Using Concept Lattices for Visual Navigation Assistance in Large Databases: Application to a Patent Database

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Abstract. The increasing size of indexed document sets that are digitally available emphasizes the crucial need for more suitable representation tools than the traditional textual list of results. Many efforts have been made to develop graphical tools able to provide both overall and local views of a collection when focusing on a particular subset of documents. However an overcrowded visual representation may not be really useful to users if they are not guided in their navigation process. Our goal is to combine the classification features of FCA and existing visualization techniques to suggest navigation paths in a visual representation through meaningful and progressive focuses. The test collection used for our study is an indexed patent base provided by our industrial partner.

Keywords: FCA, Visual navigation, Semantic navigation.

1 Introduction

The size of digitally available indexed document sets increases every day. However, associated exploring tools are often based on the same traditional model: users send their query and are then answered back with huge lists of results. There is a crucial need for more suitable representation tools where the semantics of the documents are better exploited and may be used as a guideline during navigation through the database. Formal concept analysis (FCA) helps to form conceptual structures from data. Such structures may be used to visualize inherent properties in data sets and to dynamically explore a collection of documents. Indeed the associated mathematical formalization is useful not only to organize the database but also to infer some of the reasoning during the information retrieval process. This paper presents a method that combines FCA and Information visualization techniques to assist visual navigation in large collections. This research has been done in response to an industrial demand: one of our partners is facing the problem of visualizing and browsing a large collection of indexed patents.

The following section will present the context of our research. The state of the art is presented in section 3, particularly concerning information retrieval using FCA and visualization techniques to explore large databases. Section 4 develops our method that combines FCA and visualization tools to assist users for browsing a large collection. Section 5 deals with our current work on a real database provided by our industrial partner. The last section concludes with some of the limits to and perspectives of our approach.

2 Context and Problem Setting

Searching for technical solutions to improve innovation within big companies, I-Nova[1], our industrial partner, develops collaborative platforms to internally share some parts of the company's knowledge. It may be sets of *ideas*, patents, laws, etc. The efficiency of this sharing relies on the participation of every type of employee. Therefore the interface must be intuitive enough to favor the participation of people not familiar with such environments. The major problem consists in visualizing and browsing a large collection of indexed documents. The current platform makes use of a classical search engine which lists retrieved indexed documents (patents, here) corresponding to a certain set of keywords. Two main problems arise: human operators cannot have an overall view of the whole collection and they cannot evaluate changes in the result sets when adding or removing a keyword, because a new list is displayed for each new query. These drawbacks are particularly semantically noisy for the browsing process. We may note here that this problem is the same as the one encountered by people using web search engines like Google.

Much research has been done to graphically represent indexed document sets in general [30], of which several aim to represent patent databases. In MultiSOM [16], the keywords are divided into subsets corresponding to different aspects of the indexation (costs, techniques, etc.) and a self-organized map is computed one by one for each subset, presenting different points of view on the database. When focusing on a specific item of the collection on one particular map, the user can switch to another map presenting the position of the item in the collection with respect to another aspect. This solution solves the problem of providing an overall view of the collection. However users have lost the ability of selecting a subset of patents through a set of keywords and they have no information about why one patent is close to another in the overall view.

Because on the one hand browsing an overall view may be unsuitable for focusing on a particular keyword and on the other hand displaying local results without any overall information causes users to get lost, we present in this paper a method that assists users' navigation from overall to local views. The idea is to "sum up" the collection by coherent local views corresponding to subsets of patents/keywords. These views are ordered as a lattice, defining possible navigation paths that will be suggested to users.

The views' lattice is actually a concept lattice [12]. Using FCA and concept lattice for information retrieval is not new [10] but in these approaches, contents of nodes,

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i.e. local view, are still displayed as a list of results, retaining all the above mentioned problems. Studies on visualization exploration process have been done but mainly in the medical or scientific imagery domain, focusing more on optical transitions between visualizations [14] than on semantic aspects of the information that is displayed. Before going further towards the solution that we propose, let us give some basic FCA definitions.

3 Formal Concept Analysis Background

In this section we briefly recall FCA basic definitions from [2][12].

A *formal context* is a triple (G, M, I) where G is a set of objects, M a set of attributes and I is a binary relation between the objects and the attributes, i.e. $I \subseteq G \times M$.

For a set $O \subseteq 2^G$ of objects and a set $A \subseteq 2^M$ of attributes, we define the set of attributes common to the objects in A, by

$$f : 2^G \rightarrow 2^M \qquad f(X) = \{a \in A \mid \forall\, o \in X, (o,a) \in I\}$$

the set of objects which have all attributes in O, by:

$$g : 2^M \rightarrow 2^G \qquad g(Y) = \{o \in O \mid \forall\, a \in Y, (o,a) \in I\}$$

The pair (f, g) is a Galois connection between $(2^G, \subseteq)$ and $(2^M, \subseteq)$.

A *formal concept* of the context (G, M, I) is pair (O,A) with $O \subseteq 2^G$, $A \subseteq 2^M$ and $A = f(O)$ and $O = g(A)$. A is called the *intent* and O the *extent* of the concept (A,O).

Let L be the set of concepts of (G, M, I) and let $\leq_L$ be a partial order defined as follows: $(A_1,O_1) \in L$, $(A_2,O_2) \in L$, $(A_1,O_1) \leq_L (A_2,O_2) \Leftrightarrow A_1 \subseteq A_2 \Leftrightarrow O_2 \subseteq O_1$

The pair $(L, \leq_L)$ is called the *Galois lattice* or *Concept lattice* of (G, M, I).

The *simplified extent* of a concept *(O,A)* is the set of objects which belong to O and do not belong to any lower concept. In other words, the simplified extent denotes objects that do not have any other attributes than those in A.

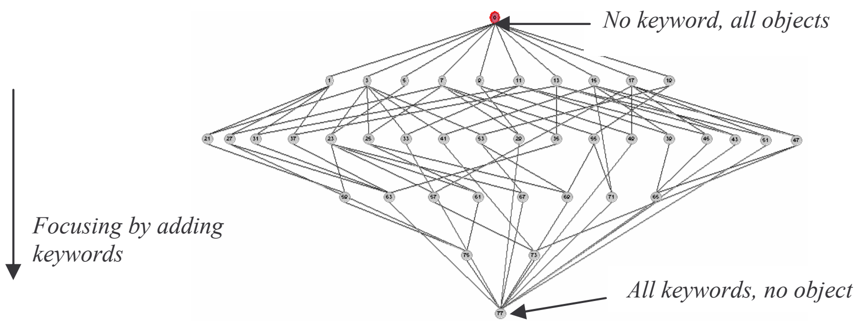

Fig. 1. The Galois lattice computed using Galicia from the patents test database (329 objects, 10 attributes).

In the following we denote indifferently objects as documents or patents and attributes as terms or keywords. The Galois lattice computed from the patent/keyword matrix of our test database is shown in Fig. 1.

4 State of the Art

Searching for a solution to assist the navigation through a large database, we focus particularly on two aspects in the following state of the art: applications that use FCA techniques for information retrieval and visualization techniques that may be used to graphically parse large sets of data.

4.1 Formal Concept Analysis for Information Retrieval

The powerful classification skills of Formal Concept Analysis have found many applications for information retrieval. Some of them have been listed in [23]. Since the early works of [13] on an information retrieval system based on document/term lattices, a lot of research leading to significant results has been done. In [7], Carpineto and Romano argue that, in addition to their classification behaviors for information retrieval tasks, concept lattices can also support an integration of querying and browsing by allowing users to navigate into search results. Nowadays several industrial FCA-based applications like Credo [7] or Mail-Sleuth [11] are available. Mail-Sleuth is an e-mail management system providing classification and query tools based on FCA. This tool allows users to navigate into data and intervene in the term classification by displaying concept lattices. Upstream research has studied the understandability of a lattice representation by novice users [11]. Image-Sleuth [10] proposes an interactive FCA-based image retrieval system in which subjacent lattices are hidden. Users do not interact with an explicit representation of a lattice. They navigate from one concept to another by adding or removing terms suggested by the system. This ensures a progressive navigation into the lattice.

4.2 Visualization Techniques to Browse Large Databases

Graphical solutions for visualizing a mass of abstract information have been studied for several decades, leading to the emergence of the information visualization domain [5]. Even with the use of a visual representation, the navigation into a large collection may not be obvious. Schneiderman has defined a visualization information paradigm called "focus + context" which recommends to first provide an overall view, then to let the user identify an area of interest (focus) and finally to display locally contextual information (context) [25]. Starting from an overall view helps users to maintain a unique mental map but they still have to achieve the focus task on their own.

In the particular case of document visualization, [5] defines two categories of solutions: on the one hand visualizations of the inner structure of a document (WebBook [6]) and on the other hand visualizations of a document collection, e.g. DocCube [20]. The work presented in this paper belongs to this second category which can also be divided into two parts depending on how the structure of the collection is managed. Some tools show this structure by representing clusters of documents (e.g. Grokker[2]) using tiling based visualization techniques such as TreeMaps [15]. Some other tools

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

do not show the collection's structure and represent the collection by a set of points into two or three dimensions dispatched according to a semantic distance usually based on indexed vectors (e.g. DocCube).

The choice between these two strategies depends on the users' needs. Showing the structure allows a more progressive navigation through clusters but reduces the probability of visual insight which the observation of similarity distances may offer. We have tried to benefit from both solutions by using the first one for the overall view and the second one for local views (see section 5.3).

4.3 Visualization Paths

The visualization exploration process has been studied for several decades. Upson et al. [31] and Card et al. [5] describe the visualization process as an analysis cycle, starting from raw data transformation, mapping onto the visual primitive, and view rendering provided to the user who performs a feed-back that restarts the cycle. The central idea of their models is that a description of the visualization process has to focus on this interaction with the user who changes the visualization parameters. The user influences all steps of the process by adjusting these parameters: from data filtering and transformation (by specifying a data threshold value), mapping onto visual primitives (by specifying another color or shape) and view rendering (by changing the orientation of the view). Upson and Card's models provide a characterization of visualization exploration as a whole global process but their granularity is not deep enough to detail and define a particular user's exploration path. Following their work two approaches have been taken: visualization space paths and derivation models.

Visualization space paths [29] consider user's visualization exploration as a navigation path in a multidimensional parameter space, a visualization result being a single point in the parameter space. Based on this model, novel visualization user interfaces such as Design Galleries [19] display an overview of the entire parameter space by random sampling. The main interest of this model is that it provides an explicit relation between visualization results and visualization parameters. However, particular relations between results are not explicit. Derivation models have been introduced to overcome this problem.

Derivation models describe how new visualization results are created from previous ones. Originally developed to provide a visual assistance to users of scientific problem solving environments, the GASPARC system [3] builds a history tree of visualization results in order to store solution parameters and related results. In Lee's work [17][18], a graph structure is used to model the visualization process for databases. Vertices stand for visualization states and edges are based upon similarities between structural attributes of the states. Jankun-Kelly et al. [14] extend these models to a more general and extensible one.

Due to the historic development of visualization applications, the majority of these works concentrate on scientific visualization (problem solving, medical imagery), rather than information visualization. Unfortunately, the semantics of the visualized data, which is what we are interested in, are then not taken into account in the cycle of the visualization exploration process.

4.4 Knowledge Maps and Multidimensional Scaling

The tests and validations of our approach are done through an agent oriented software environment that we developed. Molage (for Molecular Agents) allows visual manipulation of entities using several visual functionalities (zoom, fisheye, semantic lenses, filtering, etc.). Each entity may be typed and described by several attributes (descriptors). The collection of those entities may represent a multimedia database, e.g. music titles described by moods, textual documents characterized by a key-words' vector, pictures that are classified according to their subject, etc.

Considering the set of descriptors, each entity is characterized in a *m* dimensions' space. The collection is projected onto a 2 dimensional plane using a MultiDimensional Scaling projection (MDS – [22]). The method consists in minimizing a 'stress' function between *n* points (originally described in an *m*-dimensional space) after those points have been projected onto a space with fewer than *m* dimensions. The minimization is performed through the compression or extension of the (Euclidian) distances between the points in the smaller dimension [4]. This type of MDS approach is known as Force Directed Placement or Spring Embedding Algorithm.

We detailed the Molage environment and its use for navigating through a massive music collection in [8]. In this particular application, the musical landscape is used to semi-automatically index new music records just by "drag and drop" of a new entity on the map. It is also used to automatically build musical playlists. However some drawbacks were still present, in particular the lack of assistance for the visual navigation through the map. That is why we proposed to give some semantics to the map and to assist the building of this map in [9]. In the following, we broaden this visual assistance by proposing a method for browsing large databases.

5 A Visual Database Browsing Method

Within large databases, it is often possible to distinguish several layers that may be considered separately. Our idea is to keep the human operator's mental map as stable as possible and to give him or her some hints when he or she switches from one view to another one.

5.1 Problem Decomposition

Our approach aims to provide adapted visualizations for different abstraction layers. Information visualization techniques aim to assist the user in a visual inference task. It is very hard to reach a compromise between a strongly analytic strategy displaying results of classification methods on data and a visualization representing more faithfully all raw data. The first approach may be clearer for users but may introduce a bias in their interpretation and preclude insight by hiding unexpected information. The second approach faces the dimensionality problem of visualizing too much information at the same time. Our work proposes to satisfy both approaches by finding a compromise.

We assume that Schneiderman's overview, i.e. the overall view corresponding to the higher abstraction layer, has to emphasize the structure of the document collection because that is where the source of insight may reside at this level. This overview should be used as a kind of GPS for the further navigation into different local views. For the lower abstraction level, i.e. Schneiderman's context views, the aim is to display concrete relations between local data using the most intuitive visualization techniques. In the following we will describe the overall view and then local views but note that we propose a user interface that will show the overall view and one particular local view at the same time (see Fig. 3).

5.2 Lattice-based Overview

The concept lattice computed from the document/term (patent/keyword, for us) matrix will be used both as a support for navigation across the collection (as used in Image-Sleuth), and as a visual overview emphasizing its structure.

Rather than using traditional lattice representation such as Hasse diagrams (see Fig. 1) and graph drawing techniques [28], lattice nodes are displayed using force direct placement techniques (see section 4.4) according to a semantic distance [24].

All edges may not be represented as in Fig. 2 (left) to avoid visual overloading. We use a visual device called "topological lenses" [9] to show edges of the selected node and to emphasize nodes reached by these edges. In Fig. 2 (right), the selected node's intent is {plasma display, display device} and its simplified extent's cardinality is 1 (this cardinality indicates how many documents belong to this concept and not to any lower). Relied concepts and their intents are emphasized. Moving the cursor over a concept shows its intent. This visualization allows users to browse nodes through lattice order while evaluating the semantic distance covered at each step.

This visualization allows users to browse nodes through lattice order while evaluating the semantic distance covered at each step thanks to the similarity distance.

Several strategies could be applied in order to reduce the number of nodes to avoid visual overloading. Iceberg lattices [27] and alpha lattices [21] consist of smaller concept lattices retaining significant concepts that respect a threshold criterion based on the extent cardinality. Considering the concept lattice as an overview of the collection, these lattice reduction techniques based on the frequency of the concepts are compatible with our approach. Another lattice reduction strategy would consist in decomposing the overall lattice into smaller sub-lattices, as performed in Image-Sleuth. Partition of term space would be achieved by a domain expert or by identification of clusters of concepts with respect to the semantic distance.

Since an overview supporting navigation is already provided to users, we will present in the following how a local view associated with a lattice concept is visualized and then how users interact with local and overall views.

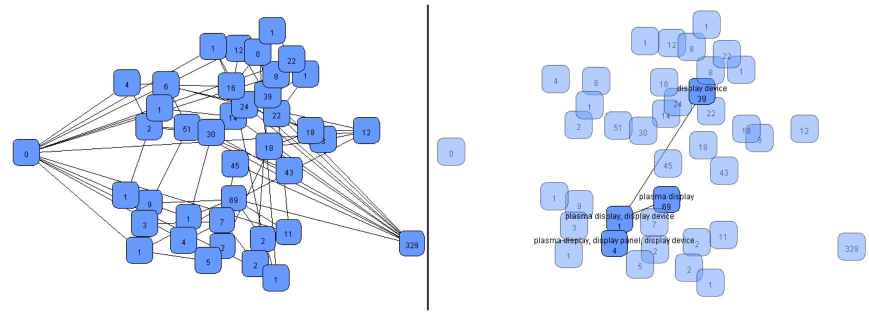

Fig. 2. The Overall view is a MDS projection of the lattice concepts with respect to a semantic distance. All edges shown (*left*). A particular concept (plasma display, display device) and his neighbors emphasized (*right*).

As presented in section 5.1 local views should represent relations and similarity between raw data. An alternative possibility concerns the use of a similarity distance between documents.

A first approach consists in computing a distance between documents once and for all. Much research has been done concerning semantic distance computation between textual documents which are outside the scope of the present paper [24]. We assume that a distance is available between documents, e.g. the semantic distance proposed in [24].

This distance may be independent from the information used as attributes in the formal context. Indeed it can be interesting to compare two indexation layers. For instance, in the case of multimedia documents, textual tags such as musical moods could be used to structure the collection and build the concept lattice whereas physical descriptors from signal processing analysis such as Mel Frequency Cepstral Coefficient [1] could be used to compute a similarity measure between documents, assuming that users' research pattern consists in using high abstraction layer features to achieve Schneiderman's focus task and then using low abstraction layer, closer to raw data, to observe local organization of information.

Using the same distance to represent all local views ensures users' mental map preservation. Actually, moving from one lattice concept to another consists in making some documents visible or not, so remaining documents' positions should not change even if the heuristic nature of Force directed placement approach may affect stability. Anyway Molage is able to fix positions for a subset of objects (here remaining documents), letting others (here newly retrieved documents) find a position with respect to semantic distance.

Another approach consists in computing a particular distance for each lattice concept, i.e. for each set of formal attributes. Assuming that each term is associated to a numeric function, each document has a numeric vector on which a MDS projection can be performed, taking into account rows corresponding to terms present in the lattice concept's intent. Moving from one lattice concept to another also consists in making some documents visible or not but positions of all documents change because a new distance is computed by adding or removing vector rows in the MDS calculation. Even if this approach provides a more precise distance adapted to local concept intent, its major drawback is that users' mental maps can become less accurate. However, Molage can dynamically perform such a selective MDS projection, allowing users to observe objects' movements when updating the distance.

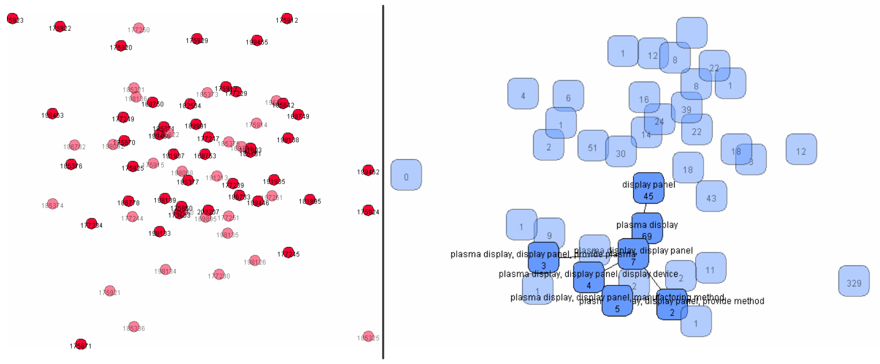

Fig. 3. The selection of a concept on the overall view (*right hand side*) displays patents contained in the concept's extent (*left hand side*) and suggests navigation paths by emphasizing new concepts on the overall view.

5.3 Interactions between Local and Overall Views

Several use cases have been identified. The most basic one consists in selecting the top node of the lattice in order to display the whole collection as a local view.
Then two possibilities occur: users can continue their navigation across the lattice by choosing one of the top nodes that has been emphasized. When users move the mouse on a particular node, documents that belong to this node are emphasized in order to preview the next visualization and to observe the distribution of these documents in the current view (see Fig. 3). When users select a new node the local view is updated to remove items that do not appear in the new node's extent. In this case, distances between documents in the different views are not recalculated and the map does not change; only the visible layer changes.

Another possibility is to select a document on the local view. The local view is then updated to visualize documents belonging to the lowest concept, i.e. the more precise, where the selected document appears. This concept is emphasized on the overall view, so that users see how far they have moved from the starting node.

6 Results

Our navigation method has been tested on real data, precisely a collection of indexed patents, provided by our industrial partner with a similarity matrix between patents. In order to reduce the size of the experimental collection, we extracted 329 patents indexed by 10 terms with an average of 0.8 term describing each patent. All these patents share the term "plasma" that does not belong to the set of 10 terms. The resulting

lattice, computed by Galicia[3] using Bordat algorithm, has 40 concepts. We submitted several screenshots to our industrial partner corresponding to different steps in a particular navigation use case. He was asked to compare the usability and user-friendliness of our method to their traditional list-based interface. Concerning the overall view, he pointed out the usefulness of the edges: "*Edges between concepts and cardinality of extents give us new information, make the navigation fun and allow us to identify the coherence of the documents related to one concept"*. Concerning the local view, he appreciated the spatialization of the documents and *"the fact that one may see at first sight how many documents are displayed in a more direct and explicit manner compared to the display of a number of results above a list of results"*. Concerning the navigation method itself, he agrees that "*it maintains a kind of mental map. That was a problem pointed out by users. The database analysis consists in two steps: an exploration step to discover and identify documents' content and then a rationalization of theses discoveries. The problem is that these two steps have to be done at the same time and with a list interface, one may forget the different discovery paths used from the beginning. The visual aspect of [our] method will surely facilitate to rationalize and save pertinent groups of documents."*
He also pointed out some drawbacks and suggested improvements: *"more information about documents should be displayed on the local view"*, *"it should be interesting to fix a local view and, when selecting a new concept, to color added documents (e.g. blue) on the local view and to differently color (e.g. violet) documents in the intersection"*. This last remark is particularly important because it matches our perspectives: to go further than navigation and to provide visual tools to assist data analysis process.

7 Conclusion and Perspectives

This paper has presented a method for visual navigation in indexed document collections combining classification behaviors of FCA to produce overviews and intuitive visualization techniques when focusing on local views. First feedbacks from our industrial partner are promising. The approach seems pertinent and results really meet the users' needs. The challenge is now to broaden the scope of our research to emphasize the analysis process during the database exploration.

As mentioned in the introduction, we aim to use FCA techniques not only to organize the database but also to infer some reasoning during the visualization navigation process. Research presented in this paper only deals with assisting users in their navigation and no information is really inferred by the system itself. This is a proper problem of information visualization. Indeed, noticing Robert Spence's definitions in [26] *"to visualize is to form a mental model or mental image of something. Visualization is a human cognitive activity, not something that a computer does"*, our goal is not to produce formal results from raw data because data analysis techniques such as FCA succeed without any visualization need. We try to explore new techniques to provide bootstraps for the cognitive activity of users. One of these would be to translate paths

[3] http://www.iro.umontreal.ca/~galicia/

in local views to paths in the overall view, in other words to express sequences of raw data by sequences of lattice concepts (each object belonging to a minimal concept).

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