

Retaining Potentially Meaningful Spatial Structural Aspects Across Discipline Specific Concept Maps

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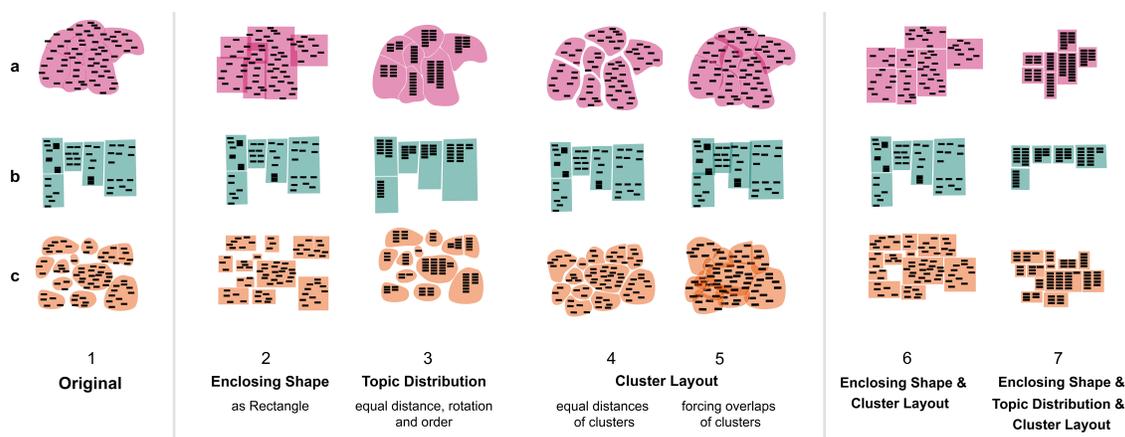


Figure 1: Exemplars combining the spatial structures of concept maps: enclosing shape, topic distribution and cluster layout. Using these spatial structures as design articulations we assess their relative impact on the concept map's interpretation.

Abstract—Recognizing commonalities across knowledge-driven outcomes that result from facilitated group workshops such as concept mapping is not straightforward due to the unpredictability of the participative process. We encountered this issue when digitizing and merging multiple concept maps that each captured discipline-specific understanding in a research project that aims to cross disciplinary boundaries. We discovered that a concept map potentially captures tacit practices in more ways than textual, which can be conveyed by spatial structural aspects like enclosure, topic distribution or cluster layout. In this study, we analyze these spatial structural aspects as ‘design articulations’, i.e. parameters that are crucial in expressing the qualities of a concept. We create a range of exemplars that demonstrate how these spatial structural aspects can be retained and even leveraged in designing visualizations when they become transposed or combined across multiple concept maps. Despite the small number of analyzed concepts maps, we believe we are able to identify discussions points regarding how nuanced aspects of the design can change the interpretation of a visualization. This research is not only relevant for any digitization process that requires the merging of manually derived documentations, but also reveals various qualitative considerations on designing for plurality in the context of information visualization.

Index Terms— information visualization, digital humanities, concept mapping, design articulations, perception

1 INTRODUCTION

Interdisciplinary collaboration is both desired and regarded as necessary for generating novel points of view in complex situations [1]. The field of digital humanities forms a prime example of this practice, as its research endeavours inherently require the collaboration between disparate disciplines, such as how computer science and literary science combine their expertise to come up with original interpretations of existing body of literature [2]. One of the core challenges associated with these kinds of interdisciplinary collaborations is related to the creation of a common, shared understanding between members [3]. Visualization researchers are accustomed to the realities of interdisciplinary work as reflected in articles that discuss interdisciplinarity as their motivation [4]–[6].

Moreover reflective research methods such as Action Design Research [7] and other design probing methods [8] have been employed in order to create and evaluate common understanding in interdisciplinary settings.

We were faced with a comparable situation within the context of a university-led, interdisciplinary research project that directly relates to the archaeological activities in the Sagalassos region of southwest Turkey, for over 20 years. Although the disciplines of Archaeology, Ecology, Human Geography and Urban Planning all actively investigate the same region, each of them is driven by different goals. As such, the disciplines recognized a need towards more effective collaboration. In order to explore and bridge some of these goals, we used concept mapping to capture the disciplinary individuality along their research themes.

Concept mapping is a commonly used methodology to externalize and organize knowledge [9] and has been studied as a way to promote interdisciplinary understanding [10]. In its core, a concept map is a visual representation of associations between words and ideas. In ecology, knowledge maps assemble fieldwork interviews as a way to document local and indigenous knowledge [11]. In education, concept maps are considered an easy and direct way to facilitate and evaluate learning along themes [12]. In design, concept maps are used to facilitate ideation. Precisely due to their versatile nature, concept maps can be generated in multiple ways, such as from interview transcripts,

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directly as digital visualizations from software, or as part of collaborative workshops.

In our setting, we aimed to compare the involved disciplines by analysing how their concept maps on the same topic differed or aligned. An obvious analysis methodology would consider the mapped information as a network, so that its relations could be revealed, compared and later merged. However, we realized that each concept map seemed to capture additional and potentially meaningful knowledge in more ways than its textual content. We believe that visual aspects like the enclosure, topic distribution and cluster layout of a concept map may also convey tacit aspects that reflect the mapping process itself.

Previous research seems to back this claim: by visually comparing the visualizations and layouts of whiteboard presentations during university lectures there was evidence of disciplinary differences in graphical preferences [13]. We could therefore expect spatial externalisations such as concept maps to also carry disciplinary meaning. In relation to concept mapping in the field of HCI, the existing literature is focused on for example how people organise ideas through concept maps [14] and on potential interaction design improvements of their functionality when digitised [15]. However, the authors have not come across related literature that attempts to retain naturally occurring structural variations of concept maps when digitised. The motivation to retain original data features in data visualization has also been previously argued by media theorist Manovich, who proposed to represent data directly instead of via abstracted shapes [16]: using image thumbnails instead of visual elements allows for domain experts to make interpretations beyond descriptive statistics, encouraging more direct and experiential ways of data exploration.

In this study, we (1) identify three types of spatial structural aspects that exist in concept maps; (2) analyse their apparent value when making sense of the layout; and (3) document how they can be retained or leveraged across concept maps. We took on a design-oriented research approach by deconstructing the spatial features as design articulations which were recombined into exemplars that demonstrate the intermediate knowledge that was gained [17]. As such, this research is relevant for any documentation process that requires the combination or merging of multiple concept maps. At the same time, it also has the potential to reveal methodological and design considerations that can be applied in infovis research and practice in general.

2 CONCEPT MAPPING

2.1 Methodology

Our analysis is based on three concept maps that were manually generated through the clustering of (sticky) notes along a common theme during three separate workshops with three disciplinary groups. Group Arch consisted of six archaeologists; group Eco of two researchers from the department of Ecology and Forestry; and group HuGeo of three researchers split between the departments of Human Geography and Urban Planning.

The theme of “change” was chosen for its wide meaning yet immediate archaeological relevancy, alongside a shared realization among all members that each of the participating disciplines conceptualize change differently, for example through a systems thinking or a human agency lens. Accordingly, all participants were asked to view change as it is understood in their own disciplines as well as specifically in their region of study. All individual participants were then instructed to make free associations to ‘change’, and transfer each topic or term to a separate sticky note. The disciplinary group as a whole was then asked to cluster all relating notes together meaningfully, and label the resulting clusters accordingly. Each group was given the same time (60 minutes), tasks and tools to create the concept map, including a rectangular whiteboard, sticky notes and markers. With the participants’ permission all sessions were recorded.

2.2 Results

Each concept map contained in total 74 (Arch), 50 (Eco) and 76 (HuGeo) sticky notes or ‘topics’, organized and labelled under 12, 5 and 7 ‘clusters’ respectively. All concept maps showed a cluster depth of one, except HuGeo had a single occasion of a cluster with sub-clusters (therefore of depth 2). In terms of content, there were only a few cases where the concept maps used the same term to describe the same topic, such as ‘Climate Change’ and ‘Evolution’. Similarly, there were only two clusters that shared a label (‘Drivers’), yet their containing topics varied. The Arch concept map grew in the form of islets of clusters. In both the Arch and HuGeo concept maps there was evident discussion and at times uncertainty about the clustering and let content overlap both conceptually and practically (i.e. the sticky notes). In information science terms, there was more redundancy in their concept maps, with several terms or ideas appearing more than once. On the other hand, the group Eco actively tried to minimize the amount of conceptual overlap which was also evident in their more structured and non-overlapping final result.

Each of the groups progressed the clustering in different ways. Group Arch developed them iteratively; group HuGeo placed emphasis on the discussions before clustering or changing any topic positions; and group Eco combined ideating and existing modelling, as they seemed to have clearer ideas of what should be placed and the relations the topics should have. We believe that these divergent thinking processes, which potentially reflect particular disciplinary characteristics such as their epistemological background, could be reflected by the spatial structural aspects in the produced visual outputs (see Figure 2). Specifically, the tendency to work top-down from broader to specific topics was reflected in group Eco’s concept map which also is in line with their systems level thinking of ecosystems. They very early on created and named the clusters before even all topics were grouped. On the other hand, the other two concept maps which are more the derivatives of bottom-up thinking, also reflect that process, by appearing more organic.

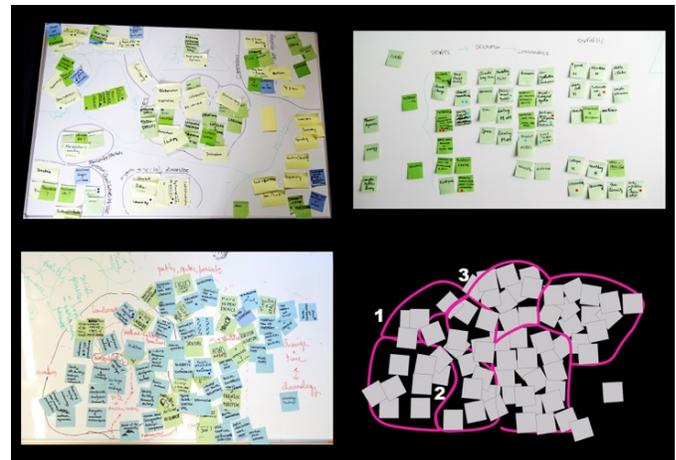


Figure 2: Final concept maps generated. They belong in order to: (left to right) group Arch, group Eco and (bottom left) to group HuGeo. (bottom right) Analyzing the structural aspects of group HuGeo.

3 STRUCTURAL ANALYSIS

3.1 Abstracting the Structural Aspects

Retaining the spatial structural aspects digitally of manually constructed artefacts is challenging, as to the best of our knowledge, no obvious digital tools or methods exist. To better identify these spatial qualities, we first replaced all content with placeholder rectangles and used the Gestalt principles as a lens to deconstruct and describe them. As such, we identified three distinct structural aspects: (1) enclosing shape; (2) distribution of the topics inside the clusters; and (3) spatial layout of the clusters. Following the bridging concepts approach [17] these structural aspects are ‘design articulations’: the

determining parameters on which the idea (here the spatial structure of a concept map) can be varied.

3.1.1 Enclosing Shape

The concept maps conveyed clusters either by topics that were located close together (gestalt principle of proximity) or by topics that appear enclosed by a surrounding line (gestalt principle of enclosure). The shapes of the clusters varied from rectangular (Eco), over circular (Arch) to continuous blob-like structures with faint borders (HuGeo). Accordingly, the abstracted versions, shown in Figure 3, retain enclosing shape differences by tracing the borders of the concept maps so that the boundaries are more clearly identifiable as separate. For example, in the case of the concept map of Arch, we ‘closed’ the shapes to completely enclose the clusters.

3.1.2 Topic Distribution

The way how notes were distributed and overlapped each other varied. Closely associated topics were made to overlap in the cases of Arch and HuGeo, whereas Eco showed no physical overlapping. Some notes were rotated (i.e. Arch and Eco), possibly to fit the more ‘organic’ growth of the clusters. For HuGeo, the position of the individual topics inside their clusters also had meaning encoded to it, which however is only evident for those having experienced the gesturing and gradual growth of the concept map, i.e. from material and landscape clusters to the topics about agency and time. Accordingly, the abstractions in Figure 3 maintained the original positioning of the notes to respect their implied relations.



Figure 3: The three digital and abstracted versions of the concept maps in order from group Arch, group Eco and group HuGeo.

3.1.3 Cluster Layout

The concept map of HuGeo conveyed a continuous flow between clusters, with borders being fuzzy and shared. In contrast, the clusters of Arch were organized as independent islets and separated by white space as its participants drew lines to indicate links and borders. The clusters from Eco were not only strictly separated with similarly sized white space, but also ordered from left to right with arrows drawn to indicate specific directions.

These aspects were equally expressed in the abstractions in Figure 3 by retaining the ratio of content to white space, and equally distributing the white space. Namely, the same distribution when digitizing and only scaled and centred the concept maps appropriately to allow them to be comparable.

3.2 Crossing the Design Articulations

In order to leverage the structural aspects to inform a final visualization that merges all three concepts maps, we proceeded to assess their relative value by transposing each articulation to each concept map (Figure 1), and analyse their visual interpretative effect. We refer to these variations as ‘exemplars’, since they exist with the sole purpose of demonstrating (giving an example) of the articulations of our idea (structural aspects). As in the abstractions, the exemplars explicitly neglect the content in order to focus solely on the impact of the design articulations.

Enclosing shape. As shown in Figure 1, when the exemplars feature rectangular clusters, while retaining all other aspects, their center of focus becomes shifted, such as how the focus point of 1a is perceived in the center, and shifts to the top in 2a. Visual perception studies such as those by Arnheim [18] explain how the mind reads images and shapes as dynamic and is fast to recognize a visual ‘pull’ towards a direction depending on the composition. As circular shapes naturally draw attention around their center point, whereas rectangular

enclosing shapes place importance on the top rather than the bottom, we thus propose that *the enclosing shape aspect influences the perception of the center point of a concept map*. This articulation can thus be used to draw focus on specific topics.

Topic distribution. The exemplars of column 3 demonstrate how topics can be arranged equally spaced inside their clusters. We find that by removing the original topic distribution the implicit relation between the clusters and their topics is broken, so that the concept map no longer visually indicates that the clusters are derivatives of the topics. For instance, in exemplar 1c the clusters are perceived to be enclosing the topics whereas in 3c the clusters are perceived to pre-exist their topics as containers that are only later on in the process filled in (as would be in a top-down thinking process). We thus reveal *that the topic distribution articulation can be indicative of the manual mapping process*. This articulation can be leveraged to exaggerate the organic, haphazard or logical, comprehensive nature of the mapping process itself.

Cluster layout. Through the exemplars of column 4 we discover that when we force the clusters are to have equal distances between them, there was no appreciable impact on the interpretation. This could be due to the difficulty to assess distances when comparing different shapes. Since to place two blobs in equal distances as two rectangles one may count from the outmost edges or their centres, making it a perceptually more complex task. However, as demonstrated in column 5 we can purposely overlap the clusters to imply closer relations. Therefore, we can only tentatively recommend the use of this articulation to convey the relations between clusters when combining more than one enclosing shape.

Combining articulations. The exemplars in column 6 have a rectangular enclosing shape while their cluster layout maintains equal spacing between the clusters. We see that the shape of the cluster as a visual attribute impacts the interpretation more than the distance between those shapes (the cluster layout). We therefore argue that *the cluster layout emerges as having secondary importance in comparison to the enclosing shape*.

The exemplars of column 7 combine all three aspects: the cluster layout is equal spaced; the enclosing shape is rectangular and embracing; and the topic distribution is equally aligned. While these exemplars are efficient in terms of conveying the number and relative order of clusters and topics, they retain the least amount of original structural aspects and as such most closely resemble a common digitization or abstraction of one or more concept maps. Put differently, the abstraction of structural aspects *increases the cognitive power to compare quantitative and ordinal statistics, to the detriment of the tacit and inherent traces of the topic structures and mapping process itself*.

By turning the design articulations into exemplars, we created a more informed design space of the potential outputs. In the following section we show how this bridging concepts methodology can be utilized to merge multiple concept maps into visualizations while retaining or transposing their structural aspects.

3.3 Merging the Concept Maps

In a use-case of comparing disciplinary concept maps, the main comparison point would be the content itself, we therefore used topic distance matrices (a series of integers that implies the similarities between the topics) as a main dimension of the layouts. However, we deliberately used simulated distance matrices to focus our analysis on the spatial aspects.

Enclosing shape design. Based on the discovery that enclosing shape influences the perception of the centre, the visualization designs demonstrate how the focus can be placed in the centre (Figure 4a) or on the top (Figure 4b). In each figure, the focal point highlighted in red is the selected topic around which related topics are accordingly arranged.

Topic distribution design. We used our findings on the topic distribution aspect to decide on a spatial mapping of the rest of the topics in relation to the in focus. Figure 4a uses radial mapping, where the topic angle depends on the discipline and the topics are allowed to

overlap. Next, Figure 4b uses a linear scale to map the distances from the focal point on the top, while keeping the distances fixed between topics and not allowing any overlap. In Figure 4c, radial and linear distributions are combined to indicate a more organically accumulated thought process, which is further exaggerated by allowing topics to overlap.

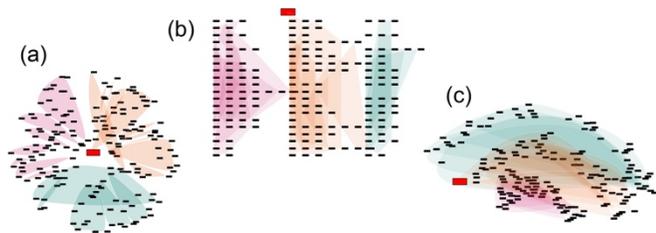


Figure 4: Visualization designs that retain structural aspects from the original concept maps. Arch (yellow), Eco (green), HuGeo (pink).

Cluster layout design. We use the findings concerning the cluster layout by either allowing or not the clusters to overlap in our visualization designs. In this case however we use the clusters on the level of the concept map they belong to as identified by colour. Since location in our designs (Figure 4) is reserved to encode the conceptual topic distance, we use the cluster layout articulation as a way to merge the different concept maps of the groups together. Figure 4a keeps the groups as islets with potential relations of equal importance as all topics are located on a circle radius. In Figure 4b the vertical dimension represents the topic distance from the focal point while the horizontal dimension is reserved for different groups. Similarly to the cluster layout found in the group Eco’s concept map, it allows for easier quantitative and ordinal estimations and comparisons and does not allow for overlap between the group clusters. Figure 4c communicates the organic process of the concept map the most, since it blurs individual groups and merged cluster boundaries and it conveys the least visual structure. Hence, we argue its quality is precisely its structural ambiguity.

4 DISCUSSION

This design-oriented analysis study has limitations and shortcomings in terms of the conclusions that can be generalized from it, as it is based on a small sample of just three concept maps. Most probably, a higher number of concept maps, or concept maps generated in other contextual circumstances might well contain different structural aspects. Concept maps might differ by the motivations and relationships between participants, their visual literacy, time constraints, the nature of the instructions, or even the availability and variety of manual tools they have access to.

On how a concept map relates to its creation process: There is an often overlooked and potentially meaningful relationship between the structural qualities of a concept map and the underlying process of its manual generation. Reflecting back to the provocative question whether concept maps might reflect tacit discipline-specific characteristics, we find subtle indications that spatial qualities like the topic distribution might be visual traces of the thinking process and existing mental models of participants. For example, elements of bottom-up versus top-down thinking were tacitly encoded in how topics were distributed over the available canvas. If the creation process should be retained or become reflected in a digitized or merged version, concept mapping moderators could (1) instruct participants to consciously reflect or jointly deliberate on how to structurally represent their collective knowledge before or even after the topic aggregation phase; (2) inform or guide participants to choose the most ideal spatial aspect strategy based on findings like presented in this paper; (3) force a spatial structural strategy beforehand, such as by offering a template poster with a predefined topic layout, background raster; or (4) create such a context that a spatial strategy organically and intuitively emerges. For example, even more flexibility could be offered with circular boards and notes, transparent

layering of versions, or inviting participants to create multiple variations of the same map.

On the structure of concept maps: It is challenging yet potentially meaningful to consciously reduce or abstract the structural qualities of a concept map in its digital version. Based on our findings, topic distribution might be an overlooked aspect. As seen from our merging visualizations, there might only be a few cases where ambiguity of visual hierarchy (as in Figure 4a) would be preferred over direct and easy comparisons (as for example in Figure 4b). However, we do already know that organic shapes are considered more aesthetic, and we also know how visual difficulties [19], [20] and stylistic choices can have beneficial effects, particularly when users are sufficiently motivated to decipher them, as is the case in our study.

On our design-oriented analysis methodology: Abstracting real-world examples into design articulations from which exemplars can be made, can broaden the visualization design space in a structured way. Our method of deconstructing the relevant dimensions of an idea (in this case the structural qualities in concept maps) and generating exemplars to value their impact on the design, allowed us to generate what is referred to as intermediate knowledge [17]. Intermediate knowledge represents the knowledge space between a general theory and a specific artefact, for example usability heuristics could be considered intermediate knowledge between the theory on human cognition and the instance of an interactive artefact. We used the intermediate design knowledge to generate potential visualization designs, of which for example the layout of Figure 4c would not have emerged without following this design process. Only by consciously exploring on the discovered articulations could we have resulted and even argued in favour of such a design. We also propose that embracing a methodology such as the bridging concepts might allow information visualization research to make design decisions and assumptions more transparent, allowing for a more critical discussion of the outputs [21].

On plurality: By consciously abstracting and articulating some tacit visual qualities that exist in manually-generated visualizations like concept maps, we encourage the discipline of information visualization to become more aware of how data representations might be read or understood differently by particular types of ‘users’. Our findings also implicitly argue for creating visualizations that are not necessarily the most cognitively effective or the most task-efficient. Instead, the choice of visualization technique could also be motivated by a desire to reflect the practices, expectations or mental structures of more qualitative characteristics, such as the data collection process, the discipline habits and practices, or the expected level of visual literacy. Visualization research is ideal to address critical data issues that are relevant to the field of digital humanities, such as expressing the situatedness and promoting plurality of truths [22], [23].

5 CONCLUSION

In our study we highlighted and addressed the tension that exists in information visualization between normalizing data and keeping it completely contextualized. More specifically, we try to bring critical thinking into the process of digitizing concept mapping, which is a method used in the humanities to achieve better and common understanding. We found that though the structural aspect of concept maps might not be representative of individual disciplines, they seem to be reflective of the thinking process that generated them. As such concept map moderators should take spatial structural aspects into serious consideration when creating, combining and digitizing them. On a methodological level, we have demonstrated the value of using design articulations and exemplars to ideate novel visualization techniques in a more structured and transparent way.

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