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Rules-based decision support system and domain ontology for diabetes diagnosis

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Abstract

Artificial intelligence must have access to objects, categories, properties and relations between all of them to implement knowledge engineering. Initiating common sense, reasoning and problem-solving power in machines is a difficult and tedious. AI decision support systems are used in multiple fields, such as the medical field. In which making a decision consists of posing a diagnosis and proposing a treatment. Various applications of decision-making support were developed in this domain. Those applications are intended to help medical workers (doctors, nurses...etc) in their process of decision making. It involves the use of powerful tools of Artificial Intelligence, such as the rules-based reasoning (RBR). Which stimulates the judgment and behaviour of a human or an organization that has expert knowledge and experience in a particular field by following a certain set of rules. Systems that use rules-based reasoning are also known as Expert Systems. An expert system is composed of a user interface, an inference engine and a knowledge base. The use of ontologies in the medical domain has seen a huge growth in recent years and was accompanied by a great success, which motivated us to create an ontology related to our field of work, the diagnosis of diabetes, to serve as our knowledge base. In this paper we proposed a rules-based decision support system for patients with diabetes. It uses the Rules-based technique for reasoning and a domain ontology for representing the knowledge to detect diabetes, its type, its seriousness and giving the appropriate care plan. This system helps both doctors and patients to check, analyse and repair solutions. It analyzes the symptoms of the patients and gives the exact types of diabetes, its seriousness level and the appropriate treatment for every patients. In addition to that, it offers an analysis of the data stored by the system, based on different factors such as: type of diabetes, age of the patient...

Keywords

Rules-based reasoning, Expert Systems, Ontology, Diabetes, Diagnosis, Decision-making, Artificial Intelligence, Medicine.

1 Introduction

Nowadays, diabetes is considered one of the most common diseases in most countries; In fact, according to the International Diabetes Federation, 425 million people were diagnosed with diabetes in the world in 2017, which represents about 5.5% of the world's population. Thus, it is expected that approximately 622 million people(8.1% of the world's population) would get diabetes comes 2040.

In the medical field, decision-making involves posing a diagnosis and determining the treatment, which is the stage where the medical worker determines the disease from which the patient suffers, using clinical symptoms, blood tests, radiological scans... etc. It is considered the core of any disease's treatment process.

The diagnosis is an intelligent act which is hardly programmable with classic techniques. Several studies have been conducted for the development of medical diagnosis methods based on Artificial Intelligence (AI) methods and techniques.There are several AI tools that lead to the realization of intelligent systems similar to the reasoning of experts in the field helping in the process of decision-making, among them the rules-based reasoning (Expert systems), which have proven their performance in the medical field, and since the use of ontologies in the medical field have seen a significant growth in the recent years, we were motivated to create an ontology related to our field of work, the diagnosis of diabetes.

The paper is organized as follows: Section 2 gives a theoretical background about Expert System, ontology, and the domain of application. The description of the system concept development is given in section 3. Section 4 presents description of the proposed architecture. Section 5 details the implementation of the system, while section 6 we discuss our work and give the system performance and conclude it in the sixth one.

2 Theoretical background:

The proposed approach combines AI paradigms previously cited, for instance Ontologies and Expert Systems.

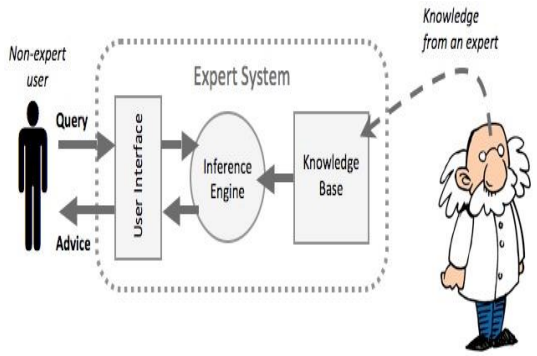
2.1 Ontology:

Gruber [1] defines an ontology as an explicit specification of a conceptualization. A conceptualization is an abstract view of the world that we hope to represent for a specific purpose. The representation of knowledge is based on a conceptualization including objects, concepts and relationships between them. Based on a technical perspective, the Sowa definition [2] considers an ontology as a specification of the kinds of entities that exist or may exist in certain domains or subjects. More formally, an ontology can be represented by a collection of nouns conceiving concepts and types of relations controlled in a partial order by the relation type / subtype. Several types of classifications are proposed

for ontologies based on the characteristic of the ontology's components. Few of the most important types of classifications are classification according to; Purpose, in which we find: application ontology and reference ontology, Expressiveness in which we find: heavyweight and lightweight ontologies, Specify in which we find: generic, core and domain ontologies [3].In this paper we have created domain ontology.

2.2 Expert System:

In general, an expert system is a tool capable of reproducing the cognitive mechanisms of an expert, in a particular field. More precisely, an expert system is a software capable of answering questions, making reasoning based on known facts and rules. It can be used as a tool for decision support[4]. The architecture of a typical expert system consists of several modules



that interact, which is detailed in **Fig.1**.

Fig 1: Architecture of an Expert System.

User Interface: serves to simplify the communication, it can use the question-answer form, the menu, the natural language etc.

Knowledge base: is the set of data that is used by the inference engine, it contains the knowledge about solving the problem.

Inference Engine: is a mechanism for inferring new knowledge from the system knowledge base. It is based on rules of inference that govern its operation. Its function is to answer a request from a user or a server to trigger a reflection defined by its inference rules that will use the knowledge base.

2.3 Diabetes:

Diabetes mellitus, often referred to as diabetes is a chronic disease that prevents the body from properly using sugar as a source of energy. It is caused by a lack or lack of use of a hormone called insulin which is produced by the pancreas. It allows glucose (sugar) to enter the cells of the body for use as a source of energy. There are four types of diabetes[5];

Type 1 diabetes: it affects about 6% of the diabetic population and often occurs during childhood, adolescence or early adulthood, rarely in older people. It is characterized by autoimmune destruction of beta cells, that produce insulin, causing total or partial insulin deficiency and effectively requiring the patient's daily administration of this hormone, people with type 1 diabetes therefore depends on daily injections of insulin or insulin pump to ensure their survival. Genetic predispositions are one of the main factors in the onset of the disease [6].

Type 2 diabetes: Previously called non-insulin-dependent diabetes or diabetes of maturity; Type 2 diabetes affects about 91% of the diabetic population. It appears at a later age, although it is progressing today towards an increasingly young population.. Unlike type 1 diabetes, type 2 diabetes is mostly asymptomatic [7].

Gestational diabetes: it is usually type 1 (insulin-dependent) and occurs in about 3-6% of pregnant women. It corresponds to transient glucose intolerance and appears in the third trimester of pregnancy but usually disappears after delivery. Gestational diabetes is the cause of a predisposition to type 2 diabetes [8].

Neonatal diabetes: it occurs in the first days or weeks of life. It is very rare, 250 to 500 000 newborns in Europe. As many boys as girls. It can be permanent (treatment can't be stopped) or transient (insulin can be stopped, usually before the age of 6 months, but recurrence of diabetes is possible at puberty or adulthood) [9].

3 System concept development:

3.1 Goals of proposed system:

Our research work proposed a rules-based decision support system for patients with diabetes. It is an artificial intelligence technique (Expert Systems) to detect diabetes and its type, its seriousness and giving the appropriate care plan. This system helps doctors and patients to check, analyze and repair solutions.

To solve an actual problem a set of rules is followed to reach a diagnosis then another set is followed to find an appropriate treatment[10]. Once both the diagnosis and the treatment are generated and validated, the case is stored in the ontology.

3.2 Some symptoms and rules followed to reach a diagnosis:

An effort has been made to find a co-relation between the initial cases and the input parameters/attributes of the cases to arrive at the relative importance of the parameters/ attributes. Weights have been assigned to each attribute on assumptions based on conclusions by experienced medical Professionals. **Table 1** shows the different weights of some of the symptoms against the various types of diabetes[11]:

Symptoms	*Weight*			
	D1	**D2**	**D3 (DG)**	**D4 (DN)**
Age (Patient old or young)	0.9	0.9	0.7	0.9
Gender	0.5	0.5	0.9	0.5
Polyuria-polydipsia syndrome	0.9	0.9	0.9	0.9
Weight loss	0.9	0.5	0.6	0.9
Polyphagy	0.9	0.8	0.7	0.5
Asthenia	0.9	0.8	0.8	0.9
Drowsiness	0.7	0.6	0.5	0.5
Blurry vision	0.7	0.6	0.5	0.5
Dehydration signes	0.6	0.7	0.5	0.8
Polypnoea	0.6	0.7	0.5	0.8
Diabetic ketoacidosis	0.8	0.6	0.5	0.8
Bad healing	0.5	0.7	0.5	0.6
Frequent infections	0.5	0.7	0.5	0.8
Obesity	0.5	0.9	0.7	0.6
Cardiac or vascular pathology	0.5	0.8	0.6	0.5
Family history in metabolic or obstetric syndromes	0.5	0.8	0.8	0.5
Personal or family history in autoimmune diseases.	0.8	0.5	0.6	0.9

TABLE 1: Symptoms and their weight values.

In order to reach a proper diagnosis the system follows rules, to name a few:

- **IF**((Age <=2y.o) **AND** (Random blood sugar level>=2g/l) **AND**(Asthenia=="yes")) **THEN** Diagnosis = Neonatal diabetes;
- **IF**((Pregnancy=="yes") **AND** (Fasting blood sugar level>=0.92g/l) **AND** (Polyuria-polydipsia=="yes")) **THEN** Diagnosis = Gestational diabetes;
- **IF**((HB1AC>=6.5%) **AND** (Age< 40y.o) **AND** (Antibodies=="yes") **AND** (Weight loss =="yes")) **THEN** Diagnosis= Type1 diabetes;
- **IF**((Postprandial blood sugar level>=2g/l) **AND** (Age>= 40y.o) **AND** (Polyphagia=="yes")) **THEN** Diagnosis= Type2 diabetes;

3.2 System architecture:

The proposed approach includes the use of ontologies to build models of general domain knowledge. The more knowledge is embedded into the system, the more effective it is expected to be. In this Expert system the Ontology play the role of a knowledge base in which the knowledge from the expert is stored. It plays an important role as a vocabulary to describe cases. In **Fig.2.**we show the proposed architecture which is composed of two functional components, domain ontology and the Expert system application.

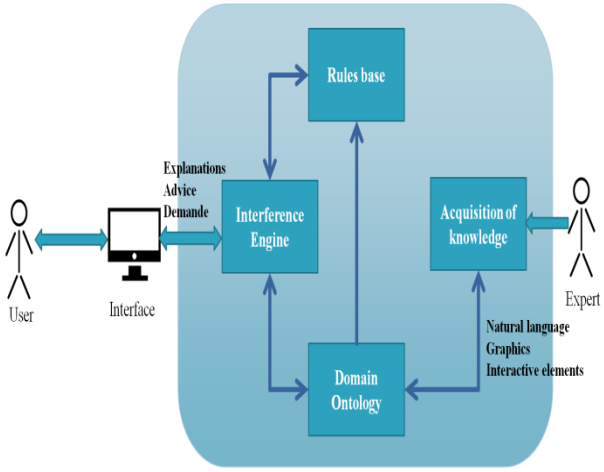


Fig.2. System Architecture.

Domain Ontology: The domain ontology is implemented to build general knowledge models and which includes vocabularies, concepts and relations for representing all knowledge concerning medical diagnosis of Diabetes, its type, its seriousness and its care plan[12].

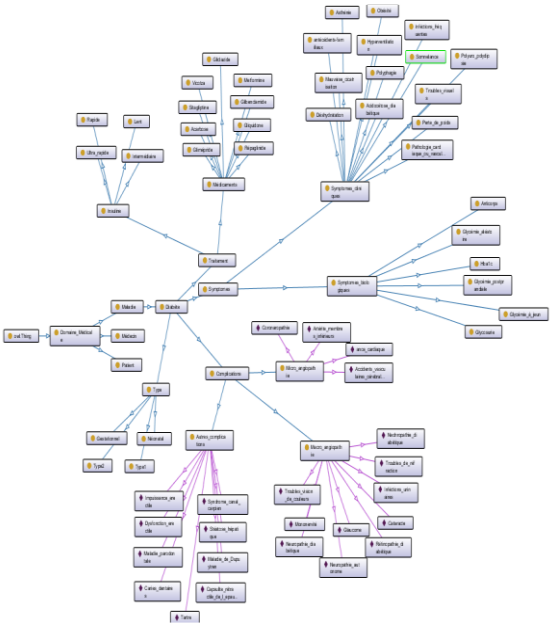


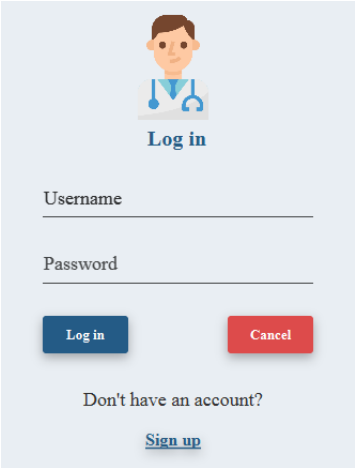
Fig.3. Graphical representation of the ontology's classes.

Expert System: This component is used for solving a diagnosis problem by following the rules that are in the IF ... THEN form.

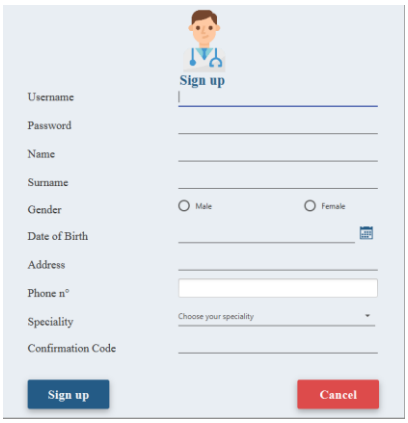
4 System implementation:

The realization of the system passed through different stages, carried out through a set of environments, tools and development libraries. To create the system we used the Java language in the environment: NetBeans IDE8.2, for the creation and modification of graphical interfaces, we used the Javafx library and the tool Gluon SceneBuilder 8.4.1. For the development of the ontology Protected tool 5.2.0 was used.

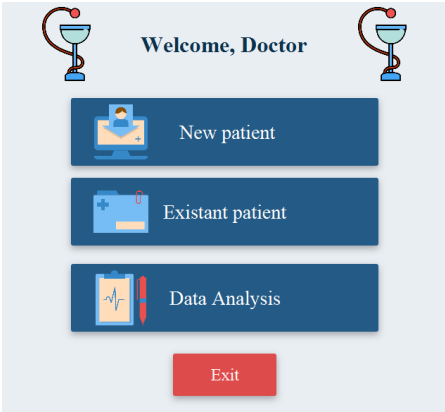
This screenshot represents the first interface of the system, it requires a username and password to log in, and if the user does not have an account, it allows them to sign up.



If the user clicks on the "Sign up" button, this window opens:

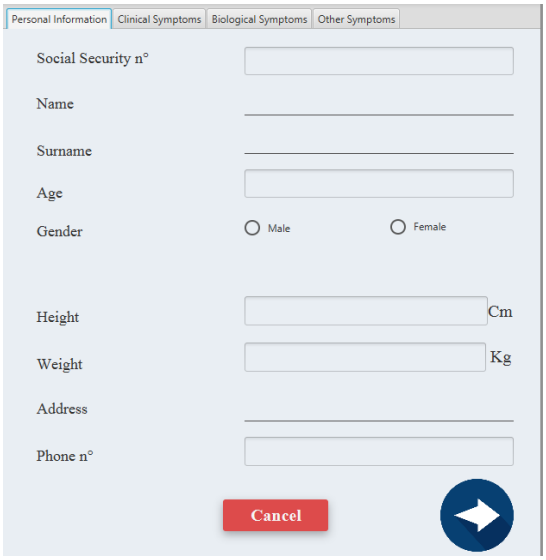


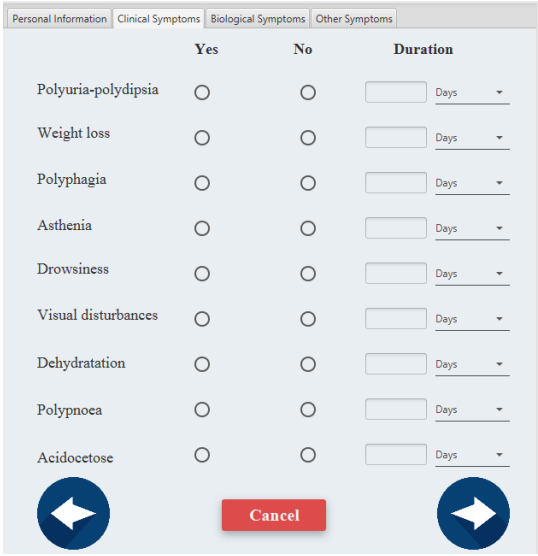
Once the user logs in, a main menu is displayed. This one allows him to add a new patient, to consult and possibly to modify an existing patient or to consult the analyzes of the data that the system contains.

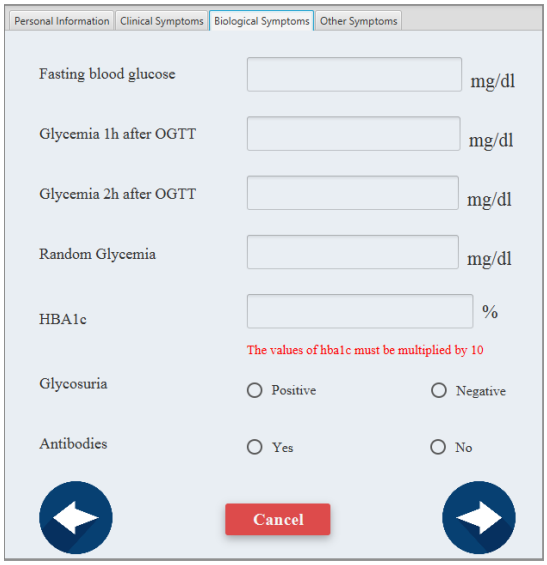


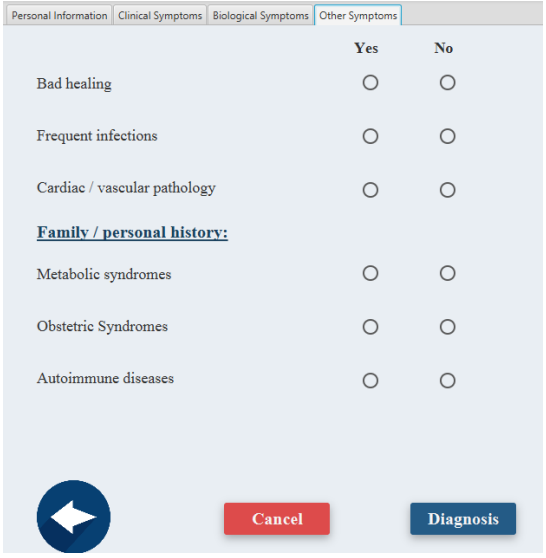
4.1 New Patient:

If the user chooses to add a new patient, this window - with multiple tabs- appears:

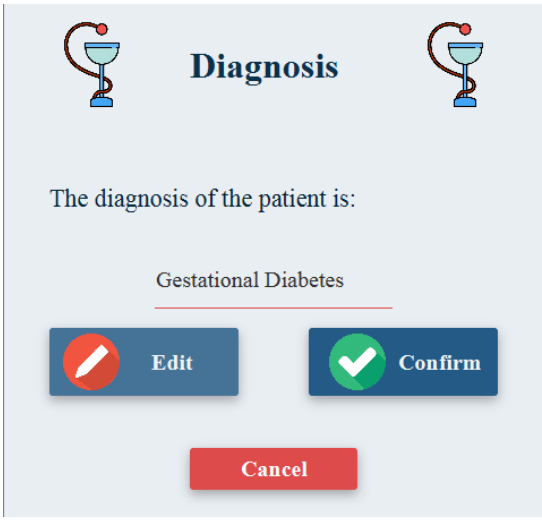




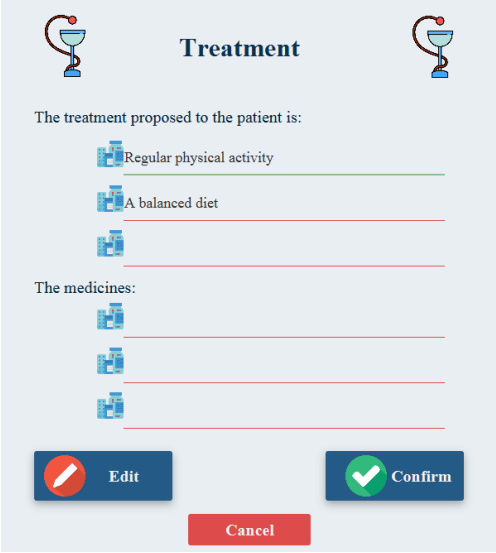




Once the user has completed all the necessary fields and presses the "Diagnosis" button, the system applies a function to find out whether the patient is diabetic or not and the type of diabetes with which he is suffering then the diagnostic window opens:



Then, the treatment window opens:

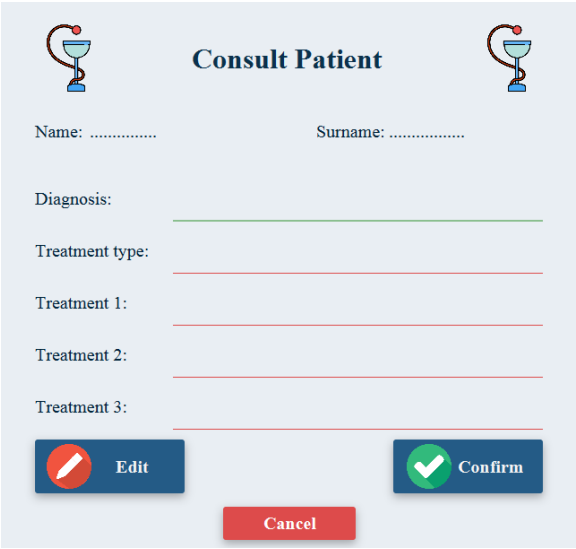


In case the treatment proposed by the system is not correct, the user can press the "Modify" button which allows him to modify the type of treatment and / or the proposed drugs, if there is no error the user validates the treatment. The system will then register the patient, his diagnosis and treatment in the database.

4.2 Existent Patient:

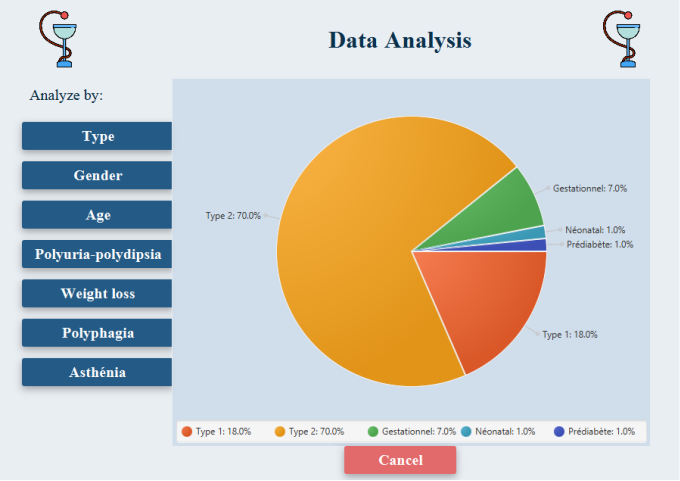
If the user chooses to consult existing patients this window that displays all the patients who have been viewed by this doctor opens:

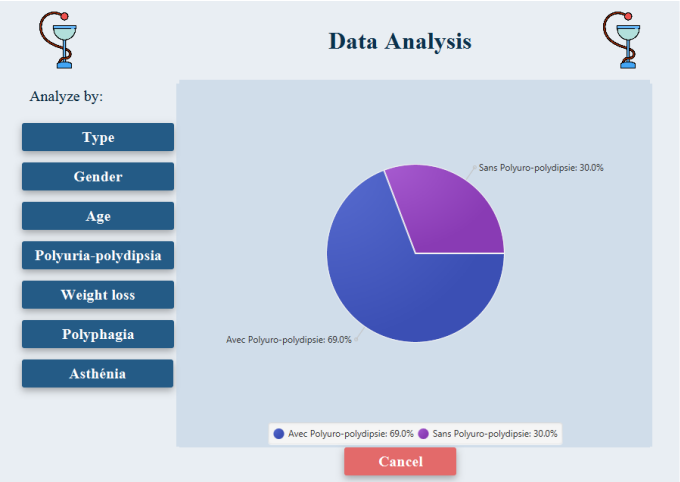
Once the user chooses a patient and clicks on the button "Consult" this window that allows him to edit the type of treatment, medication or even the diagnosis of the patient is opened:



4.2 Data Analysis:

If the user chooses to see the data analysis of the system, this window that allows him to analyze the data by type, age, sex, polyuro-polydipsia, weight loss, polyphagia or asthenia opens:





5 System Performance:

The system has been tested by a number of existing patients, obtained by a Data gathering at the Ibn Sina-Annaba UHC. Then, the results were compared to see the efficiency of this decision-support system. **Table 2** shows the obtained results;

	Cases introduced	Correct cases	Percentage
System results	**103**	**93**	**90.29%**
Data gathering results	**103**	**103**	**100%**

TABLE 2: System performance results.

6 Conclusion:

In this work, a tool has been realized that aims to help doctors to diagnose diabetes, its type and it seriousness and propose the appropriate treatment based on the clinical and biological symptoms of the patient introduced by the user (the doctor). Rules-based reasoning was used to obtain the diagnosis and the corresponding treatment.

To represent the knowledge needed for this diagnosis, a domain ontology was created, using the tool Protégé 5.2.0 [13][14].

The results provided by this tool have been compared and validated with the results obtained by experimentation at the Ibn Sina-Annaba UHC, and various other practices. It has been found that this system offers correct and efficient results at 90.29%.

The decision support system is a technique perfectly adapted to the medical reasoning and is very promising when she is applied in systems of help to the diagnosis[15].

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