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Bachelor's Thesis

Interactive Visualization of Large Concept Lattices

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Abstract

Formal Concept Analysis is mathematically method to create hierarchical relationships among objects. These objects combined with the relationships result in a structure called concept lattice. When a concept lattice is large, it cannot be easily represented in a static visualization. Interactive visualizations try to convey the insights of large concept lattices. They restrict themselves to only show small portions of the lattice and let the user incrementally explore the lattice by browsing. In this thesis, I propose a interactive visualization concept for large concept lattices where users can additionally backtrack their browsing actions. I implement this concept into a web-based tool for a given concept lattice. This concept was created from annotations of digitized historical maps. The implementation was evaluated with a user study (n=5). The results show that the given concept lattice does not contain the information users are looking for but that the visualization concept itself looks promising because users found it easy to use.

Kurzfassung

Formalen Begriffsanalyse ist eine mathematisch Methode, um hierarchischen Beziehungen zwischen Objekten zu erstellen. Diese Objekte in Verbindung mit deren Beziehungen führen zu einer Struktur namens Begriffsverband. Wenn der Begriffsverband groß ist, kann er nicht so einfach in einer statischen Visualisierung dargestellt werden. Interaktive Visualisierungen versuchen die Erkenntnisse der großen Begriffsverbänden zu vermitteln. Sie beschränken sich darauf nur kleine Teile des Verbandes zu zeigen und lassen den Benutzer schrittweise den Verband durch "durchstöbern" erkunden. In dieser Arbeit schlage ich ein interaktives Visualisierungskonzept für große Begriffsverbände vor, in dem Benutzer zusätzlich die "durchstöbern"-Aktionen rückgängig machen könne. Ich setze dieses Konzept in ein Programm für einen vorgegebenen Begriffsverband um, welches im weltweiten Netz läuft. Dieser Verband wurde von Anmerkungen über digitalisierte, historische Karten erstellt. Die Umsetzung wurde mit einem Benutzerstudie (n=5) evaluiert. Die Ergebnisse zeigen, dass der vorgegebenen Begriffsverband nicht die Informationen enthält, nach denen die Benutzer suchen, aber dass das Visualisierungskonzept selbst vielversprechend aussieht, da die Benutzer fanden, dass es einfach zu bedienen war.

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Contents

List of Figures

Glossary

JSON Language-independent data format derived from JavaScript (JavaScript Object Notation). 32, 34

1. Introduction

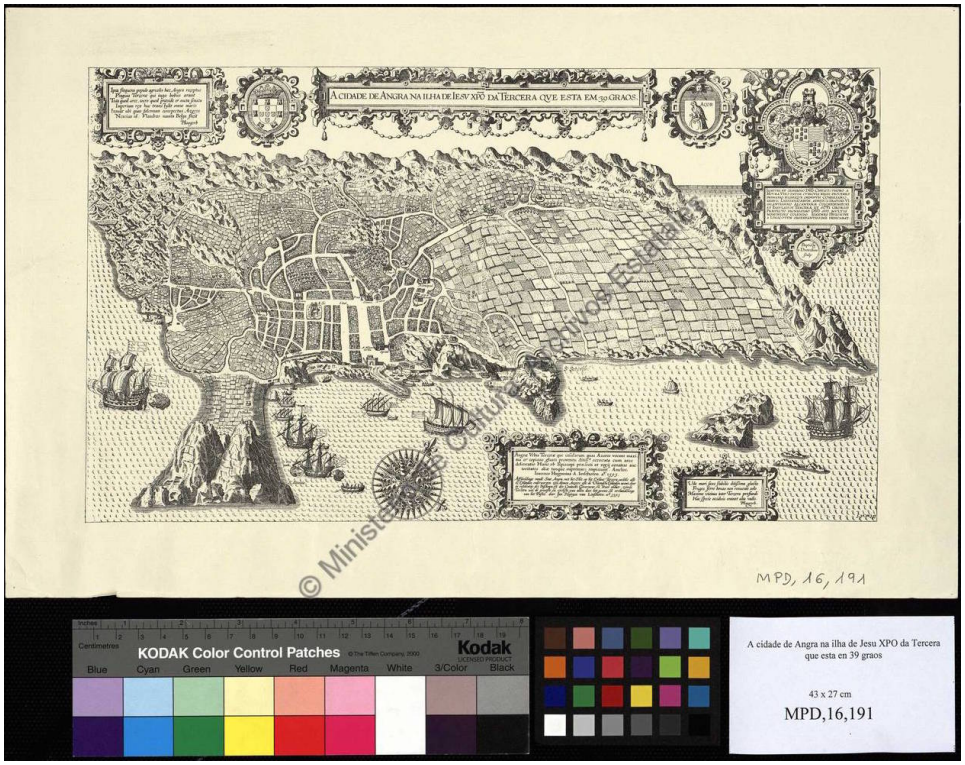

Figure 1.1: Digitized historical map

The digital revolution is affecting every part of our life. Also the humanities scholars witness a change in their work life when analog collections are digitized. They have to apply algorithms to organize and analyze huge amount of data. The term "digital humanities" evolved during the last ten years and it can be defined as an intersection between the humanities and information

technology [48]. The information retrieval research group at the computer science department of the Universidad Nacional de Educación a Distancia (UNED) in Madrid cooperates with human scholars to conduct research in digital humanities. In their current project[1], they work on historical maps. The maps have been drawn between 1503 and 1805, digitized and are available on the web[2]. These maps were annotated by human scholars. An example of a map is shown in Figure 1.1 and its annotation are shown in Figure 1.2.

Figure 1.2: Annotation of a digitized map

To extract knowledge from the collection, the research group advocates [12, 13] for the use of a mathematical technique called Formal Concept Analysis [25]. After applying this technique, the maps are organized in hierarchical structure which is called *concept lattice*. A concept lattice is a special form of a *lattice*. A lattice can be statically visualized in a Hasse diagram. An example of a Hasse diagram is shown in Figure 1.3. In this figure, you can see the power set of the set $\{x, y, z\}$ and the hierarchical relationships among them. The arrows indicate if a set (the origin) is a subset of another set (the destination). The nodes are layered in regard to the number of elements in a

[1] `http://linhd.uned.es/p/proyecto-dimh`

[2] `http://www.mcu.es/ccbae/es/consulta/resultados_busqueda.cmd?busq_codsecc=MCAGS`

set. The node with all items is in the top and the empty set is in the bottom.

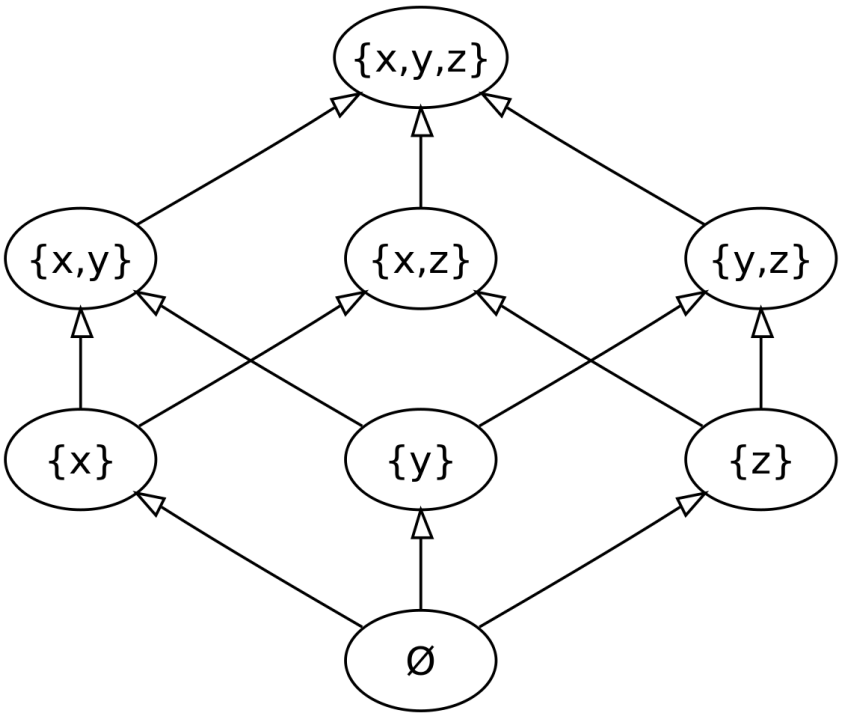

Figure 1.3: Hasse diagram, powerset of $\{x, y, z\}$ ordered by inclusion. Source: Anonymous Person [16]

Because a concept lattice is also a lattice, concept lattices can be represented in Hasse diagrams. The research group successfully created a concept lattice of the maps and visualized it with a Hasse diagram. The result is shown in Figure 1.4. They are not satisfied with the visualization because it is nearly impossible to the see anything. The labels are overlapping thereby it is hard to read them. It is not possible to distinguish between individual edges because the huge amount of them. I did a twenty week internship at their research group and it was my task to create a useful visualization.

So the scope of this thesis is the theoretical elaboration about FCA and its visualization. This will to an own concept which will be implemented with the concept lattice derived from the collection of digitized maps. The implementation will be evaluated with an user study with five participants.

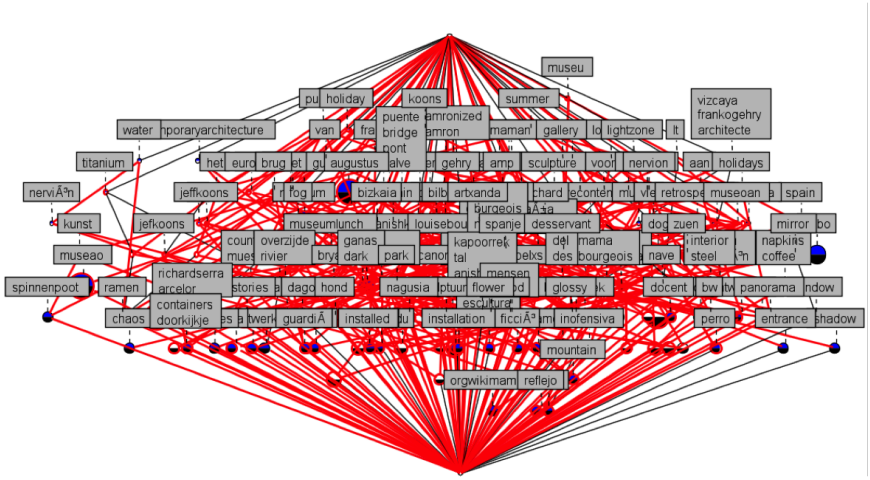

Figure 1.4: First visualization of digital humanist data with traditional FCA software ConExp

The result of the study will show if the concept and its implementation are attractive for the user. It also possible to draw some conclusions about the given concept lattice itself, because the visualization can only be as good as its content.

The remainder of this thesis is structured as follows: The background of Formal Concept Analysis and Interface Design Principles are presented in Section 2. The discussion of related work takes place in Section 3. Inferring from the related work, I will present my concept and implementation in Section 4, which will evaluated in Section 5. Built upon the conclusion of the evaluation, a new version of my work including a description about future words are presented in Section 6, before eventually concluding in Section 7.

2. Background

This sections gives background knowledge before we can discuss related work in the following section. First, it gives an introduction into formal concept analysis taken from the work from Ganter and Wille [25]. Second, it introduces some basic interface design principles.

2.1 Formal Concept Analysis

Formal Concept Analysis (FCA) is a mathematically well-founded technique to analyze data. FCA creates relationships among objects specified by attributes. It derives from old philosophical ideas and was formalized by Rudolf Wille. First, I describe the formal definitions and explain them with examples. Second, I give examples for the use of FCA in information retrieval.

2.1.1 Definition

FCA [25] is constructed from a formal context. A *formal context* is defined as a tripple $K = (G, M, I)$ where G is a set of objects[1], M is a set of attributes[2] and I is a binary relation $I \subseteq G \times M$. I specifies whether an object has an attribute or not[3]. Table 2.1 illustrates an example from David Eppstein [23] where G comprises the integers from 1 to 10 and M comprises the attributes composite, even, odd, prime and square.

Let the operator $'$ for $A \subseteq G$ be defined as following:

$$A' = \{m \subseteq M \mid I(g, m)\ \forall g \in A\}$$

[1] G derives from German *Gegenstände*
[2] M derives from German *Merkmale*
[3] I derives from German *Inzidenzrelation*.

Table 2.1: Formal context, integers 1 to 10 as objects with attributes

	composite	even	odd	prime	square
1			×		×
2		×		×	
3			×	×	
4	×	×			×
5			×	×	
6	×	×			
7			×	×	
8	×	×			
9	×		×		×
10	×	×			

A' is the set of those attributes that are present in all objects from given A.

Let the operator $'$ for $B \subseteq M$ be defined as following:

$$B' = \{g \subseteq G \mid I(g, m)\ \forall m \in B\}$$

B' is the set of objects that have at least the attributes given in B.

If for $A \subseteq G$ such that $A = A''$, then A is called *closed*. The same is true for $B \subseteq M$ and $B = B''$.

For example, let a set of objects be defined as $A_1 = \{1, 4\} \subseteq G$. This results into: $A_1' = \{square\}$ and $A_1'' = \{1, 4, 9\}$. A_1 is not closed but $A_2 = \{1, 4, 9\} \subseteq G$ is called closed because $A_2 = A_2''$.

A *formal concept* is a pair of (A, B) where $A \subseteq G$ and $B \subseteq M$ and $A = B' \wedge B = A'$. Informally, all objects in A share exactly the same attributes in B. A is a set of objects called the *extent* of a formal concept. B is a set of attributes called the *intent* of a formal concept. The extent and the intent of all formal concepts are always closed.

From the example in Table 2.1, we can derive several formal concepts. Three randomly chosen concepts are shown in Table 2.2.

Table 2.2: Three formal concepts from the formal context in Table 2.1

Concept	Extent	Intent
C_1	{4,6,8,10}	{composite, even}
C_2	{2,4,6,8,10}	{even}
C_3	{9}	{composite, odd, square}

It is always possible to define an order relation on the formal concepts. Let us introduce the relation $\leq$ as follows:

$$(A_i, B_i) \leq (A_j, B_j) \Longleftrightarrow A_i \subseteq A_j$$

With the help of $\leq$, we can derive relationships from the concepts in Table 2.2. We see that $C_1 \leq C_2$. This means that C_1 is more specific than C_2 and C_2 is more general than C_1. We can also see that C_3 is unrelated to C_1, and that C_3 is unrelated to C_2.

A formal context with $\leq$ is called a *concept lattice* of the context. It can be shown, that for two formal concepts C_i and C_j, there always exists a formal concept C_x such that $C_i \leq C_x \wedge C_j \leq C_x$. That means that there is always a formal concept wich is "above" in the hierarchy and also related to the two formal concepts C_i and C_j. A formal definition would exceed this section. The interested reader is advices to read "The Basic Theorem on Concept Lattices" as described by Carpineto and Romano on page 13 in their work [9].

In the next section we will take a look at the static visualization of concept lattices.

2.1.2 Static Visualization

It is often said that a picture is worth a thousand words. To convey the information of a concept lattice, it can be visually represented in a *Hasse diagram* [25]. Figure 2.1 shows the Hasse diagram of the concept lattice derived from the formal context described in Table 2.1.

A Hasse diagram is a graph where the vertices represent formal concepts and edges represent the relation $\leq$ among the formal concepts. An edge between formal concepts C_i and C_j is drawn, when $C_i \leq C_j$ and there does not exist a formal concept C_x such as $C_i \leq C_x \leq C_j$. To increase the readability,

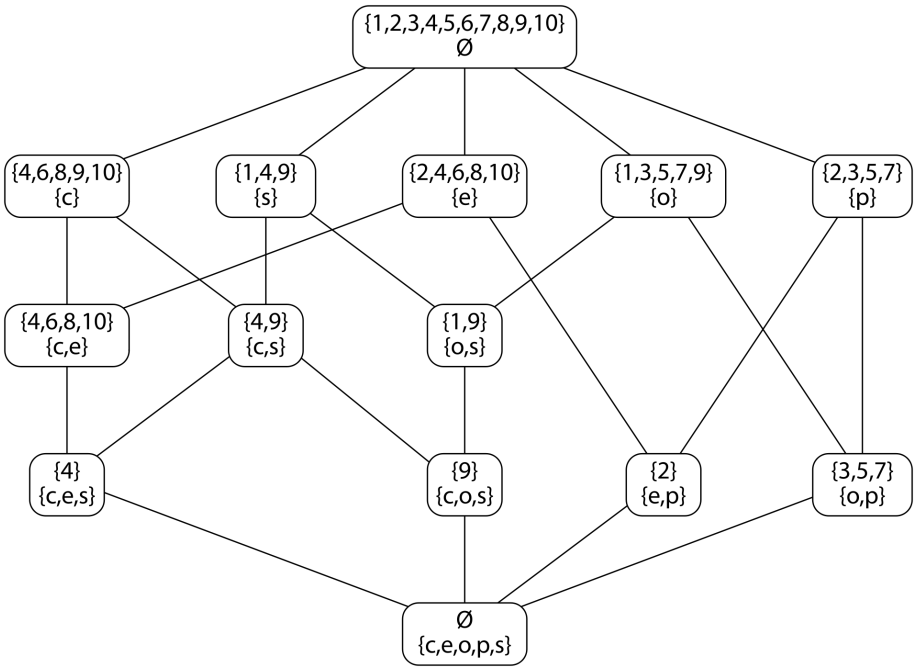

Figure 2.1: Hasse diagram, with the integers 1 to 10 as objects and attributes square (s), prime (p), composite (c), even (e), and odd (o). Source: Eppstein [23]

the nodes are ordered in layers. The concepts in top are more general, the concepts in the bottom are the more specific ones.

There are two special concepts: *supremum* and *infimum*. The supremum is vertex node in the top and the attributes in its intent are those which are present in all objects. In most cases its intent is empty. The infimum is the vertex in the bottom and the objects in its extent are those which have all attributes. In most cases its extent is empty.

After this general introduction, we will describe in the next section how we can apply FCA to information retrieval.

2.1.3 FCA and information retrieval

Up to now, we only showed primitive examples to illustrate the basics of FCA. So where was it applied? According to Poelmans et al. FCA has been "applied in many disciplines such as software engineering, knowledge discovery and information retrieval" [43]. They did two comprehensive surveys on the application of FCA [43, 42].

In the case of IR on a document collection, the objects are the documents. These documents are described by index terms. These index terms are the attributes of the objects. In Table 2.3 are documents described by index terms take from Godin et al. [26]. The concept lattice is visualized in Figure 2.2.

Table 2.3: Documents described by Index Terms, from Godin et al. [26]

Document	Index Terms
1	{animal, bear, canada, child, cow-boy, dream, fantasy, immigration, indian, magic}
2	{animal, cat, child, fantasy, magic, tale}
3	{animal, child, dog, fair, fantasy, love, parade}
4	{child, fantasy, friendship, game, rope}
5	{creativity, child, fantasy, game, music, sound}
6	{animal, child, dream, fair, fantasy, friendship, octupus}

Carpineto and Romano [11] describe that a concept can be seen as a query (intent) with a set of retrieved documents (extent) and that neighboring concepts can be seen as minimal query changes. When the user queries a FCA-based system, the intents of the formal concepts are checked for a match (or a partial match if there is no match in the first place). So for instance with the query "child fantasy friendship" the document 4 and 6 wold be retrieved. You find the concept in the middle of the Hasse diagram. The neighboring concepts are connected with an edge.

Sacco and Tzitzikas [44] describe two information access modes: *focalized search* and*exploratory search*. In focalized search, the user is interested to find relevant information to a given query. In opposite to exploratory, where the user explores relationships among items in a data collection. While FCA provides the user with the ability to do focalized search, it offers sophisti-

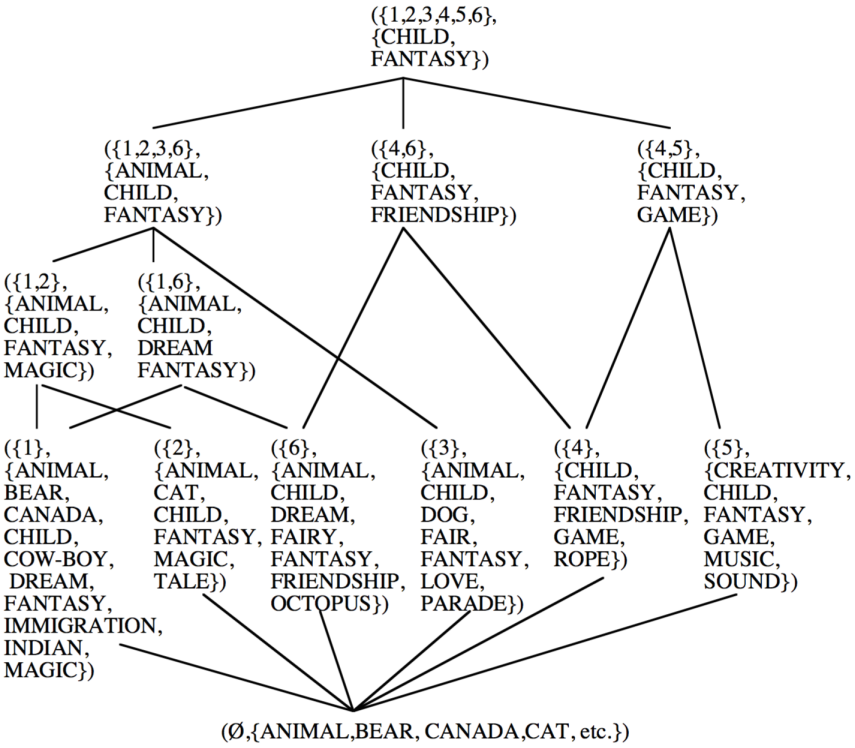

Figure 2.2: Hasse diagram from concept lattice derived from 2.3. Source: Godin et al. [26]

cated exploratory capabilities. When the user queries the system (as described above), not only the documents of the formal concepts are retrieved, but she can also see the position in the lattice. Is the concept in the upper half and thereby more general? Or is it in the bottom half and thereby more specific? What are the related formal concepts? How do they differ? Would there be a lot more documents if I would remove a term from the query? All this questions can be answered and because the whole lattice is already computed, relatively fast. Without going into detail, a major problem of FCA is the time-consuming creation of a lattice. But this focus of this thesis is the visualization of concept lattices and not the creation of concept lattices. This section should give a slight introduction and the interested reader is advised to study the work from Carpineto and Romano [9] for a detailed investigation.

This work develops an interface for one specific datasets. That is why it is important the lattice structure of this dataset how it was created. The next section described the dataset.

2.1.4 The Data

In the following, I will described how the research group created the data on which this thesis is based.

The research group asked human scholars for a list of 100 words. The list should contain words that they are interested in. From this list, the index terms of the documents were computed. A document was described by an index term, if it occurs at leaste once in the document. From the index terms, they computed the concept lattice. There were 7492 documents with 100 possible attributes (the index terms). The lattice consisted of 131379 formal concepts.

Because this thesis focuses on the user interface, let us review user interface design principles before we discussed related work in Section 3.

2.2 Interface Design

The user interface is responsible for the interaction with users. The interaction of humans with computers has its own research area, Human-Computer Interaction (HCI), and one of its pioneers is Ben Shneiderman. In the following, two principles from him are presented: The "Eight Golden Rules of Interface Design" [46] and the "Visual Information Seeking Mantra" [45].

2.2.1 Eight Golden Rules of Interface Design

These rules [46] are genreal advices for user interface designers which should apply to all interfaces. The rules are named and explained with my own remarks.

- Strive for consistency: Use similar actions in similar situations. Use identical terminology, colors, fonts etc. throughout the system.
- Cater to universal usability: Design for the needs of a diverse user group (skill level, age, gender and others)

- Offer informative feedback: Give system feedback for every action.
- Design dialogs to yield closure: Sequences of actions should be grouped. Give feedback on completion of a group.
- Prevent errors: Design the system that the user cannot even do errors in the first place. But if she does some, offer instructions how to recover.
- Permit easy reversal of actions: Actions should be undone. This gives the user confidence to explore the system.
- Support internal locus of control: The user should think that she is in charge of control.
- Reduce short-term memory load: Reduce the number of things the user has to keep in mind while using the system.

There exits alternative principles for instance: Donald Norman's Design Principles [41] or Jakob Nielsen's "10 Usability Heuristics for User Interface Design" [40]. They are very similar and only differ points not worth mentioning.

These principles can be applied to all user interfaces. In the next section, design principles will be presented which are more related to this work.

2.2.2 Visual Information Seeking Mantra

The visual information seeking mantra (the Mantra) was introduced by Ben Shneiderman [45] and is based on his experience with past projects. Albeit the Mantra was intended to be a "descriptive and explanatory" [6], "in effect, the Mantra has become a prescriptive principle for many information visualization designers" write Craft and Cairns [15].

The Mantra describes design principles for interfaces when user view collection of items. This items are described by multiple attributes. The starting principles are: overview first, zoom and filter, and then details on demand. These four principles will be explained below and extended by three other principles.

- Overview: Gain an overview of the entire collection.
- Zoom: Zoom in on items of interest.

- Filter: Filter out uninteresting items.
- Details-on-demand: Select an item or group and get details when needed.
- Relate: View relationships among items.
- History: Keep a history of actions to support undo, replay, and progressive refinement.
- Extract: Allow extraction of sub-collections and of the query parameters.

Some tasks need more explanation.

Zoom and Filter

This task are responsible for reducing the complexity of the data collection. 'Zoom' means that the user focuses on items she wants to see. 'Filter' means that she can hide items which are not interesting for her.

History

It is important to give the user the possibility to easily recover from mistakes or loss of interest. In addition, "it is rare that a single user action produces the desired outcome. Information exploration is inherently a process with many steps, so keeping the history of actions and allowing users to retrace their steps is important." writes Shneiderman [45].

Extract

Once interesting objects are found, the user should have the possibility to extract them from the system. Shneiderman describes printing, emailing or saving the item to the disk as 'extraction'.

2.2.3 Final Remarks

The presented ideas are based mostly on the experience of one person: Ben Shneiderman. The huge number of citations show that his work is influential but Craft and Cairns [15] call for empirical justification of the Mantra. HCI is a young research area and they will come better and more polished guidelines the future. Until then, the work from Ben Shneiderman seems to

be valid starting point.

Those principles are up to interpretation and adaption. Every system is different and has its different needs. For this reason, let us review what other people did and how they designed their interface for FCA-based systems.

3. Related Work

After introducing formal concept analysis in Section 2.1, let us review and discuss related work. In the first three sections, we go over different FCA-based approaches. Eventually, we evaluate one FCA-based approach in detail: The Virtual Museum of the Pacific. In Section 3.4, a non-FCA based approach is shown which is related to FCA: Faceted Search.

3.1 Full Hasse Diagrams

The traditional, static visualization of concept lattices are Hasse diagrams as describes in Section 2.1. Eklund et al. [21] conducted user studies and proclaim that non-FCA-experts can read Hasse Diagrams if you fine-tune the Hasse diagram. For instance by choosing appropriate colors, using symbols and carefully positioning the vertices in layer.

But in the domain of information retrieval you get formal contexts with a lot of objects. Hasse diagrams scale bad for large concepts lattices. Kuznetsov et al. [35] describe this resulting visualization: "Representing concept lattices constructed from large contexts often results in heavy, complex diagrams that can be impractical to handle and, eventually, to make sense of." Especially the high connectivity of the graph results in enormous edge crossing. The Figure 1.4 shown in Section 1 shows the first result of the research group. The visualization is useless because it is not even possible to see all the labels. In the next section we describe techniques to improve the situation.

3.2 Pruned Hasse Diagrams

The Hasse diagrams can be pruned by reducing the number of vertices. The different techniques are discussed in the next section.

3.2.1 Reduce Number of Formal Concepts

One way to reduce the number of vertices is to compute the *iceberg lattices* as described by Stumme et al. [47]. They result after the application of a data mining technique "frequent item-set mining" from Agrawal et al. [1]. Only formal concepts are selected which are considered "frequent". A formal concept is frequent if its intent, the set of attributes, is frequent. Let B be the intent and $minSupport \in [0, 1]$, then B is frequent if $|B'|/|G| \geq minSupport$. This means the attribute set has to specify a high portion of objects; at least $minSupport$. This approach has some drawbacks as Kuznetsov et al. [35] point out that "exotic" or "emergent" concepts that are not represented by a large number of objects can be interesting too and should not been overlooked. They propose to only select "stable" concepts [35]. The intent of stable concepts does not depend much on each object of the extent. It is also possible to apply traditional cluster techniques like fuzzy K-Means clustering to FCA [34].

While all these techniques undoubtable reduce the number of formal concepts, it is to question if the results are any helpful. In our case of information retrieval, we apply FCA to explore the data and get insights about the lattice structure. When pruning the nodes, you are losing many data relationships, many formal concepts and, consequently, the "power" of FCA as exploratory technique is significantly reduced. When we deal with large concept lattices, the number of nodes has to be very low if we want to represent them with Hasse diagrams. Nowadays, the question is not how do I visualize 16 formal concepts as in Figure 2.1 - it is more how can I analyze 160.000 formal concepts.

Pruning alone is not a proper way to handle large concept lattice. But it can be useful to reduce the clutter. It can be useful in combination with techniques that are presented in Section 3.3.

3.2.2 Nest Formal Concepts

Another approach are *nested line diagrams* - line diagrams are another name for Hasse diagrams. For this, all attributes are partitioned into layers. For example, if you just have two layers, an attribute is either in layer one or two. For the first layer: You built up a Hasse diagram with the attributes *solely* of the first layer. For each vertex in the resulting Hasse diagram, you built up a Hasse diagrams *inside* the vertex. This secondary Hasse diagrams are built from the concept lattice derived from the objects in the vertex (the objects that are the extent of the formal concept). This can be done for an arbitrary number of layers. An example from Carpineto and Romano [9] is shown in Figure 3.1. The general idea should be clear without explaining the context - if not Carpineto and Romano [9] describe it more in detail.

But how to partition the attributes? You have to select the partitions manually. The manual selection might be good idea of small concept larges but in our case it is not feasible.

3.3 Local View

Instead of showing the full Hasse diagram, the user can have a local view on the lattice. We will give an overview about the basic idea and applications before we review one real-world application in detail.

3.3.1 Basics

One could argue that you just have to visualize everything and then allow to zoom on nodes. This techniques is common among network visualizations [29]. But because of the high connectivity of the graph, this is not helpful to Hasse diagrams. You can see this at the tool 'FCART' presented by Neznanov and Parinov [39]. In Figure 3.2 they visualize a concept lattices comprising more than 20000 concepts.

Even though they chose a grey color for the edges, the screen is almost filled only with the grey. In addition, they labels of the nodes in the top and bottom are overlapping which makes it hard to read them. Let us review some other approaches in the next section which completely break with the Hasse diagram.

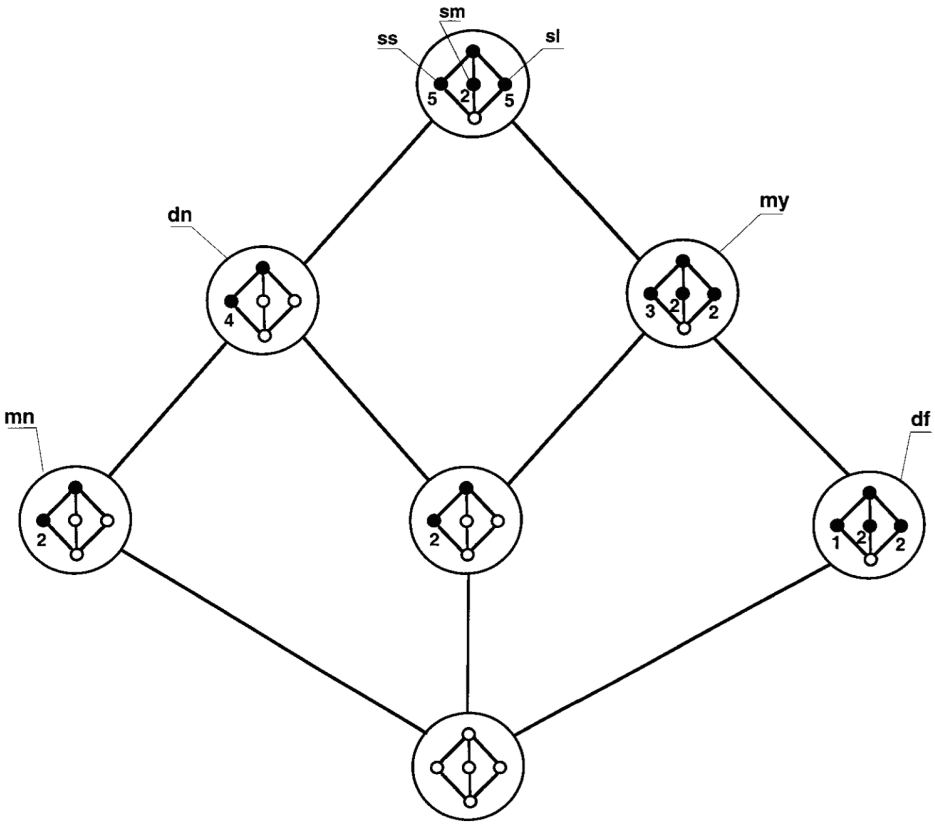

Figure 3.1: Nested Hasse diagram with two layers. Source: Carpineto and Romano [9]

The local view on a Hasse diagram is called *conceptual neighborhood* by Eklund et al. [20, 22] or *hybrid navigation* by Carpineto and Romano [8]. The basic idea is always the same: The interface is always focused on exactly *one* formal concept. The user can navigate through the lattice by going up (becoming more general) or going down (becoming more special). Which means removing terms or adding terms. They also offer the possibility to query the system. In most cases, the user would start with a search and focuses on the corresponding formal concept if it exists. From there, the user can fine-tune the search. The idea originated from the information retrieval field and was first proposed by Godin et al. [27].

At least three ideas underly this approach. First, users tend to start with a

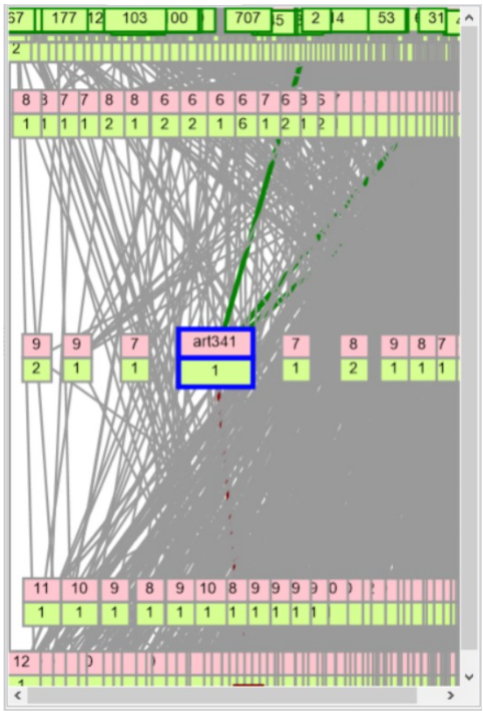

Figure 3.2: FCART, Hasse diagram with over 20000 formal concepts, focus on node with blue borders. Source: Neznanov and Parinov [39]

short query and then refine their needs. Hearst [28] write while referring to [37, 4]:

> "A commonly-observed search strategy is one in which the information seeker issues a quick, imprecise query in the hopes of getting into approximately the right part of the information space, and then doing a series of local navigation operations to get closer to the information of interest."

Second, it easier for the users to choose from suggestions than to formulate a query. Aula [2] writes that searching is more demanding method for locating information than browsing, as it involves several phases, such as planning and executing queries, evaluating the results, and refining the queries, whereas browsing only requires the user to recognize promising-looking links.

Third, after the initial search, the neighboring concepts are basically suggestions to the users. This prevents them from getting empty results. This is

related to the design principle: "Prevent errors" presented in Section 2.2.1. Zero results are not really errors, but they can be seen as a failure in a search process.

Godin et al. [26] evaluated their FCA-based approach in comparison to boolean retrieval and hierarchical retrieval and proclaim that their experiment suggests that retrieval using a concept lattice may be an attractive alternative since it combines a good performance for subject searching along with browsing potential."

3.3.2 Applications

Carpineto and Romano picked up the idea from Godin et al. and developed a FCA search engines ULYSSES [7, 8]. The user can fine-tune what neighboring vertices are displayed by bounding the information seeking space. They are not only showing directly adjacent vertices but also vertices that do not exceed a given distance. It is also possible to restrict the space to vertices which are above, below, left or right of the focus. The system is shown in Figure 3.3.

In their work, CREDO [10], Carpineto and Romano followed the look of ordinary search engines. The presentation of the concept lattice is not oriented at the Hasse Diagram. It looks more like a folder structure. It is shown in 3.4. Work that is similar comes from Koester [33], Dau et al. [17], Nauer and Yannik [38] and Cigarran et al. [14]. In all these cases, FCA is applied in slightly different manner. The search is done with ordinary search engines in the background (e.g. Yahoo!) and the concept lattice is built from the results of the search. So for every new search, there is a new concept lattice. This is different from our approach, where there is just one static concept lattice.

Let us now review work of FCA on document collections. Eklund et al. applied FCA to email organization [21], image browsing [19, 18] and a later work is the 'Virtual Museum of the Pacific' [20, 22]. We will focus on the museum because it does exactly what we are trying to do: Visualize a concept lattice built from image metadata. Furthermore it is a rare example of FCA outside of the academic community. It also runs in the browser and it was built in 2009 - so it is fairly recent. In addition, they conducted a usability study with museum experts and non-experts [22].

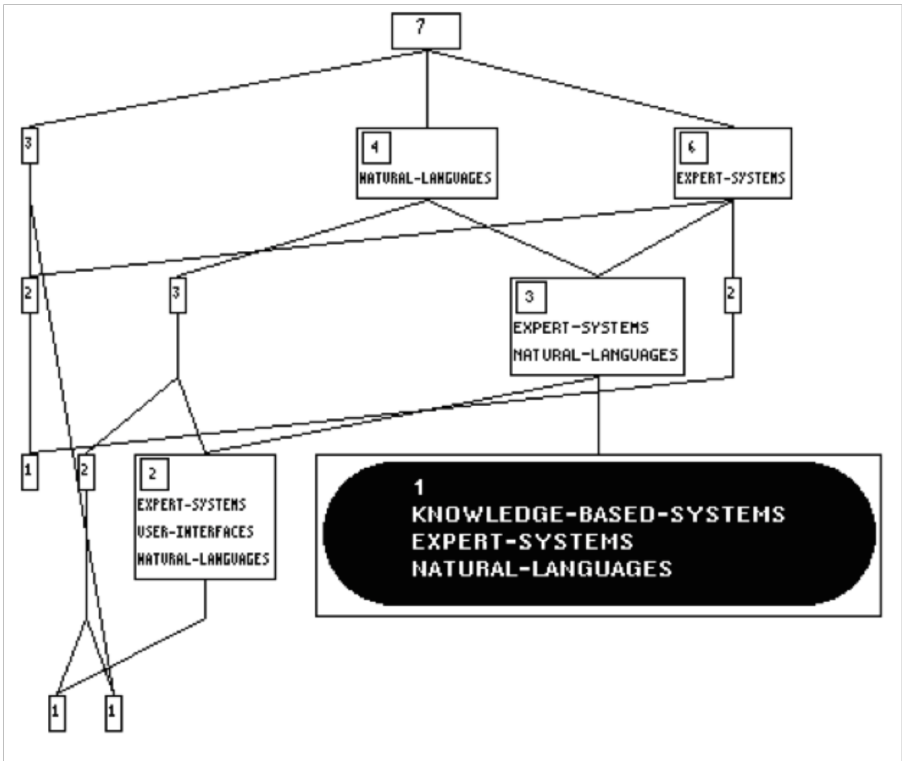

Figure 3.3: ULYSSES with focus on the black node. Source: Bach [3]

3.3.3 Virtual Museum of the Pacific

The museum was created to give user the possibility to browse images of museum objects. It is available on the web[1] and it is advised to take a look at it before continue reading.

After the login, the user can either search on the collection or get an overview over the collection by clicking "tag cloud" or "browse perspective". The interface sets the objects, the images, in the focus of the interface. This is, in my opinion, a good decision. The user is probably more interested in the objects than in the concept lattice. The lattice is just an artificial structure

[1] `http://epoc.cs.uow.edu.au/vmp/` - Credentials are required. Use username: filter and password: 45755

Figure 3.4: CREDO, after query "xml" and browsing after "editor(5)" and "windows free(2)". Source: Carpineto and Romano [10]

that was built around the objects.

Above the objects is the intent of the focused formal concept. It is possible to remove terms from the current selection to generalize (go up in the lattice). Below the objects are terms suggested to specify the information needs (go down in the lattice). The view changes when the users decide to add or remove terms. The sidebar categorizes the attributes into topics. It looks like they have created a taxonomy for their attributes. This allows the users to filter out interesting terms. But the manual selection is time-intensive and it does not scale very well. It is also to question if FCA should be applied to datasets with a taxonomy. More information will follow in section 3.4. To get details on demand, you have to click on an item. From there you can also find related items. This views offers a good view.

Now to the problems. It is possible to search but this search is very rudimentary. They should have stick to well-proven user search interface principles as described by Hearst [28]. The biggest problem is the missing "home" or

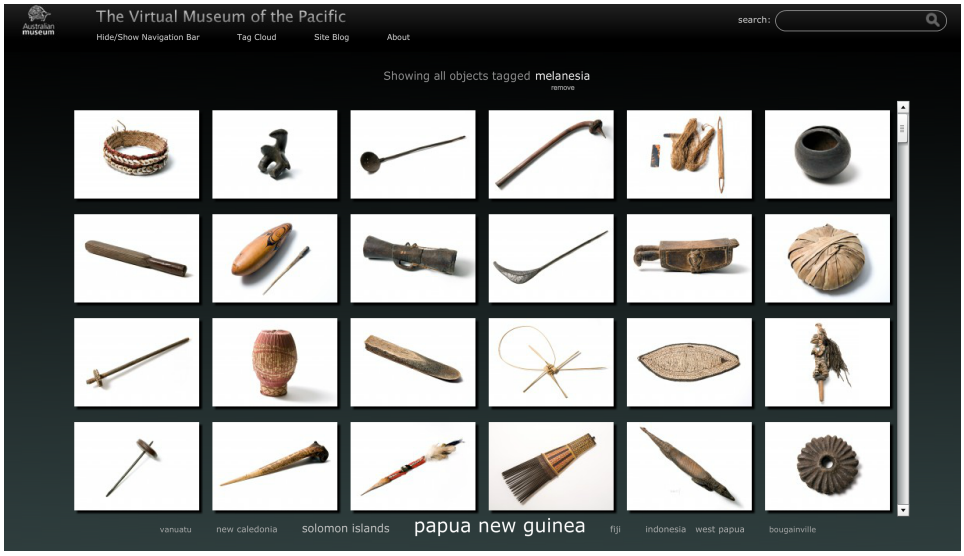

Figure 3.5: The Virtual Museum of the Pacific, focus on concept "melanesia"

"reset" button and the absence of any form of history. As Shneiderman [45] point out "Information exploration is inherently a process with many steps, so keeping the history of actions and allowing users to retrace their steps is important." We saw in Section 2.1.3 that FCA can bee seen as a exploratory technique. Not implementing *any* possibility to backtrack is a huge problem. You can see in the evaluation that users were confused. Eklund et al. write [22]:

> Users also had difficulty understanding the notion of conceptual navigation as a way of navigating an information space, rather than a fixed hierarchy with a well defined 'home' state. [..] Many users felt 'lost' within [the FCA-based] style of navigation. A recommendation was put forward so that users could at least back track through the navigation sequences (in the form of a 'Back' button) or that users could easily go back to a 'home' or 'reset' state.

In my opinion, they are not addressing these problems - even thought the navigation is *the* problem with FCA. It feels like that they are blaming the problems on the unfamiliarity of the users when they write [22]: "there were a number of common issues, mostly relating to the unfamiliarity of the

interface“. This is a weak argument because users are always unfamiliar with new interfaces. But after all, this evaluation gave valuable insight into the perception of users with a local view navigation.

3.3.4 Conclusion

The Virtual Museum of the Pacific is one of the view examples of FCA that breaches out of traditional static visualizations. They idea to show only the directly related formal concepts is promising because this scales better than Hasse diagrams. My idea is based upon the work from the museum but addresses critical problems: the missing orientation, the missing history and rudimentary search implementation. The idea is described in section 4. Before that, let us review a related non-FCA-based technique, but feel free to skip it.

3.4 Faceted Search

This section should only give a small overview about this technique. Completely introducing it is beyond the scope of the thesis. Excessive information can be found in the work from Sacco and Tzitzikas [44]. To keep things short, this technique is explained with an example. Figure 3.6 shows a screenshot of Flamenco as described by Yee et al. [50].

This interface is similar to the ”local view“ on Hasse diagrams presented in Section 3.3. The main idea: The dataset comprises several dimensions called *facets*. The user can restrict dimension to certain values. Only items are shown which fulfill the restrictions given by the user. In addition, the user gets suggestion for further restrictions. In Figure 3.6, you can that you see the location is restricted to ”Asia“ and shapes etc. are restricted to ”fabrics“. On the left, you can see the suggestions and how many items would be left after restricting.

Sacco and Tzitzikas [44] say that although FCA and Faceted Search are apparently two distinct approaches to information modeling and access, and they use a different terminology, they are closely related. They also mention that faceted search reduces the cognitive efforts because it ensures that the results are manageable. It feels like, that faceted search is superior to the local view on concepts lattice, if the dataset consist of more than one dimension. So for this reason, the use of FCA for this particular dataset is

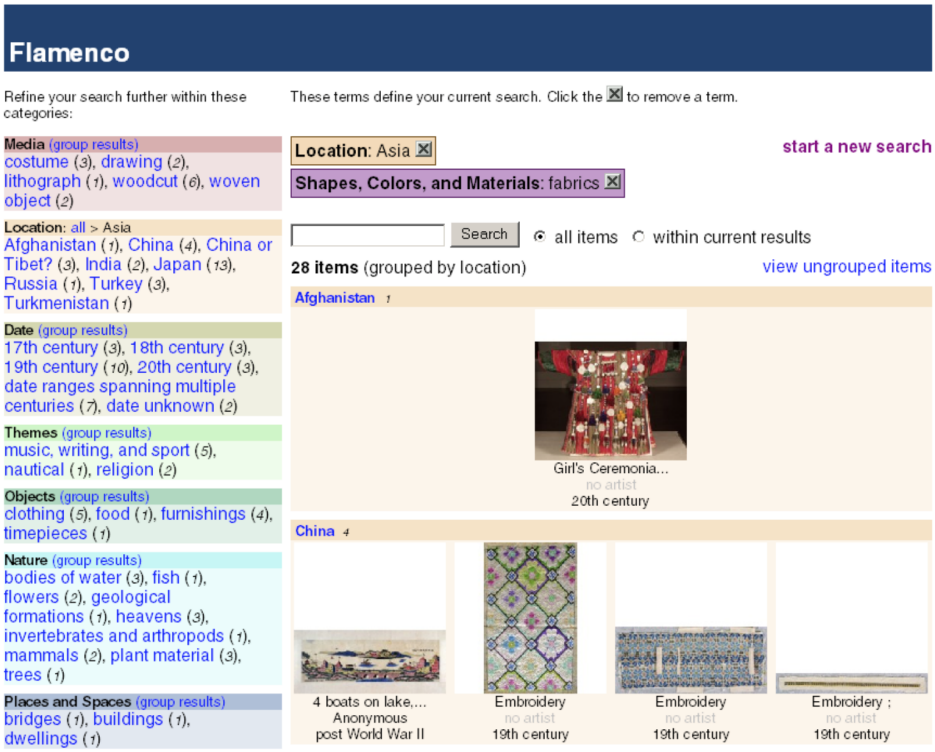

Figure 3.6: Flamenco, only items that are from Asia and made from fabrics are shown. Source: Yee et al. [50]

to question because it actually comprises several dimensions. Nevertheless, the research group applied FCA and it was my task to visualize the results. The interface is described in the next section.

4. Fancy FCA 1.0

First, a concept is described to visual large concept lattices. Second, this concept is implemented as an interactive web application. The data (in form of a concept lattice) for this implementation comes from the research group and how the data was created is described in XX. Third, the concept and the implementation are discussed.

4.1 Concept

The concept of the interface is inferred form the discussing related work in Section 3. It is mainly influenced by the Virtual Museum of the Pacific discussed in Section 3.3.3. They follow the idea to only give a local view on the Hasse diagram. This is done because the concept lattices of most formal contexts are too large to visualize them in a Hasse diagram. In this form, the interface always focuses on one formal concept called *the Focus*. Only directly related children of the Focus are shown. The initial state of the Focus lies on the supremum. The supremum is the most general formal concept. The user has to possibilities to change the Focus:

1. She can select a child of the Focus as new Focus.
2. She can "jump" to a completely new Focus by using a search on the lattice[1]

Let us demonstrate this with an example shown in Figure 4.1. After searching on the lattice after the attribute "e", the Focus is set to the formal concept surrounded with a dashed circle. Now, only the nodes surrounded

[1] It is very important to realize, that the search is NOT done on the documents. It is only done on the attributes of the objects of the formal context. Informally, the search is only done on the index terms of the documents. If the users search for terms that are not the index terms of any documents, it will result in an error.

with a black circle are visible to the user. This two formal concepts are called *the Suggestions*, because they suggest the users which attributes to add to the current selection of the Focus. In this case, there is one suggestion to add "c" to the focus and refine the selection from 5 objects (2,4,6,8,10) to 4 objects (4,6,8,10). And the suggestion to add "p" to the focus and refine the selection to one objects (2). They are the children of the Focus and therefor per definition more specific than the Focus.

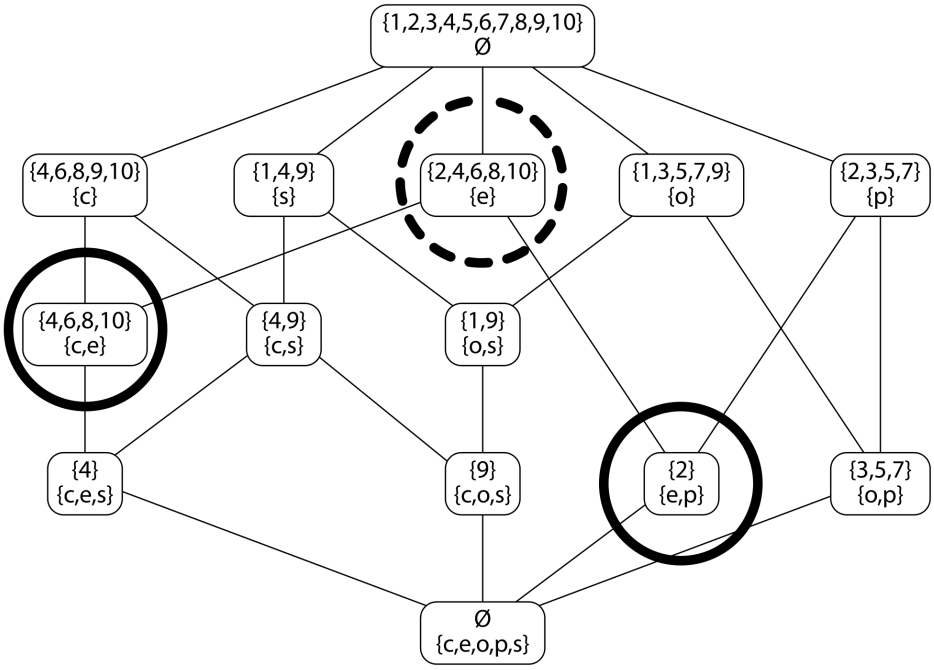

Figure 4.1: After searching for "e" lies the Focus on the formal concept with a dashed circle. Only his children (black circles) are visible to the user.

4.1.1 Interface Components

After describing the general navigation, we can identify already two important components of the interface: A *Search Bar* and the *Suggestions*. The users are probably also interested in the *Results*. The Results are those objects from the Focus. We discussed the problems of the Museum earlier an and realized that the users need origination. Therefore we add *Breadcrumbs*.

And they want a history of actions we call this component just *History*. The components of the interface are completed with a *Menu* and you can see the general layout in Figure 4.2. Each component is described in detail now.

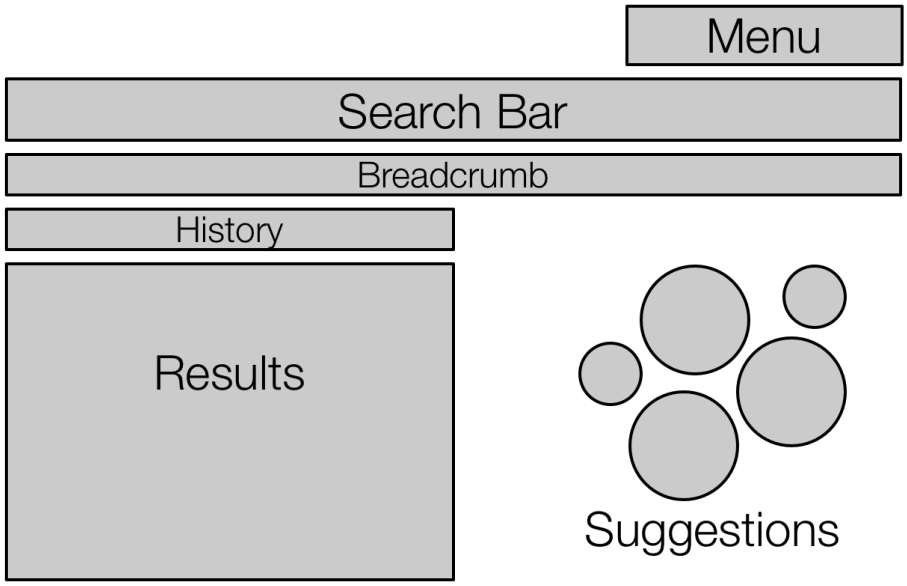

Figure 4.2: Wireframe of the interface of Fancy FCA 1.0

Search Bar and Results

All users know web search engines. In my opinion, it easy for users to work with a new system if it looks similar to system they already know. That is why the overall look of the interface should remind users of a search engines. The general advices to design user search interfaces by Hearst [28] should be followed. Results should be ordered in a vertical list. Each list item consists of a title and body. The title describes the items in short and the snippet goes more into detail. The can review the result in detail by clicking on the title. The title links to a web page where the user can investigate the result in detail. The user should have the possibility to bookmark the result. She can do it, if she is logged into the side. But it is also possible to use the site without being logged in.

Suggestions

The different suggestions are shown as a bubble cloud. Each bubble stand for one formal concepts and it is only label with terms that should be added. The size of the bubble corresponds to the number of the document the concept has. The exact number is shown as tooltip when the user hovers over the bubble.

Breadcrumb

Breadcrumbs are included to give the user orientation. The Breadcrumbs indicate how the user got to the current focus. Of a given Focus, it shows the previous formal concepts of the Focus. It is really hard to describe it abstract. So let us take a look at an example. The user starts with the initial Focus. From there he searched for "x". Then he clicked on the suggestion "y". The breadcrumbs show "Home / x / y". The current Focus has the terms "x y". Each part of the breadcrumbs links back the previous focus. If you click on "x", the Focus changes back to the Focus with "x". If you click on "Home", you end up in the initial Focus.

History

With the history, the user can look back is navigational history. It exceeds to possibility of the Breadcrumbs because it gives more information. The breadcrumb only go back in a current navigation process. The users can always see the complete history of the current session. If she is logged in, the history of all time is shown.

4.1.2 Usecases

The UML use case diagram is depicted in Figure 4.3.

4.2 Implementation

The implementation was done with data provided from the research group. So they gave the already computed lattice and all the information of the documents. You can find the system running here and 30-seconds video of it here.

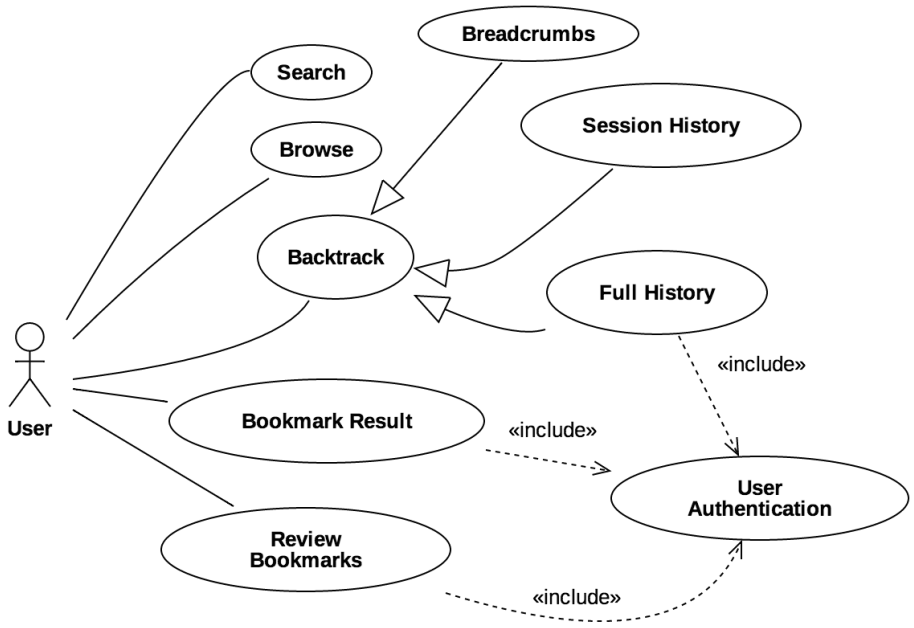

Figure 4.3: UML use case diagram for Fancy FCA 1.0

The implementation is done as a web application because all users have already a web browser installed. There is no setup necessary. The implementation of a web application can be split up into backend and frontend development. The backend is responsible for the programming code that runs on the server. The frontend is responsible for the code that runs in the browser. Let us start with the backend.

4.2.1 Backend

It has to be decided first, which programming language and framework to use for the web application. I chose Express.JS [2] of the runtime environment Node.JS[3] because it uses the programming language Javascript. Javascript is also used for the frontend. So we only need to stick to one programming language. But instead of writing Javascript we use CoffeeScript[4] which adds semantic sugar to Javascript and compiles to Javascript.

[2] `http://expressjs.com`
[3] `https://nodejs.org`
[4] `http://coffeescript.org`

We need a database to store data. The research group wanted to store logs[5] of the user interaction. In addition, we have to save the history of users and their bookmarked documents on the server. For this, I use MySQL as database because it was already installed on the server where the software should run. Because of the use of an Object-relational mapping (ORM) framework, Sequelize [6], it is easily possible to change the database. The ORM creates an abstraction and it allows the programmer to interact with the database without writing raw SQL queries.

4.2.2 Frontend

Because the interface is a webpage, the used technologies were HTML, CSS and Javascript. HTML is the markup language to create webpages and the backbone of the web. CSS adds style to the webpages. Javascript add interactivity to the webpages. But like in the backend, instead of writing pure Javascript I programmed in CoffeeScript which was compiled into Javascript. I used the framework Bootstrap[7] because it allows me to quickly create appealing webpages. Bootstrap has templates for all kind of components like forms, buttons, navigational elements, a grid system, icons etc.. Instead of reinventing the wheel, I use Bootstrap to use basic components.

Now let us take a look a some screenshots of the system to demonstrate the implementation. In Figure 4.4, you can the initial state of the interface. The bubble cloud on the right shows the Suggestions. It is a little bit unorganized, but the initial state has to show the most Suggestions. This is because this state is the most general formal concept. For the layout of the bubbles, I use the Javascript framework D3[8] [5]. D3 utilized SVG to draw elements which are also accessible via the Document Object Model (DOM) API, which means I can catch events like "mouse over an item" or "click on an item". The word cloud is a customized graph force-directed layout based on the work from Vallandingham [49].

You can see in Figure 4.5 the use of a "typeahead" which can also be called "auto-complete". For this, I use the Javascript library Twitter typeahead.JS[9]. In Figure 4.6, we can see two screenshots which both focus on

[5] The logs were never evaluated because the tool was never used in production.
[6] `http://sequelizejs.com`
[7] `http://getbootstrap.com`
[8] `http://d3js.org`
[9] `https://twitter.github.io/typeahead.js`

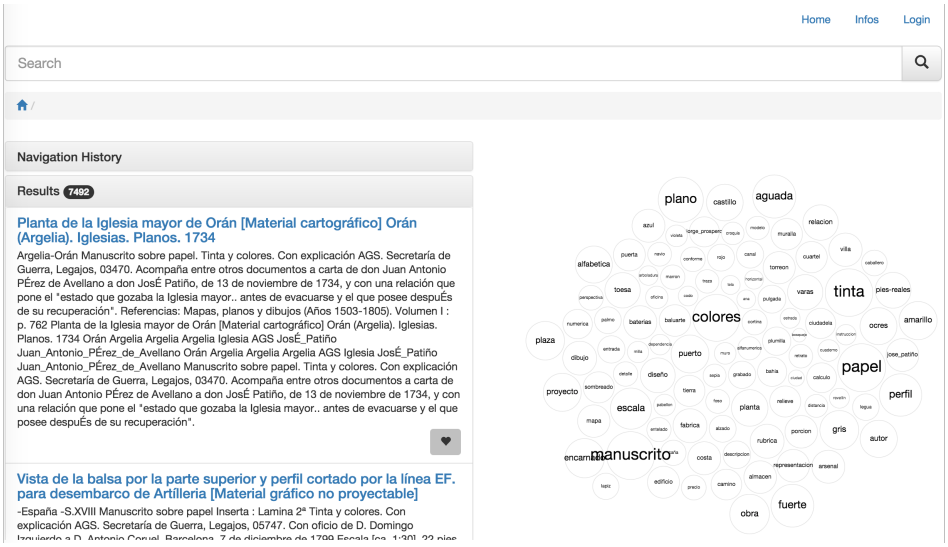

Figure 4.4: Fancy FCA 1.0, initial state

the left part of the interface. Let us start with the left one. In there, we can see various components. Starting with the search bar, we can see the terms of the Focus. We are looking for documents which the index terms "papel tinta fabrica". Below the search bar, you can see the breadcrumbs. They allow, for instance, to backtrack to just the Focus "papel tinta", if the user clicks on "tinta". Below the breadcrumbs, you can see the label "Navigational History". But first, let us take a look at the "Results". The number after "Results" show how many results are there. In this case 227. Let us take a look how the result items are presented. First, there is a title. If you click on the title, you will get to an external webpage, with further information. Below the title is a snippet of the result. The terms of the Focus are highlighted. In the bottom right corner, you see the icon to bookmark this item. Now imagine to to click on the "Navigational History" label. You would end up in the view right. You can see that the "Navigational History" is uncollapsed. It shows a list of History. If you click on a item, the Focus changes.

When the user starts browsing, a JSON file with all the data is downloaded to his client. The file contains the information of the lattice and also about the documents. The programming logic which controls the interface, is done in the frontend. This reduces the communication between the client (the

Figure 4.5: Fancy FCA 1.0, search interfaces offering Typeahead

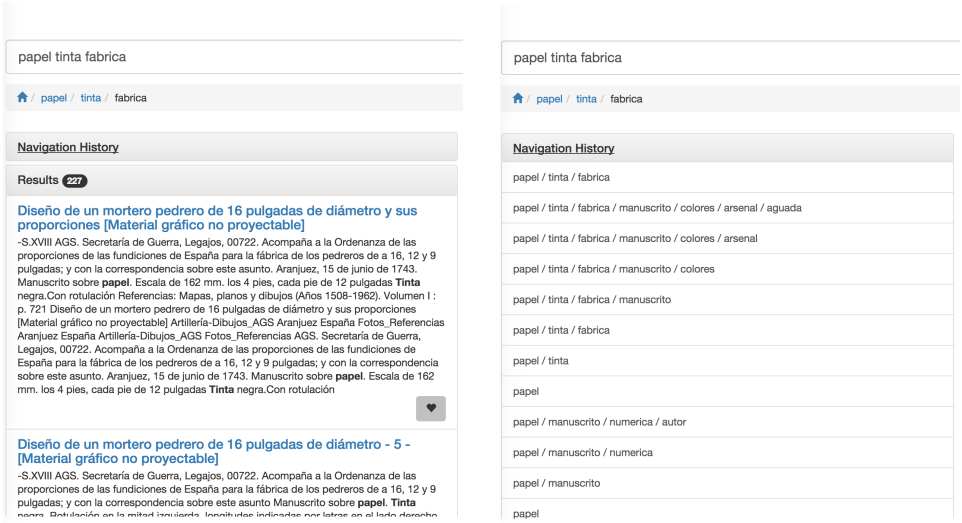

Figure 4.6: Fancy FCA 1.0, the Focus is "papel tinta fabrica". In the left picture, you see the Results. In the right picture, you see the Navigational History.

browser) and the server to a minimum.

4.3 Discussion

For the concept, it is to question, if the word cloud is an appropriate technique to show the Suggestions. The Suggestion consists of terms and a number of documents. This information can also be shown in a table. A table is a structured to present information. But the word cloud avoid a

clear order in the data. In a table, probably only the top suggestions would be considered. This is dangerous, because the number of documents a suggestions represents, should not guide the users. What is also to question, is that only children of the Focus are currently presented. For now, the parents of the Focus are ignored. They should be added. Maybe in a next iteration.

The whole has a problem because the JSON file with all the data is huge. The user has to download over eight megabytes before he can start using the interface. This can be fixed by porting the logic from the frontend into the backend. By doing this, only the data that is currently need would be send to the client. It would also be a good idea to include thumbnails of the the maps to the result. This could not be done, because it was not possible to get thumbnails of the maps.

5. Evaluation

The design of an interface is highly subjective. User studies can help to evaluate an interface. For this, a brief review of different techniques for human studies is given first. Then we describe the setup of the study, describe the results and finally discuss and conclude.

5.1 Background

We will only scratch the surface here. A comprehensive introduction into "Methods for Evaluating Interactive Information Retrieval Systems with User" gives Kelly [31]. A shorter introduction gives Hearst in Chapter 2 in her book "User Search Interfaces" [28].

5.1.1 Basics

So we want to measure usability, but how is it defined? The ISO 9241-11, 1998 [30] defines three aspects of usability:

- Effectiveness: Accuracy and completeness with which users achieve specified goals.
- Efficiency: Resources expended in relation to the accuracy and completeness with which users achieve goals.
- Satisfaction: Freedom from discomfort, and positive attitudes towards the use of the product.

5.1.2 Experiment vs. Evaluation

It is important to distinguish between the terms 'experiment' and an 'evaluation'. Kelly [31] writes:

> Evaluations are conducted to assess the goodness of a system, interface or interaction technique and can take many forms [..] Experiments have historically been the main method for interactive system evaluation, but experiments can also be conducted to understand behavior [..] Two important characteristics of experiments are that there are at least two things being compared (e.g., system type) and that some manipulation takes place [..] In some types of [interactive information retrieval] studies only a single system is evaluated. This is a weaker form of evaluation since it is not possible to demonstrate how much better users perform or how different their behaviors and inter actions are since there is no point of comparison. Traditional usability tests are examples of this type of evaluation. Traditional usability tests are usually conducted with a single version of a system, with the goal of identifying potential usability problems.

In this thesis, the system is only evaluated to find usability problems. No comparisons among other systems are conducted but should be done in further investigations.

5.1.3 Informal Usability Testing

Hearst [28] describes Informal Usability Testing as "Showing designs to participants and recording their responses". It is often used in short iterative cycles to quickly evaluate a design. In this thesis, only informal usability studies are conducted because the conductors do not have proper equipment nor any experience with user studies.

5.1.4 Questionnaires

A questionnaire comprises a set of questions and is cheap and fast way to gather information from people. Kelly et al. [32] describe two types of questions as follows:

> Questionnaires can be comprised of closed questions, open questions or a mixture of both. *Closed questions* are questions that provide a fixed set of responses with which subjects must respond. It is common practice for usability questionnaires to include closed questions in the form of statements such as, the system was easy to learn to use. Subjects are typically provided with 5–7-point Likert-type scales for responding, where one scale

> end-point represents strong agreement and the other represents strong disagreement. [..] *Open questions*, on the other hand, do not provide a response set and subjects are able to provide any type of response they feel is appropriate.

5.1.5 Thinking Aloud

Kelly [31] writes by referring to Ericsson and Simon [24]: "The think-aloud method asks subjects to articulate their thinking and decision-making as they engage in [interactive information retrieval]". The comments from the participants have to be collected. Either by recording the session or by taking notes. It is hoped that the conductors can learn from the thinking process of the participant. There exist variations of this technique. Because it can be exhausting, challenging and awkward to talk to yourself all the time, participants are encouraged to report either at some fixed times or when the feel the need.

5.2 Setup

Sadly, I only had minor influence on the setup of this study because I was not allowed to set it up. The conductors in charge where amateurs and did not had any experience with human studies. The evaluation was done with five people with a background in humanities. Only from three participants were the demographic collected: Female 60 years old, female 49 years old, male 44 years old. All participant listed to an introductory presentation which was given in Spanish. I do not know what was that to them because my Spanish is not good enough. The participants were split into two groups: One with three participants and one with two participants. There were split because there was not enough time to do individual session.[1] All members of the group sat in front of the interface and the participants rotated in front of the interface. I was responsible for the group with three participants. From the group with two people, it was not possible collect any data during data study. All participants filled in a questionnaire afterwards. So just I describe the procedure of the group I was responsible of. After the introductory lecture, all participant got a handout. The handout consists of four parts:

1. A description of the interface. But this was an academic text and not meant to be a manual. I doubt that anybody read it.

[1] But to be honest, I am not really sure why it was decided to do this.

2. Four Tasks the participants should do. They are included in the Appendix D. These tasks were ridiculous long and the third task was not even doable!

3. A questionnaire witch ten closed questions from USE questionnaire [36]. B

4. Fourth open questions as asked by Kelly [32]. C

So from the other group, we had no data while there were using the interface and I cannot tell how they did it. In my group, I encouraged the participants to talk to me while they were using the interface. I did not force them to speak to all the time, but I asked them time to time. The session was recored with an iPhone 6 Plus[2] and analyzed afterwards. The instructor wanted the participants to do the tasks, but I knew that the task were complete nonsense and persuaded the participants to just use the interface. But after some time, I had no excuse left to not do the tasks and I finally surrendered and let them do the tasks. But this was okay, because I already collected enough data. After around 55 mins the session was done and the participants filled in the pen-and-paper questionnaires - in Spanish. The instructor allowed the participants to fill out the questionnaire in Spanish[3]. This made the open questions nearly worthless because the translation process was not carefully done[4].

5.3 Results

It was hard to extract knowledge from this chaotic evaluation setup. I group the results into two categories: closed questions and everything else as *comments* to keep things short. There were not any major differences among the comments so we can group it togethter. It is also worth mentioning, that this evaluation study was the first time for the participants, that they were confronted with a FCA-based approach. This lead to some comments on the approach itself.

[2] `https://www.apple.com/iphone-6`

[3] Spanish people believe that their English is very bad. Which is not totality true but you believe anything if you repeat it often enough.

[4] Why? Because they did not fucking care

5.3.1 Comments

All participants wrote down and said, that they were missing the possible to refine the search by a time range, location and author of the map. They said, that this is the very important for their work. One participant could not believe, why the search was not working when she search "Valencia". The term was not included in the word list and thereby not in the lattice. She mentioned, that this should get fixed immediately. Two results gave suggestions to improve the result list. Both said, that the thumbnails should definitely be included and that they were not interested in the text snippet. By removing the text snippets and thereby reducing the height of a result item, they could see more results at once. They were very interested to see as much titles as possible. No participant used the possibility to save documents. One participant highlighted, that he wanted to see related

In regard to the interface in general, the comments were positiv. The participants liked the clean design. One participant wrote that using the system was funny. Two participants said, that they liked the interface but not the content. Two participants wrote it easy to use. I observed, that the users did not used the search very often. They were interested in the skimming over the bubble cloud.

5.3.2 Closed Questions

Out of the five participants only three filled out the questionnaire. All results are in the Appendix B. The average responses are shown in Table 5.1. The results correspond to the comments made by participants. The weakest results got the sentences "It meets my needs" and "It does everything I would expect it to do". We elaborated on this, that the participants want to refine their information needs etc.. The best result got the sentence "It is easy to use". It looks like the participants liked the interface.

5.4 Accessibility Analysis

In addition to the evaluation session, there was an evaluation regarding accessibility[5]. It was conducted by people from the UNED: Miguel Angel Marqueta and Covadonga Rodrigo San Juan. The report can be found in Appendix A. Their comments were overall positive buy they highlighted some problems with the interface: It is possible to zoom in the bubble

[5]If people with disabilities can use the interface.

Table 5.1: Responses from closed questions. Participants (n=3) had to choose between 0 (disagree) and 7 (agree).

	Average Response
Usefulness	
It is useful.	$6.\bar{6}$
It meets my needs.	$4.\bar{3}$
It does everything I would expect it to do.	$4.\bar{3}$
Ease of Use	
It is easy to use.	7
It requires the fewest steps possible to accomplish what I want to do with it.	$5.\bar{6}$
I don't notice any inconsistencies as I use it.	5
Ease of Learning	
I learned to use it quickly.	$6.\bar{6}$
I easily remember how to use it.	$6.\bar{6}$
Satisfaction	
I am satisfied with it.	$5.\bar{6}$
It is fun to use	$5.\bar{6}$

cloud, but there are no buttons on the screen for it. In the current state, the zooming can only be done with a mouse or a touchpad. They also pointed out, that it is hard to see if the result list updates. They updating process of the result list should be more visual.

5.5 Conclusions

Zobel[51] proclaims that far too many human studies in computer science are amateurish and invalid. I have to admit, that this study is one of those amateurish studies. In addition, it is hard to draw conclusions because of the low number of participants. But it can be said that FCA, in this implementation, does not suits the needs of the user. It is very confusing for the

users that they cannot search for arbitrary terms on the lattice. It is also the a major problem, that the users cannot refine their informations needs along dimension. They want to specify time ranges or locations. FCA cannot offer this because it only works on one-dimensional data. For the future, techniques like faceted search as described in Section 3.4 should be applied. This could result into an interface similar to `http://www.oldmapsonline.org/`

For the interface itself, it looks like that the users found it easy to use and easy to learn it. But there exist problems with the presentation of the result list. But also other problems were found. This problems should be addressed in future iterations of the software.

6. Fancy FCA 2.0

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

7. Conclusions

First, at described in the introduction, digital humanities is about building tools for human scholars. Building tools it NOT the primary focus of computer science research. Computer science research is mainly focused on finding new algorithms, refining algorithms, apply algorithms to new problems etc.. There are not famous for being the best software engineers. It is a very bad idea, to take computer science researchers and say to them: "Now build some tools for human scholars." as this was done in this case. As this thesis showed, this approach was an utter failure. The researchers want to apply bleeding-edge methods as FCA when building this tools. But all the human scholars needed, was a very simple search interface with some custom query filters. But, at least of an ordinary information retrieval scientist, is not very interesting and so they are trying some fancy stuff. To do real research in digital humanities, people needed who live and breathe digital humanities. I think, this is the reason why wise people coined the term "digital humanities" to make clear that it is fundamentally different from computer science.

Second, I proposed a method to visualize large concept lattice. It focuses only on small parts of the lattices and the user can incrementally explore the lattice. Thereby she feels confident to explore the lattice because she can always backtrack to earlier actions. I can say with slight confidence[1], that the user liked this approach. But further user studies with experiments are needed to judge if my proposal suits the needs of the users.

Third, for the use of FCA in IR, the evaluation showed that it is difficult. If the concept lattice is build from word list of possible index terms, it can irritate the user why only a small portion is in the concept lattice. This does not look promising and should be dropped.

[1] The evaluation setup was very chaotic.

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A. Appendix: Accessibility Report

Informe de

Descripción/Objeto	Brief Accessibility Analysis for Visualization Tool
Destinatario	Johannes Filter

Editado	Revisado y Aprobado
Miguel Angel Marqueta	**Covadonga Rodrigo**

Índice

1. Destinatario

2. Documentación/herramientas de referencia

3. Contenido

This a brief accessibility analysis for a visualization tool for NLP group of LSI department of UNED. It is only a list of good and bad things pointed out in a first view. It would be necessary, perhaps, a deeper analysis of this tool but in any case it must be considered as a starting point of a better accessibility document.

Good points:

- Good, nice and clear interface.
- Good color contrast. It must be checked in detail for each component with a specific tool (Contrast Color Analyzer).
- Good size and type font.
- Good layout of interface (Disposition Interface in two parts).
- Good decision of edit box. Simple and clear (with suggestion elements).
- Good navigation with tab key. Except for alternating with two display parts.
- Good choice of “heart icon” for “like button”. But it must be checked with Contrast Color Analyzer.

Bad points (They must be checked):

- It is necessary to add tooltips for 4 main links (Home, login…)
- It is necessary to check in accessibility of “right panel” in order to verify whether screen readers can read JavaScript code for “cloud images”. It must be with checked it with tools like “Jaws” or “NVDA” (this last one is free, open source).
- It is necessary to add access key for resizing, (zoom in, and zoom out) now it’s only mouse implemented.
- Although keys in “Navigation History” it’s a good design with breadcrumbs It is necessary to add keyboard navigation by arrows.
- It is necessary change bold font in “No result” advice. It must be checked in with Contrast Color Analyzer to verify it. It is necessary whether screen reader can read this notice when it appears on screen. Probably it will be possible if focus is set to this notice automatically, but it must be checked.

Conclusion:

In general accessibility of this tools is good, but we propose to check in detail this earlier points and to evaluate the full accessibility of these to ensure a better knowledge of the real accessibility state of this tool. At least we propose some changes and to verify some other to ensure a basic accessibility.

B. Appendix: Closed Questions

Results Closed Questions

	I	II	III	IV	V	Average
Age, Gender		60, F	49, F	44, M		
Background	Historian Expert	Historian Expert	Historian Expert	Historian Expert	Historian Expert	
Usefulness						
It is useful.		7	6	7		6 2/3
It meets my needs.		4	5	4		4 1/3
It does everything I would expect it to do.		4	5	4		4 1/3
Ease of Use						
It is easy to use.		7	7	7		7
It requires the fewest steps possible to accomplish what I want to do with it.		5	6	6		5 2/3
I don't notice any inconsistencies as I use it.		4	5	6		5
Ease of Learning						
I learned to use it quickly.		7	7	6		6 2/3
I easily remember how to use it.		7	7	6		6 2/3
Satisfaction						
I am satisfied with it.		7	5	5		5 2/3
It is fun to use.		4	6	7		5 2/3

C. Appendix: Open Questions

- What were the most positive things about using this system and why?
- What were the most negative things about using this system and why?
- How would you improve this system and why?
- Is there anything else that you would like to tell us about this system and your experiences using it?
- In comparison with other systems (Interface of Catálogo Colectivo de las colecciones de Mapas and previous work of this research group). Do you think it is more useful? If yes, which part of the system is more useful.

D. Appendix: Tasks

1. The user is not looking for a particular topic. He/she starts with the general empty overview of the topic. He/she picks a word from the word cloud and navigates to new concepts. He/she repeats this procedure for several times. He/she is using the breadcrumbs to go up again and looks for some other words. He/she finally finds one interesting item and studies it on the original AGS website.

2. The user wants to find information about one term ("mapa") that interests him. Before he/she starts browsing, he/she logs into his user account. After that, he/she typed in the search interface the term and makes use of the type-ahead. He/she finally gets to the desired concept and reviews the concepts. He/she decides to get more specific ones and refines the search by clicking on words in the cloud. He/she finds interesting documents and bookmarks them for later investigations. He/she goes back again by using the breadcrumbs and chooses another term. He/she finds other interesting items and bookmarks them.

3. A humanist expert is working in the DIMH project. He/she has an extensive knowledge about the historical scenario related to the project: the engineers in the service of the Spanish Monarchy in the XVI and XVII centuries. He/she is trying to draw some conclusions about the work conducted by these engineers and also about the different aspects related to their works (e.g., typology of their projects, technical details about their way to work, relationships between them and the monarchy, preferred locations for their projects...). To that end, he/she makes use of the AGS collection, which includes an extensive catalogue of draws, maps and plans about different projects conducted by those engineers. He/she is used to manually analyze this kind of collections; however, the size of the AGS dataset (almost 8000 files) makes the manual analysis difficult. Therefore, he/she takes advantage of

the visualization tool showing the dataset modeling and organization to analyze its information. In particular, he/she is interested in the analysis of the projects carried out by Jose Patino. The user is aware that Jose Patino carried out some projects in the city of Sevilla, and he/she wants to have more information about these projects as well as to find some other projects with similar characteristics in other cities

4. The same humanist expert is now looking for information about projects made in the coast (e.g., fortifications in the coast). He/she knows that the engineers used different metrics (e.g., pies-reales, varas) to measure the distances. Moreover, he/she believes that it could be some relation between these metrics and the date of the projects. More in particular, he/she believes that "varas" was not used before the XVII century, while "pies-reales" was a common metric, even in the XVI century. Furthermore, he/she wants to explore if there is also another aspects (i.e., beside the temporal issue) related to each one this metrics.

Ich versichere hiermit, die vorliegende Arbeit selbst verfasst, Zitate gekennzeichnet und keine anderen als die offengelegten Quellen und Hilfsmittel benutzt zu haben.