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# Combining different standards and different approaches for health information retrieval in a quality-controlled gateway

**Lina F. Soualmia**[a,b,*], **Stéfan J. Darmoni**[a,b]

[a] *CISMeF Team, L@STICS, Medical School, Rouen University Hospital, 1, Rue de Germont, 76031 Rouen Cedex, France*
[b] *PSI Laboratory, INSA and Rouen University, Place Emile Blondel, BP 68, 76131 Mont Saint Aignan Cedex, France*

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**Summary** Internet as source of information is increasing in preeminence in numerous fields, including health. We describe in this paper the CISMeF project (acronym of Catalogue and Index of French-speaking Medical Sites) which has been designed to help the health information consumers and health professionals to find what they are looking for among the numerous health documents available online. The catalogue is founded on two standards: a set of metadata and a terminology based on the MeSH thesaurus which has the same structure and use as an ontology of the medical domain. The structure of the catalogue allows us to place the project at an overlap between the present Web, which is informal, and the forthcoming Semantic Web. Many features of information retrieval and navigation through the catalogue were developed. These features take into account the kind of the end-user (health professional, medical student, patient). The CISMeF-patients catalogue is a sub-catalogue of CISMeF and is dedicated to the patients and the general public. It shares the same model as CISMeF whereas MEDLINE and MedlinePlus do not. We also propose to couple two approaches (morphological processing and data mining) to help the users by correcting and refining their queries.

## 1. Introduction

The amount of health information available on the Internet is considerable. Information retrieval remains problematic: users are now experiencing huge difficulties in finding precisely what they are looking for, among the tons of documents avail-

* Corresponding author.
*E-mail address:* lina.soualmia@chu-rouen.fr (L.F. Soualmia).

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able online. Generic search engines (for example Google[1]) or generic catalogues (for example Yahoo[2]) cannot solve this problem efficiently because they usually offer a selection of documents that turns out to be either too large or ill-suited to the query. Free text word-based (or phrase-based) search engines typically return innumerable completely irrelevant hits requiring much manual weeding by the user, while missing important information resources. Free text search is not always efficient and effective: the sought page might be using a different term (synonym) that points to the same concept; spelling mistakes and variants are considered as different terms; search engines cannot process HTML *intelligently*. We propose in this paper to combine two knowledge-based methods (natural language processing and knowledge discovery in databases) in the KnowQuE (Knowledge-based Query Expansion) [1] prototype meant to focus and expand a user query and cope with the problems of free-text based search into the catalogue CISMeF[3] [2] (acronym of Catalogue and Index of French-speaking Medical Sites). CISMeF has been developed since 1995 to help health professionals, as well as students and the general public, with their search for electronic health information. All the resources (documents and Web sites) indexed in the CISMeF catalogue are described by the librarians using the vocabulary of a structured terminology that may be assimilated to the concept of ontology in the medical domain, and a set of metadata based on the Dublin Core [3]. The first KnowQuE module is composed by a morphological knowledge base that has been built according to the terminology. Recent works [4—6] present the contribution of morphological processing to information retrieval in French. For example for a query on '*asthmatic child*' the module should return documents on '*children with asthma*'. Lexical resources (in French) are needed for the medical vocabulary. The second module is founded on association rules [7] between terms, extracted from the indexed resources by a data mining technique. These association rules are used in the information retrieval process. For example the association rule '*prevention of breast cancer* → *mammography*' is extracted because '*prevention of breast cancer*' and '*mammography*' are frequently used conjointly to index the resources. Applying the association rule, a query on '*mammography*' should return documents on '*prevention of breast cancer*'. The resources stored in the CISMeF catalogue are indexed with a set of metadata and according to a terminology, founded on the MeSH thesaurus, which has the same structure and use as an ontology of the medical domain. The structure of the catalogue allows us to place the project at an overlap between the present Web, which is informal, and the forthcoming Semantic Web [8]. The paper is organized as follows: The section "Towards a medical Semantic Web'' describes the modeling of the CISMeF metadata and terminology and "Ontology exploitation'' the exploitation of these two standards in the Web site of the catalogue, mainly information retrieval and navigation. ''Enhancing information retrieval'' will detail two approaches to enrich the terminology and hence to improve information retrieval. ''Conclusion and future work'' includes the conclusions and outlines some future directions for work.

## 2. Towards a medical Semantic Web

The Semantic Web [8] is an infrastructure that has to be built. It aims at creating a Web where information semantics are represented in a form that can be understood by humans as well as machines, better enabling computers and people to work in co-operation. One of its advantages is to bring sufficient information on the resources, by adding annotations in the form of *metadata* and to describe formally and significantly their content according to an *ontology*. This infrastructure must be formalized. The current Web is informal: it is mainly composed of HTML pages, hand-written or generated automatically, for human treatment only. Ontologies and metadata are two major components for the construction of the Semantic Web. Ontologies are powerful tools that may remove ambiguity: they provide a controlled vocabulary of terms and some specification of their meaning and are very useful for interoperability, browsing and searching. Metadata describe Web information resources enhancing information retrieval and enabling accurate matches to be made while being totally transparent to the user. Many projects and tools using ontologies have been developed for information retrieval but also for classifying and indexing.

The CISMeF catalogue describes and indexes a large number of health information resources ($n$ = 13,452). CISMeF references high quality information resources. A resource can be a Web site, Web pages, documents, reports and teaching material: any support that may contain health information. CISMeF and Doc'CISMeF, its associated search tool, take into account the diversity of the end-users and allow them to find good quality resources. These resources are selected according to strict criteria by the team of librarians and are indexed according

[1] http://www.google.com.

[2] http://www.yahoo.com.

[3] www.chu-rouen.fr/cismef.

to a methodology [2] which involves a four-fold process: resource collection, filtering, description and indexing. CISMeF is a quality-controlled gateway such as defined by Koch [9]. The following elements characterize a typical quality-controlled subject health gateway and are fulfilled in CISMeF: selection and collection development, collection management, intellectual creation of metadata, resource description (a metadata set), resource indexing (with controlled vocabulary system). In order to include only reliable resources, and to assess the quality of health information on the Internet CISMeF uses the main criteria (e.g. *source*, *description*, *disclosure*, *last update*) of the Net Scoring [10] and the HIDDEL language (High Information Description Disclosure Evaluation Language) [11]. We describe in the following the set of metadata elements and the terminology ''oriented'' ontology [12] used in the catalogue.

## 2.1. The CISMeF metadata

The notion of metadata appeared before Internet but its interest has grown with the number of electronic publications and digital libraries. ''The Semantic Web dream is of a Web where resources are machine understandable and where both automated agents and humans can exchange and process information''.[4] The solution proposed by the W3C is to use metadata to describe the data contained on the Web and to add semantic markup to Web resources, thus describing their content and functionalities, from the vocabulary defined in ontologies. Metadata are data about data or in the Web context, data describing Web resources. When properly implemented, metadata shall unambiguously describe resources, so enhance information retrieval.

In CISMeF we use several sets of metadata. Among them there is the Dublin Core (DC) metadata set, which is a 15-element set, intended to aid discovery of electronic resources. The resources indexed in CISMeF are described by 11 of the elements of Dublin Core: *author*, *date*, *description*, *format*, *identifier*, *language*, *editor*, *type of resource*, *rights*, *subject* and *title*. DC is not a complete solution; it cannot be used to describe the quality or location of a resource. To fill these gaps, CISMeF uses its own elements to extend the DC standard. Eight elements are specific to CISMeF: *institution*, *city*, *province*, *country*, *target public*, *access type*, *sponsorships* and *cost*. The user type is also taken into account. CISMeF defined two additional fields for the resources intended for the health professionals: indication of the *evidence-based medicine* and the *method* used to determine it. In the teaching resources 11 elements of the IEEE 1484 LOM (Learning Object Metadata) ''Educational'' category are added.

In 1995 the metadata format was HTML. In 2000, in order to allow interoperability with other platforms the XML language became the metadata format. Since December 2002 RDF, a basic Semantic Web language, has been used within the EU-project MedCIRCLE framework [11] in which CISMeF is a partner. This project was initiated to qualify the quality of health information and to guide consumers to trustworthy health information. The vocabulary of the HIDDEL metadata is included in an ontology (represented in RDF Schema) and the resources are described in RDF according the concepts of the HIDDEL ontology.

## 2.2. The CISMeF terminology

The catalogue resources are indexed according to the CISMeF terminology, which is based on the MeSH (Medical Subject Headings) [13] thesaurus of MEDLINE and its French translation. The MeSH was selected because it fulfills the aims of medical librarians and it is well known by the health professionals. Approximately 22,000 descriptors (e.g.: *abdomen*, *hepatitis*) and 84 qualifiers (e.g.: *diagnosis*, *complications*) compose the MeSH thesaurus in its 2003 version. These concepts are organized into hierarchies going from the most general on the top of the hierarchy to the most specific in the bottom of the hierarchy. For example, the descriptor *hepatitis* is more general than the descriptor *hepatitis viral A*. The qualifiers, also organized into hierarchies, allow to specify which particular aspect of a descriptor is addressed. For example the association of the descriptor *hepatitis* with the qualifier *diagnosis* (noted *hepatitis/diagnosis*) restrict the *hepatitis* to its *diagnosis* aspect. The specializations relations between concepts are extracted from the MeSH text files to define the subsumption relationships in the CISMeF descriptors hierarchy ($n$ = 9765).

MeSH descriptors and qualifiers are organized into hierarchies that do not allow a complete view concerning a specialty. The descriptors and qualifiers in CISMeF are brought together according to *metaterms* (e.g.: *Cardiology*). Metaterms ($n$ = 67) concern medical specialties and it is possible to know the sets of the MeSH descriptors and qualifiers that are dispersed in several trees and are semantically related to the same specialty. In addition to

[4] I. Horrocks, IEEE Intell. Syst. (2002).

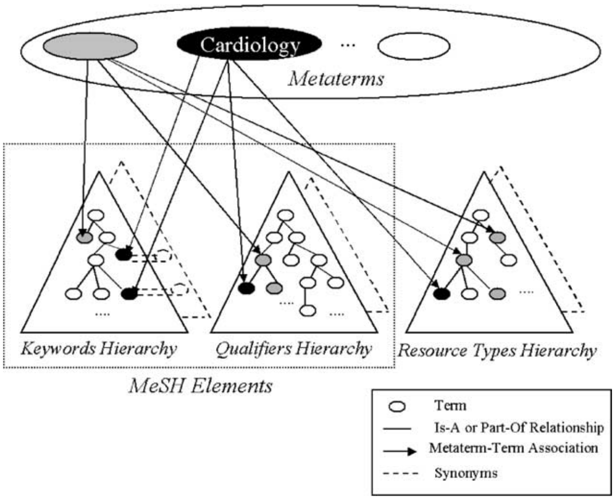


**Fig. 1** The CISMeF terminology structure.

the set of metaterms, the CISMeF team has modeled a hierarchy of *resource types* (*n* = 127). They describe the nature of the resource (e.g.: *teaching material*, *clinical guidelines*) and are a generalization of the MEDLINE publication types. In fact metaterms have been created to optimize information retrieval in CISMeF and to overcome the relative restrictive nature of MeSH descriptors. For example a search on ''*guidelines in cardiology*'' or ''*databases in virology*'', where *cardiology* and *virology* are descriptors and *guidelines* and *databases* are resource types, will yield few or no answers. Introducing *cardiology* and *virology* as metaterms is an efficient strategy to obtain more results because instead of exploding one single MeSH tree (Information retrieval and navigation), the use of metaterms will result in an automatic expansion of the queries by exploding other related MeSH or CISMeF trees besides the current tree.

The CISMeF terminology (Fig. 1) has the same structure as a terminological ontology [14]:

- The vocabulary, that describes major terms of the medical domain, is well known by the librarians and the health professionals.
- Each concept has:
  - a preferred term (descriptor) to express it in natural language,
  - a set of properties,
  - a natural language definition that allows to differentiate it from the concepts it subsumes and those that it is subsumed by,
  - a set of synonyms,
  - a set of constraints to apply to the qualifiers. For example the qualifier '*Complications*' could only be used for the '*Diseases*' arborescence and not for the '*Anatomy*',
  - a set of equivalences. For example the association '*Hepatitis/chemically induced*' is equivalent to the descriptor '*Hepatitis, toxic*'.

All the information described and the annotations related to the resources indexed in the catalogue are stored in a relational database, managed by Oracle®, and exploited in the CISMeF Web site.

## 3. Ontology exploitation

### 3.1. Resource indexing and classification

The CISMeF ontology is exploited for several tasks: resource indexing (manually and automatically), visualization and navigation through the concept hierarchies and information retrieval using the Doc'CISMeF search engine. Each catalogue resource is indexed according to the vocabulary of the ontology (terms being descriptors, qualifiers, and resource types). Using heuristics and a rule-based classification algorithm [15], the related specialties to a resource are deduced due to the existing semantic links between (metaterm, descriptor), (metaterm, qualifier) and (metaterm, resource type) and are ranked according to their level of importance.

### 3.2. Information retrieval and navigation

The navigation through the ontology, based on alphabetical and thematic indexes, allows the user to know the terms that represent the concepts used in the domain and also their positions in the different hierarchies. Each term has its own Web page and a set of links, which represent preformatted queries, enabling the user to retrieve all the resources that are related to this term. S/he can also restrict the search according to his category: resources intended for health professionals, students, patients and the general public. The other and main utility of the ontology is its exploitation by the search engine. Different modes are possible. ''*Simple search*'' is done via an interface in which the user can tape in queries in natural language (French or English, with or without accents, capital letter or not). ''*Advanced search*'' is a more precise search: it uses frames and drop-down lists and different attributes (keywords, titles, year) can be combined with Boolean operators (And, Or, NOT). ''*Logical search*'' done with Boolean operators and a specific query language with particular characters. Currently, the *simple search* is based on subsumption relationships. If the query (a word or an expression) can be matched with a concept of the ontology, then the result of the query is the union of the resources that are instances of the concept, and the resources that are instances of the concept it subsumes, directly or indirectly, in all the hierarchies it belongs to (explosion). For example a query on ''*hepatitis*'' will return as answer all the resources related to *hepatitis* but also those related to *hepatitis A*, *hepatitis B*, etc. If the query cannot be matched to a concept of the ontology, the search is done over the other fields of the metadata elements set. In the worst case, a full-text search is carried out. Doc'CISMeF is interoperable with PubMed. A query is transformed automatically into the PubMed syntax. French queries cannot be matched directly with PubMed, as it accepts only English keywords. But by using Doc'CISMeF it is possible: the query is translated automatically into its correspondent in English and by clicking a generated link a new query into the PubMed syntax is performed, only if the query corresponds to a MeSH descriptor or a qualifier.

### 3.3. CISMeF-patients: a sub-catalogue dedicated to the general public

Due to the important quantity of information for the patients and the general public, written by health professionals, medical institutions and associations of patients, the sub-catalogue CISMeF-patients [16] was designed in 1997. CISMeF-patients and CISMeF share the same terminology. CISMeF-patients is a specific view that corresponds to the metaterm *Patient* in the CISMeF catalogue. Popularized synonyms were associated to the terms at each level of the model. The synonyms are terms used in the current language (e.g. '*mania*' is a popular synonym of '*bipolar disorder*') and were determined thanks to a collaboration with the patients' associations. The navigation into CISMeF-patients can be done through an index of medical specialties ($n$ = 34). A general index of all terms used in CISMeF-patients is also available ($n$ = 343). This avoids the layperson to type its queries on the search interface. Preformatted queries are applied on Doc'CISMeF and are generated automatically when a user clicks on a keyword link. Therefore, the user is neither obliged to know the MeSH descriptor, nor the query language used in the Doc'CISMeF search tool. The corresponding query generated is: patient [metaterm] And [descriptor]. For example, in the case of clicking on '*mania*' the generated query is: patient [metaterm] And bipolar disorder [descriptor]. The patient resource types are the following ones: *hot lines*, *associations of patients*, *news group and discussion list for patients*, and *patient and health consumer information*.

Another type of access is available via the '*life periods*'. It is similar to the 'life events' of HealthInsite. These periods are: *birth*, *child*, *adolescence*, *adult* and *aged*. By clicking on the links, it is possible to obtain automatically the related information resources of these periods. For example, the query generated automatically on Doc'CISMeF for *Birth* is the following one: new born [descriptor] And patient [resource type]. The major difference between MedlinePlus and CISMeF-patients is the structure of the terminology. CISMeF-patients and CISMeF share the same terminology whereas MedlinePlus and MEDLINE do not: another terminology has been built for MedlinePlus. CISMeF-patients and CISMeF also share the same search tool Doc'CISMeF. The benefit of sharing the same terminology and search tool is the possibility to extend the patient query to another one using another resource type than *patient*. For example '*clinical guidelines*' for evidence based medicine resources, or '*education*' for teaching resources. A patient searching information about '*leukemia*' will have access to '*patient*' resources. There are two links to other preformatted queries to find other resource types: leukemia [descriptor] And clinical guidelines [resource type] and leukemia [descriptor] And educational material [resource type].

### 3.4. Other features: major topics and search strategies

Any search could be limited to Major Topics of each level of the CISMeF terminology. Major Topics exist in the MEDLINE database for descriptors and qualifiers. In CISMeF Major Topics are extended to resource types and metaterms. This task is manually performed by CISMeF medical librarians for resource types, and automatically performed for metaterms: a metaterm is Major for a CISMeF resource if and only if at least one descriptor, qualifier or resource type, which is semantically linked to this metaterm is Major for the same CISMeF resource (minor if not).

Another kind of preformatted queries has been modeled: the *search strategies*. A search strategy is a medical concept defined by a Boolean expression composed by several other concepts of the ontology. For example: dental surgery = (dentistry, operative [descriptor] Or tooth extraction [descriptor]) Or (tooth replantation [descriptor] Or ((dentition [descriptor] Or tooth diseases [descriptor]) And surgery [qualifier])) urological surgery = urology [metaterm] And (surgical procedures, operative [descriptor] Or surgery [qualifier]).

## 4. Enhancing information retrieval

The submitted queries over the search engine are seldom matched to the vocabulary. We have extracted and analyzed the kind of queries of the http server and their associated number of answers between the 15th August 2002 and 6th February 2003. 1,552,776 queries were extracted. Among them 892,591 (58.62%) were submitted via the *simple search* interface and 365,688 (40.97% of the simple queries) had no answer. To enhance this kind of information retrieval, which is largely used over the catalogue, we have developed the KnowQuE [1] prototype founded on morphological processing and association rules mining. The details of the results obtained are presented in [17,18].

### 4.1. Morphological processing

A major task in information retrieval is to match a query with a document. It may be achieved by query normalization (lemmatization by reducing a word to its lexeme, stemming by reducing a word to its root form) or by query enrichment (by adding inflexions or derivations). In the Web, the user queries are frequently composed by few words. Many works have addressed ‘terminological variation’, which can be processed at different levels: characters [19] (spelling and accenting mistakes, case variants), words and their morphological variants [20—22], syntax [22], or concepts with general-language [23]. Phonemic matching is yet another method to match words based on their pronunciations. Finally, recent works [4—6] show the contribution of morphological processing for information retrieval in French. The general observation is that lemmatization brings about a statistically significant improvement and that stemming additionally improves the results, but in a non-statistically significant way.

#### 4.1.1. Principles

To reduce the silence of the system and the number of empty answers, the morphological processing in the first KnowQuE module is founded on the following operations:

*Query segmentation*: the query is segmented into words by using string tokenizers (e.g.: * $,!§;|@).
*Character normalizations*: we apply two types of normalization at this step:

(1) *Lowercase conversion*: all the uppercased characters are replaced by their lowercase version.
(2) *Deaccenting*: all accented characters (e.g.‘‘*éèêë*’’) are replaced by non-accented (‘‘*e*’’). (words in the French MeSH are not accented, and words in queries can be accented or not, or wrongly accented (‘‘*athlètisme*’’).

*Stop words*: we eliminate the stop words (such as *the, and, when*).
*Exact expression*: we use regular expressions to match the exact expression of each word of the query with the terminology. For example ‘***accident***’ will be matched with the term ‘*circulation **accident***’ (but not with ‘***accident**s*’ and ‘*chute**accident**elle*’).
*Morphological knowledge:* we replace each word by its *root* in the morphological family. The root is generally the simple form of the term. A morphological family of a term is composed by its *inflexions* (for example {*accident*, *accidents*}) and *derivations* (for example {*probability*, *probabilistic*}). If the user query is ‘‘*children with asthma*’’ it will be replaced by the Boolean query ‘‘*child* [*descriptor*] *AND asthma* [*descriptor*]’’. The problem is that this kind of knowledge base does not exist yet for the French medical language [24].

#### 4.1.2. Extracting derivations and expanding queries

To build a morphological knowledge-based according to the CISMeF terminology, we have used a French general-domain lexical resource [25]. It is not specific to the medical domain but it allowed us to obtain 2732 morphological families of descriptors (total of 9401; 3388 are composed by one word), 55 families of qualifiers (total 84; 55 of one word) and 28 families of resource types (total 127; 28 of one word). In this first step we have only considered the terms that are composed by one word. The root of a morphological family is the matched descriptor with the terminology (qualifier and resource type respectively) even if it is not in its simple form. By analyzing the other terms composed by two or more words, we have found that 1935 terms (1899 descriptors; 8 qualifiers; 22 resource types) are *semi-matched*. We consider that a term is *semi-matched* when at least one of the words that compose it is matched. For example the descriptor ‘‘*accidents*’’ has as family: {*accident*, *accidents*, *accidenté*, *accidentées*, *accidentel*, *accidentels*, *accidentelle*, *accidentelles*, *accidentellement*, *accidenter*}. Therefore, the descriptor ‘‘*accident circulation*’’ is semi-matched because *accident* is matched and not *circulation*. The semi-matching is useful for the *exact expression* step (Table 1).

We have implemented the algorithm in Java with an ODBC connection to the CISMeF Oracle 8.i database. The different functions of the algorithm (Segmentation, Normalization, Stop Words,

**Table 1** Coverage of the vocabulary

| | Keywords | Qualifiers | Resource types | Terms |
|---|---|---|---|---|
| No. of terms matched | 2732 | 55 | 28 | 2815 |
| One word matching (%) | 80.64 | 100 | 100 | 81.33 |
| Semi-matching | 4631 | 63 | 50 | 4750 |
| Total (%) | 48.80 | 75 | 39.37 | 49.11 |

Exact Expression and Morphological Knowledge) were expressed using SQL queries and regular expressions.

For preliminary results, we have tested the algorithm on a set of 77,382 queries with empty answers, which correspond to 48,255 distinct queries. The size of the queries is small. The 12,974 queries (26.89%) are composed by one word; 16,347 (33.88%) by two words; 10,972 (22.74%) by three words; 4360 (9.03%) by four words; 3602 are composed by more than four words (7.46%).

The 48,255 null queries were segmented into 121,958 words. By applying the different steps of our algorithm, a total of 92,887 terms (76.16%) were matched with the terminology and the morphological base, but 29,071 terms remained unknown (23.84%) (Table 2). Many of the unknown words were spelling errors but, in addition to morphological knowledge, semantic knowledge is necessary, for example *heart* and *cardiac* are semantically related and a syntactic analysis is not adapted.

We have performed a quantitative analysis to match the null queries of the users with the terminology enriched by a morphological knowledge base. As in [4] the ongoing qualitative evaluation is done by the medical librarian.

## 4.2. Data mining

These association rules are used in the information retrieval process. For example the association rule '*prevention of breast cancer* → *mammography*' is extracted because '*prevention of breast cancer*' and '*mammography*' are frequently used conjointly to index the resources. Applying the association rule, a query on '*mammography*' should return documents on '*prevention of breast cancer*'.

**Table 2** Matching the queries

| | Matched terms | % |
|---|---|---|
| Segmentation | 12579 | 10.31 |
| Normalization | 20447 | 16.77 |
| Stop words | 21022 | 17.24 |
| Exact expression | 28837 | 23.64 |
| Morphological knowledge | 10002 | 8.20 |
| Total | 92887 | 76.16 |

The second KnowQuE module is founded on *Association Rules* mining. We apply this data mining technique on the CISMeF database. Our first goal is to extract knowledge in the form of new and interesting association rules between couples of (descriptor/qualifier) from the indexed resources. The second goal is to exploit these association rules in the query expansion process. Association rules were initially used in data analysis and in data extraction from large relational databases [7]. We are interested in the discovery of Boolean association rules.

### 4.2.1. Definitions

A Boolean association rule (AR) is expressed as:

$$AR : i_1 \wedge i_2 \wedge \cdots \wedge i_j \Rightarrow i_{j+1} \wedge \cdots \wedge i_n \tag{1}$$

This formula states that if an object has the items $\{i_1, \ldots, i_j\}$ it also tends to have the items $\{i_{j+1}, \ldots, i_n\}$. To evaluate an association rule, objective measures (based on statistics) and subjective measures (based on human expertise) exist.

The AR *support* (2) represents its utility. This measure corresponds to the proportion of objects that contains at the same time the rule antecedent and consequent

$$\text{support(AR)} = |\{i_1, i_2, \ldots, i_n\}| \tag{2}$$

The AR *confidence* (3) represents its precision. This measure corresponds to the proportion of objects that contain both antecedent and consequent among those containing the antecedent

$$\text{confidence(AR)} = \frac{|\{i_1, i_2, \ldots, i_n\}|}{|\{i_1, i_2, \ldots, i_j\}|} \tag{3}$$

### 4.2.2. Knowledge extraction process

The knowledge extraction process is achieved in several steps: the data and context preparation (objects and items selection), the extraction of the frequent itemsets (compared with a minimum support threshold), the generation of the most informative rules using a Data Mining algorithm (compared with a minimum confidence threshold), and finally the interpretation of the results.

An extraction context is a triplet $C = (O, I, R)$, where $O$ is the set of objects, $I$ the set of all the items and $R$ a binary relation between $O$ and $I$. An itemset is frequent in its context $C$ if its support is higher than the minimal threshold initially fixed (by the user). The extraction problem of frequent itemsets has an exponential complexity in size of $n$, the number of the potential frequent itemsets is $2^n$. The itemsets form a lattice [26] which construction is time and space consuming. The most known algorithm used to extract frequent itemsets is Apriori [7]. In our case we use the A-Close algorithm, which calculates the *closed frequent itemsets* [27] using the semantic based on the closure of the Galois connection [28], reducing by that itemsets space size studied. The algorithm calculates the generators of the frequent closed itemsets. The generators of a closed itemset $I_{close}$ are the itemsets of maximal size which closure is equal to $I_{close}$. New bases for association rules are deduced from the closed frequent itemsets and their generators. These bases consist of minimal non-redundant association rules [27].

In our case, the extraction context is the following: the objects are the annotations used to describe the indexed resources $O$ = {annotations}. The relation $R$ represents the indexing relation between an object and an item with $I$ = {(Keyword/Qualifier)}, the couples of (descriptor/qualifier). We have implemented the A-Close algorithm in Java and tested it on several sets of resources by fixing the support to 10 documents and the confidence to 100% (exact rules) to have an objective measure (Table 3).

### 4.2.3. Evaluation

All the extracted rules (260) were evaluated by an expert (medical librarian) (Table 4). An interesting association rule is one that confirms a hypothesis or states a new hypothesis. In our case, there may be several cases of interesting association rules in function of the existing relationships between the terms of the terminology.

**Table 3** Number of resources and rules extracted for 10 specialties

| Specialty | No. of resources | No. of rules |
|---|---|---|
| Environment | 1254 | 53 |
| Neurology | 1137 | 25 |
| Pediatrics | 906 | 57 |
| Diagnosis | 883 | 33 |
| Therapeutic | 782 | 18 |
| Oncology | 644 | 20 |
| Cardiology | 558 | 2 |
| Psychiatrics | 515 | 3 |
| Allergy | 509 | 36 |
| Gastroenterology | 501 | 13 |

**Table 4** The different kind of rules for each specialty

| Specialty | NW | SA | B | FS | OT |
|---|---|---|---|---|---|
| Environment | 13 | 4 | 7 | 5 | 24 |
| Neurology | 8 | 4 | 1 | 0 | 12 |
| Pediatrics | 0 | 2 | 2 | 1 | 52 |
| Diagnosis | 26 | 3 | 0 | 1 | 3 |
| Therapeutic | 3 | 3 | 2 | 0 | 10 |
| Oncology | 17 | 1 | 1 | 0 | 1 |
| Cardiology | 0 | 0 | 0 | 0 | 2 |
| Psychiatrics | 0 | 1 | 0 | 0 | 2 |
| Allergy | 26 | 3 | 2 | 1 | 4 |
| Gastroenterology | 4 | 1 | 0 | 0 | 8 |

NW: new rules, SA: See Also, B: Brothers, FS: Father—Son, OT: other (not interesting).

It could associate:

- a (in)direct son and its father in the hierarchy (FS),
- two sibling terms that belong to the same hierarchy (same (in)direct father) (B),
- a See Also relationship that exists in the terminology (SA),
- a new relationship considered interesting (NW).

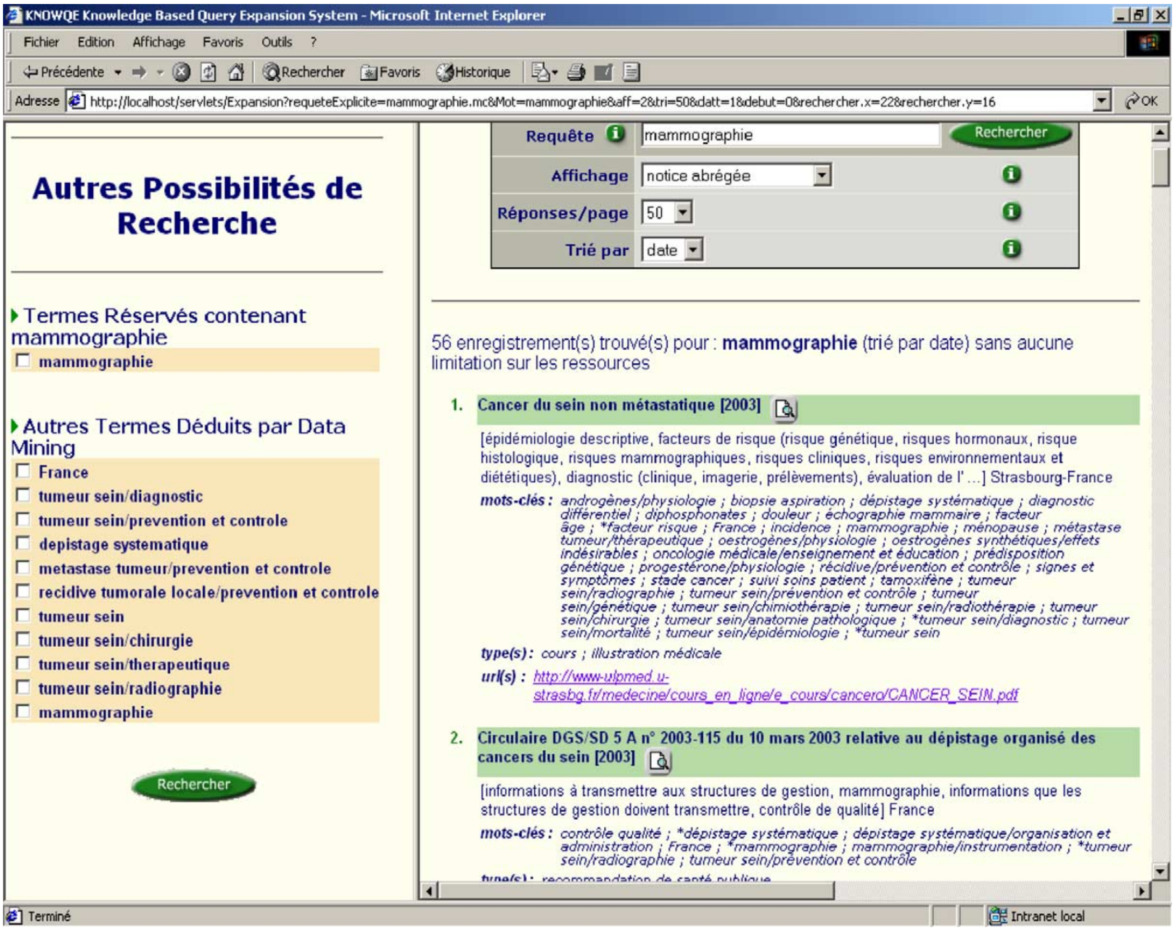
Among the 260 rules, 142 (54.61%) were considered interesting by our expert:

*breast cancer/diagnostic* ⇒ *mammography* (support = 25 documents, confidence = 1),
*aids/prevention and control* ⇒ *condom* (support = 10 documents; confidence = 1).

Among the interesting rules we have obtained:

- 68.31% new rules (NW),
- 14.49% See Also relationships (SA),
- 10.56% Brother relationships (B),
- 05.63% Father—Son relationships (FS).

The Father—Son relationships are already used in the information retrieval process. The other types of interesting association rules could be used to expand the users' queries. A set of elements (descriptors and couples (descriptor/qualifier)) deduced from the association rules are proposed (Fig. 2) to the user who may expand the query by choosing and adding some of them. For example the query '*mammography*' may be replaced by '(*mammography*) [*descriptor*] *OR* (*breast cancer/prevention and control*) [*descriptor/qualifier*]'. The CISMeF team has found these results to be interesting and has included the validated association rules in the CISMeF database in the form of couples (antecedent, consequent).


KNOWQE Knowledge Based Query Expansion System - Microsoft Internet Explorer
Fichier Edition Affichage Favoris Outils ?
Précédente
Rechercher
Favoris
Historique
Adresse
OK
Terminé
Intranet local

Adresse: http://localhost/servlets/Expansion?requeteExplicite=mammographie.mc&Mot=mammographie&aff=2&tri=50&datt=1&debut=0&rechercher.x=22&rechercher.y=16

Requête: mammographie [Rechercher]

Affichage: notice abrégée

Réponses/page: 50

Trié par: date

## Autres Possibilités de Recherche

Termes Réservés contenant mammographie

- □ mammographie

Autres Termes Déduits par Data Mining

- □ France
- □ tumeur sein/diagnostic
- □ tumeur sein/prevention et controle
- □ depistage systematique
- □ metastase tumeur/prevention et controle
- □ recidive tumorale locale/prevention et controle
- □ tumeur sein
- □ tumeur sein/chirurgie
- □ tumeur sein/therapeutique
- □ tumeur sein/radiographie
- □ mammographie

[Rechercher]

56 enregistrement(s) trouvé(s) pour : **mammographie** (trié par date) sans aucune limitation sur les ressources

1. **Cancer du sein non métastatique [2003]**

   [épidémiologie descriptive, facteurs de risque (risque génétique, risques hormonaux, risque histologique, risques mammographiques, risques cliniques, risques environnementaux et diététiques), diagnostic (clinique, imagerie, prélèvements), évaluation de l' ...] Strasbourg-France

   **mots-clés :** *androgènes/physiologie ; biopsie aspiration ; dépistage systématique ; diagnostic différentiel ; diphosphonates ; douleur ; échographie mammaire ; facteur âge ; *facteur risque ; France ; incidence ; mammographie ; ménopause ; métastase tumeur/thérapeutique ; oestrogènes/physiologie ; oestrogènes synthétiques/effets indésirables ; oncologie médicale/enseignement et éducation ; prédisposition génétique ; progestérone/physiologie ; récidive/prévention et contrôle ; signes et symptômes ; stade cancer ; suivi soins patient ; tamoxifène ; tumeur sein/radiographie ; tumeur sein/prévention et contrôle ; tumeur sein/génétique ; tumeur sein/chimiothérapie ; tumeur sein/radiothérapie ; tumeur sein/chirurgie ; tumeur sein/anatomie pathologique ; *tumeur sein/diagnostic ; tumeur sein/mortalité ; tumeur sein/épidémiologie ; *tumeur sein*

   **type(s) :** *cours ; illustration médicale*

   **url(s) :** *http://www-ulpmed.u-strasbg.fr/medecine/cours_en_ligne/e_cours/cancero/CANCER_SEIN.pdf*

2. **Circulaire DGS/SD 5 A n° 2003-115 du 10 mars 2003 relative au dépistage organisé des cancers du sein [2003]**

   [informations à transmettre aux structures de gestion, mammographie, informations que les structures de gestion doivent transmettre, contrôle de qualité] France

   **mots-clés :** *contrôle qualité ; *dépistage systématique ; dépistage systématique/organisation et administration ; France ; *mammographie ; mammographie/instrumentation ; *tumeur sein/radiographie ; tumeur sein/prévention et contrôle*

   **type(s) :** *recommandation de santé publique*

**Fig. 2** Interface of query expansion using association rules (in French).

## 5. Conclusion and future work

We have discussed in this paper some of the problems of information retrieval on the Web. We have presented particular aspects of the CISMeF project, which has been developed to assist health professionals, medical students, patients and the general public in their search for health information on the Web. All the available tools of the catalogue have been developed to be useful for all users. We have also proposed to use two methods to enhance information retrieval. The natural language processing is used to build morphological knowledge base and data mining enables association rules discovery between concepts. Query expansion is now possible in CISMeF thanks to morphological processing and association rules. The third method we are experiencing is terminological reasoning. It is founded on a formal terminological knowledge base built by automatic translation of the terminology into the OWL DL-based language [29] and the resources of the catalogue into instances (or individuals) of the OWL concepts and roles (or classes and relations). As in [30—32], reasoning mechanisms are involved here to verify the knowledge-based consistency but in our case it is mainly to answer queries. By this formalization of the terminology [33] and thus the MeSH, such a formal ontology issued from the MeSH is promising and may be exploited in many applications, based on the MeSH thesaurus, mainly bibliographic databases such as MEDLINE and health gateways, also contributing to the Semantic Web.

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