Web Service-based System for Hepatobiliary System Diseases Prognosis and Treatment

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***Abstract*— Hepatobiliary system is one of the most important systems in the human body. It is responsible for many processes, which are necessary to keep body regulated and healthy. In our previous research, we exploited the existing Medical Ontologies for building a new Hepatobiliary System Diseases (HSD) Ontology in pathology domain. This Ontology is represented in the Web Ontology Language (OWL) that has recently become the standard language for the semantic web. In its current format, the HSD Ontology can be accessed only by the computer science specialists. In this paper, we present a system for Hepatobiliary system diseases prognosis and treatment. The system shares the Ontology knowledge by replying the inquiries of both physicians and medical students. The presented system is a web service-based, thus it can be integrated with intelligent systems. The proposed system utilizes the causal relations among diseases to predict the incoming diseases. During the patient visits, the system supports the physician by diagnosing the case, suggesting a treatment plan, and expecting the patient status progress. The system has been evaluated using a real dataset of 40 anonymous patients, and the diagnosis accuracy of the system is 92.5%.**

Keywords*— Knowledge Sharing; Web Services; Diagnosis and Treatment; Medical Ontology; Hepatobiliary System Diseases;

I. INTRODUCTION

Hepatobiliary system is one of the most important systems in the human body. The Hepatobiliary system contains four organs (Liver, Gallbladder, Bile Duct, and Pancreas), which are responsible for many functions. These functions are necessary to keep body regulated and healthy. Besides, it plays an important role in many body functions like storage of various substances, protein production, and detoxification [1, 2]. Some of diseases infecting this system lead to serious complications [3]. Up to authors knowledge, there is no a complete system available for prognosing, treating, and inquiring for the Hepatobiliary system diseases. Also, there is no Ontology that contains all the diseases of the Hepatobiliary system. Recently, the medical Ontologies play a central role in sharing the medical knowledge and integrating the information about different organisms [4, 5, 6, 7]. In our previous work [8], we exploited the existing medical Ontologies for building a new Hepatobiliary System Diseases (HSD) Ontology. This Ontology is represented in the Web Ontology Language (OWL) that has recently become the standard language for the semantic web. In this paper, we present a complete system for prognosing and treating the Hepatobiliary system diseases. The system utilizes the causal relations among diseases to predict the incoming diseases. Besides, it shares the Ontology knowledge by replying the inquiries of both physicians and medical students. As the proposed system is a web service-based, it can be integrated with intelligent systems to share Ontology knowledge and to prognose the patient diseases. To show how the system is very beneficial, some of case studies are presented for the HSD Ontology sharing, patient diagnosing and treatment, and expecting the patient progress. The system has been evaluated using a real dataset of 40 anonymous patients, and the diagnosis accuracy of the system is 92.5%.

The rest of this paper is organized as follows. Section 2 reviews the recent related medical systems in Hepatobiliary system diseases domain. Section 3 presents the system architecture. Section 4 describes the Hepatobiliary System Diseases Diagnosis and Treatment Module, while Section 5 describes the HSD Ontology Query Module. Section 6 presents the System Implementation and Experimental Evaluation. Finally, section 7 concludes the most important points in this paper.

II. RELATED WORK

In the past years, the big numbers of artificial intelligence research has been aimed towards the development of expert systems for problem solving in the medical diagnosis [9, 10, 11, 12]. There are many research works have been achieved to build medical Ontologies and systems for different diseases [13, 14]. For example, in [15], the authors presented the architecture of the proposed Viral Hepatitis Ontology Sharing Web Service approach. The main aim of this approach is the Viral Hepatitis Ontology sharing Web Service that accesses the Viral Hepatitis OWL Ontology to share its primitives (concepts and properties) among physicians, students of medicine, and intelligent systems. The Viral Hepatitis Ontology Sharing Web Service includes the service operations needed for Ontology sharing and Viral Hepatitis diseases diagnosing. The OWL Viral Hepatitis Ontology contains the

Viral Hepatitis diseases and their signs, symptoms, and laboratory-findings.

In [16], the authors developed a disease Ontology based on River Flow Model and a browsing tool for causal chains defined in it. The Ontology based on Ontological consideration of causal chains that capture characteristics of diseases appropriately. The definition of disease as causal is very friendly to clinicians since it is similar to their understanding of disease in practice. Furthermore, it includes much information about causal relationships in disease than other disease Ontologies or medical terminologies such as SNOMED-CT. They are refining the Ontology through reviewing definitions of disease concepts and organizing definitions of clinical disorders into abnormality Ontology based on YAMATO.

In [17], the authors developed to design an expert system for diagnosis types of diabetes. This system has been coded with VP_Expert Shell and tested in Shahid Hasheminezhad Teaching Hospital affiliated with Tehran University of Medical Sciences and the final expert system has been presented. There are many patients are not aware of their disease and how to control it. Some of these patients do not access the physicians during necessary times. Besides, system can be highly helpful for the patients and provide necessary information about the indications and diagnosis.

In [18], the authors developed the recommendation system of anti-diabetic medication for doctors. In this system, medicine consultant information was imported into the anti-diabetic drug knowledge system. Besides, it used ‘‘the American association of clinical endocrinologists medical guidelines for clinical practice to the management of diabetes mellitus’’ of HbA1c and medicine consultant of weights. The system will improve a selected candidate which is anti-diabetic medicine elements for system construction. Protégé was used to build the anti-diabetic medicine Ontology to store the regulations of anti-diabetic medicine. The main constituent elements of the Ontology are classes, attributes, and relationships.

In [19], the authors presented a description of the process of Ontology construction for gallbladder ultrasound images. This Ontology is inspired and based on the knowledge base created, which used decision support system “SonaRes” to ultrasound diagnostics. This system has accumulated the experience of the skillful experts-sonographists in the domain of hepato-pancreato-biliary zone examination. This experience and knowledge are organized and formalized in this system for gallbladder and pancreas.

In [20], the authors developed diagnosis module (Liv&PanFES) consists of the expert system and fuzzy logic techniques to perform diagnostic tasks. A set of rules will be defined using the patient disease database as well as the expert knowledge on the disease domain. The designed expert system uses the rules to diagnose patient's illness base on their laboratory tests. In addition, fuzzy logic is integrated to enhance the reasoning when dealing with fuzzy data. The combination of expert system and fuzzy logic that forms a hybrid (expert-fuzzy) system could increase the system performance and has been implemented successfully, see more studies [21, 22, 23]. From the above study, we found that there is no Ontology that contains all the diseases of the Hepatobiliary system, also no computerized system that can help the physician to diagnose the case, suggest a treatment plan, expect the patient progress, and predict the incoming disease based on causal relations. For this reason, we built a new Ontology which includes Hepatobiliary system diseases and a system covering the inadequacies in the previous researches.

III. System Architecture

As shown in figure 1, the proposed system architecture contains three modules: The user interface, the HSD Ontology Query, and the Diagnosis and Treatment modules. In addition to these modules, the system includes the HSD Ontology and the patient medical record. The user interface module enables both physicians and medical students to inquire the system, to prognose and to treat the patient diseases. The main aim of the HSD Ontology Query module is to share the Ontology knowledge. For example, it replies by the symptoms, signs, disease causal relations, and treatment for an input disease. Finally, there are two main objectives for the Diagnosis and Treatment module: Supporting the physicians and students for diagnosing and treating the Hepatobiliary system diseases, and predicting the incoming diseases by utilizing the causal relations among diseases. These modules are a web service-based to enable the integration with the intelligent systems for Ontology knowledge sharing and for prognosing the patient diseases.

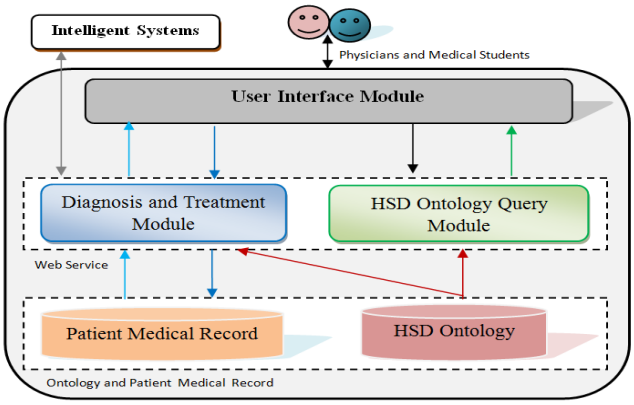

Fig. 1. The Proposed System Architecture

A. The HSD Ontology

In our previous research [8], we exploited the existing Medical Ontologies for building the HSD Ontology in the pathology domain. This Ontology is represented in the Web Ontology Language (OWL). It includes 224 classes and 258 instances. Figure 2 shows a sample of the HSD Ontology. As shown, the “Hepatobiliary_System” class contains the “Organ” class, which is inherited by four subclasses: “Liver”, “Gallbladder”, “Bile_Duct” and “Pancreas”. Each Organ class

is infected by a set of diseases. For example, the "Hepatitis_C" class is a subclass of "Liver_Disease", which infects the Liver Organ. For each disease class, there are associated three classes for causal relation, treatment, and symptom and sign. For instance, the "Hepatitis_C_Causal_Relation", "Hepatitis_C_Treatment", and "Hepatitis_C_Symptom_and_Sign" are the associated classes with the "Hepatitis_C" class. For more details about this Ontology, kindly refer to our previous work [8].

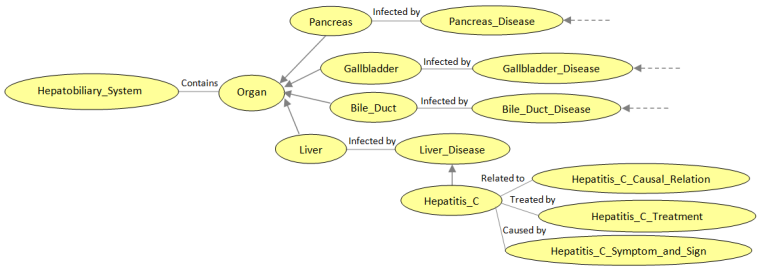

Fig. 2. A sample of HSD Ontology

B. The Patient Medical Record Model

The Patient Medical Record is used to retrieve, store, modify, and delete the patient data and his visits. As shown in figure 3, the Patient Medical Record contains three entities: Patient Information, Visit, and Patient History. The Patient Information entity aims to represent the general information such as Patient ID, Patient Name, Patient Address, and Age. Also, it has a relationship with the Visit entity and Patient History entity. The Visit entity stores the patient visit data, which contains the Visit ID, Patient ID, Diagnostic Disease, and Disease Causal Relation. It has a relationship with three entities: Visit Lab, Symptoms and Signs, and Treatment. Finally, the Patient History entity represents the patient's history, which contains Patient ID, Patient History ID, Chief Complaint, and Present Illness. It has a relationship with the entities: Patient Family History, Patient Social History, Patient Past History and Patient Past Treatment, which represent information about the patient history.

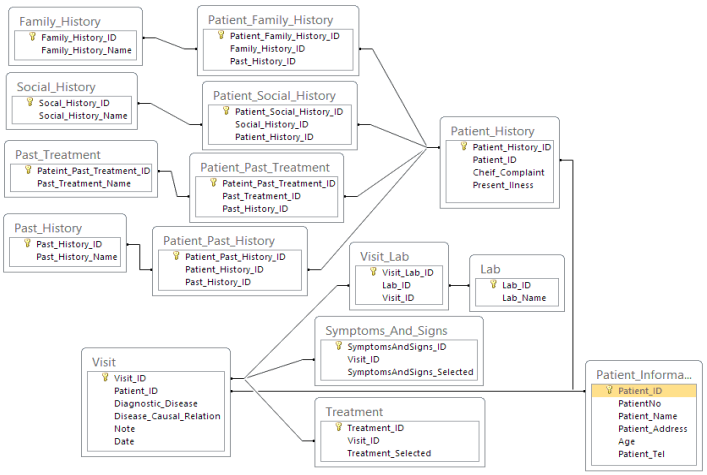

Fig. 3. Patient Medical Record Model

IV. HEPATOBILIARY SYSTEM DISEASES DIAGNOSIS AND TREATMENT MODULE

To diagnose and treat the Hepatobiliary system diseases, the module web service should contain a set of operations that can be invoked through the Internet during the usage scenario. By analyzing the module requirements, twelve web service operations should be provided. Table 1 shows those operations in terms of operation description, inputs, and outputs. For example, the user and intelligent systems can benefit the web service operations as follow: -

- The *RetrieveSymptomsForDisease()* operation is responsible for returning a list of symptoms for the input disease.
- The *RetrieveCommonDiseasesForSymptoms()* operation is responsible for returning a list of common diseases for the input symptoms.
- The *RetrieveSignsForDisease()* operation is responsible for returning a list of signs for the input disease.

TABLE I. WEB SERVICE OPERATIONS OF DIAGNOSIS AND TREATMENT MODULE

Web Service Operation	Description	Input	Output
DiagnoseSymptomsAndSigns()	Retrieve the causing diseases for the input symptoms and signs	List of symptoms and signs	A Disease
RetrieveSymptomsForDisease()	Returns a list of symptoms for a specific disease.	A Disease	List of symptoms
RetrieveSignsForDisease()	Returns a list of signs for a specific disease.	A Disease	List of signs
RetrieveTreatmentsForDisease()	Returns a list of treatments for a specific disease.	A Disease	List of treatments
RetrieveDiseaseCausalRelations ForDisease()	Returns a list of disease causal relations for a specific disease.	A Disease	List of disease causal relation
RetrieveLaboratory-findings ForDisease()	Returns a list of laboratory- findings for a specific disease.	A Disease	List of laboratory-findings
RetrieveCommonDiseases ForSymptoms()	Returns list of diseases causing the input symptoms.	List of symptoms	List of Diseases
RetrieveCommonDiseases ForSigns()	Returns list of diseases causing the input signs.	List of signs	List of Diseases
SavePatientID()	Save patient ID for a specific patient.	Patient ID	Patient ID
SavePatientHistory()	Save Patient History for a specific patient.	Patient History	Patient History
PatientTreatmentPlan()	Save Patient Treatment Plan for a specific patient.	Visit	Patient Treatment Plan
QueryOfPatientID()	Returns patient ID, Patient History, List of symptoms and signs, laboratory- findings, List of treatments, treatment plan and disease causal relation.	Patient No	Patient ID, Patient History, List of symptoms and signs, laboratory- findings, List of treatments, treatment plan and disease causal relation.

To show how the system is very beneficial, in the following, a scenario of patient diagnosing and treatment is presented. This scenario aims to help the physicians or medical students to differentially diagnose the Hepatobiliary system diseases. As shown in figure 4, the scenario starts with invoking the *RetrieveSymptomsForDisease()* and *RetrieveSignsForDisease()* operations to retrieve the symptoms and signs causing the input diseases. After that, the *RetrieveCommonDiseasesForSymptoms()* and *RetrieveCommonDiseases ForSigns ()* operations retrieve the common diseases causing the input symptoms and signs.
This step is repeated if the physicians (or medical students) want to add more symptoms/signs. Then, the *DiagnoseSymptomsAndSigns()* is invoked to diagnose the current input symptoms and signs. Also, the *RetrieveLaboratory-findingsForDisease()* is invoked to confirm the diagnosis result by retrieving the laboratory-

findings caused by the diagnosed disease. Finally, The *RetrieveTreatmentsForDisease()* and *RetrieveDiseaseCausal RelationsForDisease()* operations return the treatments and causal relations for diagnosed disease. For example, if the physician wants to diagnose a set of symptoms and signs: the "Abdominal Pain", "Aching Limbs", "Chills, "Diarrhea", "Jaundice" and "Urine Is Dark", the "Alagille Syndrome", "Cholangitis", "Reye Syndrome", "Hepatitis C", etc., diseases will be returned as the common diseases causing those symptoms and signs. The Hepatitis C disease will be diagnosed as a final diagnosis. Also, the Laboratory-findings for Hepatitis C disease can be returned to confirm the final diagnosis, and then the treatments "Amoxicillin", "Clarithromycin", "Interferon + Ribavirin", etc., will be returned for the final diagnosis. Finally, the Hepatitis C causal relations "Liver failure", "Liver Cirrhosis", "Liver Neoplasms", etc., will be returned for the final diagnosis.

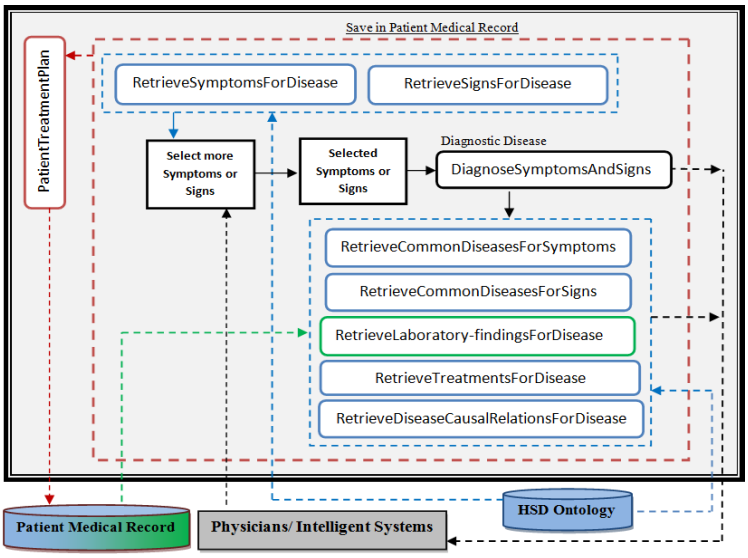

Fig. 4. Hepatobiliary System Diseases Diagnosis and Treatment Scenario

V. THE HSD ONTOLOGY QUERY MODULE

To achieve the objectives of Hepatobiliary system diseases sharing, and inquiring module, the web service should contain a set of operations that can be invoked through the Internet in the usage scenarios. By analyzing the module requirements, thirteen web service operations should be provided. Table 2 shows these operations in terms of operation description, inputs and outputs. For example, the user and intelligent systems can benefit the web service operations as follow: -

- The *ViewHierarchicalHSDOntology()* operation is responsible for returning the HSD Ontology in OWL file.
- The *QueryOfCommonDiseasesForSymptomOrSign()* operation is responsible for returning a list of common diseases for the input symptom or sign.
- The *QueryForSymptomsSignsTreatmentsOrDiseaseCausalRelations()* operation is responsible for returning a list of symptoms, signs, treatments or disease causal relations for the input disease.

TABLE II. WEB SERVICE OPERATIONS OF THE HSD ONTOLOGY QUERY MODULE

Web Service Operation	Description	Input	Output
ViewHierarchicalHSDOntology()	Returns the whole HSD Ontology file.	-	OWL File
QueryForSymptomsSignsTreatments OrDiseaseCausalRelations()	Returns symptoms, signs, treatments or disease causal relations for a specific disease.	A Disease	List of symptoms, signs, treatments and disease causal relation
RetrieveSymptomsForDisease()	Returns a list of symptoms for a specific disease.	A Disease	List of symptoms
RetrieveSignsForDisease()	Returns a list of signs for a specific disease.	A Disease	List of signs
RetrieveTreatmentsForDisease()	Returns a list of treatments for a specific disease.	A Disease	List of treatments
RetrieveDiseaseCausalRelations ForDisease()	Returns a list of disease causal relations for a specific disease.	A Disease	List of disease causal relation
QueryForCommonSymptomsSigns OrTreatmentsInDiseases()	Returns the common symptoms, signs or treatments for specific diseases.	List of Diseases	List of symptoms, signs and treatments
RetrieveCommonSymptoms ForDiseases()	Returns the common symptoms for specific diseases.	List Of Diseases	List of symptoms
RetrieveCommonSignsForDiseases()	Returns the common signs for specific diseases.	List Of Diseases	List of signs
RetrieveCommonTreatments ForDiseases()	Returns the common treatments for specific diseases.	List Of Diseases	List of treatments
QueryOfCommonDiseasesForSymptom OrSign()	Returns list of the common diseases for symptom or sign.	Symptom Or Sign	List of diseases
RetrieveCommonDiseasesForSymptom()	Returns the common diseases for specific symptom.	Symptom	List of diseases
RetrieveCommonDiseasesForSign()	Returns the common diseases for specific signs.	Sign	List of diseases

Many different scenarios can be achieved by the physicians, medical students, and intelligent systems to exploit the web service operations in different ways. By analyzing the needs of both physicians and medical students by asking a domain expert, we found that there are important usage scenarios for learning and inquiring: "Query for Symptoms, Signs, Treatments or Disease Causal Relations", "Query for Common Symptoms, Signs or Treatments", and "Query for Common Diseases".

A. *Query for Symptoms, Signs, Treatments or Disease Causal Relations Scenario*

This scenario aims to help the physicians, medical students, or intelligent systems to retrieve the symptoms, signs, treatments or disease causal relations for a specific disease. As shown in figure 5, the scenario workflow is initiated by invoking the *QueryForSymptomsSignsTreatmentsOrDiseaseCausalRelations*() operation, which then invokes the *RetrieveSymptomsForDisease(), RetrieveSignsForDisease(), RetrieveTreatmentsForDisease()* or *RetrieveDiseaseCausal RelationsForDisease()* operation that returns the symptoms, signs, treatments or disease causal relations for the input disease respectively.

For example, if the physician or medical student queries for the symptoms and signs of the Liver failure disease, the "Bleeding easily", "Confusion", "Diarrhea", etc., symptoms and signs will be returned. Also, if the physician or medical student queries for the treatments of the Liver failure disease, the "Anesthetic Agents (Propofol)", "Liver Transplantation", "Osmotic Diuretics (Mannitol)", etc., treatments will be returned. Finally, if the physician or medical student queries for the causal relations of the Liver failure disease, "Liver failure", "Liver Cirrhosis", "Liver Neoplasms", etc., disease causal relations will be returned.

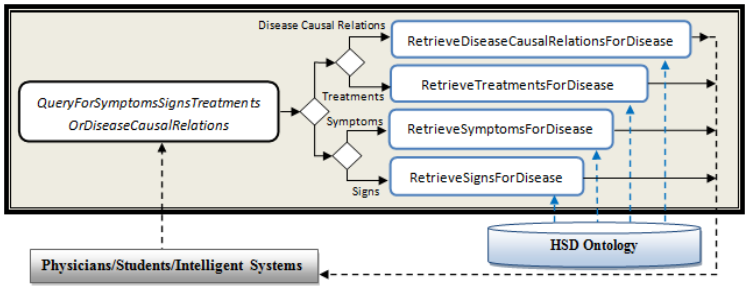

Fig. 5. Query for Symptoms, Signs, Treatments or Disease Causal Relations Scenario

B. *Query for Common Symptoms, Signs or Treatments in Diseases Scenario*

This scenario aims to help the physicians, medical students, or intelligent systems to retrieve the common symptoms, signs or treatments for a set of diseases. As shown in figure 6, the scenario workflow is initiated by invoking the *QueryForCommonSymptomsSignsOrTreatmentsInDiseases()* operation, which then invokes the *RetrieveCommonSymptoms ForDiseases(), RetrieveCommonSignsForDiseases()* or *RetrieveCommonTreatmentsForDiseases()* operation that returns the common symptoms, signs or treatments for the input diseases respectively.

For example, if the physician or medical student queries for the common symptoms or signs of the Liver failure and Liver Neoplasms diseases, the "Fatigue", "Jaundice", "Losing Appetite" symptoms, signs will be returned. And also, if the physician or medical student queries for the common treatments of the Liver failure and Liver Neoplasms diseases, the "Liver Transplantation" treatment will be returned.

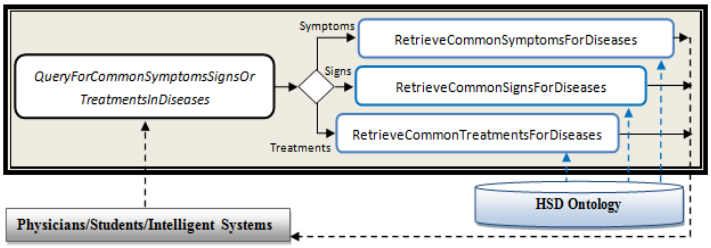

Fig. 6. Query for Common Symptoms, Signs or Treatments in Diseases Scenario

C. *Query for Common Diseases of Symptom or Sign Scenario*

This scenario aims to help the physicians, medical students, and intelligent systems to retrieve the common diseases for specific symptom or sign. As shown in figure 7, the scenario workflow is initiated by invoking the *QueryOfCommonDiseasesForSymptomOrSign()* operation, which then invokes the *RetrieveCommonDiseases ForSymptom()* or *RetrieveCommonDiseasesForSign()* operation that returns the common diseases for the input symptom or sign respectively. For example, if the physician or medical student query about the diseases causing the Fatigue symptom, the "Autoimmune Hepatitis", "Hepatitis A", "Hepatitis B", etc., diseases will be returned.

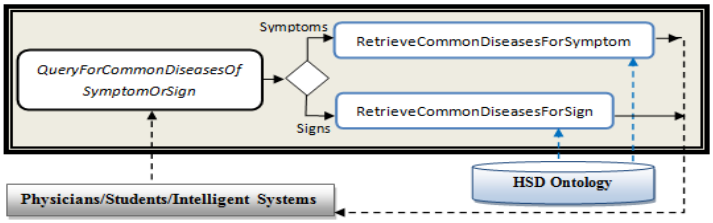

Fig. 7. Query for Common Diseases of Symptom or Sign Scenario

VI. System Implementation and Experimental Evaluation

As shown in the proposed system architecture, the system consists of five main components: the user interface module, the HSD Ontology Query module, the Diagnosis and Treatment module, the Patient Medical Record, and the HSD Ontology. The system modules were developed as a web service using the C# language and the user interface was developed using the ASP.NET (Active Server Pages Technology). To show how the system is very beneficial for physicians and medical students, during the patient visits, two different diagnosing case studies will be presented for the Hepatitis C disease in the following subsections.

The system utilizes the causal relations among diseases to predict the incoming diseases and to present them visually. The first case study shows the improvement of a patient from visit to visit, because he followed the physician's instructions. On the other hand, the second case study shows how the patient was getting worse, because he did not follow the physician's instructions. As shown in figure 8, the user interface contains three menu items. Firstly, the "HSD Ontology" menu item aims to visualize the HSD Ontology. Secondly, the "Query Hepatobiliary System Diseases" menu item aims to show the diseases, symptoms and signs, treatment, disease causal relations, common symptoms and signs, and common treatment, which are related to Hepatobiliary system diseases. Finally, the "HSD Diagnosis" menu item enables the physician to diagnose, treat, and follow the patient status as shown in figure 9.

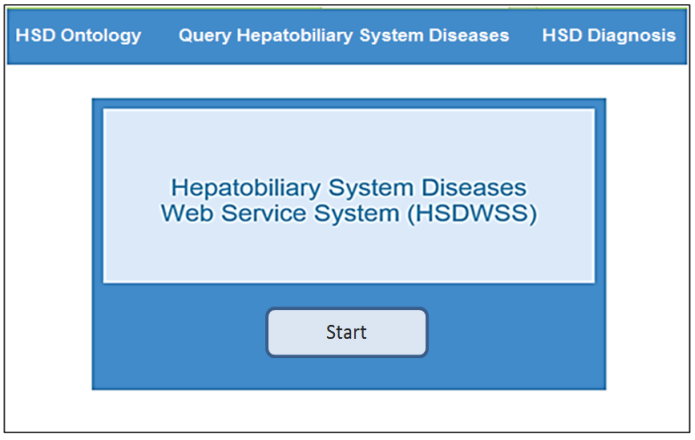

Fig. 8. The System User Interface

A. *The Recovering Case Study*

After selecting the HSD Diagnosis menu item, the diagnosis a screen will appear, as shown in Figure 9. During the first patient visit, the physician wanted to diagnose the "Abdominal Pain", "Aching Limbs", "Chills", "Diarrhea", "Jaundice", and "Urine Is Dark" symptoms and signs by selecting them and clicking the "Diagnosis" button. The system retrieved the diseases causing the selected symptoms and signs under the "Common Diseases" list box: "Alagille Syndrome", "Cholangitis", "Reye Syndrome", "Hepatitis C", etc. Besides, the system displayed the final diagnosis, which is the Hepatitis C disease under the "Diagnostic Disease" list box. To confirm the final diagnosis, the physician can show the Laboratory-findings needed for the Hepatitis C disease by clicking the diagnosed disease (LFT Test, Hepatitus C antigen, and Hepatitic C antibody), which are displayed under the "Progress Notes" text box.

In addition, by clicking the diagnosed disease, the treatments and disease causal relations for Hepatitis C disease are displayed under the "Disease Treatments" and "Disease Causal Relation" list boxes. As shown, the physician selected the suitable treatment plan to be taken by the patient, which is "Interferon + Ribavirin". After saving the case, figure 10 shows the patient case summary. To show the Hepatitis C causal relations with other disease visually, the physician can click "Causal Relation" button from the summary window as shown in figure 11.

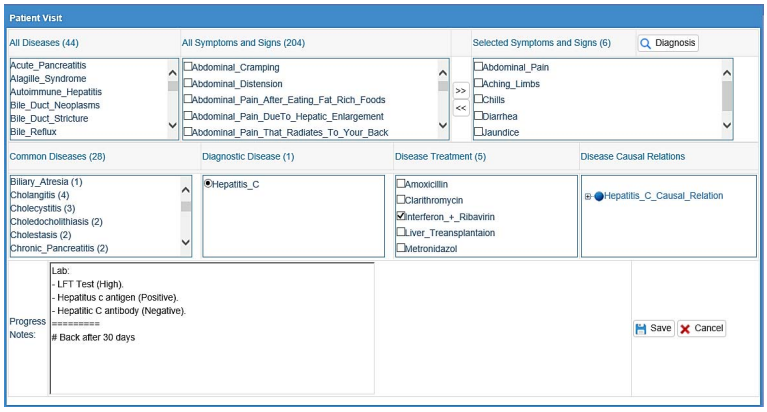

Fig. 9. Diagnosis Screen

Visit.	Patient No.	Symptoms\Signs Selected	Diagnostic Disease	Treatment Selected	Progress Notes
1	1	▪ Abdominal_Pain ▪ Aching_Limbs ▪ Chills ▪ Diarrhea ▪ Jaundice ▪ Urine_Is_Dark	Hepatitis_C Causal Relation	▪ Interferon_+_Ribavirin	Lab: - LFT Test (High). - Hepatitus c antigen (Positive). - Hepatitic C antibody (Negative) ========= Back after 30 days

Fig. 10. Summary of Visit (1) in Case (1)

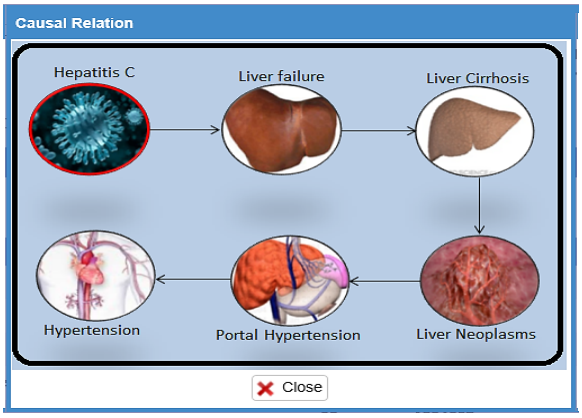

Fig. 11. Hepatitis C Causal Relation

After 30 days from the first visit**,** the physician wanted to diagnose the "Abdominal Pain", "Aching Limbs", and "Urine Is Dark" symptoms and signs by selecting them and clicking the "Diagnosis" button. The system retrieved the diseases causing the selected symptoms, and signs: "Biliary Atresia", "Cholecystitis", "Hepatitis A", etc. Besides, the system displayed the final diagnosis, which is the Hepatitis C disease. To confirm the final diagnosis, the physician can show the Laboratory-findings needed for the Hepatitis C disease by clicking the diagnosed disease (LFT Test, Hepatitus C antigen, and Hepatitic C antibody), which were displayed.

In addition, by clicking the diagnosed disease, the treatments, and the disease causal relations for Hepatitis C disease were displayed. As shown, the physician selected the suitable treatment plan to be taken by the patient, which is "Interferon + Ribavirin". After saving the case, figure 12 shows the patient case summary.

Visit.	Patient No.	Symptoms\Signs Selected	Diagnostic Disease	Treatment Selected	Progress Notes
2	1	▪ Abdominal_Pain ▪ Aching_Limbs ▪ Urine_Is_Dark	Hepatitis_C Causal Relation	▪ Interferon_+_Ribavirin	Lab: - LFT Test (High). - Hepatitus c antigen (Positive). - Hepatitic C antibody (Positive). ========= #Continue on treatment. #Back after 10 days.

Fig. 12. Summary of Visit (2) in Case (1)

After 10 days from second visit, the physician wanted to diagnose the "Malaise" symptom by selecting it and clicking the "Diagnosis" button. The system retrieved the diseases causing the selected symptom: "Hepatitis C", and "Primary Sclerosing Cholangitis". Besides, the system displayed the final diagnosis, which is the Hepatitis C disease. To confirm the final diagnosis, the physician can show the Laboratory-findings needed for the Hepatitis C disease by clicking the diagnosed disease (LFT Test, Hepatitus C antigen, and Hepatitic C antibody), which were displayed. In addition, by clicking the diagnosed disease, the treatments, and the disease causal relations for Hepatitis C disease were displayed. As shown, the physician selected the suitable treatment plan to be taken by the patient, which is "Interferon + Ribavirin". After saving the case, figure 13 shows the patient case summary.

After 20 weeks from the third visit, there are no symptoms and signs observed on the patient. The first case study shows the improvement of a patient from visit to visit, because he followed the physician's instructions.

Visit.	Patient No.	Symptoms\Signs Selected	Diagnostic Disease	Treatment Selected	Progress Notes
3	1	▪ Malaise	Hepatitis_C Causal Relation	▪ Interferon_+_Ribavirin	Lab: - LFT Test (Normal). - Hepatitus c antigen (Negative). - Hepatitic C antibody (Positive). ========= #Continue on treatment. #Back after 20 weeks days.

Fig. 13. Summary of Visit (3) in Case (1)

B. The Getting Worse Case Study

In this case study, we are going to show how the patient state is getting worse if he don't follow the physician's instructions. In this case study, the procedures occurred during the first two visits of the first case study will be same in this case study. Therefore, there is no need to be repeated.

In the third patient visit, the physician wanted to diagnose the "Abdominal Pain", "Aching Limbs", "Bleeding Easily", "Jaundice", "Sleepiness", "Swollen Abdomen" and "Urine Is Dark" symptoms and signs by selecting them and clicking the "Diagnosis" button. The system retrieved the diseases causing the selected symptoms, and signs: "Cholangitis", "Hemochromatosis", "Cholestasis", etc. Besides, the system displayed the final diagnosis, which is the Hepatitis C, and Liver failure diseases. To confirm the final diagnosis, the physician can show the Laboratory-findings needed for the Hepatitis C and Liver failure diseases by clicking the diagnosed diseases (LFT Test, Hepatitus C antigen, Hepatitic C antibody, and Blood urea), which were displayed.

In addition, by clicking the diagnosed diseases, the treatments and disease causal relations for Hepatitis C, and Liver failure diseases were displayed. As shown, the physician selected the suitable treatment plan to be taken by the patient, which is "Interferon + Ribavirin". After saving the case, figure 14 shows the patient case summary. To show the Hepatitis C causal relations with other disease visually, the physician can click "Causal Relation" button from the summary window as shown in figure 15.

Visit.	Patient No.	Symptoms\Signs Selected	Diagnostic Disease	Treatment Selected	Progress Notes
3	3	▪ Abdominal_Pain ▪ Aching_Limbs ▪ Bleeding_Easily ▪ Jaundice ▪ Sleepiness ▪ Swollen_Abdomen ▪ Urine_Is_Dark	Hepatitis_C Liver_failure Causal Relation	▪ Interferon_+_Ribavirin	Lab: - LFT Test (High). - Hepatitus c antigen (Positive). - Hepatitic C antibody (Positive). - Blood urea (High). ========= Alarm: If Blood urea is high, the patient must be transferred immediately to the ICU due to hepatic encephalopathy before worse. ======== # Continue on treatment. # Back after 30 days.

Fig. 14. Summary of Visit (3) in Case (2)

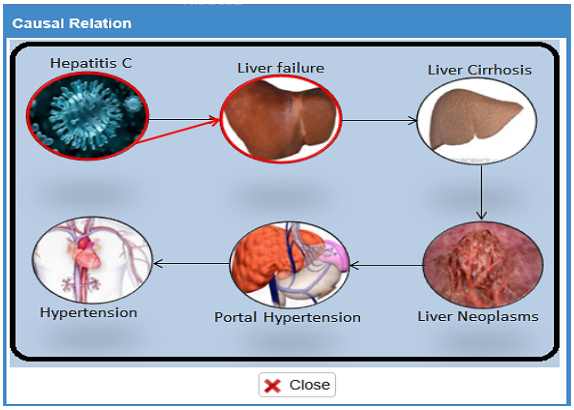

Fig. 15. Liver failure Causal Relation

After 30 days from third visit, the physician wanted to diagnose the "Abdominal Pain", "Aching Limbs", "Bleeding Easily", "Fatigue", "Orange Tint to the Urine", "Sudden Weight Gain", "Swelling Legs", "Jaundice", "Sleepiness", "Swollen Abdomen", and "Urine Is Dark" symptoms and signs by selecting them and clicking the "Diagnosis" button. The system retrieved the diseases causing the selected symptoms and signs: "Autoimmune Hepatitis", "Choledocholithiasis", "Cholestasis", etc. Besides, the system displayed the final diagnosis, which is the Hepatitis C, Liver failure, and Liver Cirrhosis diseases. To confirm the final diagnosis, the physician can show the Laboratory-findings needed for the Hepatitis C, Liver failure, and Liver Cirrhosis diseases by clicking the diagnosed diseases (LFT Test, Hepatitus C antigen, Hepatitic C antibody, and Blood urea) and CT scan, which were displayed.

In addition, by clicking the diagnosed diseases, the treatments and disease causal relations for Hepatitis C, Liver failure, and Liver Cirrhosis diseases were displayed. As shown, the physician selected the suitable treatment plan to be taken by the patient, which is "Antidotes (Penicillin G or Silibinin or Activated Charcoal or N-Acetylcysteine)". After saving the case, figure 16 shows the patient case summary. To show the Liver Cirrhosis causal relations with other disease visually, the physician can click "Causal Relation" button from the summary window as shown in figure 17. The second case study shows how the patient was getting worse, because he does not follow the physician's instructions.

Visit.	Patient No.	Symptoms\Signs Selected	Diagnostic Disease	Treatment Selected	Progress Notes
4	3	▪ Abdominal_Pain ▪ Aching_Limbs ▪ Bleeding_Easily ▪ Fatigue ▪ Jaundice ▪ Orange_Tint_ToThe_Urine ▪ Sleepiness ▪ Sudden_Weight_Gain ▪ Swelling_Legs ▪ Swollen_Abdomen ▪ Urine_Is_Dark	Hepatitis_C Liver_failure Liver_Cirrhosis Causal Relation	▪ Antidotes (Penicillin G Or Silibinin Or Activated _Charcoal_Or_N-Acetylcysteine)	Lab: - LFT Test (High). - Hepatitus c antigen (Positive). - Hepatitic C antibody (Positive). - Blood urea (High) ========= CT Scan. ======== The second alarm: If Blood urea is high, the patient must be transferred immediately to the ICU due to hepatic encephalopathy before worse.

Fig. 16. Summary of Visit (4) in Case (2)

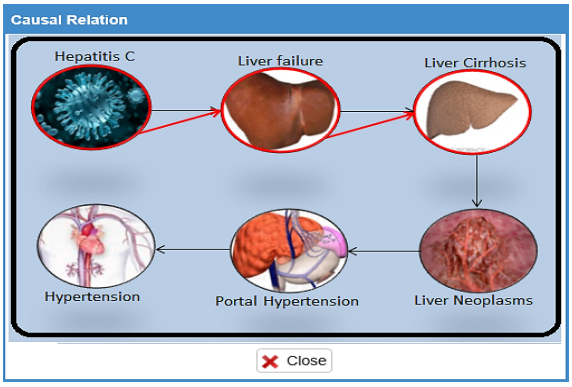

Fig. 17. Liver Cirrhosis Causal Relation

C. *Experimental Evaluation*

To evaluate the introduced system, the system was implemented and experimented using a real dataset of 40 anonymous patients. The system was developed as a web service using the C# language and the user interface was developed using the ASP.NET (Active Server Pages) technology. The empirical experiments were conducted on an Intel (R) CPU (2.0 GHz) with 4 GB of RAM.

The correct diagnosis accuracy of the system is 92.5%, and the partial diagnosis accuracy of the system is 7.5%. The diagnosing accuracy was calculated using formula (1). Obviously, the system gives a relatively high accuracy in diagnosing the Hepatobiliary system diseases.

$$\text{Diagnosing accuracy} = TC/TT*100 \qquad (1)$$

Where TC is the total number of test cases diagnosed correctly and TT is the total number of the test cases.

VII. CONCLUSIONS

Hepatobiliary system is one of the most important systems in the human body. It is responsible for many processes, which are necessary to keep body regulated and healthy. In this paper, we presented a complete system for prognosing and treating the Hepatobiliary system diseases. The system utilizes the causal relations among diseases to predict the incoming diseases. Besides, it shares the Ontology knowledge by replying the inquiries of both physicians and medical students. As the proposed system is a web service-based, it can be integrated with intelligent systems to share Ontology knowledge and to prognose the patient diseases. To show how the system is very beneficial, some of case studies were presented for the HSD Ontology sharing, patient diagnosing and treatment, and expecting the patient progress. The system had been evaluated using a real dataset of 40 anonymous patients, where the diagnosis accuracy of the system is 92.5%.

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