Automatic Tagging as a Support Strategy for Creating Knowledge Maps

Leonardo Moura DE ARAÚJO
DIMEB – Digitale Medien in der Bildung, University of Bremen
Bremen, Germany

and

Doris Caliz RAMOS
CETTICO, Polytechnic University of Madrid
Madrid, Spain

ABSTRACT

Graph organizers are powerful tools for both structuring and transmitting knowledge. Because of their unique characteristics, these organizers are valuable for cultural institutions, which own large amounts of information assets and need to constantly make sense of them. On one hand, graph organizers are tools for connecting numerous chunks of data. On the other hand, because they are visual media, they offer a bird's-eye view perspective on complexity, which is digestible to the human eye. They are effective tools for information synthesis, and are capable of providing valuable insights on data. Information synthesis is essential for Heritage Interpretation, since institutions depend on constant generation of new content to preserve relevance among their audiences. While Mind Maps are simpler to be structured and comprehended, Knowledge Maps offer challenges that require new methods to minimize the difficulties encountered during their assembly. This paper presents strategies based on manual and automatic tagging as an answer to this problem. In addition, we describe the results of a usability test and qualitative analysis performed to compare the workflows employed to construct both Mind Maps and Knowledge Maps. Furthermore, we also talk about how well concepts can be communicated through the visual representation of trees and networks. Depending on the employed method, different results can be achieved, because of their unique topological characteristics. Our findings suggest that automatic tagging supports and accelerates the construction of graphs.

Keywords: Knowledge Map, Mind Map, Automatic Tagging, Heritage Interpretation, Information Synthesis, Museum.

1. INTRODUCTION

According to an IDC[1] study [1], data volumes overall are predicted to reach a staggering 44 zettabytes (44 trillion gigabytes) by 2020. One of the drivers to an increasing production of data and data-related applications is the recognition by businesses, institutions, and governments that the quality of their core competencies can be positively affected by the knowledge inferred from data. With this in mind, obtaining knowledge from information and data is key for society's main economical, social and political organizations, such as media outlets, NGO's, cultural institutions and universities just to name a few.

As society moves towards a data driven future, knowledge workers are not only expected to search, collect, and organize information, but also critically analyze and compare many different sources in order to derive meaningful knowledge. Information synthesis plays a central role in research and design processes, since it is the ability to infer relationships among many different kinds of sources (see [2], [3]). It occurs in between initial data gathering and more advanced stages where high level decision-making implements actual projects and/or products. Being able to organize and handle complexity, find clarity, and at the same time produce rich interpretations is a non-trivial task, especially when it concerns large sets of chaotic data. However, when successfully executed, information synthesis drives innovation and promotes real competitive advantage for businesses and institutions.

One of the main problems in making sense of data is the complexity involved in synthesizing information meaningfully and effectively. The degree of difficulty in obtaining and presenting knowledge increases in a parallel manner to the heterogeneity and amount of data one needs to deal with. Data and cognitive overload is a problem [4] that drives the conceptualization and the development of methods and techniques in order to try to minimize this issue. Tools based on graph organizers offer a solid framework for structuring and making sense of information. From tree diagrams to networks, from tight hierarchies to complex interconnected graphs, mapping techniques have helped individuals to handle complex information for centuries [5]. These graph organizers are able to simplify complex scenarios, make abstract concepts concrete, and enable search processes and sequential inferences [6].

Tree diagrams (used by e.g. Mind Maps) and networks (used for modeling Concept Maps and Knowledge Maps) offer a unique interpretative layer that places itself on top of raw data. Mind Maps and Knowledge Maps are able to capture and transmit meaning by either offering a framework where data can be structured with, or making explicit the underlying arrangement of information. This is vital for sensemaking, since, as put by Klein et al. [3], sensemaking is "a motivated, continuous effort to understand connections" [3]. Not only structure, but also well-encoded visual representations (such as color, shape, position, etc. [7]) are able to influence individuals' cognitive workload and support effective comprehension of information [8]. In this sense, these maps are suitable to assist a wide range of activities, from Research and Development [2] departments to formal [9] and informal educational environments (see [10]).

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

In this paper, we discuss the main differences between the topology of tree diagrams in comparison with the structure expressed by networks, and their impacts in serving as tools for organizing, learning, and communicating ideas. While tree diagrams are simpler to be structured and comprehended, networks offer challenges that required new strategies to support individuals in creating the maps by minimizing the complexity involved in handling information. In this regard, we present our research results concerning the application called Lisa Platform [11] in comparison to a traditional computer-assisted mind mapping tool.

The Lisa Platform was originally conceptualized to assist curatorial research, by both providing a schema for managing content, and producing structured data on top of which other applications could be built upon. The software is based on Entity Tagging as a strategy for creating curated Knowledge Maps. In addition, the platform provides the Automatic Tagging functionality for accelerating the workflow and aiding the user in identifying and relating similar concepts from different sources and resources.

2. THE RELEVANCE OF GRAPH ORGANIZERS TO CULTURAL INSTITUTIONS

The relevance of graph organizers to cultural institutions can be summarized in the following main points. To begin with, these tools provide an easy-to-use framework for making sense of complex information and data. In this case, they are particularly interesting for institutions when e.g. performing curatorial research or creating exhibition concepts, since research and exhibitions consist of a constellation of interrelated topics that need to be made explicit. Such visual representations have the power to explain information and data in a way that could not be represented otherwise [12]. This is especially the case when considering how to display the hidden web of connections among the numerous objects within an exhibition that form the actual backbone of the exhibition itself. The structure of the graph is a powerful medium for driving interpretation by putting objects into context, because they provide the binding properties and the "big picture" necessary for contextualization and interpretation.

Besides supporting interpretation and promoting creative insights [13, p. 143], tree diagrams and networks have been used to organize and represent many topics in a numerous branches of science, such as genetics, linguistics, philosophy, computer science, genealogy, and so on [14]. Researchers, specialists, and curators can utilize graph organizers to support their own work and display these representations within exhibition spaces in order to communicate and promote understanding about topics [15]. Evolutionary tree diagrams, for example, are generated following scientific methods from taxonomy, which is a scientific framework to classify biological organisms according to shared characteristics. Because of their simplicity and clarity, these diagrams can be effortlessly introduced in exhibitions that deal with e.g. evolutionary history in order to support visitors' interpretation in museums spaces [10].

Finally, if these graph organizers are able to organize and store the data they gather in a structured way complying with a standard format, the reuse of data is then enabled unleashing therefore a whole range of applications powered by these Knowledge Bases. It is important to point out that, data has always been a central point of synergy in museums. From the very beginning of their existence, card catalogs and file cabinets have supported exhibitions in many different ways. They provided important information about objects assisting curators in constructing narratives by organizing exhibitions in chronological, thematic, or taxonomic manners.

However, information systems for cultural heritage have not yet accounted for deep structural changes brought by contemporary information technology. The majority of cultural heritage applications that deal with data focus on the ordinary management of collections. They do little to support curatorial research, produce rich interpretation of artifacts, and provide a platform for content creation. In this sense, in order to be able to model information beyond the limitations of forms (text fields), to obtain a bird's eye view of the rich and diverse information the institution has, and to extract relevant insights from it, researchers and curators of cultural institutions rely on third party tools that are capable of producing more than just lists.

The Lisa Platform offers a comprehensive answer to the limitation of Information Management Systems for cultural heritage, because it provides a human-data interface that is capable of modeling information with flexibility, making it suitable to not only organize collections, but also be used during research and content production. By using graph organizers as an interface, the manipulation of data does not require specialized technical skills from the user, but it can done with a higher degree of intuitivity, as demonstrated by our evaluation (see 6. Results).

3. GRAPH ORGANIZERS

Knowledge Maps belong to the same family as two other different mapping techniques, namely Mind Maps and Concept Maps. Mind Maps were originally conceptualized by Tony Buzan [16] as hierarchical diagrams. Because of their appearance, they are also known as spidergrams or spidergraphs. Mind Maps are usually focused on one main concept, with branches depicting sub-concepts radiating out from it [17]. The representation is structured into levels, where different levels depict higher or lower statuses. The branches are unlabeled and non-directional.

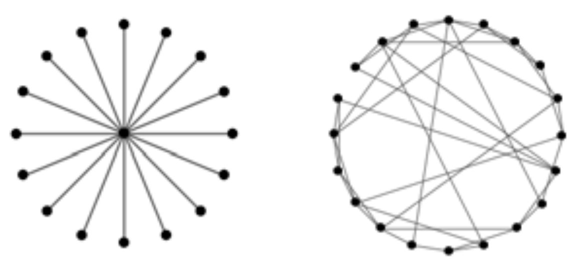

Figure 1*. Conceptual representations showing the main topological differences between tree diagrams (left) and networks (right)*

Mind Maps have already a long tradition and have been used for brainstorming, note taking, communicating ideas, etc [18]. All these high demanding cognitive tasks are especially important in e.g. classrooms to assist learning. A study conducted by Dhindsa et al. [9] showed that they "significantly improved information organization in students' cognitive structures when these gains were compared to those in a classroom where traditional teaching style was used” [9]. Besides information organization, pictures, colors and shapes allowed by Mind Maps, seem to be particularly effective in consolidation and memory stabilization after a timespan if compared with traditional note taking (see [19], [20]). Mind Maps can also be applied as evaluation tools for qualitative analysis in order to better depict and present the impression of individuals about certain topics of interest [21].

A Concept Map, on the other hand, is a top-down (from concepts to examples) network diagram showing the relationships between different concepts [22]. The relationships (also called edges, cross-links, or connections) among concepts have greater importance in Concept Maps than in Mind Maps. Concept Maps, created by Joseph Novak [23], are able to depict more complex ideas than Mind Maps, because they allow for the inclusion of cross-links, which are “relationships or links between concepts in different segments or domains of the Concept Map” [23] and “often represent creative leaps on the part of the knowledge producer” [23]. In this sense, they are not limited by a tree graph structure. According to Novak et al. [23], the Concept Map "serves as a kind of template or scaffold to help to organize knowledge and to structure it”. Concept Maps accept link that are either labeled or unlabeled, and directional or non-directional.

In regard to sensemaking, Kolko [2] says that “the Concept Map itself represents the creators' mental model of a concept, but it also informs and shapes that mental model during creation, as it allows designers to see both the holistic scale of the concept and also critical details within the concept. As it affords action-based understanding at both a gross and fine level, both its creation and its usage become tools for sensemaking” [2]. In addition to that, Concept Maps also offer a conceptual framework for constructivist assimilation, promoting therefore meaningful learning, because they are effective tools for linking new with old information [19].

Finally, concerning Knowledge Maps, Hanewald et al. [17] says that they are “a graphical display of information in which the importance and relationships between the various elements of knowledge are portrayed in the form of a map”. In this sense, they are more similar to Concept Maps than Mind Maps. O’Donnell et al. [24] points out that a Knowledge Map is a kind of Concept Map with obligatory directional and labeled links. One of the main differences between Concept Maps and Knowledge Maps is the standardized vocabulary. In addition, Knowledge Maps have no predefined starting or ending node.

4. THE LISA PLATFORM’S KNOWLEDGE MAPS

Popular Information Management Systems for Cultural Heritage (such as MuseumPlus, The Museum System, eHive, etc)[2] are effective tools for cataloging objects and managing exhibitions, but they do not support creative work and high-level interpretation of the institutions’ information assets. That is because of their architecture and presentation. These system have still a strong influence of the times when cultural institutions were engaging in establishing and managing their own self-made database systems with file cabinets and flashcards. They are used to store data concerning measurement of objects, used techniques, management of loans and exhibitions, and so on, but they are not able to e.g. model and capture the subjective impressions the researcher or curator had when collecting information and thinking about the objects and the history they carry. These systems are also unable to assist discussions between curators, managers, and designers when planning an exhibition. Usually, the institution staff needs to rely on other tools in order to create a common view among all members of a project.

Institutions use Mind Maps and Concept Maps when tasks require a more flexible approach to interpretation and creativity (see [15], [12]). On one hand, however, if these tools are better in supporting creative work, on the other hand, they lack the structure of a solid architecture regarding a data model on the background that allow for searchability, categorization, and reuse of data which are features supported by current Information Management Systems for Cultural Heritage. The Lisa Platform is an answer to this issue, because it combines both mapping as a human-data interface, and a flexible data model based on Knowledge Graphs to store information. The Knowledge Graph is a flexible yet powerful representation of data used by e.g. Google, Facebook, Microsoft, and so on to enhance search results [28], power AI assistants [29], provide valuable insights from social networks [30], and so on.

The Lisa Platform’s Knowledge Map is a visual graph organizer and a method for supporting the direct human cognitive handling of numerous, complex, and diverse sets of concepts. The Knowledge Maps can be defined as graph representations that are made of directional and labeled links with standardized vocabulary, and do not have predefined formal starting or ending nodes. A pre-defined vocabulary, which is a special characteristic of Knowledge Maps, enables consistency across heterogeneous information and data. For better exemplify the method used by the Lisa Platform’s Knowledge Maps, we can compare with the ones used by Mind Maps and Concept Maps as techniques for supporting information handling.

In the case of Mind Maps, the user must start by inserting a central topic in the middle of the canvas. It is recommended to use a picture in order to increase the degree of memorability concerning the content presented in the map. Sub-topics are then branched out from the central topic and keywords are used to define them. The map increases in detail as a greater depth is achieved by adding branches and sub-branches. Color schemas and other images can also be used to improve the reading of the map. It is important to point out that the tree structure is the most important guiding principle in Mind Maps. It organizers and imposes thought processes that aim at e.g. deconstruct higher concepts subdividing them into their constituting lower parts.

As for Concept Maps, before starting to generate them, the user must define a *Focus Question* [23]. This question works as a stimulus for thinking, because it provides a context and specifies a problem the map should help to resolve. After that, the user must identify key concepts and state them in a list with general concepts at the beginning, and the more concrete and less general concepts at the end of it. Only then, the map should be created. In this sense, Concept Maps have also a hierarchical backbone, because general concepts should be positioned on the top of the map, and the less general ones on the bottom. After positioning all concepts on the canvas, cross-links should be

[2] URL of the mentioned Information Management Systems: http://www.zetcom.com/en/products/museumplus/, http://www.gallerysystems.com/products-and-services/tms/, http://ehive.com/

drawn in between concepts. The relationships should also be labeled with words that can describe the meaning of the connections. Kolko [2] points out to the importance of Concept Maps as tools for creativity, especially in supporting abductive thinking and sensemaking. These high cognitive creative capacities are a result not only of visualizing and trying to understand the content in the maps, but especially of the process of constructing the maps. Concept Maps help in identifying core taxonomies, prioritizing of taxonomy elements, and creating semantic connection between elements [2].

In order to conceptualize the method for constructing the Lisa Platform's Knowledge Map, we got inspiration from the Grounded Theory [25]. Grounded Theory prioritizes the discovery of knowledge that comes not from a prior literature review on a topic, which is usually the first step in scientific research, but rather the development of a theory that is part of a process grounded in empirically collected and systematically analyzed data. However, Grounded Theory can also be use for reviewing literature, as demonstrated by Wolfswinkel [26]. Because of that, Grounded Theory is successfully employed in Social Sciences for Qualitative Data Analysis. It follows also a similar principle as the one used by Mind Map and Concept Map techniques in regard to being a method for the discovery of new knowledge, since all of these methods assist data analysis and information synthesis.

One of the most essential parts during the process employed by the Grounded Theory is Coding. Codes are defining keywords "used to qualify certain bits of data" [27] From sources, usually texts, the individual must select relevant excerpts (such as sentences or paragraphs), identify what they talk about, and categorize them under concepts/keywords that are useful to describe the phenomena mentioned by the text. The researcher then, when encountering new relevant excerpts, must either create new codes or use an already existing one in order to categorize the information. By applying the Grounded Theory, a hidden graph structure is shaped on the background. Not only relationships between different sources and excerpts can be established, but also connections among the codes themselves.

The Lisa Platform's Knowledge Map employs a similar process for handling information in the sense that the maps are created based on excerpts of text or annotations, which are tagged according to two different coding schemas. At a lower level, the user must find in the text important keywords/concepts in order to tag them under a pre-defined vocabulary. At a higher level, all annotations and excerpts must be given a title, which should be described under a limited amount of characters. This restriction enforces the summarization of the ideas found in the texts. Therefore, identification and categorization of concepts, and summarization of ideas is an essential part of the method for creating Knowledge Maps. As the user tags important keywords, the Knowledge Map is being rendered as a result. The clustering of annotation nodes based on shared entities assists the user in synthesizing information and drive meaningful sensemaking of connections, which can be then established by giving labels to relationships. There is however no formal hierarchical structures besides the relationships semantically labeled as such.

Entity Tagging and Automatic Tagging

The great majority of tools available on the market for individual or collaborative use that are employed to map information through either Mind Maps (Bubbl.us, MindMeister, XMind, MindManager, etc)[3] or networks (Cmap, GraphCommons, Inspiration Maps, etc)[4] offer mainly two different approaches for generating the maps. The user can insert nodes and relationships one by one, manually drawing the maps, and/or import data through data serialization formats (if the application supports this option), such as CSV, XML, JSON, and so on, what can accelerate the assembly process.

When manually inserting information, these tools offer little support to the user. The support is usually related to restrictions imposed by the graph structure the application is developed for, especially in the case of Mind Maps. On one hand, this can be positive, because by restricting the user's actions, it is possible to enforce the method used by these techniques as well as best practices. On the other hand, on the negative side, the representations created with these tools do not capture the numerous semantic possibilities networks can communicate[5]. For example, it is common in applications such as Bubbl.us, XMind, or MindManager to have the option to insert a new topic/node as a parent, child, and sibling node (see figure 2). These structural instructions that control the way nodes are inserted is what gives the tree diagram its spider shape.

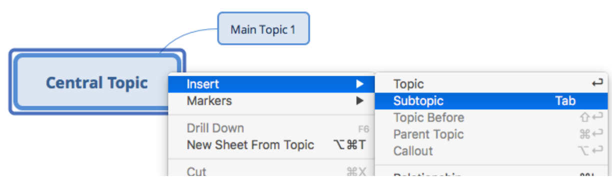

***Figure 2**. The XMind application restricts users to obey the Mind Map structure by allowing only hierarchical organization and manipulation of data*

Because networks offer a lot more possibilities regarding the way nodes are connected between themselves, such an approach as the one used by Mind Maps that imposes structural restrictions to the growth of graphs would not work, because they are not restricted to the tree graph structure. Knowledge Maps for example have no starting or ending nodes, which is a strong defining difference if compared especially with Mind Maps that always will have a central topic from where all other branches originated. Instead, we argue that the best way for supporting users in creating complex networks is by semantic means, as the ones used by the Lisa Platform, because it affords automation and scalability.

The Lisa Platform provides the user with the option to construct Knowledge Maps by tagging entities using its standard vocabulary. In order to do so, the user must identify relevant keywords that are able to express the meaning of the annotation or excerpts from texts. These annotations can be themselves extracted from sources such as PDFs or websites. This process is known as Entity Tagging. Based on that, annotations with

[3] URL of the mentioned Mind Map software: http://www.bubbl.us, http://www.mindmeister.com, http://www.xmind.net, http://www.mindjet.com/mindmanager.

[4] URL of the mentioned Concept Map software: http://cmap.ihmc.us, http://graphcommons.com, http://www.inspiration.com/inspmaps.

[5] Although in recent versions, many of these applications have incorporated network characteristics by allowing cross-links and nodes that can be positioned outside of the tree structure.

shared entities can be identified and clustered together. In this sense, e.g. two annotations will be related by the entity or entities that connect them both. The user then is able to consolidate this relationship by assigning to it a proper value and meaning.

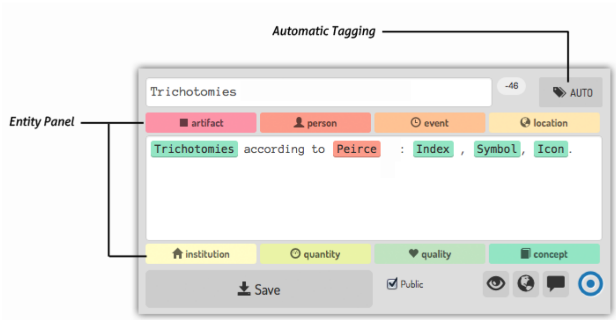

Figure 3. *Knowledge Maps generated from entities extracted from annotations and excerpts*

Entity Tagging in the Lisa Platform is done both manually and automatically. In case of entities being extracted manually, the user highlights the most important keywords of the annotation text and tags them by selecting one of the nine different core entity types available: *action, artifact, concept, event, institution, location, person, quality,* and *quantity* (see Figure 3). The tagging procedure is used as a mean for the system to learn what are the important entities/keywords within the scope of a certain project/research topic together with their entity types. After tagging, the user then adds a label to the annotation text, and stores the information that is represented and encapsulated on the map as an *annotation node*. An annotation node can then have one or several entities related to it.

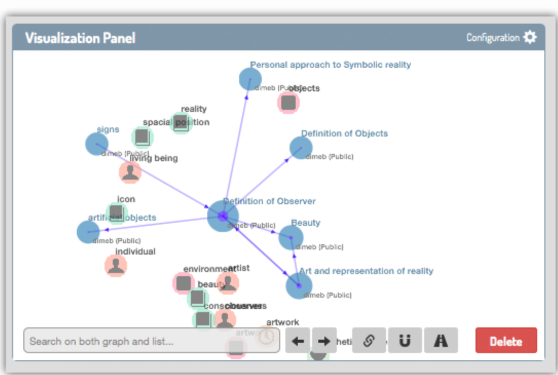

Figure 4. *Knowledge Maps generated from entities extracted from annotations and excerpts*

The automatic Entity Tagging is performed based on the already learned entities/keywords. The next time the user would like to store an annotation in the system, he or she has the option to use the automatic-tagging functionality (auto-tag) in order to automatically identify and tag keywords. The user has the option to accept or reject the identified entities as well as insert or tag new keywords. By not only implementing semantics as a mean to create the maps, but also a user-friendly interface together with the auto-tag capability, the overall process of constructing the maps is accelerated.

As explained, the annotation nodes are clustered together depending on their shared entities. Topics, expressed by the titles of the annotation nodes, are positioned close to each other by the amount of entities they share. With this strategy, it is possible to identify different topics that must most likely be understood together, because they share strong correlations. On the contrary, it is also possible to identify topics that do not closely relate, because they are shown far apart. This feature is especially useful considering a project containing many different sources, because the system might provide valuable insights on the implicit background structure of knowledge. Once the user is able to determine clearly the semantic connections among the annotation nodes, he or she can manually establish relationships between the annotation nodes in order to further complete the meaning of the Knowledge Map.

If, on one hand, implementing manual and automatic Entity Tagging to support the construction of Knowledge Maps can influence the topology of the map created, on the other hand, this same topology is what promotes scaffolding for the user to further enrich the his or her understanding of the topic that is being dealt with. When the user starts the construction of the map, it is not possible to know which shape the map will take. This is different from a Mind Map, because these kinds of maps must obey the tree format. Therefore, manual tagging as well as the auto-tag functionality should be seen as the essential part in the process of creating the Knowledge Maps, because the relationships, which are necessary for generating meaningful maps, are the result of a cooperation between the application, by clustering nodes together, and the user's insights, by declaring and straightening connections.

5. METHODOLOGY

A usability test was applied in order to evaluate the production workflow of both Mind Maps and Knowledge Maps. In the case of Knowledge Maps, we were especially interested in the use of manual and auto-tag functionalities as strategies for structuring the maps and accelerating their creation process. We also paid attention to how well topics could be communicated through the visual representation of the tree and the network. In the case of the Lisa Platform, the manual and automatic tagging features generate Knowledge Maps that afford the correlation of concepts expressed by the proximity of nodes and also by the identification of hubs. Hubs are important because they indicate the existence of "hot topics" [31] due to their high degree of centrality, which can be measured by the number of incoming and outgoing edges/relationships [32]. This is also another reason why Knowledge Maps are able to model a more complex and complete picture of a topic, as opposed to tree diagrams produced by Mind Map applications that are semantically limited and offer only a hierarchical understanding of how concepts relate to each other.

The test was applied to a mixed-gender group of ten participants (amount considered as acceptable according to Nielsen [33]) who were researchers, master students, and PhD candidates. The participants were presented with four different texts of similar topic, level of difficulty, and length. They were asked to create two different maps, being the first a Knowledge Map, based on two of the texts, and the second a Mind Map based on the other two texts left. The participants were asked to use respectively the Lisa Platform and a popular Mind Map web application called Bubbl.us, which is a simple and very representative application in the field of mind mapping tools.

Before the creation of each map, it was provided instructions on how to use each application. The participants were required to know only a few basic functionalities necessary to create the maps. Time was given for text comprehension and map construction, with the same amount of time distributed between the Knowledge Map and Mind Map phases. The test was entirely performed on a desktop computer. Furthermore, all the participants were recorded and were asked to think out aloud while creating the maps.

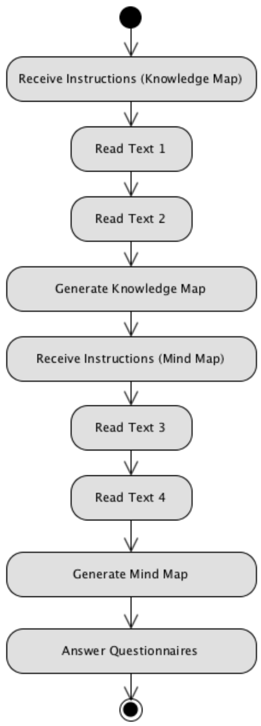

Chart 1. *Flowchart representing the usability test workflow*

Besides observing the participants during their interaction with both applications, we have also given them two different questionnaires to be answered after the test with the software. An open-ended questionnaire with questions about their impressions concerning the efficacy of Knowledge Maps in comparison with Mind Maps in regard to modeling and expressing the information contained in the texts. The following questions were asked:

1. In your opinion, which one of the map approaches would facilitate/aid your research/study better? Why?
2. In your opinion, which one of the maps is able to better represent the information contained in the texts? Why?
3. Did the process of making a Knowledge Map helped you to better understand or notice some information that wasn't obvious before?
4. Did the process of making a Mind Map helped you to better understand or notice some information that wasn't obvious before?
5. Please, explain aloud your personal mental strategy to organize the information into a Knowledge Map.
6. Please, explain aloud your personal mental strategy to organize the information into a Mind Map.

The other questionnaire contained the standardized questions of the System Usability Scale (SUS) ([34, Ch. 21]. The SUS test is a reliable tool for measuring the usability of software applications. It gives software engineers and designers a classification mechanism to measure effectiveness (how well are the users' objectives achieved), efficiency (how much effort and resources should be user spend for achieving these objectives), and satisfaction (how satisfactory was the experience). The main measure to understand the results of SUS is based on the average results obtained by applying this test over the years, in this sense a "SUS score above a 68 would be considered above average and anything below 68 is below average" [35]. The SUS average is shown as the vertical line dividing the bars of the Chart 2. The SUS questionnaire contained the following questions, based on which the participants had to give a scale from "strongly disagree" (1) to "strongly agree" (5) (see [35]):

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

6. RESULTS

The evaluation of Knowledge Maps created with the aid of the auto-tag functionality was positive. When asked which one of the map approaches would better serve as a tool for supporting their research or study, nine in ten participants said that Knowledge Maps would better support them during their research or study. Among the reasons, they claimed that the tool helped in keeping track of references systematically at the same time connecting different sources based on shared key concepts. Having filters and search capabilities were also functionalities that according to the participants are important to organizing research, especially when the amount of information accumulates over time. One participant also found important to have a pre-defined tagging vocabulary to keep the overall organization of information consistent. And, finally, for another participant, the highlight of tagged concepts (with a set of pre-defined colors) within the annotations assisted in the faster identification of key concepts when reviewing information already stored in the system. The auto-tag functionality is especially relevant for binding new annotations with pre-existing ones, accelerating the assimilation and contextualization of new information. Overall, participants declared that using the auto-tag functionality to establish linkage between annotations was done effortlessly and faster if compared with the methods offered by Bubbl.us.

In addition, when asked which of the two applications could better support the representation of the information contained in the texts, six of the participants marked Lisa Platform, three participants marked Bubbl.us, and one participant was not sure about which application to choose. Some of the participants who preferred the Mind Mapping tool found that they had more control over the final look of the map, because the tool allowed them to position the node/box on a specific area of the screen, and because the relationships could be manually drawn between nodes/boxes, although limited to the hierarchical structure of the tree. On the other hand, for other participants the maps produced with the Lisa Platform ware better for representing information, because it was possible to create a map of higher definition based on the many different tags. The fact that annotations carry references of the sources and users need to summarize their annotations in short titles to be able to save them, also helped in perception of the good efficacy of Knowledge Maps in representing information.

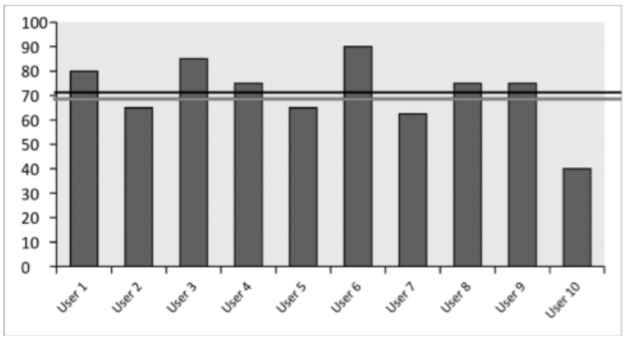

***Chart 2**. Lisa Platform's SUS score results*

Finally, participants had to independently grade both map approaches on how effective they were in allowing them to notice meaningful connections between information that was not obvious during reading. Most of participants (seven out of ten) claimed that the Knowledge Map approach was effective in allowing them to perceive new information. The other three participants claimed that this approach was very effective. In regard to Mind Maps, most of the participants said that this approach was reasonably effective, while one declared Mind Maps were very effective, and one found this approach not effective. Many participants pointed out that because the auto-tag functionality was able to connect annotations automatically in a way they did not expect, the Lisa Platform made them notice something new.

The results of the SUS test were also positive, with an average score of 71,25 (represented by the back line of Chart 2 - 3,25 points above the average of 68 points [36]) considering all participants. Since the system requires participants to learn some of its functionalities in order for users to know how to use it, we expected the interface and flow to be challenging for some of the participants, however the SUS test demonstrated that creating Knowledge Maps with the manual and auto-tag feature did not present a problem, which means that participants were able to understand and use these functionalities to achieve their goals. Taking the average of questions individually for all participants, the test showed us that participants were confident using the system, as suggested by the average SUS score of 87.5 on question 9 of the SUS questionnaire ("I felt confident using the system" [34, Ch. 21]), and found it easy to use, as suggested by the SUS score of 82.5 on question 3 ("I thought the system was easy to use" [34, Ch. 21]).

However, there were problems found in the Lisa Platform according to the participants. The space available for the visualization of the Knowledge Maps was small and the Visualization Panel (Figure 2) could neither be resized nor presented in full-screen. In addition, participants complained about the impossibility of positioning the nodes on the desired fixed locations on the panel, since in this version of the platform, the nodes were adjusted only automatically. The visualization of the Knowledge Maps on the Lisa Platform uses the Force-Directed Graph Layout Algorithm of the D3 Library [37] to render the map on the screen. This algorithm is able to simulate attraction among nodes based on the relationships in between them (if a relationship is present, an attractive force is established in between the nodes). Although it is possible to define a fixed position for the nodes and therefore cancel the attractive force, keeping their positions dynamic allow them to cluster together. Therefore, we opted for not allowing fixed positions of nodes. Finally, the animation provoked by the simulation, which made nodes to arrange themselves at the initialization of each map rendering, was disorienting according to some participants.

7. DISCUSSION

As mentioned before, the great majority of the individuals interviewed affirmed that the Lisa Platform is more suitable for supporting research than the Mind Mapping tool. These affirmations are backed by the following observations pointed out by interviewees:

- the tool is able to manage and referencing sources such as authors, papers, books, videos, etc keeping track of them in a systematic way;
- the tool offers a pre-defined vocabulary for categorizing information, and because of that is capable of providing consistency in how the information is structured;
- reviewing information stored with the tool is facilitated because of the highlighted keywords displayed within the texts. This point is especially important for the accurate identification of concepts within text excerpts. The highlights also obey a pre-defined schema of colors to differ categories.

These points presented above also support the claim that the Lisa Platform is "a tool one can think with" rather than a tool " good for presenting something", as described by two of our interviewees when talking about the applications. One of the main observations we have noticed was that while the Lisa Platform incorporates a method for creating maps through identification of important keywords, and categorization of these keywords using the pre-defined vocabulary for structuring the maps, the mind mapping tool requires that the user to pre-process information mentally before "drawing" the map with the program. In this sense, the Lisa Platform aids synthesis of information through its interaction with the user, instead only serving as a drawing tool.

However, some participants pointed out that they found that the mind mapping tool gave them more control over the shape of the map. When asked about which tool helped them to better represent the information contained in the texts, we got mixed opinions. Our interpretation for this result can be explained as the following: while with Mind Maps one adapts the content to the shape, with Knowledge Maps one adapts the shape to the content. Mind Maps have very simple and predictable relationships. They usually follow a category-subcategory logic or a macro-to-micro hierarchical ordering of topics. The relationships in Knowledge Maps are arbitrary and can represent many different kinds of connections. The simplicity and predictability of Mind Maps make them suitable for neat communication of ideas if these are limited to hierarchies or/and topic-subtopics. However, the Knowledge Maps offer a better view of a great variety of relationships, being a more complex but more accurate representation of the content. Therefore, depending on what the user would like to display, one or the other technique can be used.

According to the result obtained from our tests, the process of making Mind Maps did not promote the discovery of new knowledge or insights. As identified through our observations and questionnaires, a mental strategy for creating Mind Maps, the majority of our participants answered that they tried to understand the texts and then summarize the main ideas creating very short sentences out of them; the branches and sub-branches were add as a result of the information contained in the texts. On the other hand, a different mental strategy was used to create Knowledge Maps. This strategy is defined by the procedural rhetoric of the software, and consists of selecting an excerpt of a text, understanding its meaning, searching for keywords that best represent the meaning of the excerpt, tagging these keywords according to a pre-defined vocabulary or/and using the automatic tagging functionality for receiving recommendations from the system about shared entities. Because the manual and automatic tagging establish cross-references automatically concerning the other information already stored in the system, the Lisa Platform is able to connect information the user did not expected.

8. CONCLUSIONS

Graph organizers are powerful tools for both structuring and transmitting knowledge. When planning the test, we found important to compare the two map approaches in order to make their differences explicit, and therefore be able to draw conclusions more easily on the effectiveness of each approach. The tree graph structure of Mind Maps provides them with simplicity and predictability, making them suitable for fast and neat communication of simple ideas. The Knowledge Map's structure is entirely dependent on the content they represent, not being possible to predict how they will be shaped beforehand. In this sense, Knowledge Maps do provide a more accurate representation of the content, but the process of constructing the maps and analyzing them is more complex.

The downside of networks is that, when manually constructed, they required more time to be created [22], and when growing in size, they become "complex, illegible, and untransformable" [38, p. 131]. Thanks to computation, some of these problems can be overcome. Therefore, we were especially interested in analyzing the auto-tag feature as a strategy for minimizing complexity and accelerating the constructions of Knowledge Maps. We found that the auto-tag functionality was easy to use, promoted the fast identification of important keywords in new text, and contributed with new insights, because it allowed the clustering of different annotation nodes together, which the user did not expect. Having a pre-defined tagging vocabulary to keep the overall organization of information consistent is also part of the auto-tag architecture and was appreciated by the participants.

In addition, we were also interested in collecting feedback from participants about the topological characteristics of Knowledge Maps that afford the identification of important concepts as well as the correlation between sources, which is especially valuable for research. Participants found Knowledge Maps to be suitable for research, because the system is able to keep track of references systematically at the same time connecting different sources based on shared key concepts. In addition, because the information is structurally stored, the user is able to search and filter the maps.

Not only in formal but also in information settings [10], where information should be understood, processed, and communicated quickly and accurately, well-encoded Mind and Knowledge Maps provide a framework to handle simple and complex ideas by influencing individuals' cognitive workload. The advantages are the faster comprehension and the higher acquisition of content, as opposed to purely text-based support materials. It is important to point out that each map approach has their advantages and disadvantages, and e.g. hierarchical categorization can undoubtedly be better expressed with simple tree diagrams. However, when dealing with some specific scenarios, where intrinsic relationships of an ecosystem must be understood, Knowledge Maps can be a useful tool.

9. FUTURE WORK

Based on the feedback of the usability test a new version of the application has been developed. Besides improving the presentation of the Knowledge Maps as an interface between the user and the content, we are exploring the possibilities of the Knowledge Graph as an enabler of intelligent recommendations based on Machine Learning techniques. Also, to boost recommendations, we are working in methods for integrating the platform with external Knowledge Bases, in order to assist the user in expanding the Knowledge Maps.

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