Improving Searchability of a Music Digital Library with Semantic Web Technologies

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***Abstract*—Traditional search systems are usually based on keywords, a very simple and convenient mechanism to express a need for information. This is the most extended way of searching the Web, although it is not always an easy task to accurately summarize a natural language query in a few keywords. Working with keywords means losing the context, which is the only thing that can help us deal with ambiguity. This is the biggest problem of keyword-based systems. Semantic Web technologies seem a perfect solution to this problem, since they make it possible to represent the semantics of a given domain. In this paper, we present three projects, Harmos, Semusici and Cantiga, whose aim is providing access to a music digital library. We will describe two search systems, a traditional one and a semantic one, developed in the context of these projects and compare them in terms of usability and effectiveness.**

I. Introduction

For some years now, we have been living in a world where the Web has been dominated by plain textual contents. These have been reachable thanks to search engines and directories, which have been designed to work in a keyword environment. The main problem of a keyword-based system is ambiguity. Unfortunately, the meaning of a keyword can only be determined by its surroundings (if available). The concept of "context" can not be applied in this situation.

The same happens when we look for multimedia resources, which are becoming more and more important lately. A picture (or a video or audio file) can not usually be reduced to a set of words[1]. In order for users to share this kind of contents, they must provide some keywords to make them reachable by other users. In this way, a conventional system can give access to both textual and multimedia resources. There are hundreds of relationships between the semantic descriptors used to tag the multimedia resources. However, this information is not taken into account when a search is processed.

The type of queries a keyword-based system can accept are quite limited and semantically poor. A keyword in a text field can mean anything. We have no information about its nature: it could be the name of a city, an address, the title of a book, a date, a person's name or even an identifier. If we named that text field, we could partially restrict the meaning of the keyword, e.g. the keyword is a date. But what is the semantics of this date? In the context of the projects this paper presents, it could be the date a master class was recorded, the date a composition was composed, the birth date of a composer... We need to move to a new search paradigm that allows us to ask more semantically complex questions, e.g. "I want to find compositions by Nordic composers."

Changing the search paradigm or, let us say, the system interface, would not be enough to provide better results. We could find a way to let the user express very accurately what she is looking for but we will need to change the structure that supports the knowledge of the system if we really want to exploit the semantic relationships that link all the concepts involved. An ontology may help us define rules that would enrich the knowledge base with more information than what is explicitly stated.

In this paper, we will present the changes we have introduced in a traditional system in order to improve its searchability both in terms of usability (changing the interface) and effectiveness (changing the structure that supports the knowledge base). We will also discuss how we have progressively improve our system in the context of three projects we have been or are involved in: Harmos, Semusici and Cantiga.

In Section II, we will present our previous and current work in the field, describing the three projects we have just introduced. In Section III, we will describe MagisterMusicae, the system built for Harmos. In Section IV, we will explain how we have improved this system in the context of Semusici and Cantiga. In Section V, we will describe Cantiga Search System. An evaluation of the improvements of this system over the one introduced in Section III will be conducted in Section VI. Finally, we will review some related projects and present our conclusions and future work in Sections VII and VIII, respectively.

II. Research Context

A. Previous Work

The work presented in this article comes from the experience in several projects related to music digital libraries with the common aim of providing Internet access to music resources hold by different institutions. The collection we have been working with contains more than 700 audiovisual hours

[1] It is possible to automatically extract features from multimedia resources and use them as tags, but it is a costly process.

of recorded master classes, property of Fundación Albéniz [1]. These resources have been tagged according to a set of tags that define a vocabulary of pedagogical concepts, which we will talk about later.

The first of this series of music related projects we have been involved in was European eContent Harmos project. Harmos produced a collection of audiovisual contents belonging to the music heritage, where education was the principal focus and the project's main objective. The resulting system is available at http://www.magistermusicae.com. We will describe this system in the next section. The aim of the second project, Semusici, was to improve Harmos system by applying Semantic Web technologies. The main output of this project was Semusici ontology.

B. Cantiga Project

The goal of the last of this series of projects, Cantiga, is to investigate how Web 2.0 technologies can be applied to the cataloging and search of music resources. In this project, we are trying to develop a platform that will help users annotate and find contents of digital libraries from different music institutions. This platform is also intended to provide a framework to help these institutions communicate (both internally and externally) and interact, allowing them to create workflows. These workflows should help automating such tasks as translation, quality control and other administrative procedures. The system will also support federated search across all the libraries available.

In order to decrease the high cost of manual cataloging, the system uses advanced tools to semi-automatically extract features from the multimedia resources. This will help users annotate these resources, which will make it easier to retrieve them. We are also using Semusici ontology to classify the resources. Using a formal structure to model the domain will make searching faster and will increase the precision and recall of the system. The reason is that users will be able to produce more accurate queries and will get a whole set of semantically related results.

III. MagisterMusicae Search System

MagisterMusicae, the system developed in the context of Harmos, is a simple search system based on facets. This is a search paradigm in which keywords are placed in slots[2], the so-called *facets*, that have a certain semantics. The main interface consists on a series of drop down menus (as shown in Fig. 1) that allow the user to search a master class given the instrument it is oriented to, the teacher giving the lecture and the composer who composed the piece of music being played in the class. To simplify the process of searching, a teacher can only be selected in case an instrument has already been chosen. Also, a teacher has to be selected before chosing a composer.

The advanced search interface (Fig. 2) allows the user to select a series of keywords

[2]In this case, the user is asked to select values instead of filling text fields.

Fig. 1. MagisterMusicae Basic Search Interface

belonging to seven different categories: Instruments, Teachers, Students, Concepts, Composers, Works and Movements. This makes it possible to look for a master class without knowing anything about the instrument it is addressed to. There is much more information about the master classes available in the knowledge base (dates, places, languages...) that can not be used to build a query in this system. Including a tab for every single category would probably have made users refuse the system.

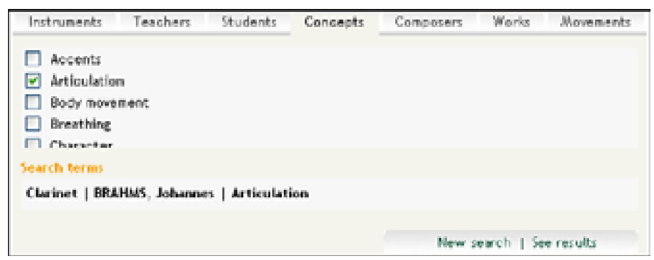

Fig. 2. MagisterMusicae Advanced Search Interface

Neither of the two search systems allow the user to type any term of her choice, as they both provide a guided search service. Internally, MagisterMusicae uses a relational database to store the information (no ontology is used). The selected keywords are used to build a simple SQL query which is expected to deliver a list of master classes fulfilling all the requirements the user has posed.

IV. Improving Searchability

The system we have just described has certain limitations, which will be discussed in the next section. The following subsections will present our work in improving the way users access the contents of the Fundación Albéniz master classes collection. We have been particularly concerned about the effectiveness of the system in terms of number of results delivered when the knowledge base has no explicit information about some fact. This is a key point in Semantic Web technologies, since the structures they propose have the ability to make explicit knowledge that is implicit in a given domain [2].

A. Applying Semantic Web Technologies

As we have already said, Semusici intended to improve the results of Harmos by introducing Semantic Web technologies. An ontology was built in order to support all the information contained in Harmos database. As we will see later in this section, most of the knowledge is hidden behind the relationships between the concepts involved. An ontology, by definition, represents a formal model of the common interpretation of the entities and relationships of a given domain (or, as Gruber said, "an explicit specification of a conceptualization" [3]). Therefore, it has great powerful retrieval and inferential capabilities. Another reason why we chose this structure is that it makes it possible to easily import information from external sources in order to enrich the knowledge base.

The knowledge base we have been working on has two distinct parts. The first one captures all the information that can be useful to answer any query that is not directly related to the pedagogical aspects of a master class. For instance, "Show me all the recordings related to composers born in the 18th century." This part of the knowledge base contains all the information about the context of a master class, mainly biographical and bibliographical data.

The other part of the knowledge base is the concepts taxonomy. This taxonomy contains over 350 pedagogical concepts that are used as tags to describe the recordings. It was built from Harmos pedagogical taxonomy [4] following a bottom-up strategy in order to redistribute the concepts in a way their relationships could be exploited[3]. This taxonomy aims to cover the whole spectrum of music practice and teaching, focusing on pedagogical aspects, such as technique (general or specific of an instrument), mechanics, musicology, musical elements (rhythm, melody, harmony, form...), etc.

Semusici ontology consists of more than 150 classes and almost 40 properties. We may distinguish four substructures:

- A Domain ontology. It includes classes such as `Composition`, `Instrument`, `Composer`, `Teacher`, and other concepts that characterize a composition, such as `Genre`, `Style` or `Form`. It also contains the class `Person`, representing those who are involved in a master class or have composed a piece of music, and the class `Place`, which will help us geographically locate the master classes, as well as indicate where a person was born or dead.
- The Instrument taxonomy, which is part of the domain ontology. Instruments have been classified according to the family they belong to. Every instrument is an instance of a class representing its family (`StringInstrument`, `WindInstrument`, `PercussionInstrument`...). The taxonomy these families conform has been modelled using SKOS [5].
- A Resources ontology. This ontology models the multimedia resources that support the master classes (mostly videos, but also audio files and documents) and their features. It includes concepts such as `Class`, `Multimedia` and its subclasses `Video`, `Audio` and `Document`, and the properties `title`, `date`, `language`, `targetAudience`, etc.
- The Concept taxonomy. This taxonomy contains the new and improved distribution of the pedagogical concepts assigned to the master classes and has also been modelled using SKOS. The different categories are arranged hierarchically under the class `Concept`. Properties such as `relatedTo`, `partOf` and `elementOf` are used to semantically relate concepts.

[3]The original distribution had very little semantic information and the elements in each level were not always equally specific.

B. Linking the Ontology with External Data Sources

We also decided to include links to external data sources. Our aim was to populate our ontology with information that is not usually provided by the annotators, but is related to the subject of the master classes. There are many sites that offer a wide variety of RDF data sources, like Geonames [6], MusicBrainz [7], CIA Factbook [8], DBpedia [9], etc.

We wanted to provide a way to allow the system perform geographical entailments. We chose CIA Factbook as our source. The CIA Factbook is an annual publication of the Central Intelligence Agency of the United States with information about the countries of the world. The Factbook provides a summary of the demographics, geography, communications, government, economy, and military of 266 countries, dependencies and other areas in the world.

We linked our geographical resources (instances of the class `Place`) with the corresponding entries in the CIA Factbook. This means we can now relate composers, compositions and master classes in terms of their location. We could even geolocate them and draw a map with all the items associated to each place, in order to help users find information in a more visual way. Moreover, this newly incorporated knowledge can help us find resources in an area of any size, even if the only information we have is the name of a city somehow associated to those resources (being the place where the class took place, the place where a composer was born...).

C. Alternative Search Paradigms

The purpose of the Semantic Web is to improve the way users access the vast amount of information that is available through the Internet. The systems providing this access have made users change their natural way of expressing their need for information, that is using natural language. At this moment, the use of keyword-based queries is so extended that is difficult to conceive any other mechanism of searching the Web. For most people, it is very simple and fast to summarize what is in their heads in a few words (which is actually very little information about what they are looking for).

The main problem of keyword-based systems is ambiguity. The correct meaning of a word can not be determined without considering its context. Unfortunately, in a traditional keyword-based system there is no such context. The key to solve this is adding semantics both to the query and the resources users are looking for. Of course this would mean to restructure the whole Web, which is impossible. But applying this to restricted domains can really improve the search.

There are many ways users can express their need for information without losing the context. A popular paradigm of search is faceted search. As we have already seen (as it is the case of MagisterMusicae), we build the context of the query by navigating through different categories, which are usually arranged in a taxonomy.

In order to fully keep the context of the query, users should express it in natural language. Unfortunately, it is very difficult for a system to correctly process a natural language query. We would then need a solution combining both the advantages of semantics and keywords. The nearest solution to a natural language processing (NLP) system would be a template-based one.

In a template-based system, we associate a template to a keyword (or a set of keywords). This makes it possible to produce more complex queries. For instance, we could specify that the date in the example we proposed in the Introduction is "the date when the composer of the composition that is referred to in the master class I am looking for was born." The only thing the user has to do is select the template that best suits the semantics of the keyword she wants to search for.

The number of templates should be limited to a few ones in order not to overwhelm the users with too many alternatives. Otherwise, they may feel they are choosing an option among the available ones. Instead, we want to provide them with an intuitive way to build the request they have in mind. Users may be able to quickly choose the proper context to what they know about what they are looking for.

V. Cantiga Semantic Search System

The prototype built in the context of Cantiga is a result of all the improvements presented in the last section. Its core is an extended version of Semusici ontology and its interface is based on templates. We analyzed the current state of the knowledge base and discarded those queries that would not retrieve any content. This dramatically decreased the number of possible templates. However, the underlying ontology allows a much more diverse set of queries, based on properties of compositions and composers that have not yet been used. This will make it possible to include a whole lot of new queries when the knowledge base grows.

We have adapted the traditional one-level model of templates into a hierarchical one. Instead of using a single level of templates, we decided to group the queries according to common components of meaning, in order to let the user combine these pieces and build a whole template. Our intention is to give her the impression of being progressively restricting the meaning of the piece of information she wants to search for. Besides, we do not want to overwhelm her by offering her too many options at a time, as we have already said.

We built a tree with the fragments of templates. This tree has up to 5 levels of depth. Each branch defines a restriction on the meaning of the piece of information the user is looking for. A total of 35 templates were defined, each of them represented by a path that goes from the parent node to each leaf node of the tree.

The parent node of this tree is *"Which classes,"* since that is what the user is ultimately looking for. The first level contains fragments of queries about the parameters of a master class. For example, we find the piece *"were held in X?,"* which means that the value "X" introduced by the user is not only a place, but "the place where the master classes took place." In the case of *"are addressed to X?,"* "X" is "the audience for whom the classes are meant."

Whenever we found a parameter representing a complex concept, e.g. a `Composition`, a new level was added to the tree. Following this example, we created a second level whose parent node is "*refer to a composition*." This level contains new fragments of queries concerning the properties of a composition, e.g. "*of the form X*," "*composed by*," etc. We proceeded the same way until every path reached a leaf node, i.e. one that contained a field to be filled by the user.

This way, the user would build a template selecting the path that best restricts the meaning of the term she intends to look up, e.g. "*Which classes refer to a composition composed by someone born in X?*" The interface of this system can be seen in Fig. 3.

VI. Evaluation

Cantiga seach interface proved to be much more easy-to-use and intuitive than MagisterMusicae's. First, in MagisterMusicae the user was expected to select an instrument before continue searching, which is pretty convenient in case one is a performer or a music student. However, this is a huge drawback if you are just interested in master classes taught by a certain teacher or referring to a certain piece of music, no matter what instrument they are focused on.

Of course there is the advanced search interface, but still this is not the interface presented to the user in the first place. Neither of MagisterMusicae interfaces allows the user to provide any keyword of her own. She will need to find the piece of information she already knows among hundreds of options in order to select the proper value.

Cantiga search interface, on the other hand, provides a simple way to build a query that is really expressed in natural language. As opposed to MagisterMusicae's case, the user will not be selecting search parameters but the context of a keyword she will be able to provide. In the worst case, the user will have to make five selections (which is the number of levels of the template tree) in order to complete a whole template. However, the feeling she will get is the feeling of building a sentence and not just adding conditions to a query. In short, Cantiga template system provides a natural way that feels closer to the way human beings express restrictions.

One thing that has not been considered in Cantiga is conjunctive queries. While MagisterMusicae advanced search

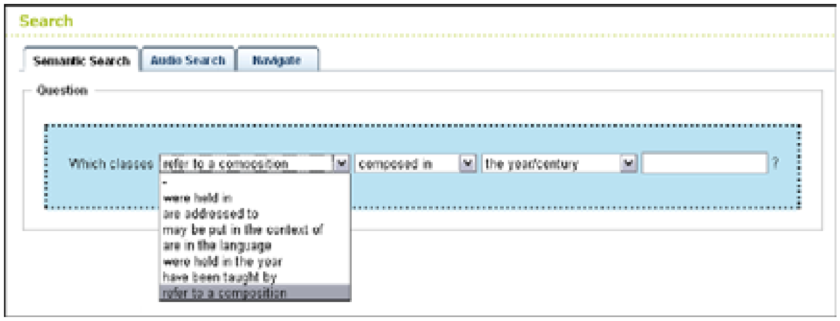

Fig. 3. Cantiga Semantic Search System

allows the user to look for a master class establishing more than one condition, Cantiga search system is only able to take one piece of information provided by the user at a time. This could be arranged by letting the user choose not just one template, but any number of them (one for each known detail about the master class she is looking for). For example, "*Which classes refer to a composition composed by someone born in X and composed for an instrument of the Y family?*"

About the coverage, we tested both systems in order to check if they met the users' needs. We took 73 sample queries that were collected[4] during the specification phase of the ontology building process as a test set. We had previously used those queries as competency questions [10] in order to select the concepts the ontology was expected to formalize. This set included all kinds of questions, from rather simple ones (e.g. "I want to find classes taught by Argentinian teachers") to very complex biographical ones (e.g. "Find all the classes referring to composers who used to work on commission").

It turned out only 8 out of the 73 queries were considered in the first system, whereas 18 were included among the 35 templates of Cantiga search system. Even if we increased the number of facets, only 13 more queries could be processed by MagisterMusicae search system. This limitation is due to the lack of flexibility of the facet search paradigm, in terms of semantics. It is impossible to express a complex relationship in a system based on facets. For instances, we could never build a query such as "Which classes have been taught by a teacher whose first name is the same as Liszt's?" or "Find all the classes referring to works composed by the author of 'Tosca.' "

The combination of a semantic layer and a template-based interface is what makes Cantiga search system much more powerful. That is why up to 30 more of the test queries could be included as templates in this system. In fact, the reason why there are yet 25 more questions that could not be processed by this system is that they deal with rare concepts we decided not to include in the ontology.

Perhaps the greatest value of Cantiga search system lies in its expandability. Adding a new query to this system can be done by just adding the corresponding template, whereas adding a new query to MagisterMusicae's involves not only including a new facet, but also showing every possible search value the user could introduce. And this would only be possible assuming the semantics of the query can be expressed using facets.

[4]A survey was carried out among musicians and music students and lovers in order to find out what kind of queries they would like to be able to ask.

Finally, there is still another important reason why Cantiga search system performs better than MagisterMusicae. Let us say a user wants to look for master classes about strings technique. The knowledge base may have no record of any class related to the concept "strings technique," yet the system would be able to retrieve some results concerning "violin technique" or "double bass technique." The reason for this is that the ontology contains information that links these concepts. The mere fact of placing them in a hierarchy represents some implicit knowledge that can be used in situations such as this (i.e. a parent-child is inferred).

The interconnection with an external datasource such as the CIA Factbook also allows to search using all kind of geographical data. For instance, the system would provide an answer to "Which master classes have taken place in a European country?," although such information is not present in our knowledge base. We could even find "master classes referring to a composer born in any country bordering Austria."

VII. Related Work

In the past few years, there has been interesting research on the field of semantic search. In [11], the possibilities of using a view-based search paradigm to create intelligent search interfaces on the Semantic Web are explored. This thesis also presents a survey on semantic search related projects. Five research directions are identified: augmenting traditional keyword search with semantic techniques, basic concept location, complex constraint queries, problem solving and connecting path discovery. Our system would be part of the third group. According to this analysis, the main concern of this group is developing user interfaces that make creating complex query patterns as intuitive as possible. Other examples following this direction would be [12], [13] and [14].

There are some other approaches to template-based semantic search. In [15], a non-hierarchical template system is presented. This system uses templates of queries expressed in natural language with variable parts for substitution purposes.

These queries correspond to real-life questions and problems, just like in our case. The system was built into the JeromeDL [16] system, a semantic digital library engine that uses Semantic Web and Social Networking technologies to improve browsing and searching for resources.

This template-based system intends to provide access to publications, such as articles, books, etc., using only five templates. We have to consider that the domain it covers is much more limited than the one covered by Cantiga. The semantics of these templates is rather simple. Therefore, in this case it would not be necessary to split up the templates. Still, a flat structure such as this would not be acceptable if the number of templates increased. Another difference with our system is that it works with conjunctive queries, as one of the templates presents two slots to be filled by the user.

A more complex solution to semantic search is proposed in [17]. They present an approach for translating keyword queries to DL conjunctive queries using background knowledge available in ontologies, i.e. formally interpretating keyword queries. As we too did before, they discuss whether users really want to express themselves using natural language or maybe they find working with queries satisfying enough.

Finally, we can find some interesting web portals related to semantic search in the specific domain of music resources. The most important one is mSpace [18]. This service provides access to musical contents using bibliographical information associated to those contents, their classification and the relation between the corresponding categories. There are also some other interesting works on applying Semantic Web technologies to digital libraries, like [19] or [20].

VIII. Conclusions and Future Work

In this paper, we presented our work in the field of semantic search through three projects whose purpose was to provide access to a music digital library. We have compared two different systems developed in the context of these projects in terms of usability and effectiveness. The semantic search system proved to be more flexible and powerful than the traditional one, thanks to the use of an ontology and a template-based interface.

We have proposed a solution to semantic search that combines both the advantages of semantics and keywords. Our hierarchical template-based prototype does not support user-generated natural language queries, but it includes a set of real-life questions that can be extended as needed. We will keep on researching new ways of searching that do not entail the drawbacks of a NLP system, but allow a more flexible and intuitive way of expressing the semantics of a query.

Finally, we have enriched our ontology by linking it to the CIA Factbook. We are currently working on linking it to other DBpedia datasets in order to improve the coverage of the system. We would also like to exploit a lexical resource such as WordNet [21] to perform semantic query expansion.

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