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Expert Database System Architecture and Implementation on Object Relational Databases

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Abstract: An expert database system is an expert system which is developed on databases using DBMS technology to manage facts and rules. Frame-based expert systems are widely used as the knowledge representation for such expert systems with large knowledge bases. Many systems have the ability to connect to external databases. Facts stored in databases can be loaded into expert system's knowledge base and inference is performed by the inference engine of the expert system. In many cases, such external facts are required several times for each inference. Thus, a lot of communication traffic takes place. This research work present the design and implementation of a frame-based object-relational database system which has a tight coupling between the expert system and the external knowledge base. The external knowledge base also use frame as its knowledge representation. More over, it has its own inference engine so that inference can be perform on the knowledge base side and the results, not only simple facts, are sent back to the expert system for further inference. A medical consultation system is used as an illustrated example an Oracle 10g object relational DBMS is used as the database platform.

Key-Words: - Frame, Expert System, Object-Relational Database

1 Introduction

Frames are widely used as the knowledge representation of large, complex expert systems [1]. However, most such expert system shells have internal frame-based knowledge bases. They are internal in the sense that frames are loaded and stored in the main memory of the expert system during consultation sessions. The knowledge bases do not have the advanced data management facilities such as indexing, query optimization, concurrency control and recovery control which are common in modern database management systems (DBMS).

During a consulting session, there are facts that are obtained from the user interactively and facts that are obtained from inferences. Inference rules in conventional expert systems are executed by the inference engine on the expert system's machine. It mainly uses facts obtained interactively from users. Facts from external databases are sometimes loaded into the knowledge base when required by the inference process. In simple systems, relations that contain both relevant and irrelevant facts are loaded into the knowledge base. In more advanced systems only related facts are loaded. In both cases, there are no inferences on the external database (or knowledge base) side.

Our approach is different. We propose an architecture that includes an inference engine on the external knowledge base side as well as one on the expert system shell side. This approach enables inferences to be performed on the external knowledge base side so that only the inference results are sent back to the expert system instead of sending facts several times during an inference process performed by the expert system's inference engine.

Due to the similarity between the frame and the object relational concepts, a prototype system is implemented on an object relational database using Oracle 10g DBMS.

2 Frames

Frame was introduced by Marvin Minsky in 1974 [2]. It is a knowledge representation that has both the data structure and inference capability. It is suitable for the representation of concepts and classifications. It is also suitable for the representation of a taxonomy hierarchy [3][4].

A frame comprises a frame name, slots or attributes of the frame and facets [5][6]. For clarification, frames can be classified into class frames and instance frames. Class frames are used to describe group of objects or class of objects and can also be organized into taxonomy. A class frame therefore has parent and children as common slots. Slots from a parent frame can be inherited to its children. Instance frames, on the other hand, describe particular object instances. They are the leaf node of the taxonomy and have no children [4][5][6][7][8].

Facets are used to control slot values and corresponding operations. It can be used to establish initial slot value, slot data type, possible value range and next activity to be performed. Validation rules, trigger operations and derivation rules are common facets as well.

Frames are similar to objects in object programming and databases but the most important difference between them is the former lacks the encapsulation property. Objects are encapsulated but frames are not. Attributes of an object class cannot be seen from object users. They can only see method signatures. Objects without encapsulation which is well known under the name "object relational" are therefore a perfect match of the frame concept. This is the reason why an object relational DBMS is employed in this research project.

3 Coupling between expert system and databases

As mentioned earlier, the coupling between an expert system and a database system extends the capability of the former to have access to larger databases [9]. There are several systems that have the capability such as the Perk database [10], EcoCyc [9], PARKA-DB [11] and Sophia [12]. All of them employ relational databases to record facts.

The Perk database connects to a database using OKBC operations [10] and refers to frames in the database by loading frames into the main memory for inferences. Its later versions employ object views and uses indexes to point to the required frames. EcoCyc system and PARKA-DB keep frames in relational database and load them into the main memory when required. Sophia also keeps frames in relational database and use SQL query for frames loading. All of them do not have the inference capability on the database side. Only tuples of relations are transfer to the expert systems.

In the following section, we propose an architecture which employs an inference engine on the database side. Frames are kept in an object relational database. The expert system can request derived facts which can be obtained as a result from the inference that takes place on the database side. Since the database side has frames and the inference capability, we therefore call it an external knowledge base.

4 The System Architecture

Fig.1 shows the architecture of the FORXDB (Frame-based Object Relational Expert Database system). The novel feature of this architecture is that it has an inference engine on the knowledge base side (the server side) as well as the client side. Frames are on both the knowledge server side and expert system (client) side. The client-side frames are those that involve user interaction and fact acquisition. Inference on this side can lead to a reference to the facts on the external knowledge server that can be inferred from other server-side frames.

The client expert system side comprises the user interfaces both for the expert and the user, the frame-based internal knowledge base, the knowledge base maintenance tool and the client-side inference engine. The external knowledge server comprises an inference engine, an object relational DBMS, the frame-based knowledge base and other databases that belong to other information systems. These systems are the data sources of the external knowledge base.

In a consultation session, the user consults the client-side frame-based expert system. The main purpose of this client-side inference is to gather current information on the subject matter. The inference rule in the first frame will choose the most suitable next frame to go to. Several frames may be visited on this client side before the client expert system gathers enough information which are to be sent to the knowledge base system on the server side for further inference.

Inference on the external knowledge base side focuses on using existing facts which are already stored in the knowledge base and other relevant information systems. The result of this knowledge base inference is sent back to the client-side expert system and finally to the user.

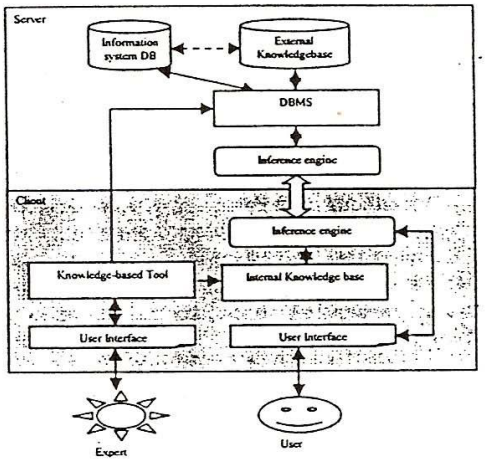

Fig. 1 The FORXDB System Architecture

5 Implementation Issues

5.1 The Meta Tables

The FORXDB on frames is kept in system tables. Fig. 2 shows an Object Role Model (ORM) [13] diagram that describes frames. Corresponding meta tables with some sample data are shown in Fig. 3.

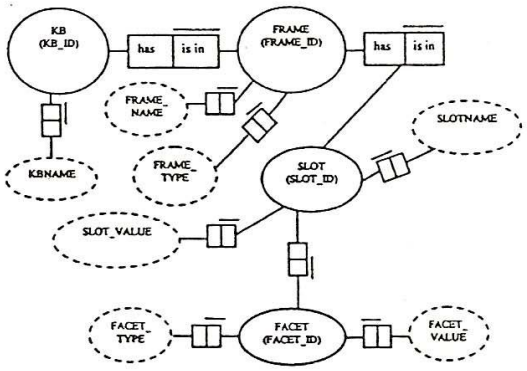

Fig.2 An ORM schema that describe frames

KB

KB_ID	KBNAME
100	Sensor

FRAME

FRAME_ID	KB_ID	FRAME_NAME	FRAME_TYPE
1	100	Thermostat	Class
2	100	Thermostat1	Instance

SLOT

SLOT_ID	FRAME_ID	SLOTNAME	SLOT_VALUE
1	1	Air_Conditioner	
2	1	Furnance	
3	1	Mode	
4	1	Setting	
5	1	Temperature	
6	1	Room	
7	2	Parent	Thermostat
9	1	Children	Thermostat1

FACET

FACET_ID	SLOT_ID	FACET_TYPE	FACET_VALUE
1	3	Default	Heat
2	4	Default	68
3	5	Default	65

Fig.3 Meta tables obtained from Fig.2 and some sample data

5.2 External Database Data Source

In this project, data from existing information systems are used as the data source to the FORXDB system. Inferences are performed on frames which refer to other frames until a fact is found in a database. Methods are employed in order to refer to facts on the data source without copying them permanently to the frames. Thus avoid data inconsistency when updates are made to the data source.

In this project, Oracle 10g object-relational DBMS is used to manage the external knowledge base. Since Oracle 10g has a feature called dblink which allows an Oracle DBMS to refer to other Oracle databases and use SQL data manipulation statements directly on them. In the case that the external databases are not Oracle, a utility called OCA (Oracle Open Client Adapter) can be used to retrieve facts from them. In the implementation of the FORXDB system, only fact retrieval is required so we are well-equipped with data access tools.

Facts which can be obtained from an external source are predefined by the expert. For example, patient records in hospital information systems are needed for a medical expert system consultation. If the required records are not available, then the expert system will ask the user interactively. Frames that interact with external databases are instance frames. Their corresponding class frames have attached procedures in the facet. The instance frames actually inherit these procedures from them.

5.3 Object Relational Database

An object relational database supports non-atomic attributes. A table needs not represent a relation in the traditional sense. Multi-valued attributes, composite attributes and simple attributes are allowed. User-defined data types (UDT) are also allowed. These UDT comprises other attributes and methods and are fully encapsulated.

The concept of types and instances are clearly distinct. Unlike some simple relational database implementation that mixed the concepts of relational schema and relation in to a table, object relational allowed types (or row types) to be separately declared from table instances. Fig.4a shows a sample table Student with a composite attribute NAME and a multi-valued attribute COURSE.

Student

ID	NAME		COURSE
	FIRST	LAST	
st031	Jane	Hunter	Economy
			Pianning
st072	Richard	White	Computers in Engineering

Fig 4 An object relational table

The corresponding row type and table definitions together with some sample insertions are shown below:

```
CREATE ROW TYPE Student (
 id CHAR(5),
 name ROW (first VARCHAR(12), last
VARCHAR(20)),
 course SET (VARCHAR(128) NOT NULL)
);
CREATE TABLE students OF TYPE Student;
INSERT INTO students
VALUES (
 'st031',
 ROW('Jane', 'Hunter'),
 SET('Economy', 'Planning')
);
INSERT INTO students
VALUES (
 'st072',
 ROW('Richard', 'White'),
 SET('Computers in Engineering')
);
```

Subtype hierarchies and methods are also supported. The following SQL codes show the creation of the super type EMPLOYEE and subtypes PROGRAMMER and REPRESENTATIVE.

```
CREATE TYPE EMPLOYEE AS OBJECT (
 NAME VARCHAR2(20),
 SALARY NUMBER(6,2)
) NOT FINAL;
CREATE TYPE PROGRAMMER UNDER
EMPOLYEE (
 LANGUAGE VARCHAR2(12),
 PROJECT VARCHAR2(30)
);
CREATE TYPE REPRESENTATIVE UNDER
EMPLOYEE (
 REGION VARCHAR2(30)
);
CREATE TABLE employees OF EMPLOYEE,
CREATE TABLE programmers OF
PROGRAMMER;
CREATE TABLE representatives OF
REPRESENTATIVE;
```

The object relational table is neither a relation nor an object since it allows non-atomic attribute without encapsulation. The encapsulated part is a user-defined data type.

6 A Prototype Medical Diagnosis Expert System

Medical diagnosis is a process that requires skilled and qualified physicians. In remote areas where doctors are not available when required, other less qualified health care personals may have to do the job. A medical diagnosis expert system will be an invaluable tool in such situations. Patient's records, symptoms and illness history are essential information for the diagnosis process. It is clear that some information should be available on external databases (such as the patient's records) and others have to be obtained from patient's interviews.

A frame-based expert system uses set of rules for inference. Rules are facets in slots. There is a trigger mechanism that checks activities on a slot. If add, if need, if change and if remove are typical facets which take action when slot value is manipulated. In the FORXDB system, forward chaining is employed. Since the system has 2 inference engines, one on the client side and another one on the knowledge base (knowledge server) side, inference can be done on both sides. The client side first takes care of user interaction to

obtain current information interactively while the server side takes care of the inference from recorded or historical information.

In the medical diagnosis system, the client - side inference engine guides patient through relevant questions based on the given symptoms. Fig.5 shows an instance frame Basic Question1 which is created from a class frame Basic Question. The user specifies the earache symptom and the corresponding slot value is set to true. The If Change attached procedure of the slot will refer to the frame instance "symptoms to earache" which leads to further information on the patient. Finally, patient information frame instances are created. It will be submitted to the knowledge base system on the server side for further inference.

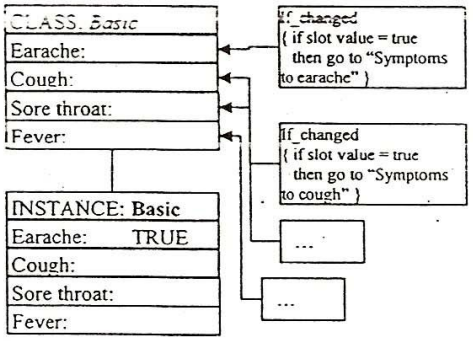

Fig. 5 Sample frames on the client side.

There are two techniques that are employed for the server side inference. The first one is to keep the frame instances from the client side as server side frame instances. Methods on the slots will direct inference to the final goal. The second technique is to keep information from the client as parameters of store procedures which in turn, carry on the inference. This second approach is suitable for small amount of information is received from the client side. Fig. 6 summarizes the inference activity in the frame system.

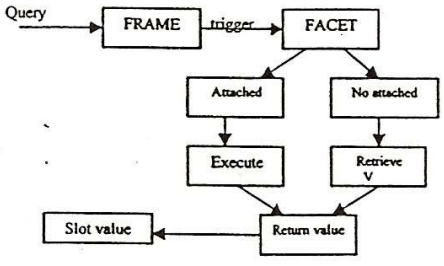

Fig. 6 Frame inference mechanism

Frames on the client expert system side guide the patient's interview process and send information obtained to the server whose frames access external databases and perform diagnosis. Appendix A shows server-side frames of ear-related problems and appendix B shows client-side frames of earache cases.

8 Conclusions

The paper presents a frame-based expert system architecture that has an inference engine on both the client consulting expert system and on the knowledge base. Inferences that are performed on the client side are mainly user's interviews and interactive fact gathering. Inferences on the knowledge base side are performed based on already known facts recorded on the databases. Frames are implemented using object relational database technology.

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Appendix A: Some server-side frames of ear-related problems.

frame	slot	slot value	facet	facet value
basilar skull fracture	Parent	-		
	Earache	yes	default	yes
	Head injury	yes	default	yes
	Cerebrospinal fluid otorrhea	yes	default	yes
Secondary otalgia (referred pain)	Parent	-		
	Earache	yes	default	yes
	Pain on pulling the auricles	no	default	no
Primary otalgia (Disease of the Ear)	Parent	-		
	Children	External Ear ,Middle Ear, Inner Ear		
	Earache	yes	default	yes
	Pain on pulling the auricles	yes	if changed	if slot value = no then go to "Secondary otalgia"
External Ear	Parent	Primary otalgia		
	Children	otomycosis ,acute cellulitis ,furunculosis, herpes, relapsing polychondritis		
	Pain and swelling of external ear	yes	default	yes
			if changed	if slot value = no then go to "Middle Ear"
Middle Ear	Parent	Primary otalgia		
	Children	AOM, OME, Trauma to TM		
	Otitis media	yes	default	yes
			if changed	if slot value = no then go to "Inner Ear"
Inner Ear	Parent	Primary otalgia		
	Children	Bell palsy, Temporal bone tumor		
Otomycosis	Parent	External Ear		
	Characteristic of ear wax	{white plaque ,black spore}*	constraint	{white plaque ,black spore}
Acute cellulitis	Parent	External Ear		
	Infection and inflammation	yes	default	yes
Furunculosis	Parent	External Ear		
	Small firm tender red nodule in skin	yes	default	yes
Herpes	Parent	External Ear		
	Itch	yes	default	yes
	Burning pain	yes	default	yes
	Small red bumps or blisters appear around auricles and mouth	yes	default	yes
Relapsing polychondritis	Parent	External Ear		
	inflammation and deterioration of cartilaginous tissue	yes	default	yes
	inflammation of other connective tissue	{hearing loss ,eyes inflammation, joint inflammation}*	constraint	{hearing loss ,eyes inflammation, joint inflammation}
	Serology test	negative	default	negative
Ear Trauma	Parent	External Ear	Ear Trauma	Parent
	Trauma to auricles	yes	default	yes
Foreign body	Parent	External Ear	Foreign body	Parent
	Foreign body	yes	default	yes
Impacted cerumen	Parent	External Ear	Impacted cerumen	Parent
	partial loss of hearing	yes	default	yes
	a sensation of fullness in the ear	yes	default	yes
Acute otitis media (AOM)	Parent	Middle Ear		
	Pus in the middle ear	yes	default	yes
	Infection	yes	default	yes

			If changed	If slot value = no then go to "OME"
	redness of the eardrum	yes	default	yes
Otitis media with effusion (OME)	Parent	Middle Ear		
	Glue ear	yes	default	yes
	Presence of fluid in the middle ear	yes	default	yes
	Infection	no	default	no
			If changed	If slot value = yes then go to "AOM"
Trauma to TM	Parent	Middle Ear		
	Trauma to eardrum	{Barotrauma, Blunt trauma, Laceration}*	constraint	{Barotrauma, Blunt trauma, Laceration}
Bell palsy	Parent	Inner Ear		
	Unilateral or bilateral acute facial nerve palsy	yes	default	yes
Temporal bone tumor	Parent	Inner Ear		
	-	-		

* one of them

Appendix B: Some client-side frames of earache cases

frame	slot	slot value	facet	facet value
Basic Question	Earache		if changed	if slot value = yes then go to "Symptoms to earache"
	Cough		if changed	if slot value = yes then go to "Symptoms to cough"
	Sore throat		if changed	if slot value = yes then go to "Symptoms to sore throat"
	Fever		if changed	if slot value = yes then go to "Symptoms fever"
Symptoms to earache	Earache	yes	default	yes
	Severe head injury		if changed	if slot value = yes then go to "Emergency"
	Pain on pulling the auricles		if changed	if slot value = yes then go to "Primary otalgia"
Emergency	Cerebrospinal fluid otorrhea		if changed	if slot value = no then go to "Symptoms to earache" and set "Severe head injury" = no else admit
Primary otalgia	Characteristic of external ear		default	normal
			constraint	{Normal ,Inflammation}
	Characteristic of ear wax		default	normal
			constraint	{normal, white, black}*
	Itche		default	no
			constraint	yes/no
	Inflammation		default	no
			constraint	yes/no
	Characteristic of eardrum		default	normal
			constraint	{normal ,redness of the eardrum ,glue ear ,perforation of eardrum}*
	symptoms about facial nerve		default	normal
			constraint	{normal ,Unilateral or bilateral acute facial nerve palsy}