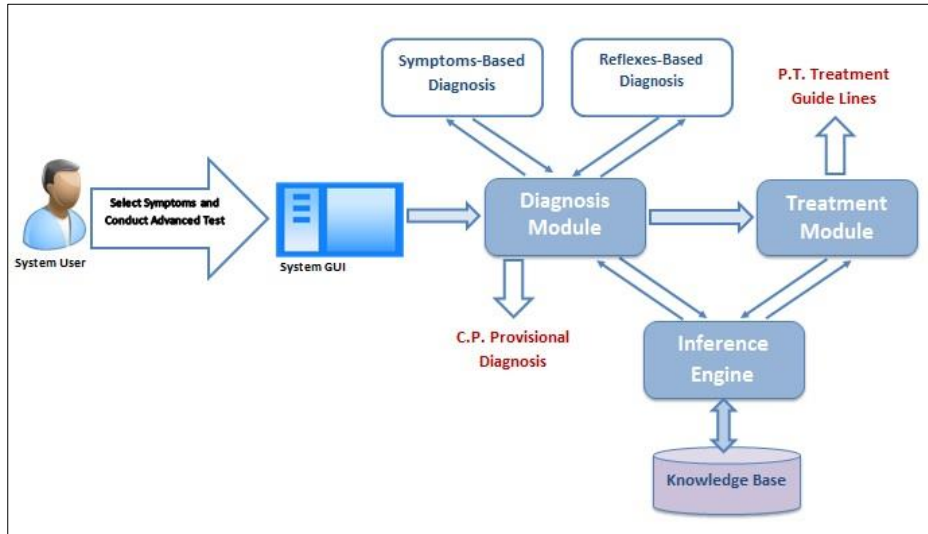
<b>Actor</b>	Doctor or Physiotherapist
<b>Scenario</b>	<ol style="list-style-type: none"><li>1. From Information window, user selects specific child.</li><li>2. System retrieves annotations, data and object properties, symptoms, reflexes, and diagnosis of the child from knowledge base.</li><li>3. System display results.</li></ol>

**Use Case number 10:** Add new physical therapy treatment to treat specific symptom

<b>Actor</b>	Doctor or Physiotherapist
<b>Scenario</b>	<ol style="list-style-type: none"><li>1. From main window, user clicks on Add P.T. Treatment button.</li><li>2. System shows Add P.T. Treatment window.</li><li>3. User fills in the required information.</li><li>4. User click on Add Treatment Record button.</li><li>5. System adds the new treatment to the CPOnto owl file (Knowledge base).</li></ol>

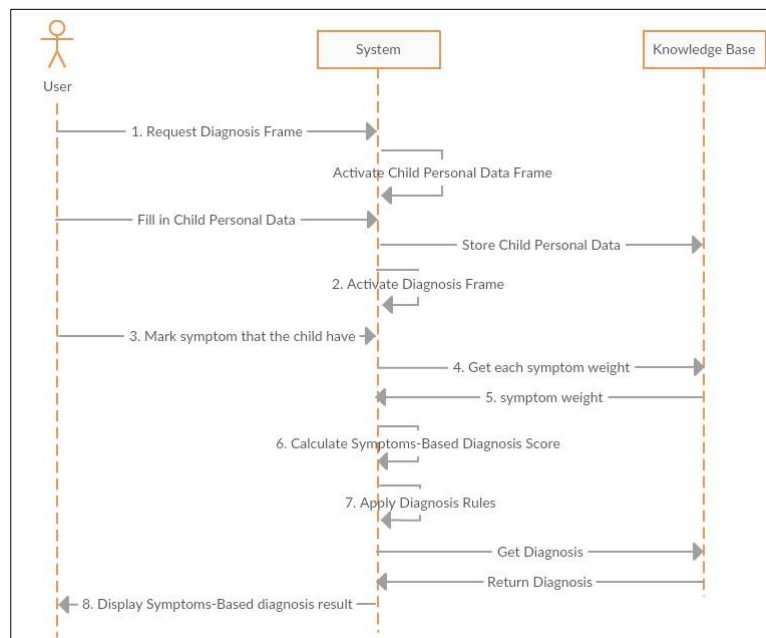
## 6.2 System Structure

CP Ontology system has four main componenets interact with each others to provide the system functional requirement. These components are Graphical User Interfaces GUI, Knowledge base which contains ontology OWL file, Inference Engine, and rules as shown in figure 6.1.



**Figure (6.1):** CP Ontology system structure

In order to diagnose cerebral palsy disability for specific child, using GUI, system user activate diagnosis interface and mark the symptoms that the child have. Then, system reads the marked set of symptoms, and then run Pellet reasoner over the ontology file. Reasoner retrieves weight for each symptom, and calculates the overall symptoms-based score. Then, based on the calculated score, system gives a recommendation. If the score is low then the system recommend reflexes-based diagnosis, otherwise the system give final diagnosis. Then, System store and display diagnosis results on diagnosis interface as Figure 6.2 shows.



**Figure (6.2):** Sequence diagram for CP diagnosis

To generate physical therapy support guidelines manual, system use the same set of marked symptoms by system user for specific child. Then reasoner retrieve a set of data

properties and object properties including asserted and inferred data and object properties which are related to the treatment of each marked symptom. Then system stores this list of data into an arraylist and then display these data on threatment interface for the user and store the treatment plan in child record.

To display basic information of specific class, individual, or property from knowledge base file (Ontology OWL file) system user select the item, then the system run reasoner to retrieve asserted and inferred data from ontology file. Then, system displays this information on an interface.

The below diagram in Figure 6.3 shows the process that followed to get the Cerebral Palsy disability diagnosis for a child based on symptoms and reflexes assesment. It enables the user to activate diagnosis interface and select the system that appear on the child. Then the system reads these symtoms and retrieves the weight of each symptom from ontology file. The system calculates symptoms-based score. Then system uses the selected symptom to identify the sub-type of Cerebral Palsy disability.

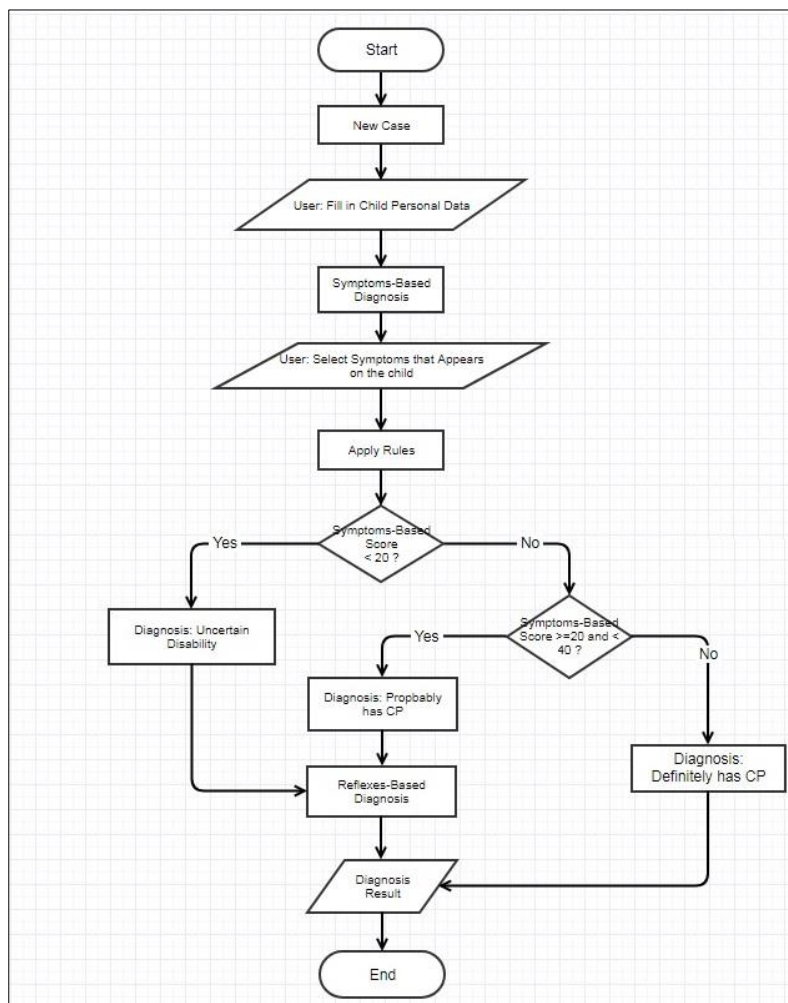
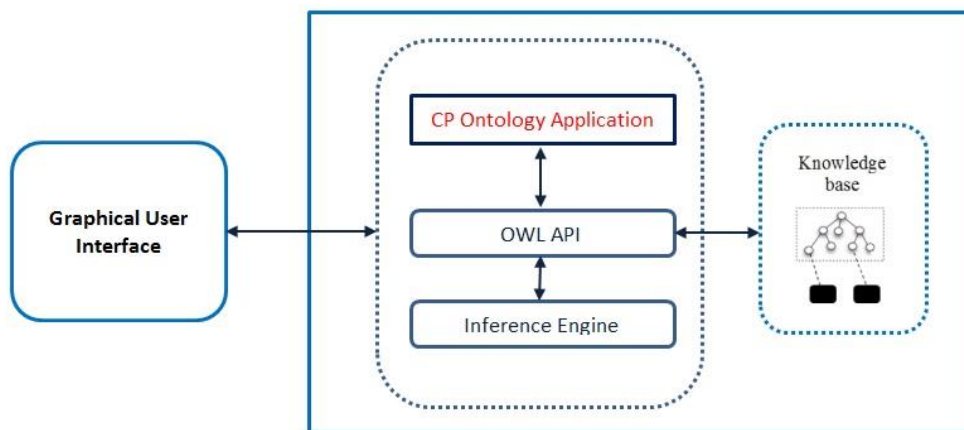


Figure (6.3): C.P. Diagnosis flow chart

The user can add a physical therapy support treatment to include it in the physical therapy manual that will be generated for the children who have Cerebral Palsy disability.

### 6.3 System Design

The requirements that have been identified previously in section 6.1 are transformed into a system design which will be used as a prior step of system implementation. As Figure 6.4 shows, CP Ontology system components are interacting with each other in order to perform functional and nonfunctional tasks.

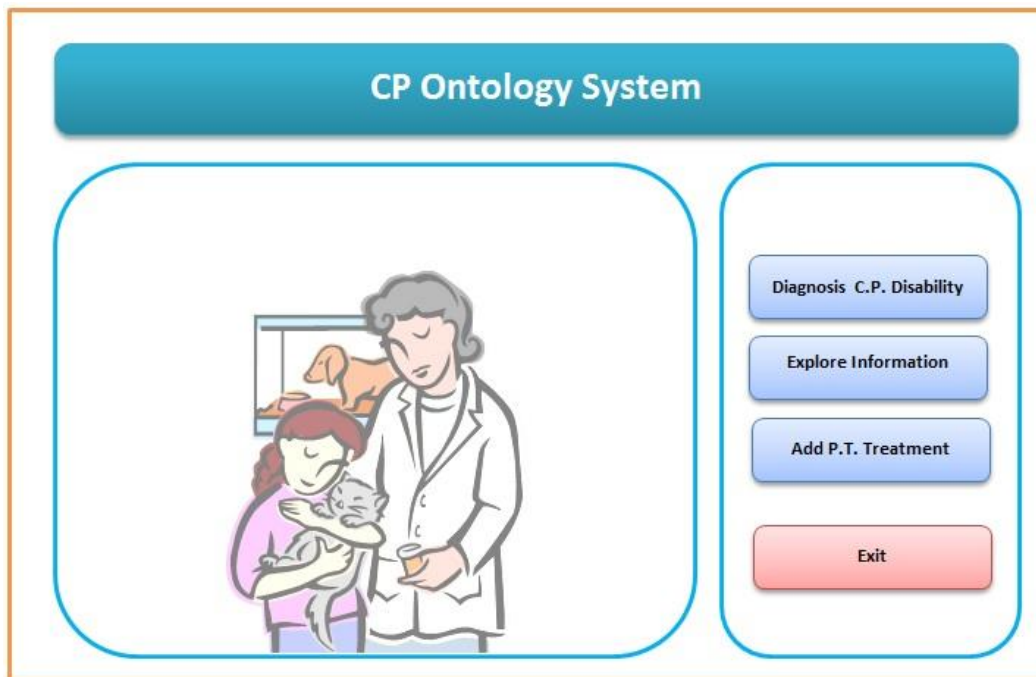


**Figure (6.4):** Components of CP Ontology system

The proposed system has been designed to provide easy access and easy use by the users. Where, all interactions between user and system components are done through graphical user interfaces. These interfaces are simple and easy to use where it includes simple components such as labels, tables, checkboxes, buttons, and dropdown lists.

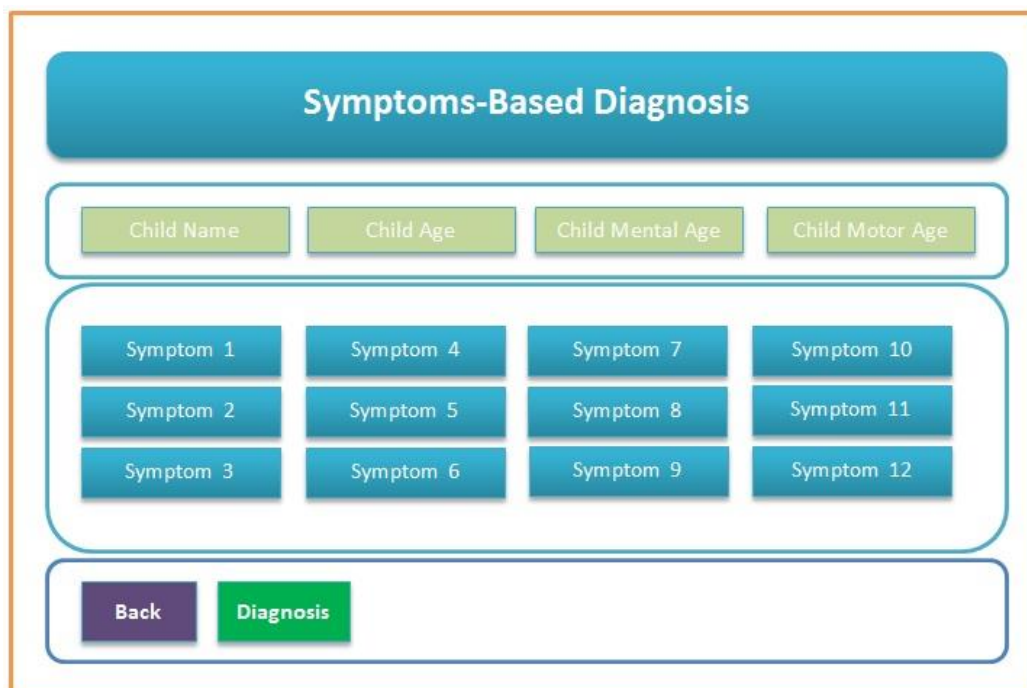
GUIs of CP Ontology system interact with other components of the system through application component. CP Ontology application component interact with OWL API component in order to access the knowledge base file (Ontology OWL File) and OWL API use Pellet Reasoner to retrieve asserted and inferred properties and individuals from the knowledge base as shown in Figure 6.3.

- **Graphical User Interfaces:** CP Ontology system have GUIs as intermediate between user and system other components. There are seven main interfaces in the application designed with very little items to make it easy to use. These interfaces enable the user to diagnose C.P. disability, generate physical therapy support guidelines, add new physical therapy treatment, and display information about CP.



**Figure (6.5):** Design of main interface of CP Ontology application

Figure 6.5 shows the design of the main interface of CP Ontology application which contains four buttons, three of them to activate interfaces of CP Diagnosis, Explore Information, and Add Treatment Interfaces.



**Figure (6.6):** Design of Symptoms Based Diagnosis interface

Figure 6.6 shows the simple design of symptoms based diagnosis interface, which contains basic child personal information, symptoms, and diagnosis button. This interface designed to be easy to understand and easy to use.

- **CP Ontology Application:** CP Ontology application has been developed using Java through NetBeans IDE. NetBeans provide OWL API which used to access, retrieve, and store information from OWL Ontology file with a set of methods. Section 6.4 show detailed information about system application.
- **OWL API:** It is a java API designed to be installed in Java platforms in order to read and write data from OWL ontology files.
- **The Knowledge Base:** The knowledge base has been built using OWL ontology. This OWL Ontology is a file contains CP ontology and individuals. OWL ontology file contains symptoms of cerebral palsy disability and its three subtypes. In addition to that it contains the treatments of each symptom. Moreover, it contains a set of individuals who already diagnosed.
- **Reasoner:** We used Pellet reasoner with OWL API in order to read inferred properties that created by reasoner and to ensure the consistency of CP Ontology.

## 6.4 CP Ontology Application

In this section, we present the implementation of CP Ontology system according to the system design presented in section 6.3. This section will be presented in four subsections which are Connecting Knowledge Base with system application, Diagnosis Cerebral Palsy disability, Explore related information and Add new physical therapy treatment.

### 6.4.1 Connect CP Ontology Application with Knowledge Base

Our knowledge base represented through the created Ontology OWL file. We connected CP Ontology OWL file with CP Ontology Application Using OWL API. The below box contains the code that has been used to access knowledge base.

```
private static final String BASE_URL =
    "http://www.semanticweb.org/mzurob/ontologies/2017/1/untitled-ontology-68";
private static OWLObjectRenderer renderer = new DLSyntaxObjectRenderer();
public static File file = new File("d://Updated CP Ontology.owl");
OWLOntologyManager manager = OWLManager.createOWLOntologyManager();
OWLOntology ontology = manager.loadOntologyFromOntologyDocument(file);
OWLReasonerFactory reasonerFactory = PelletReasonerFactory.getInstance();
OWLReasoner reasoner = reasonerFactory.createReasoner(ontology, new SimpleConfiguration());
OWLDataFactory factory = manager.getOWLDataFactory();
PrefixManager pm= (PrefixManager) manager.getOntologyFormat(ontology);
Map<String, String> prefixMap = pm.getPrefixName2PrefixMap();
((PrefixOWLOntologyFormat) pm).setDefaultPrefix(BASE_URL + "#");
```



### 6.4.2 Cerebral Palsy Disability Diagnosis

CP Ontology application have seven main interfaces in order to accomplish the requires functions. When the system user want to diagnose Cerebral Palsy disability for new case, there are five steps should be performed.

#### Step 1. Request Cerebral Palsy diagnosis window

When the user wants to start Cerebral Palsy diagnosis process, he/she click *Diagnosis C.P. Disability* button in the main interface.



Figure (6.7): Main interface of CP Ontology application

Figure 6.7 shows the main interface of CP Ontology application which contains four buttons, three of them to activate interfaces of CP Diagnosis, Explore Information, and Add Treatment Interfaces.

#### Step 2. Fill in Child Personal Information

Figure (6.8): Child personal data interface

As shown in figure 6.8, the first step in diagnosis process is to fill in the child personal data. The main required data are child name, DoB, gender, birth weight, and current weight.

CP Ontology application creates new instance of Child class and stores this data belong it in the ontology OWL file through data and object properties. As a sample, the below box shows the method *addIndvToClass* that used to creates new individual from Child class in the Ontology OWL file.

```
public void addIndvToClass(String className, String indvName)
    throws OWLOntologyStorageException
{
    OWLClass person = factory.getOWLClass(":" + className + "", df.pm);
    OWLNamedIndividual newIndv2 = factory.getOWLNamedIndividual(":" + indvName + "",
        df.pm);
    OWLClassAssertionAxiom classAssertion = factory.getOWLClassAssertionAxiom(person,
        newIndv2);
    AddAxiom addAxiomChange = new AddAxiom(ontology, classAssertion);
    manager.applyChange(addAxiomChange);
    manager.saveOntology(ontology);
    System.out.println(!reasoner.getPendingChanges().isEmpty());
}
```

### Step 3. Go to Symptoms-Based Diagnosis

In the previous step, system created new individual for Child class. Now, we can start diagnosis process through symptoms-based diagnosis window.



**Figure (6.9):** Symptom-Based Diagnosis interface

Figure 6.9 shows the symptoms-based diagnosis interface which used to diagnose Cerebral Palsy disability based on the symptoms that are appear on the child. This interface is simple and easy to use. System user just chooses the child age, mental age, and motor age. Then,

marks the symptoms that the child has and click Diagnose button to get symptoms-based diagnosis result.

The system firstly read the weights of the marked symptoms from the knowledge base OWL API as shown in the below code. Then, the system adds the marked symptoms as object properties using *Has\_Symptom* object property to the new instance (new child instance).

```

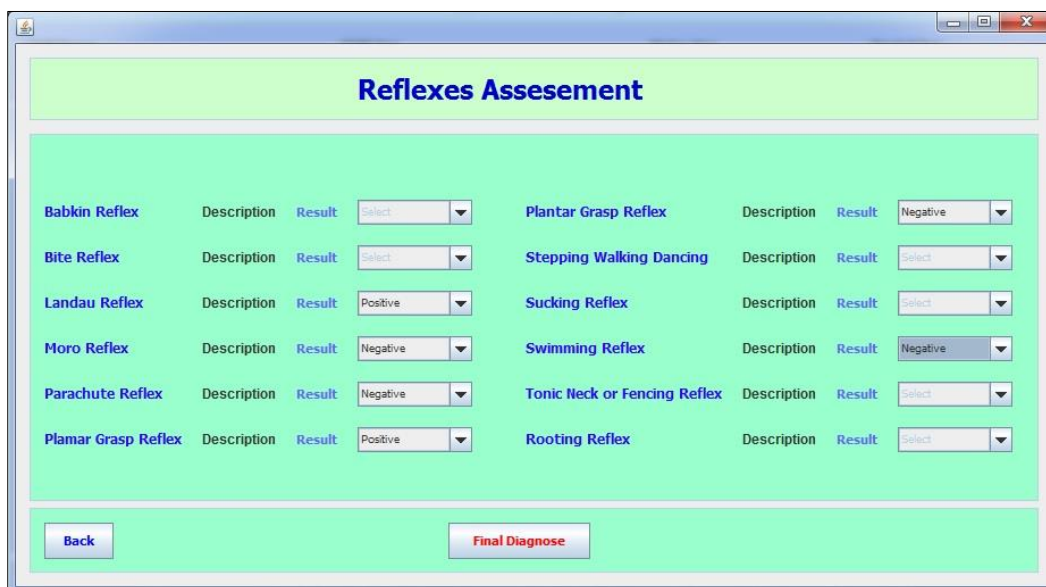
if(this.symptom_AbnormalCurrentWeight.isSelected())
try {
cp_disability_score = cp_disability_score + getSymptomScore("Abnormal_Current_Weight");
addObjectPropertyToIndv(childName,"Has_Symptom","Abnormal_Current_Weight");
} catch (OWLOntologyCreationException ex) {
Logger.getLogger(DiagnosisFrame.class.getName()).log(Level.SEVERE, null, ex);
} catch (OWLOntologyStorageException ex) {
Logger.getLogger(DiagnosisFrame.class.getName()).log(Level.SEVERE, null, ex);
}
}

```

In the same figure, system recommended Reflexes-Based diagnosis through an alert message. This recommendation created because the symptoms-based diagnosis result was *Probably Has CP*.

**Step 4. Go to Reflexes-Based Diagnosis**

If the symptoms-based diagnosis result is *Uncertain Disability* or *Probably Has Cerebral Palsy*, then CP Ontology system recommend Reflexes-Based diagnosis as shown in figure 6.9.



**Figure (6.10):** Reflexes Assesment interface

As shown in Figure 6.10, system activates reflexes assesment based on the symptoms based diagnosis. There are 12 reflexes to be assessed. Based on child age, some of them are inactive. From this interface, the system user can ask for reflex description through *Description* label that lise next to each reflex name.

The system reads from CP ontology OWL file the weights of active and assessed reflexes and calculate *Reflexes-Based Score*. Then add this information to the new child instance through object and data properties as shown in below code.

```

if(this.Landau_jComboBox.getSelectedItem().toString().equals("Negative"))
{
    try {
        reflexesScore = reflexesScore + getReflexScore("Landau");
        addObjectPropertyToIndv(dFrame.childName,"Negatively_Reflexed_To","Landau");
    } catch (OWLOntologyCreationException ex) {
        Logger.getLogger(ReflexesAssesementFrame.class.getName()).log(Level.SEVERE, null, ex);
    } catch (OWLOntologyStorageException ex) {
        Logger.getLogger(ReflexesAssesementFrame.class.getName()).log(Level.SEVERE, null, ex);
    }
} else
if(this.Landau_jComboBox.getSelectedItem().toString().equals("Positive"))
{
    try {
        addObjectPropertyToIndv(dFrame.childName,"Positively_Reflexed_To","Landau");
    } catch (OWLOntologyStorageException ex) {
        Logger.getLogger(ReflexesAssesementFrame.class.getName()).log(Level.SEVERE, null, ex);
    }
}
}

```

**Step 5. Show Diagnosis Summary**

Then, system store diagnosis basic information in knowledge based and then display it on diagnosis summery interface as shown in figure 6.11.



**Figure (6.11):** Diagnosis summary interface

**6.4.3 Explore Information**

If the user want to generate a physical therapy support manual he/she have to click *Generate Manual* button after making the symptoms based diagnosis to get a manual for supporting physical therapy treatment as Figure 6.12 shows.

Physical Therapy Treatment Guid Lines		
Symptom	P.T. Excercise	Photo
Sitting_Problems	Sit_with_body_bent_forward_and_legs_together	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Sitting_Problems	Sitting_by_stabilizing_Legs	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Sitting_Problems	Sit_with_legs_apart_and_turned_outward.	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Sitting_Problems	Sitting_with_the_legs_in_a_ring	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Sitting_Problems	Sit_the_child_on_your_belly	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Standing_Problems	Standing_by_catching_a_stick	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Standing_Problems	Standing_using_Standing_Frame	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Standing_Problems	Standing_by_catching_a_cart	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Epilepsy	Neurologist	
Poor_Balance	Sit_with_body_bent_forward_and_legs_together	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Poor_Balance	Standing_by_catching_a_stick	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Poor_Balance	Sitting_by_stabilizing_Legs	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Poor_Balance	Standing_using_Standing_Frame	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Poor_Balance	Sit_with_legs_apart_and_turned_outward.	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Poor_Balance	Sitting_with_the_legs_in_a_ring	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Poor_Balance	Sit_the_child_on_your_belly	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Poor_Balance	Standing_by_catching_a_cart	C:\Users\VM Zurob\Desktop\Thesis\Support Photos\ICP Sy...
Feeding_Problems	Nutrition_Specialist	
Floppy	Wheel_Board	C:\Users\VM Zurob\Desktop\ICP_OnTo_Support\Images\WPT ...
Head_Fall_Off	Wheel_Board	C:\Users\VM Zurob\Desktop\ICP_OnTo_Support\Images\WPT ...
Convulsions	Neurologist	

**Figure (6.12):** Physical therapy support manual interface

When system user conducting symptoms based diagnosis, for each marked symptom, the system reads the physical therapy treatments from system knowledge base through the code shown in the below box.

```

public void getSymptomTreatment (String symName) throws OWLOntologyCreationException
{
    OWLNamedIndividual individual = factory.getOWLNamedIndividual(":"+symName, pm);
    OWLObjectProperty Treated_By = factory.getOWLObjectProperty(":Treated_By", pm);
    OWLDataProperty Photo = factory.getOWLDataProperty(":Photo", pm);
    for (OWLNamedIndividual ind : reasoner.getObjectPropertyValues(individual,
    Treated_By).getFlattened()) {
        this.addSymptomsTreatmentToList(symName,renderer.render(ind),
        getDataPropertyValue(renderer.render(ind),"Photo"));
    }
}

```

The user can also explore information about the concepts and relations that are included in the knowledge base through *Explore Information interface* as Figure 6.13 shows.

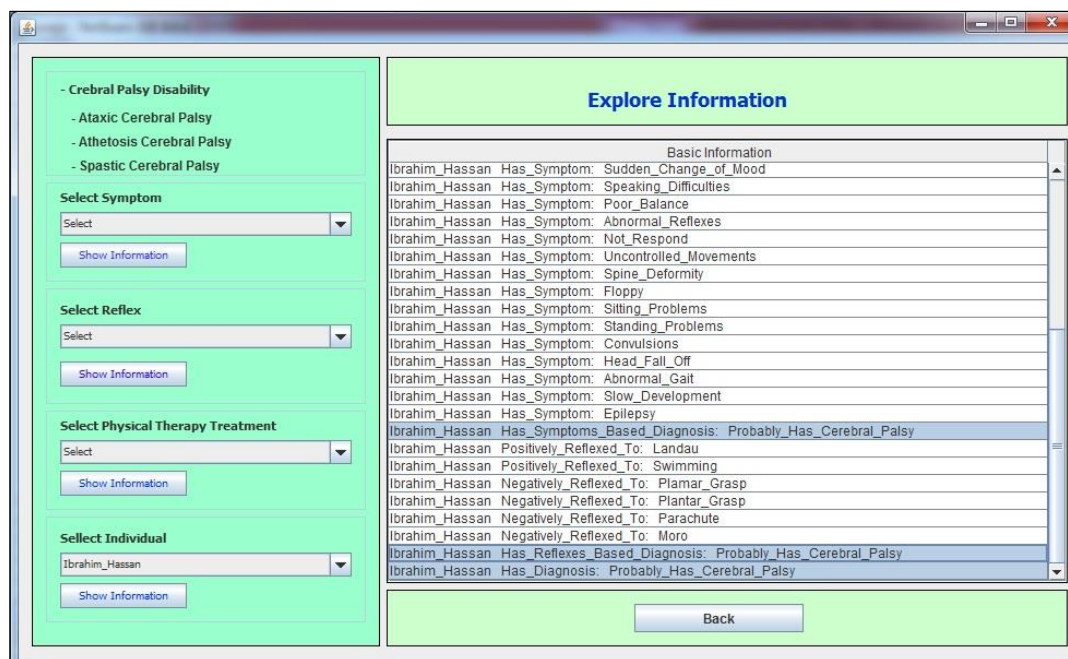


Figure (6.13): Explore information interface

Through this window, system retrieves asserted and inferred data and object properties including diagnosis information. For example, to retrieve object and data properties of specific symptom, we used the below code. There are 5 object properties and 2 data properties used to describe relationship between Symptom class and other classes.

```
private void jButton2ActionPerformed(java.awt.event.ActionEvent evt) {
    try {
        resultTempList.clear();
        resultTableModel.setRowCount(0);
        getObjectPropertyValues(symptoms_jComboBox.getSelectedItem().toString(),"Treated_By");
        getObjectPropertyValues(symptoms_jComboBox.getSelectedItem().toString(),"Affects");
        getObjectPropertyValues(symptoms_jComboBox.getSelectedItem().toString(),"Is_Asymptom_OF");
        getObjectPropertyValues(symptoms_jComboBox.getSelectedItem().toString(),"Has_Diagnosis");
        getObjectPropertyValues(symptoms_jComboBox.getSelectedItem().toString(),"Appears_On");
        getDataPropertyValues(symptoms_jComboBox.getSelectedItem().toString(),"Has_Score");
        getDataPropertyValues(symptoms_jComboBox.getSelectedItem().toString(),"Produces");
        printTempList ();
    } catch (OWLontologyCreationException ex) {
        Logger.getLogger(CPDIsabilityFrame.class.getName()).log(Level.SEVERE, null, ex);
    }
}
```

#### 6.4.4 Add new Physical Therapy Treatment

System user can add new physical therapy support treatment using interface appears in Figure 6.14. This called *Add P.T. Treatment Exercise* which enables the user to add new treatment with its complete information including treatment name, treatment class, the symptom that the treatment is treating, discription, purpose of the treatment and support photo.

**Figure (6.14):** Add P.T. Treatment Exercise interface

To accomplish this task, we used two methods to add new PT Treatment individual with its data properties and object properties. The below code shows the methods that have been used for this purpose.

```

public void addDataPropertyToIndv(String indvName, String dataPropertyName, String dateValue)
throws OWLOntologyStorageException
{
    OWLDataProperty dataProperty = factory.getOWLDataProperty(":" + dataPropertyName + "",
        df.pm);
    OWLNamedIndividual newIndv = factory.getOWLNamedIndividual(indvName, df.pm);
    OWLDataPropertyAssertionAxiom hasAgeAssertion =
        factory.getOWLDataPropertyAssertionAxiom(dataProperty, newIndv, dateValue);
    manager.addAxiom(ontology, hasAgeAssertion);
    manager.saveOntology(ontology);
    System.out.println(!reasoner.getPendingChanges().isEmpty());
}
public void addObjectPropertyToIndv(String indvName1, String ObjectPropertyName, String
indvName2) throws OWLOntologyStorageException
{
    OWLObjectProperty ObjectProperty = factory.getOWLObjectProperty(":" + ObjectPropertyName +
        "", df.pm);
    OWLNamedIndividual indv1 = factory.getOWLNamedIndividual(":" + indvName1 + "", df.pm);
    OWLNamedIndividual indv2 = factory.getOWLNamedIndividual(":" + indvName2 + "", df.pm);
    OWLObjectPropertyAssertionAxiom assertionObjectProperty
        = factory.getOWLObjectPropertyAssertionAxiom(ObjectProperty, indv1, indv2);
    AddAxiom addObjectProperty = new AddAxiom(ontology, assertionObjectProperty);
    manager.applyChange(addObjectProperty);
    manager.saveOntology(ontology);
    System.out.println(!reasoner.getPendingChanges().isEmpty());
}

```

## 6.5 Summery

In this chapter, we represent Cerebral Palsy disability diagnosis development phases. It is mainly included three phases which are system analysis phase, system structure phase and system design phase.

In system analysis phase, we analysed our proposed system through its functions which are presented through a set of use cases that describe those functions. In system structure phase, the components of the system and its functions are presented. In system design phase, we present system components and interaction between these components.



# **Chapter 7**

## **Experimental Evaluation and Discussion**

## Chapter 7

### Experimental Evaluation and Discussion

In this chapter, we present the quality evaluation of our approach including consistency and correctness of CP Ontology for describing cerebral palsy disability domain, and the developed CPonto Application for implementing rules and provide required information. The proposed CP Ontology has been evaluated through ontology concepts evaluation and through a set of DL and SPRQL queries, and CP Ontology Application has been evaluated through a test dataset included 50 records for children who are previously diagnosed in Cerebral Palsy Center of Palestine Avner for Childhood Foundation. The test set included normal children, children with Cerebral Palsy disability, and children with other disabilities. Diagnosis results that come from pur system have been evaluated by comparing it with the previous diagnosis for the same children which done inside Cerebral Palsy Center of Palestine Avner for Childhood Foundation.

#### 7.1 CP Ontology Evaluation

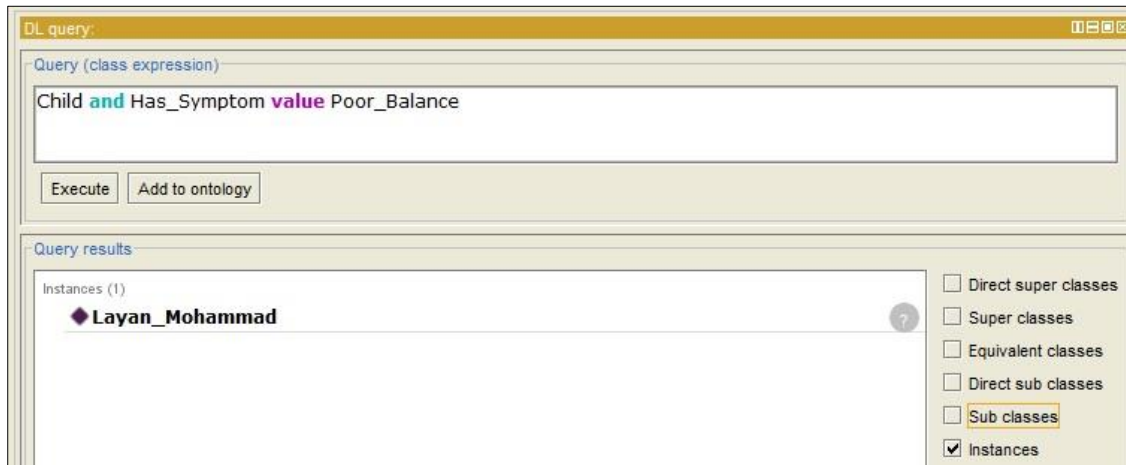
In this section we evaluated the quality and consistency of CP Ontology. To reach this objective we followed three approached which are: Ontology Reasoning; Querying the Ontology; Domain Expert review.

##### 7.1.1 Ontology Reasoning

Automatic reasoning is an important because we have to be sure about the correctness of the created ontology. Reasoning will enable us to check the consistency of the ontology, check for the unintended relations between classes, and check for unintended classifications of instances (Antoniou et al., 2012). To do this, we used automatic reasoning by using Pellet Reasoner. We run the reasoner over the ontology through Protégé platform. CP Ontology was consistenet and successfully used as a knowledge base by the system application.

##### 7.1.2 Querying the Ontology

Querying the OWL ontology aims at retrieving information from ontology file. Therefore, if the ontology correctly built, then we can retrieve correct and relevant information. The results of conducted queries are indicators to the quality of ontology file. For this purpose, we used DL and SPARQL queries. In chapter 5 section 5.4 we evaluated CP Ontology through a set of DL and SPARQL queries. The queries were built to answer a set of questions, and the retrived results were correct and relevant. Figure 7.1 shows the result of a DL query to retrieve the children who has Poor\_Balance symptom.



**Figure (7.1):** DL query to retrieve children who has Poor Balance symptom

As shown in the below box and Figure 7.2, a SPARQL query correctly retrieved the symptoms and the physical therapy treatments of each symptom, and purpose of each physical therapy treatment.

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX uni: <http://www.semanticweb.org/mzurob/ontologies/2017/1/untitled-ontology-68#>

SELECT ?symptom ?treatment ?purpose
WHERE { ?symptom uni:Treated_By ?treatment.
        ?treatment uni:Purpose ?purpose }

```

symptom	treatment	
Crawling_Problems	Swinging_legs_back_and_forth	"To treat or reduce stiffness."@
Irregular_Steps_While_Walking	Standing_using_Standing_Frame	"To enable the child who cannot stand alone"
Standing_Problems	Standing_using_Standing_Frame	"To enable the child who cannot stand alone"
Position:_Knee_bent_or_legs_separated	Standing_using_Standing_Frame	"To enable the child who cannot stand alone"
Legs_Turn_In	Sit_with_legs_apart_and_turned_outward.	"To help baby to sit."@
Sitting_Problems	Sit_with_legs_apart_and_turned_outward.	"To help baby to sit."@
Standing_Problems	Standing_by_catching_a_cart	"To provides easier balance and keeps swa
Abnormal_Gait	Wheel_Board	"To enable the child to move use his/her ha
Walking_Problems	Wheel_Board	"To enable the child to move use his/her ha
Not_Use_Hands	Hands_use	"To encourage the child to use hands."@
Fist_Grip_Thumb	Hands_use	"To encourage the child to use hands."@
Regular_Shake_of_Arm_and_Hand	Hands_use	"To encourage the child to use hands."@
Not_Use_One_Hand	Hands_use	"To encourage the child to use hands."@

**Figure (7.2):** Results of a SPARQL query to retrieve symptom, its treatment, and treatment purpose

The below SPARQL query used to retrieve the symptoms that are appear on the child named “Layan Mohammad”. It is also show the description of each symptom.

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX uni: <http://www.semanticweb.org/mzurob/ontologies/2017/1/untitled-ontology-68#>

```

```

SELECT ?child ?symptom ?description
WHERE {
  ?child uni:Has_Symptom ?symptom.
  ?symptom uni:Produces ?description.
  ?child uni:Name ?name.
  FILTER (?name = "Layan Mohammad"^^xsd:string) }

```

child	symptom	description
Layan_Mohammad	Poor_Balance	"Child has difficulty beginning to sit and stand. the child with ataxia walks bent forward v
Layan_Mohammad	Sudden_Stiffen	"she may suddenly stiffen like a board, so that no one feels able to carry or hug her."@
Layan_Mohammad	Not_Respond	"The baby may not respond or react as other babies do."@
Layan_Mohammad	Very_Quiet	"The child may be very quiet or passive and almost never cry or smile."@
Layan_Mohammad	Position:_Shoulder_and_Head	"Shoulders and head press back, fist grips thumb, and legs turn in."@
Layan_Mohammad	Not_Breath_Right_Away	"Body skin will turn blue due to breathing problem which may cause brain damage."@
Layan_Mohammad	Seizures	"Child become unaware and stiffen."@
Layan_Mohammad	Not_Use_Hands	"He may not able to use his both hands."@
Layan_Mohammad	Slow_Development	"Compared to other children in the village, the child is slow to hold up his head, to sit, or
Layan_Mohammad	Blue_Skin	"Body skin will turn blue due to breathing problem which may cause brain damage."@
Layan_Mohammad	Feeding_Problems	"The baby may have difficulties with sucking, swallowing and chewing."@

**Figure (7.3):** Results of a SPARQL query to the symptom that are appear on specific child

As shown in figure 7.3, as a result of the above SPARQL query, there are eleven symptoms have been successfully retrieved which appear on specific child named “Layan Mohammad” with the description of each symptom.

### 7.1.3 Domain Expert review

A domain expert has been requested to evaluate the identified list of concepts and relation that describing CP disability domain. We had one question for them which is “Is the attached list of concepts and relations fit to discripe Cerebral Palsy domain in order to get a provisional diagnosis for the children whose ages are between 1 day and 3 years?”.

Based on the experts, the lists of symptoms, reflexes, and properties that we have are covering the required information to get the provisional diagnosis of Cerebral Palsy disability. Regarding the basic rules that connect symptoms and reflexes with other factors such as child age and incidents history, the domain expert took main part in building them. This means these rule are fit to manage relationship between diagnosis factors including symptoms, reflexes, child age, and child incedent history. One reflex we need to add which is “Rolling” as the domain expert said.

## 7.2 Evaluation of CP Ontology Application

In this section we will show the evaluation results of the developed CP Ontology system by diagnosing a test set of real CP and non CP cases that are previously diagnosed. We will

calculate the precision and recall in order to get the accuracy of the application to perform the proposed tasks and objectives.

### 7.2.1 Testing Dataset

For the purpose of evaluating CP Ontology application we 70 health records of children aged from 1 month to 36 months from Cerebral Palsy Center of Palestine Avner for Childhood Foundation. The collected records contained different types of disability such as cerebral palsy, epilepsy, Down's syndrome, mental disability, and normal children. The records contained mainly three types of health information which are personal information, medical information, and provisional diagnosis and recommendations.

Each record contained 55 attributes. Some of personal information is Name, Gender, Age, Mother Age, and Father Age. Most of the other attributes are medical 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 may have CP, and 4 cases have uncertain disabilities. Male cases represented 40% of test set and female represented 60%.

### 7.2.2 Testing Results

Using CP Ontology application, we diagnosed the cases that mentioned in the test dataset. Our diagnosis approach provided Cerebral Palsy diagnosis to the cases based on the available information in test dataset. Diagnosis results were as shown in Table 7.1.

**Table (7.1):** CP Ontology application diagnosis results of test dataset

Diagnosis Category	# of Cases in Test dataset	CPonto Application Testing Results	
		Matched	Not Matched
Cerebral Palsy	47	43	4
Probably Cerebral Palsy	19	13	6
Uncertain	4	3	1
<b>Total Cases</b>	<b>70</b>	<b>59</b>	<b>11</b>

As shown in the above table, 43 children with Cerebral Palsy disability out of 47 have been correctly diagnosed by the application, which mean 91.4% of the cases that previously diagnosed as children with Cerebral Palsy had the same diagnosis by the approach. Only 4 children previously diagnosed as children with Cerebral Palsy, but have different diagnosis results by the application, where 3 of them diagnosed as *Probably Has Cerebral Palsy* and 1 of them diagnosed as *Has Uncertain Disability*.

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. This means that, 68.42%

of the children who previously diagnosed as *Probably Has Cerebral Palsy* had the same diagnosis results by the application, and the rest of the children had different diagnoses, where 1 of the diagnosed by the application as *Definetely has Cerebral Palsy* and 5 diagnosed as *Has Uncertain Disabilities*.

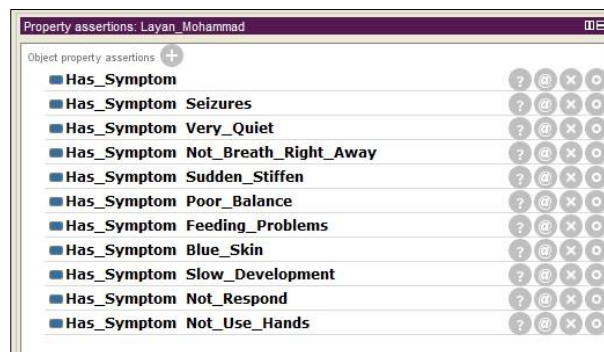
From the table, 4 cases in the test dataset have been previously diagnosed as *Has Uncertain Disabilities*. Our application gave matched diagnosis results to 3 of them. Which mean, our application successfully identified 75% of uncertain disabilities.

### 7.3 Discussion

As we mentioned at the beginning of this chapter, CP Ontology system’s components have been evaluated to ensure consistency, coverage, correctness, and functioning of the ontology and application.

In section 7.1 we evaluated our developed ontology through Reasoning, queries and domain expert review. According to the result of using Pellet Reasoner over CP Ontology, the developed ontology is consistent. In addition to that, the reasoner was able to discover new facts from the existed ones. This means that the ontology is correctly built and the instances are correctly added to the ontology file.

As shown in section 7.1.2, CP Ontology has been queried through a set of DL and SPARQL queries in order to check the ability of the built ontology and reasoner to provide valuable and related information. As a result of those queries, the ontology and reasoner retrieved the related information. For example, in figure 7.1, a DL query written to retrieve the children who has Poor Balance symptom. In CP Ontology we have only one child has Poor Balance symptom. This means that the query retrieved the related child. Another example shown in figure 7.3, where a SPARQL query written to retrieve symptoms that specific child have. Referring to the ontology file, the specified child “Layan Mohammad” have 11 symptoms as figure 7.4 shows.



**Figure (7.4):** Object properties of the individual “Layan Mohammad”

It’s clear that the ontology file and reasoner give complete and correct answers to the written queries.

To be sure that the built ontology covers CP disability domain, a domain expert review the developed ontology through its concepts and relations. Only one concept not represented as the domain expert said which a symptom that called “Rolling”. Using Precision and Recall we can evaluate the coverage of CP ontology of CP disability domain.

Precision is the number of correct concepts in the ontology relative to the total number of concepts in the ontology (See equation 7.1). Recall is the number of correct concepts in the ontology relative to total number of possible concepts (See equation 7.2) (Al Tayyar, 2000).

$$\text{Precision} = \frac{\text{The number of correct concepts in the ontology}}{\text{Total number of concepts in the ontology}} \quad (7.1)$$

$$\text{Recall} = \frac{\text{The number of correct concepts in the ontology}}{\text{Total number of possible concepts}} \quad (7.2)$$

According to the domain expert review, the identified 52 symptoms in CP Ontology are correct and only one symptom is missing. So, the precision and recall of identified symptoms as follow:

$$\text{Precision} = \frac{52}{52} = 1$$

$$\text{Recall} = \frac{52}{53} = 0.98$$

Through the domain experts’ evaluation of CP Ontology, we found that the proposed ontology has been covered CP domain through concepts and relations between these concepts which provide correct and complete description of CP disability.

As shown in table 7.1, CP Ontology application 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.

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

According to the domain expert, however CP disability domain is a complex domain; this study provided a usefull approach for diagnosing CP disability with minimum resources. The ability of CP Ontology application to correctly diagnose 84% of CP cases equals the ability of an experienced expert in disability domain to diagnose the same cases, as he said.

# **Chapter 8**

## **Conclusions and Recommendations**



## Chapter 8

### Conclusions and Recommendations

In this research study, we have developed an ontology-based approach for Cerebral Palsy diagnosis and physical therapy treatment. We started our research study by showing some statistics about Cerebral Palsy disability in the world in general, and in Gaza Strip in specific, introducing Cerebral Palsy disability domain, reviewing the previous studies of diagnosis in health domain, and identifying shortcomings in the previous studies. We found that the number of children with Cerebral Palsy disability increased in the recent years, however the treatment and diagnosis quality not improved enough. This fact reported by different local and global institutions and researches.

World Health Organization published a factsheet on 2015 mentioned that over a billion people, about 15% of the world's population, have some form of disability, and recommended the need to develop normative tools including guidelines to strengthen health care. In addition, Cerebral Palsy Center of Palestinian Avenir for Childhood Foundation asked for more researches on Cerebral Palsy disability in Gaza Strip in order to improve early diagnosis and treatment according the available resources in Gaza Strip.

From our literature review, we found that there are different previous studies published around the world in this domain, but those studies do not meet the need to diagnose Cerebral Palsy in early ages and by including most of diagnosis factors such as symptoms and reflexes assesment. Through our research study developed an effective approach to diagnose Cerebral Palsy in first three years of child life, provide supportive plan for physical therapy treatment, and share knowledge between CP Ontology system users.

The developed CP Ontology system consists of two main components which are knowledge base and application. Knowledge base is presented by the ontology OWL file which provides the basic information of Cerebral Palsy disability, symptoms, reflexes, human body parts that may affected by brain damage that cause CP disability, and physical therapy treatment activities. In our proposed system, Knowledge base took an important role by providing the required information to diagnose Cerebral Palsy disability and to build effective physical therapy treatment. The application contains the system interfaces, OWL API, and inference engine (Pellet Reasoner).

The main components of the developed approach has been evaluated. Where, the knowledge base was evaluated through reasoning, querying the ontology, and domain expert review. The results of that evaluation showed that the developed ontology is consistent, answered the queries correctly with related and full information, and covers 98% of CP disability domain.

CP Ontology application was evaluated through a test dataset that contained 70 cases of children who are previously diagnosed in Cerebral Palsy Center of Palestinian Avenir for Childhood Foundation. The results show that the application correctly diagnosed 59 cases out of 70 which mean the Recall was 84%. According to the domain expert, the study provided a usefull and effective approach for diagnosing CP disability with minimum resources and with acceptable accuracy percentage as he said.

At the end of the research study, we found that we reached our research objectives, where the proposed approach is correct, provide acceptable accuracy of Cerebral Palsy diagnosis, provide supportive guildlines for physical therapy treatment according the the need of each child, and provide a knowledge sharing between system users.

Finally, we have some recommendations based on the experience that we gain during the research regarding ontology and Cerebral Palsy disability. These recommendations are as follow:

- Research studies target disability domain in Gaza Strip is limited and need more focuus from researchers.
- It was evident that there was an urgent need to conduct more and deep researches in disability domain in order to improve the quality of health care.
- As a result of our review to the used diagnosis and information management systems inside local societies that are providing health care services to the disabled people, most of these societies do not use computerized systems to manage disabled people medical and personal information. So, we recommend the students in developers' community to target these need.
- Cerebral Palsy is one of most complicated disabilities because it has no specific causes and share part of its symptoms with other disabilities like brain atrophy.
- Ontology is ausful tool for describing concepts of Cerebral Palsy disability and relations between these concepts in order to diagnose and improve treatment of CP disability.
- Domain expert review is essential in such domains.
- Symptoms and Reflexes Assesement are strong indicators to Cerebral Palsy disability.
- Knowledge based survey is a useful tool for surveying tacit knowledge.
- Data mining techniques are not useful for inducing rules from poor quality health records.
- 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 deseases diagnosis and treatment.

# The Reference List

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## Appendix 1: Part of OWL file of CP Ontology

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IRI="#Diagnosis"/> </SubClassOf>
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<ClassAssertion>      <Class IRI="#Moving_About"/>      <NamedIndividual
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<ClassAssertion>      <Class IRI="#Young_Child"/>      <NamedIndividual
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<NamedIndividual IRI="#Swinging_legs_back_and_forth"/> </SameIndividual>

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IRI="#Pinning_Legs"/> </SameIndividual>

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IRI="#Warm_Soaks"/> </SameIndividual>

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IRI="#Stiffen"/> </DifferentIndividuals>

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    <ObjectPropertyAssertion>    <ObjectProperty IRI="#Affects"/>    <NamedIndividual
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</ObjectPropertyAssertion>

    <ObjectPropertyAssertion>    <ObjectProperty IRI="#Appears_On"/>
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    <ObjectPropertyAssertion>    <ObjectProperty IRI="#Improve_Function_Of"/>
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    <ObjectPropertyAssertion>    <ObjectProperty IRI="#Affects"/>
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    <ObjectPropertyAssertion>    <ObjectProperty IRI="#Appears_On"/>
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    <ObjectPropertyAssertion>    <ObjectProperty IRI="#Indicate"/>
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    <ObjectPropertyAssertion>    <ObjectProperty IRI="#Treated_By"/>
<NamedIndividual IRI="#Arm_Stiffen_Straight_Out"/>    <NamedIndividual
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    <ObjectPropertyAssertion>    <ObjectProperty IRI="#Indicate"/>
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    <ObjectPropertyAssertion>    <ObjectProperty IRI="#Improve_Function_Of"/>
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</ObjectPropertyAssertion>

    <ObjectPropertyAssertion>    <ObjectProperty IRI="#Indicate"/>
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IRI="#Uncontrolled_Muscles"/>    </ObjectPropertyAssertion>

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    <ObjectPropertyAssertion>    <ObjectProperty IRI="#Has_Symptom"/>
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<DataPropertyAssertion> <DataProperty IRI="#Produces"/> <NamedIndividual
IRI="#Abnormal_Shape_of_Skull"/> <Literal datatypeIRI="&xsd:string">not straight
shape of skull</Literal> </DataPropertyAssertion>

<DataPropertyAssertion> <DataProperty IRI="#Description"/>
<NamedIndividual IRI="#Action_in_the_opposite_side"/> <Literal
datatypeIRI="&rdf;PlainLiteral">have him lie so that he has to turn his head to the other side
to see the action.</Literal> </DataPropertyAssertion>

<DataPropertyAssertion> <DataProperty IRI="#Exercise_Name"/>
<NamedIndividual IRI="#Action_in_the_opposite_side"/> <Literal
datatypeIRI="&rdf;PlainLiteral">Do an action in the opposite side.</Literal>
</DataPropertyAssertion>

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<DataPropertyAssertion> <DataProperty IRI="#Photo"/> <NamedIndividual IRI="#Action_in_the_opposite_side"/> <Literal datatypeIRI="&xsd:string">C:\Users\M Zurob\Desktop\Thesis\Support Photos\CP Symptoms\PT Action in the opposite side.jpeg</Literal> </DataPropertyAssertion>
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```
<DataPropertyAssertion> <DataProperty IRI="#Purpose"/> <NamedIndividual IRI="#Action_in_the_opposite_side"/> <Literal datatypeIRI="&rdf:PlainLiteral">To treat head position on one side.</Literal> </DataPropertyAssertion>
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```
<DataPropertyAssertion> <DataProperty IRI="#Max_Child_Age"/> <NamedIndividual IRI="#Babkin"/> <Literal datatypeIRI="&xsd:integer">6</Literal> </DataPropertyAssertion>
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```
<DataPropertyAssertion> <DataProperty IRI="#Exercise_Name"/> <NamedIndividual IRI="#Sleeping_on_one_side"/> <Literal datatypeIRI="&rdf:PlainLiteral">Play on his\her side</Literal> </DataPropertyAssertion>
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```
<DataPropertyAssertion> <DataProperty IRI="#Description"/> <NamedIndividual IRI="#Tonic_Neck_or_Fencing"/> <Literal datatypeIRI="&xsd:string">Postural reflex is seen when infant lies on back with head turned to one side; arm and leg on the side toward which he or she is looking are extended while opposite limbs are flexed.</Literal> </DataPropertyAssertion>
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```
<DataPropertyAssertion> <DataProperty IRI="#Has_Score"/> <NamedIndividual IRI="#Tonic_Neck_or_Fencing"/> <Literal datatypeIRI="&xsd:int">8</Literal> </DataPropertyAssertion>
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<DataPropertyAssertion> <DataProperty IRI="#Max_Child_Age"/> <NamedIndividual IRI="#Tonic_Neck_or_Fencing"/> <Literal datatypeIRI="&xsd:integer">6</Literal> </DataPropertyAssertion>
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<DataPropertyAssertion> <DataProperty IRI="#Description"/> <NamedIndividual IRI="#Twist_child_body_from_side_to_side"/> <Literal datatypeIRI="&rdf:PlainLiteral">Try to slowly twist or help the child to twist his body from side to side.</Literal> </DataPropertyAssertion>
```

```
<DataPropertyAssertion> <DataProperty IRI="#Exercise_Name"/> <NamedIndividual IRI="#Twist_child_body_from_side_to_side"/> <Literal datatypeIRI="&rdf:PlainLiteral">Twist Child from side to side.</Literal> </DataPropertyAssertion>
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```
<DataPropertyAssertion> <DataProperty IRI="#Photo"/> <NamedIndividual IRI="#Twist_child_body_from_side_to_side"/> <Literal datatypeIRI="&xsd:string">C:\Users\M Zurob\Desktop\Thesis\Support Photos\CP Symptoms\PT CONTRACTURES twist body.jpg</Literal> </DataPropertyAssertion>
```



```

    <DataPropertyAssertion>    <DataProperty IRI="#Purpose"/>    <NamedIndividual
IRI="#Twist_child_body_from_side_to_side"/>    <Literal
datatypeIRI="&rdf;PlainLiteral">To help relax spastic muscles.</Literal>
</DataPropertyAssertion>

    <DataPropertyAssertion>    <DataProperty IRI="#Has_Score"/>    <NamedIndividual
IRI="#Uncontrolled_Movements"/>    <Literal datatypeIRI="&xsd:int">2</Literal>
</DataPropertyAssertion>

    <DataPropertyAssertion>    <DataProperty IRI="#Produces"/>    <NamedIndividual
IRI="#Uncontrolled_Movements"/>    <Literal datatypeIRI="&rdf;PlainLiteral">Slow,
wriggly, or sudden quick movements of the child's feet, arms, hands, or face muscles. The
arms and legs may seem jumpy and move nervously, or just a hand or the toes may move for
no reason.</Literal>    </DataPropertyAssertion>

    <DataPropertyAssertion>    <DataProperty IRI="#Has_Score"/>    <NamedIndividual
IRI="#Very_Quiet"/>    <Literal datatypeIRI="&xsd:int">1</Literal>
</DataPropertyAssertion>

    <DataPropertyAssertion>    <DataProperty IRI="#Produces"/>    <NamedIndividual
IRI="#Very_Quiet"/>    <Literal datatypeIRI="&rdf;PlainLiteral">The child may be very
quiet or passive and almost never cry or smile.</Literal>    </DataPropertyAssertion>

    <DataPropertyAssertion>    <DataProperty IRI="#Has_Score"/>    <NamedIndividual
IRI="#Walking_Problems"/>    <Literal datatypeIRI="&xsd:int">4</Literal>
</DataPropertyAssertion>

    <DataPropertyAssertion>    <DataProperty IRI="#Produces"/>    <NamedIndividual
IRI="#Walking_Problems"/>    <Literal datatypeIRI="&rdf;PlainLiteral">Child unable to
walk normally</Literal>    </DataPropertyAssertion>

    <DataPropertyAssertion>    <DataProperty IRI="#Description"/>
<NamedIndividual IRI="#Warm_Soaks"/>    <Literal
datatypeIRI="&rdf;PlainLiteral">Apply warm soaks to spastic muscles or have the child sit
or lie in warm water.</Literal>    </DataPropertyAssertion>

    <DataPropertyAssertion>    <DataProperty IRI="#Exercise_Name"/>
<NamedIndividual IRI="#Warm_Soaks"/>    <Literal
datatypeIRI="&rdf;PlainLiteral">Warm Soaks</Literal>    </DataPropertyAssertion>

    <DataPropertyAssertion>    <DataProperty IRI="#Photo"/>    <NamedIndividual
IRI="#Warm_Soaks"/>    <Literal datatypeIRI="&xsd:string">C:\Users\M
Zurob\Desktop\Thesis\Support Photos\CP Symptoms\PT CONTRACTURES Warm
Soaks.jpg</Literal>    </DataPropertyAssertion>

```

```
<DataPropertyAssertion> <DataProperty IRI="#Purpose"/> <NamedIndividual IRI="#Warm_Soaks"/> <Literal datatypeIRI="&rdf;PlainLiteral">To relax spastic muscles.</Literal> </DataPropertyAssertion>
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```
<DataPropertyAssertion> <DataProperty IRI="#Description"/> <NamedIndividual IRI="#Wheel_Board"/> <Literal datatypeIRI="&rdf;PlainLiteral">Adapting wheel boards for travel on rough surfaces By placing large wheels near the middle, if the smaller front caster gets stuck, the child can lift with his arms and go on. Or if a fixed front wheel is used, he can lift it off the ground to make turns.</Literal> </DataPropertyAssertion>
```

```
<DataPropertyAssertion> <DataProperty IRI="#Exercise_Name"/> <NamedIndividual IRI="#Wheel_Board"/> <Literal datatypeIRI="&rdf;PlainLiteral">Wheel Board</Literal> </DataPropertyAssertion>
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<DataPropertyAssertion> <DataProperty IRI="#Photo"/> <NamedIndividual IRI="#Wheel_Board"/> <Literal datatypeIRI="&rdf;PlainLiteral">C:\Users\M Zurob\Desktop\CP_onto_SupportImages\PT Move about Wheel board.jpeg</Literal> </DataPropertyAssertion>
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```
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```

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shoulders up helps relax tight spasms of the legs. Holding the child by his inner thighs helps
turn legs out as they separate.</Literal>    </AnnotationAssertion>

    <AnnotationAssertion>    <AnnotationProperty IRI="#Has_Lable"/>
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    <AnnotationAssertion>    <AnnotationProperty IRI="#Remark"/>
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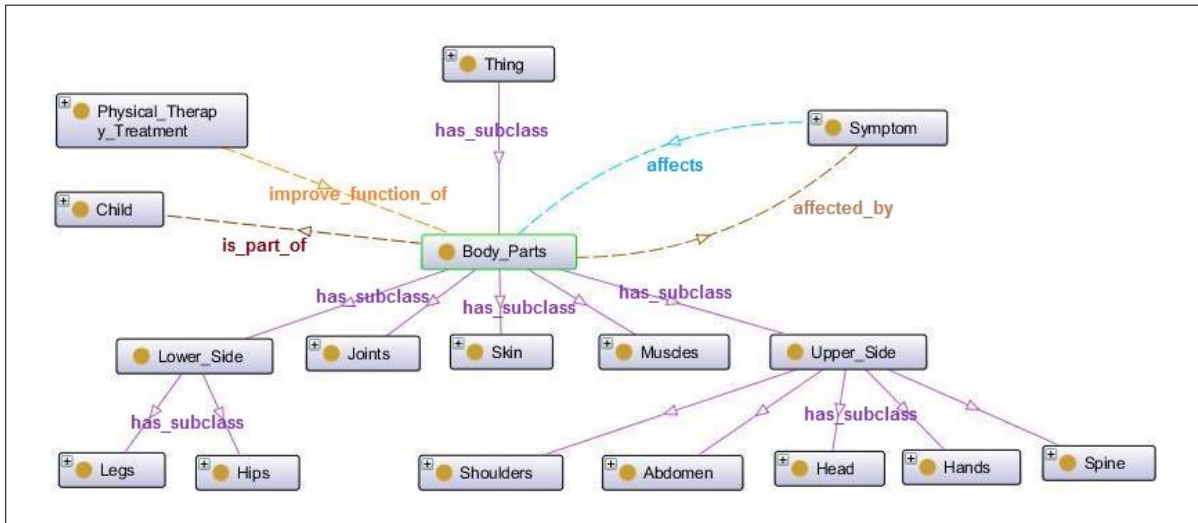
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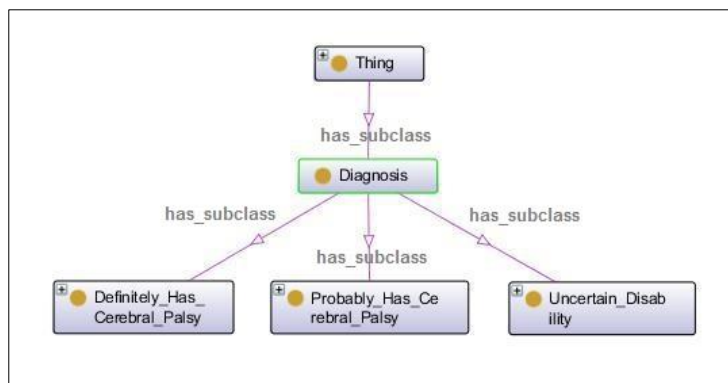
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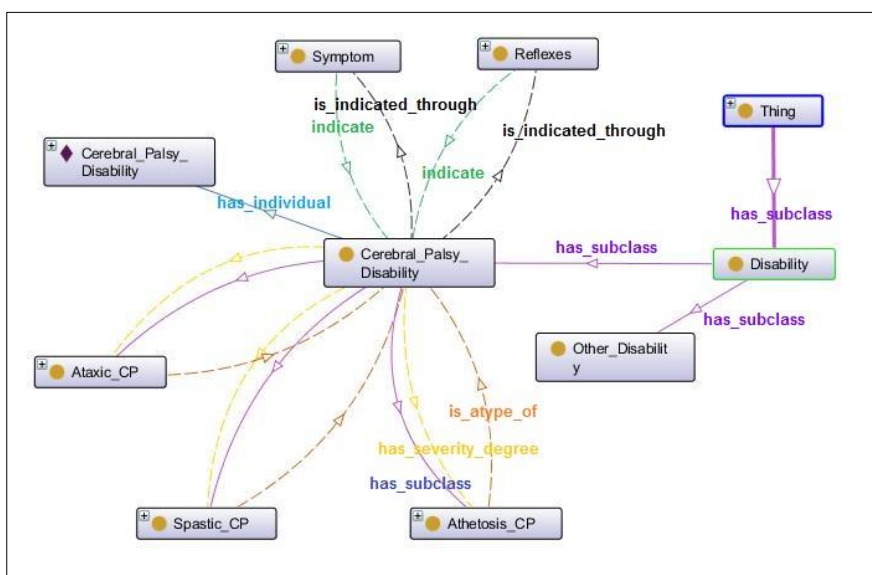
## Appendix 2: Details about CP Ontology



**Figure (App.1):** Ontology Graph of Body Parts class



**Figure (App.2):** Ontology Graph of Diagnosis class



**Figure (App.3):** Ontology Graph of Disability Class

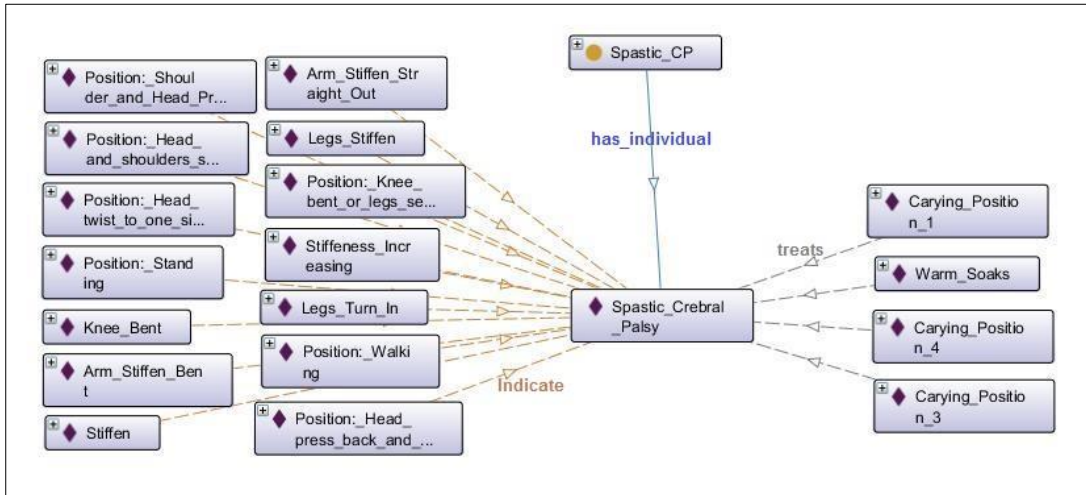


Figure (App.4): Ontology Graph of Spastic Cerebral Palsy individual

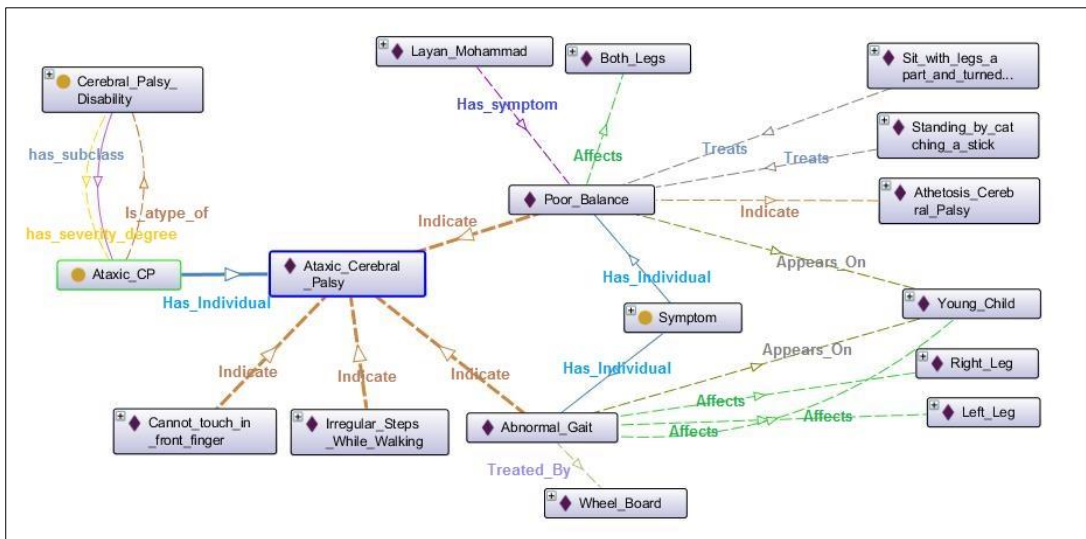


Figure (App.5): Ontology Graph of Ataxic Cerebral Palsy Individual

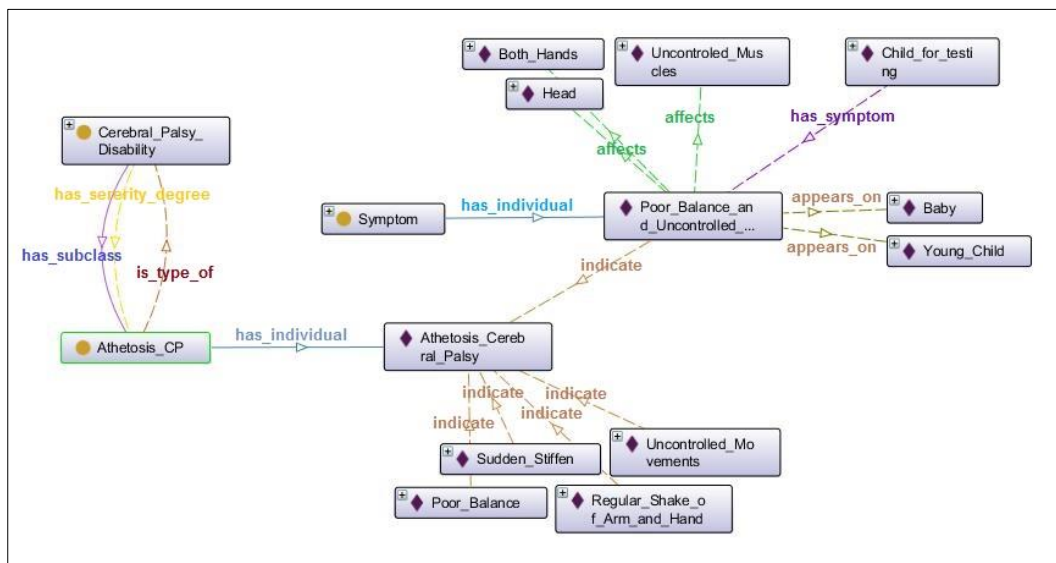
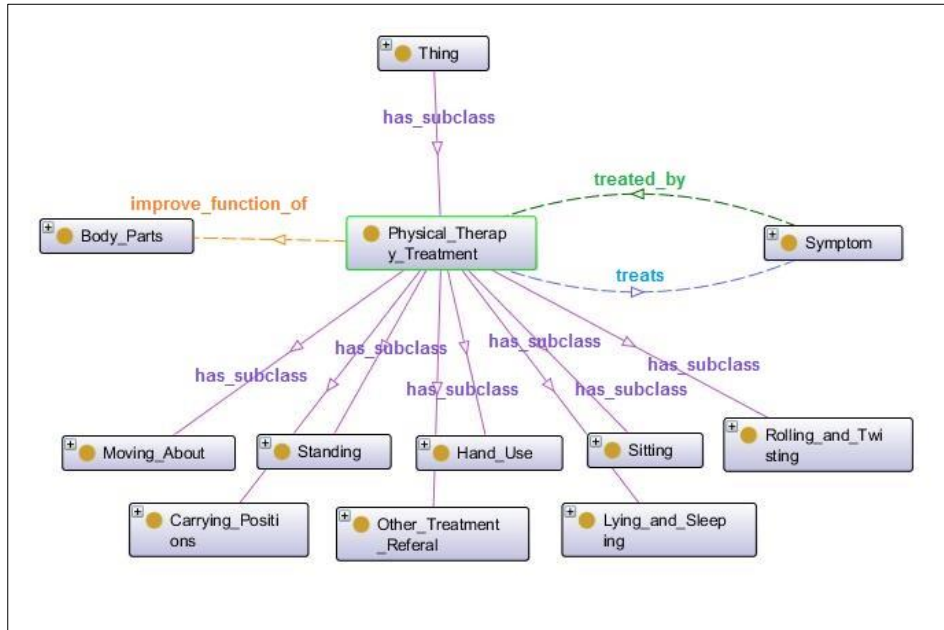
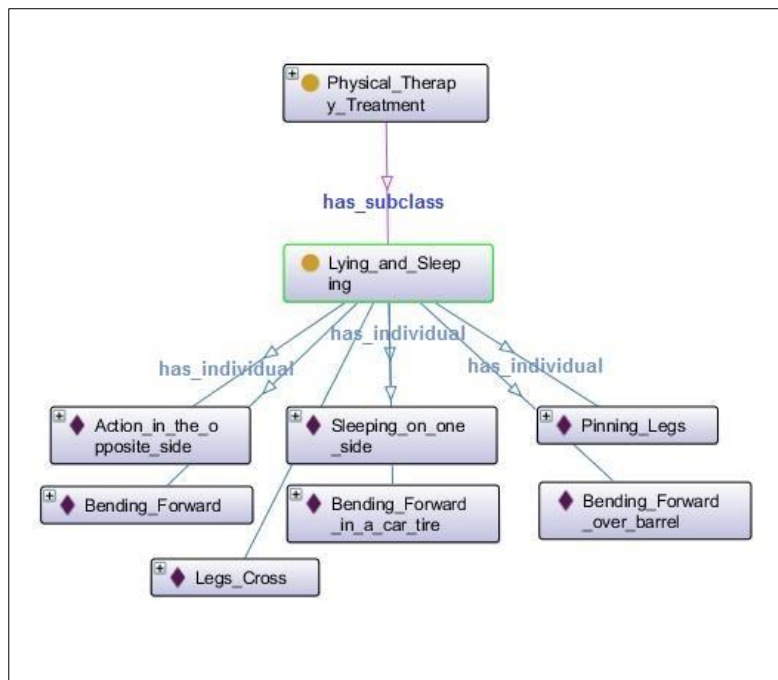


Figure (App.6): Ontology Graph of Athetosis Cerebral Palsy Individual



**Figure (App.7):** Ontology Graph of Physical Therapy Treatment Class



**Figure (App.8)** Ontology Graph of Lying and Sleeping Class

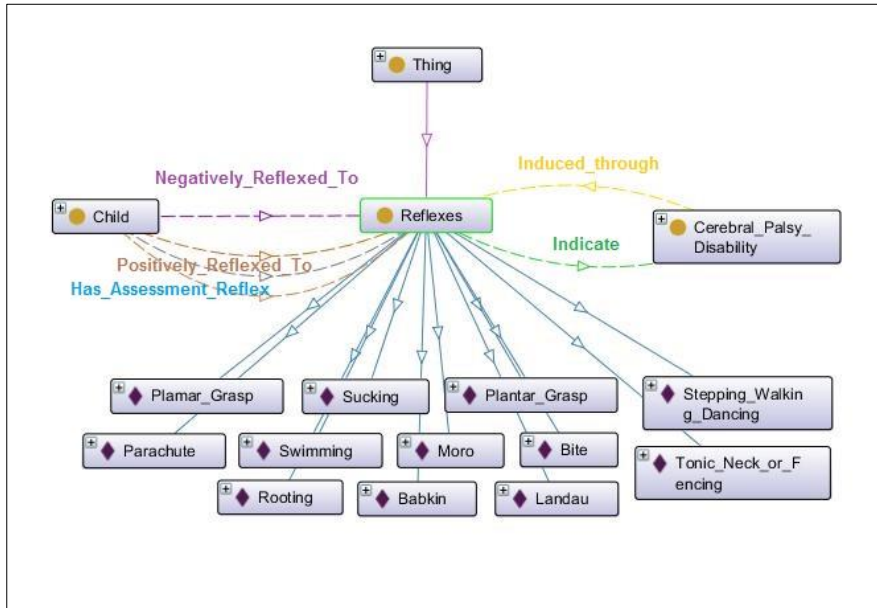


Figure (App.9) Ontology Graph of Lying and Sleeping Class

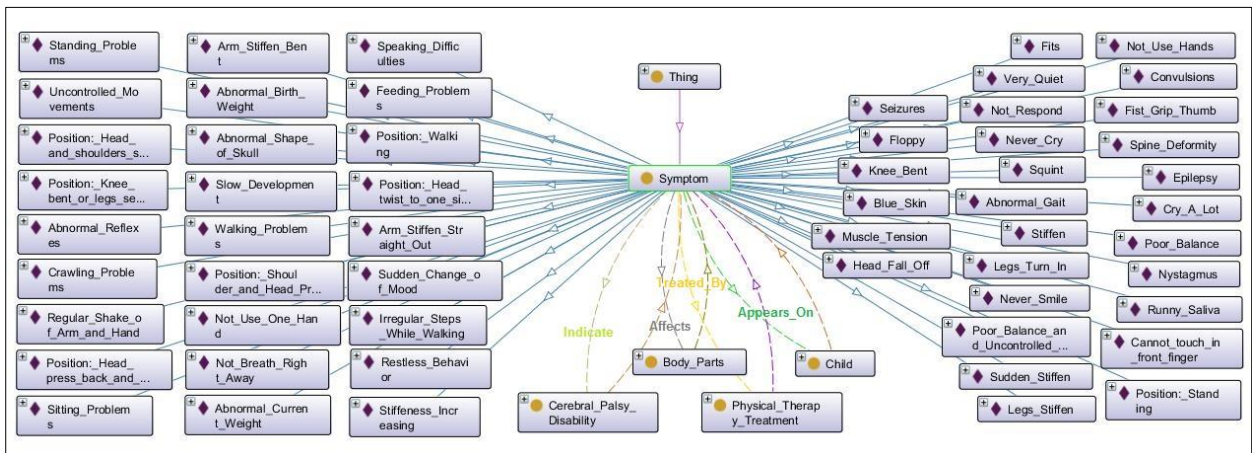


Figure (App.10) Ontology Graph of Lying and Sleeping Class

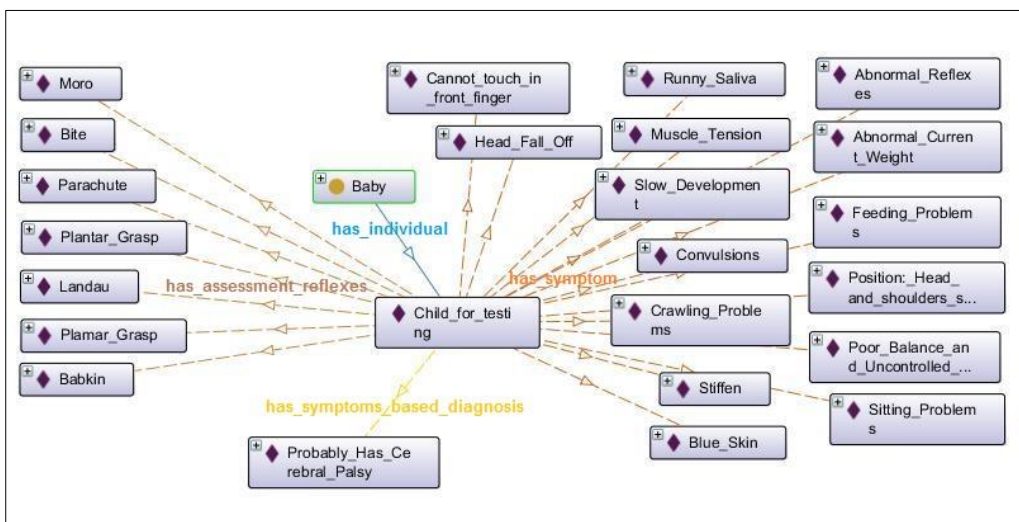


Figure (App.11) Ontology Graph of Child individual