Spanish Natural Language Interface for a Relational Database Querying System

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Abstract. The fast growth of Internet is creating a society where the demand on information storage, organization, access, and analysis services is continuously growing. This constantly increases the number of inexperienced users that need to access databases in a simple way. Together with the emergence of voice interfaces, such a situation foretells a promising future for database querying systems using natural language interfaces. We describe the architecture of a relational database querying system using a natural language (Spanish) interface, giving a brief explanation of the implementation of each of the constituent modules: lexical parser, syntax checker, and semantic analyzer.

1 Introduction

Providing simple access to database systems has become one of the problems of great interest for users and developers of database querying systems, especially since Internet became popular. Users are looking for systems that facilitate the use of databases, trying to reduce the time and effort required for learning how to use them [13]. To satisfy this demand, developers have designed and implemented friendlier interfaces. One of the most popular types of such interfaces is natural language interface (NLI).

Traditional natural language processing (NLP) has not yet provided database-querying systems with all the benefits that can be obtained from it (especially for the Spanish speaking community). Limited scope systems have been developed, mainly for a few languages such as English; some examples of these systems are California Restaurant Query, Expedia Hotels, GeoQuery [16], Hollywood [5], JobQuery [14], Masque/SQL [1], SQ-HAL [12], and SystemX [3].

Despite the long history of NLP and the numerous techniques developed, most of the work has been carried out for English; the situation with the Spanish language is far behind as compared with other major languages. This is especially worrisome, considering the spread and large population of the Spanish-speaking community in the world (390 million), and therefore the potential market for Spanish NLP tools.

P. Sojka, I. Kopeček, and K. Pala (Eds.): TSD 2002, LNAI 2448, pp. 123–130, 2002.

Most of the NLP work done so far for Spanish is devoted to applications that have little or no relation with NLIs to databases (NLIDBs), for example: text interpretation [6], spelling correctors [11], and processing tools [7,9]. Only a few projects have dealt with NLIDBs, being the most important the following: GNBD [15], SISCO [10], and Sylvia-NLQ [4].

Most of NLIDB projects for Spanish have approached database querying from the AI perspective. Thus, they have focused mainly on deductive databases and overlooked the vast majority of existing database systems: relational databases, data warehouses, and object-oriented databases. The aim of the project described in this paper is to design and implement a relational database querying system with a natural language interface for the Spanish language.

The paper is organized as follows. First, the general architecture of the system is presented. Then, the implementation of the lexical parser, syntax checker, semantic analyzer, and the result presentation module is described. Then, domain customization issues are discussed. Finally, concluding remarks are given.

2 Architecture

The architecture of the querying system consists of two main modules: Database Query module and Domain Customization module – see Figure 1.

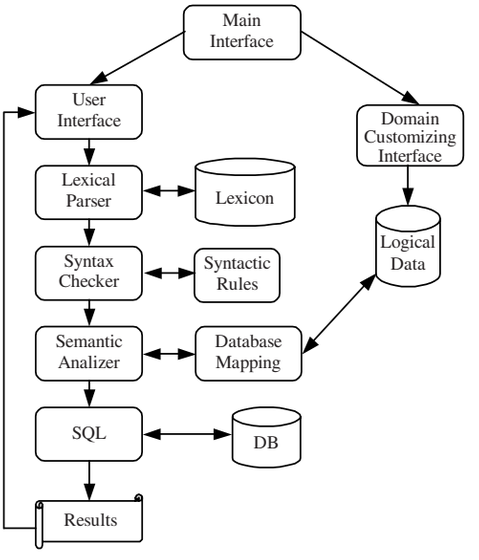

Fig. 1. System architecture.

The *Database Query module* is the main part of the system. The user types in its query through the user interface submodule. It is processed by the lexical parser, syntax checker,

and semantic analyzer, which translate it in an SQL expression. The results of the SQL query are passed back to the user again through the user interface submodule.

The *Domain Customization module* is used to customize and maintain the data and dictionaries used by the NLP modules of the system. It interacts with the system administrator through the domain customization interface submodule.

A brief description of the implementation of the main components of the query module is presented below; the customization module is discussed later.

3 Lexical Parsing

Lexical parsing is in charge of reading the input sentence (query) and dividing it into words, which are minimal meaningful units also known as tokens. Then, it identifies the tokens in the lexical dictionary (lexicon) and retrieves the information about each token. Finally, it passes the tokens with the associated information on to the syntax checker and semantic analyzer.

The lexical parser interacts with the lexicon, which contains all the words that are expected to appear in user's queries. For each word, the dictionary includes its part of speech (noun, verb, article, etc.), gender, and number; the format of this dictionary is independent of the parser code. For this project, a database was used for storing each word, its type (part of speech) represented by an integer number according to Table 1, and subtype (the combination of gender and number, when applicable).

Table 1. Representation of the syntactic category.

Word	Type
Interrogative adjective	1
Article	2
Noun	3
Adjective	4
Auxiliary verb	5
Verb	6
Adverb	7
Preposition	8
Conjunction	9
Pronoun	10
Punctuation mark	11
Relational operator	12
Error	*

4 Syntax Checker

Wrongly understood queries can cause incorrect and confusing results to be delivered to the user, which is potentially dangerous since the user may rely on them to make important decisions. Thus, of crucial importance for reliability of NLIs is verification that the query has the expected pattern that the system can understand correctly.

The syntax checker verifies that the queries have the expected structure. It checks the relationship among words according to their role in the sentence to make sure that the input sentence satisfies a predefined order or pattern.

For this purpose, the checker verifies if the string of tokens received from the lexical parser can be generated by the grammar. It informs the user if any syntactic error is detected and prevents the suspicious query from further processing.

After evaluation of existing types of syntax checkers, a state transition matrix approach [6] has been considered the most convenient because of the following reasons: the implementation of the algorithm is simple since it handles uniformly all the grammar rules; it permits to modify and add new rules to the grammar without having to change the algorithm code. The use of a state transition matrix permits the expansion of a grammar just by adding new states or syntactic categories to the matrix.

The grammar we currently use has the form of a simple bigram check: each word of the sentence is checked to be compatible with the immediately following word. Table 2 shows a fragment of the state transition matrix currently used for syntax checking. Of course, in the future a more sophisticated grammar can be implemented using the same program code but a different matrix.

Table 2. Fragment of the state transition matrix.

	I.A.	Art.	Noun	Adj.	Aux.V.	V.	Adv.
State	1	2	3	4	5	6	7
0	1	*	*	*	*	6	*
1	*	*	3	*	5	6	*
2	*	*	3	*	*	*	*
3	*	*	3	4	5	6	7
4	*	*	*	*	5	6	*
5	*	2	*	*	*	6	*
6	*	2	3	*	*	*	7
7	*	*	*	4	*	*	7

* Error

Since each syntactic category is represented by an integer number, the interaction with the state transition matrix is realized through this number. Using the state transition matrix, the syntax checker determines if the first word of the sentence is an interrogative adverb or a verb (state 0, first line of the table); if so, the current state is updated and the next iteration is performed. For example, considering the following question:

¿Cuántos créditos tiene Erika Alarcón? (1)

'How many units has Erika Alarcón?', the checker output is the following:

cuántos 'how many'	créditos 'units'	tiene 'has'	Erika Alarcón
1	3	6	3

If a syntactic error is found, i.e., the current word is not expected in the present state, the program will display a message indicating the error type and will stop the parsing process, since it will not be able to determine the next state to move into.

Additionally, the bigram method is used to verify the morphological compatibility of each pair of adjacent words. The lexical parser supplies with each input word its gender (feminine, masculine, neuter) and number (singular, plural, neuter); the value "neuter" is used when the gender is not defined (*estudiante* 'student') or not applicable (e.g., for adverbs), and similarly for the number. If two adjacent words have incompatible genders (feminine versus masculine) or numbers (singular versus plural), an error is reported.

5 Semantic Analyzer

Upon successful completion of syntax checking, the semantic analyzer extracts the meaning of the sentence and generates a logical structure. In this module, the sentence is analyzed again to identify the key words with which the system can interpret the query; in this way the analyzer obtains the meaning of the query.

This process is carried out using logical predicates [1] which constitutes the keystone of the semantic analyzer, since they permit to determine the words involved in the query for its successful execution. For this, each noun is looked up in a table where the logical predicates are stored. For example, consider the query (1) and the logical predicates shown in Table 3; the matching predicate for the question is *créditos* 'units', which needs a student *name* or *id number* as a parameter.

If a match occurs, the sentence is explored once more to obtain the data needed by the parameters of the logical predicate. When the parameter type is not explicit in the query, the analyzer looks for the parameter data in the database, in order to determine its type. This is done by finding the field name that corresponds to each of the possible parameters associated to the logical predicate.

Table 3. Fragment of the logical predicate information.

Predicate	Parameters
id number	name
especialidad 'major'	name
especialidad 'major'	id number
nombre 'name'	id number

Predicate	Parameters
créditos 'units'	name
créditos 'units'	id number
promedio 'average mark'	name
promedio 'average mark'	id number

In the example (1), the parameter data is *Erika Alarcón*. In this case the parameter type is determined by accessing first the word-to-field mapping information shown in Table 4, which indicates that the possible database fields associated to the parameter data are *STUD_ID* and *STUD_NAME*. Then the analyzer generates the following query to find *Erika Alarcón* in the field *STUD_NUM*:

```
select count(*) from STDATA where STUD_ID = 'ERIKA ALARCON'
```

In this case the database manager will not find a student whose *id number* is *Erika Alarcón*, and thus the analyzer will issue a similar query to check if there is any student with this name (using STUD_NAME instead of STUD_ID), which returns a positive answer.

Table 4. Fragment of lexicon words to database field mapping information.

Word	DB Field	Table	Database
id number	STUD_ID	STDATA	ACAD
major	STUD_MJR	STDATA	ACAD
name	STUD_NAME	STDATA	ACAD
units	STUD_UNITS	STDATA	ACAD
average mark	STUD_AVG	STDATA	ACAD

Each time a matching predicate is found and its corresponding parameter data is obtained, it is written in a structure called *logical data storage structure*. This structure holds the field names whose information is requested by the user, the database name, the table name, and the search conditions. The data structure for the example (Equation 1) is shown in Table 5. If no matching predicate is found, the system displays to the user a message asking for a reformulation of the query.

Table 5. Logical data storage structure.

Requested Data	Condition Parameter	Parameter Data	Table
STUD_UNITS	STUD_NAME	`'ERIKA ALARCON'`	STDATA

6 Results Module

The results module translates the natural language sentence into the target formal language. In this project, SQL (Structured Query Language) has been chosen as the target language for two reasons: (1) SQL is the most widely used query language for commercially available relational database engines and (2) this will enable the system to be used with many different databases.

This module accesses the logical data storage structure and extracts the field names whose data are requested and the search conditions. Using this information, the module constructs the SQL statement, which is executed with the selected database, and the result is presented to the user. The SQL query generated for the example (1) is:

```
select STUD_UNITS from STDATA where STUD_NAME = 'ERIKA ALARCON'
```

7 Domain Customization

This module was implemented in order to make the querying system independent of the underlying database, thus enabling the system to issue queries to different databases or tables without any need to modify the system software.

The domain customization module was implemented as a Java servlet so that it can be used over the Internet or intranet. This module provides an interface that permits the system administrator to establish a relationship between the words of the lexicon and the database fields, since the field names are usually abbreviated (e.g., word: *major*, field: STUD_MJR). Therefore, with this information the semantic analyzer will know which field corresponds to a given word in the query. Additionally, the system administrator can add words to the lexicon and define their syntactic category, gender, and number.

The domain customization module can only be used by an advanced user (administrator); otherwise, if an unauthorized person uses this module and enters erroneous data, the system could fail or generate incorrect results. To prevent this situation, access to this module is restricted by a password.

8 Final Remarks

Since 1997 our group has been implementing software tools that facilitate inexperienced users to query databases. One of these tools is a QBE (Query by Example) graphical interface [17] for querying relational databases via Internet. This interface allows simultaneous access to two or more databases and the formulation of queries that involve a combination of information from all open databases [8]. In order to facilitate the formulation of queries involving joins of two or more database tables, a new interface (EzQ) is being developed [2]. This new interface will permit users to formulate such queries even if they are not familiar with the concept of join (difficult to understand for users that are not information systems professionals).

A reflection about graphical interface limitations has revealed that it would be extremely difficult to further increase the ease of use of QBE interfaces to meet the needs of the majority of the Internet users, which are not information systems professionals. Therefore, in order to achieve this goal we considered necessary to include another technology: NLIs.

The work described in this paper constitutes the first step for providing the current system with an interface, as friendly as possible, that will involve both graphical and NLIs. Unlike most NLIDB projects for the Spanish language, we are approaching NLIDB issues from the information systems perspective.

Our current version of the Spanish grammar (syntax checker) handles 10 different simple and compound sentence patterns. The semantic analyzer has been tested with a specific domain (academic department database); however, it was implemented in such a way that it can be used for other domains just by changing the information supplied through the domain customization module.

Acknowledgements This work was done under partial support of CONACyT and SNI (Mexico) and RITOS-2 (CYTED).

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