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Reimagining the Mental Map and Drawing Stability

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Reimagining the Mental Map and Drawing Stability

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1 Introduction

Dynamic networks, and dynamic information in general, are an important topic across many domains. Often, the data can be expressed as a network that evolves over time. In a social network setting, understanding data from Twitter and Facebook can clarify the interaction between people and the evolution of events in real time. In a biological setting, genes and proteins interact and these interactions can change depending on an experimental treatment and expression levels of the genes change with time. An analysis of these changes can then for example be used to detect disease conditions, understand their mechanism, and treat them. In a computer network scenario, links can go down and new connections are made. In finance, trades can be expressed as a network and can be interpreted along with information about the evolving market around them. Regulators and market participants can then monitor and analyze market behavior, e.g. to detect fraud and suspicious behavior. In all of these applications, we must have effective visualizations that draw the dynamic perspective of these networks in a meaningful and comprehensible way. In order for the visualization to be successful, the user of the system must be able to follow the evolving data.

In psychology and geography, these concepts have been explored in the context of humans navigating physical environments with maps with the internal representation of the space inside the mind of the human known as the mental map or cognitive maps. In this work, a cognitive map is the internal representation of the physical space inside the mind of the human. In a dynamic information context, the cognitive map is the internal representation of the information space that is evolving over time. Thus, we can begin to separate out the mental map and drawing stability with the mental map being the internal representation and drawing stability the external representation present in the visualization.

Early work in the mental map of information spaces concentrated on users following changes in a network: either through dynamic data or interaction with this data. One dimension of comprehensibility of dynamic information is information stability. In the early 1990's, Misue et al. proposed methods for enhancing the stability of dynamically evolving graphs. In particular, the work examined what should happen to unaffected areas of the network once a local change had been made to the network. The motivation for these approaches was to increase the comprehensibility of dynamic data: if network structure changes in a local area of the plane, then areas that do not change should remain stable. Many interpretations of this concept of preserving the mental map have been considered and expanded on through the years.

One of the most common interpretations of preserving the mental map is the notion that nodes and edges of the graph should move as little as possible between successive time periods in the plane. Archambault and Purchase revealed quantitative benefits of this definition as it helps users revisit specific nodes in a dynamic graph and follow specific paths in a graph as the data evolves over time. Preserving the mental map helps users offload information to the representation as they understand that it will remain in the same place, unless the network changes substantially. In dynamic graph drawing, the majority of methods for drawing dynamic graphs in a stable way have taken the simple definition of keeping nodes in relatively the same area of the plane. However, in the original definitions of mental map preservation, more complex measures were considered, including topological properties of the drawing.

Although the mental map in information visualization has frequently been associated with dynamic data, supporting the mental map is also important for interaction. The mental map can be affected not only by changes in the representation, but by the combination of representation, interaction operations performed by the user, and the associated cognitive processes. Moving a cluster of nodes from one corner of the screen to the other will affect drawing stability in the classical definition, but might preserve the quality of the mental map perfectly. When interacting with data, changes to the representation should only influence the area interacted with and not the entire data set as a whole. When information goes off screen because of an interaction, one would expect it to come back on screen if the interaction is reverted. As such, it is not only important to engage information visualization researchers with this concept, but HCI experts and researchers in immersive analytics need to consider visualizations that support the cognitive map from an interaction perspective.

Thus, while there is already a significant body of research and a range of models for mental map and data stability, several challenges arose in recent years prompt us to revisit the concepts and to develop new approaches. These challenges concern scalability, the applicability of the models in application areas, as well as the technology of the environment in which the network analysis is performed:

- The size and complexity of the data that is represented has increased dramatically over the last years. While layout algorithms scale well and can draw hundreds of thousands of nodes and edges, how we support the cognitive models of networks needs to be adjusted to the change in scale. On the other hand, when methods like aggregation or clustering are used to reduce visual complexity, the resulting visualization will need different, more complex concepts for mental map preservation with respect to the relation between representation and raw data.

- Applications might require specific adaptions or requirements to mental map preservation. Additional data annotations and semantics play a crucial role for expert users and might need to be taken into account. Many of the original models were written from an algorithmic perspective, closely related to the corresponding network drawing approaches. While this allows for easy integration into dynamic network visualization implementations, it may not fit with specific application requirements.

- New technologies such as wall displays, table top displays, and 3D environments are available that facilitate novel visualization and interaction methods, but might be a game changer in terms of mental map preservation as existing concepts may not be directly transferable to these new devices. Topic and Aims

2 Topic and Aims

In this seminar, our goal is to revisit some of the mental map preservation definitions and to develop new definitions for drawing stability that support the comprehensibility of dynamic data. We plan to go beyond the basic definition of preserving node location in space to other definitions that can support the cognitive map of the user as they navigate the dynamically evolving information space. More specifically, we intend to pursue the following research questions:

What are new metrics and models that cover stability and mental map quality in the light of above mentioned challenges? What are new algorithms that can be developed to support the cognitive maps of users visualising dynamic data? What new methods need to be developed that better support the cognitive maps of users exploring information in specific application domains? Given new display and interaction technologies, are there new approaches for preserving the mental map that better supports the exploration of networks when using these devices? The development of techniques that support a user's mental map require the combination of expert knowledge on network / information visualisation principles and algorithms, expertise in perception and cognitive processes, as well as a good definition of requirements from practical applications. The workshop aims at examining information visualisation techniques that are better able to support the mental map of the user. Our workshop intends to study supporting the cognitive map both in dynamic network settings and with respect to interaction with devices. More specifically, the aims of the seminar are as follows:

1. To bring experts in the fields information visualisation, graph drawing, interaction and devices, psychol- ogy, and relevant application We intend to have an international audience from Europe, Asia, the Americas, and Australia that have information visualisation problems where cognitive maps of the information space should be supported.

2. To rethink algorithms that compute stable representations of dynamic data and to go beyond "keeping unchanging components in relatively the same area of the plane." What are alternatives for supporting the mental map of the user when investigating dynamic data?

3. To rethink implications of interaction on the mental map of information spaces. How does interacting with information spaces on large screens, table tops, immersive analytics environments impact cognitive maps of

information? Are there any special requirements that need to be supported?

4. Psychology and geography have considered the cognitive map. How can their definitions of cognitive maps help us understand the mental map in information visualisation?
5. What are good ways to apply our results to relevant application areas (biology, social networks, and others)?
6. To formulate future research challenges in better supporting the mental map for information visualisation research.

3 Meeting Schedule

Check-in Day: September 9 (Sunday)

- 19:00 Welcome Banquet

Day 1: September 10 (Monday)
Seminar start, welcome, and introductory presentations

- 09:00 Welcome and seminar overview by the organizers, self introduction of participants
- 10:30 Break
- 11:00 Invited presentations
- 12:00 Group photo
- 12:15 Lunch
- 14:00 Topic discussion (form working groups)
- 15:30 Break
- 16:00 Working groups
- 18:00 Dinner

Day 2: September 11 (Tuesday)
Working groups and discussions

- 09:00 Working groups
- 10:30 Break
- 11:00 Working groups
- 12:00 Lunch
- 14:00 Working groups
- 15:30 Break
- 16:00 Working groups

- 17:00 Working group report
- 18:00 Dinner

Day 3: September 12 (Wednesday)
Working groups, excursion, and banquet

- 09:00 Working groups
- 10:30 Break
- 11:00 Working groups
- 12:00 Lunch
- 13:30 Excursion
- 19:00 Banquet

Day 4: September 13 (Thursday)
Working groups, discussions and presentations

- 09:00 Working groups
- 10:30 Break
- 11:00 Working group reports and closing
- 12:00 Lunch — the seminar closes with the final lunch

4 Working Group Reports

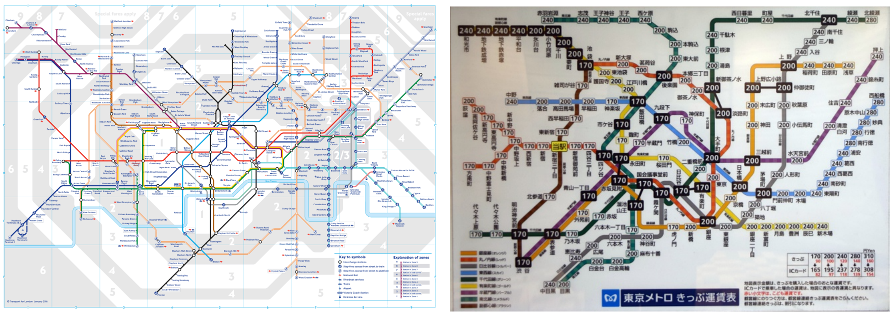
4.1 Lost in Translation: Alignment of Mental Representations for visual analytics

Participants: Daniel Archambault, Jessie Kennedy, Tatiana von Landesberger, Mark McCann, Fintan McGee, Benjamin Renoust, and Hsiang-Yun Wu

Visual analytics, which is defined as the science of analytical reasoning facilitated by interactive visual interfaces, allows us to obtain deep insights on information assessment and decision making [TC06]. Visual representations and interactions often play important roles in visual analytics since they extend humans' capability to read, explore, and understand large amounts of information [TC05]. Scientists often create visual representations basing on their imagination of the real-world phenomenon, but the representations evolve differently and lead to additional efforts for learning their variety. Figure 1 shows an simple example. The *London Underground* map consists of several arbitrary zone areas (gray and white decomposition in Figure 1(a)), which implicitly tells the prices to the travelers who consider traveling across different zones. However, on the another hand, the *Tokyo Metro* company constructs the map differently, because the prices of the transportation system in Japan are proportional to railway length between each pair of the source and the destination, which are often written as text labels on top of each station as shown in Figure 1(b). Due to the experiences with the *London Underground* map, travelers may have established a mental model based on the zone concept, and this mental model needs to be updated to align with the *Tokyo Metro* map when they come to Japan, otherwise they often get confused at first sight.

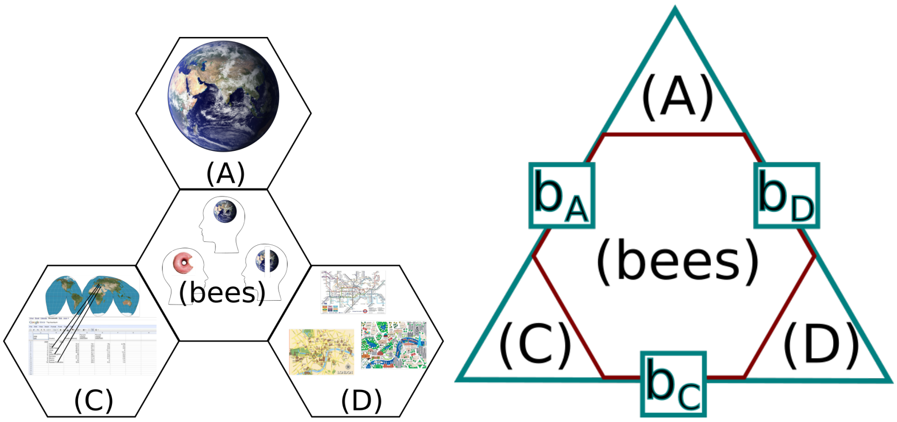
Our working group was inspired by Norman's work [Nor13] and try to summarize the visualization challenge on dynamic network together with the role of mental representation in understanding the proposed visual representation. In principle, a successful network visualization must show information to the users in a meaningful and comprehensible way so that the users are capable to understand and follow the evolving data. We discussed four concepts that form a model of the role of mental representation in the visualization process. These are the real world (the phenomenon being visualized), the data representation, the visual representation, and the set of mental representations at the intersection of the other concepts (see figure 2). We place mental representations at the center of this model as there is not one single mental representation, but several at play, often interacting with the other concepts. One mental representation might be that of the observer studying the real world phenomenon, one might be a researcher modeling the data describing the phenomenon, another might be that of the person visualizing the data, and another might be than of the consumer of the data. We discussed the role of the misalignment of mental representations in the failure of a visualization. For example, there may be a misalignment between the mental representation of a real world observer studying a phenomenon and the mental representation used to create a visualization of the phenomenon, resulting in an erroneous choice of visualization. For a visualization to be successful there needs to be a convergence of all mental representations involved. In the context of avoiding misalignment we discussed how mental representations can be changed, leading to misalignment (or possibly alignment). We discussed a notion of stability with respect to mental representations. We identified four states of a mental representation. It can be stable, (small fluctuations but on average the same), evolving (changing over time, so that eventually it may be misaligned with other mental representation), revolutionary (a sudden large change that means a sudden misalignment of mental representations, and converging (when mental representations change in such a way that they become aligned).

Four use cases, including (1) *Area Maps and Subway Maps*, (2) *Public Health Data*, (3) *Biological Taxonomies*, (4) *biological pathways*, were investigated to prove our initial assumptions on the proposed model. For *Area Maps*, referring geospatial position allocentrically or egocentrically has a substantial impact on users' spatial cognition, which may lead to losing their way by simply misunderstanding the initial setting of the map. *Subway Maps* is another example has been further discussed. *Public Health Data* allows us to analyze the correlation between people, places, events, and so on along the time, while different visual representation such as pie charts, scatter plots, node-link diagrams, or parallel coordinates could change the significance of number to the readers. Similarly, the evolutionary relationships between organisms in the world are often imagined as a tree structure in *Biological Taxonomies*. Although in reality, taxonomy could be represented by graph more effectively, it unexpectedly changes the research workflow of domain experts and were not favored in the end. Finally, the *biological pathways* provide us an abstract information about how chemical components function in nature. This abstraction has done experimentally and the dynamic visualization relies on the experimental assumption. This leads to pathway diagram in variety and becomes difficult to be used for daily communication. In summary, the mental misalignment has a strong impact on the interpretation of the real-world phenomenon so the next generation of visualization is expected to take the proposed factors into consideration.



(a) (b)

Figure 1: Various visualizations for the transportation systems, including (a) a typical *London Underground* map, (b) a *Tokyo Metro* map.



(a) (b)

Figure 2: Two models of Mental Representation, (a) emphasizing the interaction between users (*bees*) and the real world A, the data C, and the visualization D. *Bees* can be a single or multiple people. In (b), we highlight the importance of user mental representation mapping with the 'external elements' (A, C and D: b_A is a mental representation of the real world; b_C is a mental representation of the data and its structure; b_D is a mental representation of the visualization. Each of these *bees* poses a risk of misalignment that a good visualization design may address.

4.2 Metrics and Algorithms for Dynamic Clustered Graphs

Participants: Emilio Di Giacomo, Walter Didimo, Michael Kaufmann, and Giuseppe Liotta

Let $G = (V, E)$ be a graph. A *clustering* of G is a partition $\mathcal{V} = \{V_1, V_2, \ldots, V_h\}$ of the vertex set V. Each partite set V_i of $\mathcal{V}$ is called a *cluster*. The pair $\mathcal{G} = (G, \mathcal{V})$ is called a *clustered graph*. An edge (u, v) of $\mathcal{G}$ is called an *intra-cluster edge* if u and v belong to the same cluster; otherwise it is called an *inter-cluster edge*. We studied the problem of maintaining drawing stability for dynamic clustered graphs. More precisely, let $\mathcal{G}_1, \mathcal{G}_2, \ldots, \mathcal{G}_k$ be a sequence of clustered graphs, where $\mathcal{G}_i$ is the graph at time t_i obtained from $\mathcal{G}_{i-1}$ as a consequence of one of the following operations:

Edge addition: an edge is added;

Edge removal: an edge is removed;

Cluster merging: an inter-cluster edge connecting $u \in V_i$ and $v \in V_j$ is added and the clusters V_i and V_j are merged into a single cluster.

Cluster splitting: an intra-cluster edge (u, v) is removed and the cluster containing u and v is split into two distinct clusters.

Our goal is to compute a sequence of drawings $D_1, D_2, \ldots, D_k$, such that each D_i is the drawing of $\mathcal{G}_i$ (for $i = 1, 2, \ldots, k$) and has the following properties:

- each vertex is drawn as a point in the plane;
- each edge is drawn as a simple Jordan arc connecting its end-vertices;
- each cluster is represented as a simple closed region that contains all and only its vertices;
- there is no *edge-region crossings* and no *region-region crossings*. We have an edge-region crossing if an edge intersects a region boundary more than once; we have a region-region crossing, if two distinct regions intersect.

To preserve the drawing stability, throughout the drawing sequence we aim at preserving the following properties:

P1 the orthogonal relations between vertices;

P2 a very simple shape for clusters and edges.

We study the problem in three scenarios that differ in terms of what knowledge of the future the algorithm has when it transforms drawing D_{i-1} in D_i.

Full knowledge: the whole sequence of clustered graphs is known since the beginning. This scenario is suitable for off-line analysis of an evolving graph (e.g., analyze how a social network evolves over time within a desired time window). In this case the visualization algorithm can take advantage of this knowledge to compute a sequence of drawings that maximizes the drawing stability.

Zero knowledge: D_i is computed with no knowledge of the future changes. In this case, the algorithm computes D_i making the best choice to preserve the drawing stability with respect to D_{i-1}. This choice, however, might be a bad choice for the future changes. This scenario is suitable for on-line analysis of an evolving network (e.g., real-time monitoring of a network throughout a continuous stream of changes).

Partial knowledge: D_i is computed knowing the next h changes, for some integer $h > 0$. This scenario is intermediate between the previous two and can be used for an "almost" on-line analysis of an evolving network (where changes are buffered to take advantage of a partial knowledge of the future) or for off-line analysis in order to increase the efficiency (runtime) with respect to the full-knowledge algorithm.

We adopt a drawing model where all vertices lie on the same horizontal line ℓ, the edges are drawn as semicircles (arcs) and the clusters are drawn as rectangles. Notice that this model enforces property **P2** at each time step at the expenses of property **P1**. Indeed, to draw clusters as rectangles it is necessary that the vertices of each cluster are consecutive along ℓ. Suppose that because of a merging operation we need to merge two clusters that are not consecutive. In this case we have to change the ordering of the vertices thus violating property **P1**. Since there are several ways to move vertices in order to make two clusters adjacent, we adopt a cost model where the cost of each move is computed in terms of vertex swaps. Based on this cost model we devise three algorithms (one for each of the scenarios above) that compute the sequence of drawings $D_1, D_2, \ldots, D_k$ minimizing the cost function. Clearly, the algorithm for the full-knowledge scenario minimizes the cost of the whole sequence, while the one for the zero-knowledge scenario minimizes the cost for each single step. The complexity of these two algorithms is $O(nk)$, $O(n^{k+1})$, respectively, where n is the number of vertices and k the number of operations (i.e. the number of time steps). The algorithm for partial-knowledge scenario minimizes the cost for the subsequence of length h that is known at each step; its time complexity is $O(\frac{k}{h} n^{h+1})$.

4.3 Stable Dynamic Cartograms

Participants: Markus Chimani, Stephen Kobourov, Wouter Meulemans, Martin Nöllenburg, and Jaakko Peltonen

Our group considered the problem of mental map preservation in the context of dynamic cartograms. Cartograms combine statistical and geographical information in thematic maps, where areas of geographical regions (e.g., countries) are scaled in proportion to some statistic (e.g., population). This kind of value-by-area visualization has been used for many years, with the first reference to the term "cartogram" dating back to at least 1870. Since then, cartograms have been studied by geographers, cartographers, economists, social scientists, geometers, and information visualization researchers. Many different types of cartograms have been proposed and implemented, but nearly all the work is focused on static cartograms.

When visualizing data that changes over time (e.g., year-by-year population statistics), or when wanting to compare multiple cartograms[1] (e.g., population, GDP, crime) a natural problem that occurs is that of computing "stable" cartograms. Similar to the notion of mental map preservation, a cartogram is stable if the layout does not change a great deal from one moment in time to the next,

[1] See, for example, an interactive cartogram of different categories of household spendings by the New York Times `https://www.nytimes.com/interactive/2008/09/04/business/20080907-metrics-graphic.html`

except for the required re-sizing of the regions. For cartograms, the notion of stability can be formalized by measuring the change in contacts between regions, the change in the east/west and north/south relations between pairs of regions, the change in the angles between the centroids of pairs of regions, etc.

We focused on Demers cartograms [NK16], where regions are represented by interior-disjoint squares of size determined by the variable that is encoded. As a first step towards optimizing stable dynamic cartograms for an arbitrary sequence of data over time, we considered two different sets of area variables for the same underlying set of regions. More formally, we studied the following problem, where we say that two squares are *adjacent* if they touch along their boundaries.

Problem 1. *Given a Demers cartogram A consisting of n interior-disjoint squares $\{s_1, s_2, \ldots, s_n\}$ in the plane with side lengths $\{a_1, a_2, \ldots, a_n\}$ and a second set of side lengths $\{b_1, b_2, \ldots, b_n\}$, find a Demers cartogram B, such that*

1. *each square s_i has side length b_i,*
2. *any two squares s_i and s_j that are separated by a horizontal (vertical) line in A remain separated by a horizontal (vertical) line in B,*
3. *as many adjacencies of pairs of squares (s_i, s_j) in A as possible are preserved in B, and*
4. *for adjacencies of pairs of squares (s_i, s_j) in A that cannot be preserved in B, their displacement in the vertical or horizontal direction is minimized.*

We modeled Problem 1 as a linear program using real-valued variables to encode the position of each square in terms of x- and y-coordinates with a hard constraint on the prescribed size of each square. The separation constraints derived from A translate into linear constraints on the relative x-/y-positions of all pairs of squares. For all pairs of adjacent squares in A we use the objective function to minimize their distance in B, such that ideally they would have distance 0 and thus still touch. If this is not possible, their relative displacement is minimized.

We implemented a prototype of the linear program, which confirms the practicability of our approach and also lends itself to a smooth interpolation between A and B to animate the change in the data. Figure 3 shows an example of two stable cartograms A and B computed by our linear program. Future work includes the extension of our linear programming model to optimize the stability of cartograms across multiple sets of area constraints, to represent lost adjacencies by drawing explicit short and crossing-free edges between the squares, and to experimentally evaluate the quality of the dynamic cartograms according to suitable visual quality measures.

4.4 Challenges and Opportunities: The Mental Map for Graph Visualisation in Immersive Environments

Participants: Peter Eades, Andreas Kerren, Karsten Klein, Kwan-Liu Ma, and Falk Schreiber

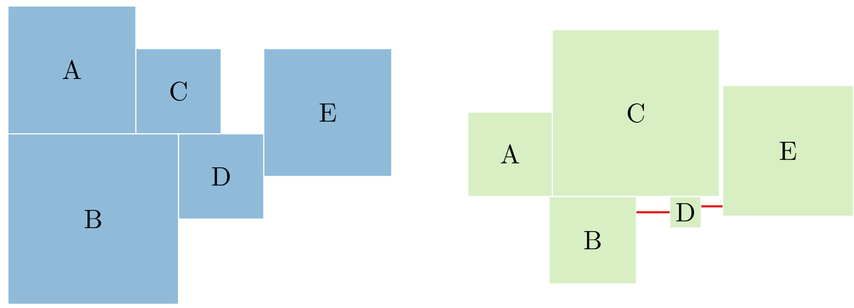


Figure 3: Input cartogram (left) and the output cartogram with minimal separation between adjacent squares in the input – the red lines indicate the two adjacencies that were separated.

Our group was investigating the differences of mental map creation and preservation in immersive environments compared to the standard workspace setup (non-immersive environments). While there is already some work on the mental map for graph visualisation in a classical desktop monitor setup, there is not only much less research on immersive graph visualisation [CDK+17, KMLM15], but also less practical experience in using immersive environments for graph exploration and analysis for both practitioners and researchers in graph visualisation. We thus started with a general brainstorming on the scope of our research during the Shonan seminar, as the topic lends itself to a variety of interesting research questions.

As a result, we decided to first focus on structuring our thoughts by defining a design space for immersive graph visualisation. We discussed the possible dimensions and aspects, with the further goal to later allow a more precise design of experiments to test our hypotheses.

We then discussed related literature; in particular we had to do a literature search on publications outside of the visualisation community, e.g. regarding influence factors of spatial navigation and mental model development, e.g. [NSSNSM+16, ZKH10, MJ12]. Due to the time constraints we are sure that we did not fully cover the relevant literature, and thus will need to look deeper into the related work.

As we are lacking a precise definition or model of a mental map, obvious questions that we discussed in the context of potential experiments are: How could the mental map be characterised for evaluation in experiments, and how can aspects of a mental map model then be captured in experimental studies not only to allow qualitative and quantitative statements, but also to falsify or confirm the model itself.

A more fundamental question that we were not able to answer during the workshop is, if the mental model is actually 3D, or if it is dependent on the input. Furthermore, in the context of collaborative graph analysis, we think it is worthwile to investigate the characterisation of a shared or common mental map, and how it could be supported by suitable visualisations.

We designed several experiments that are intended to investigate a few of the fundamental research questions. Within the next months, we plan to conduct the first of those experiments, and we are aiming to have a publication based on it.

4.5 Concepts and Processes for Mental Model

Participants: Lyn Bartram, Bongshin Lee, Luana Micallef, Kazuo Misue, and Helen C. Purchase

We identify key concepts and terminology for mental model (Figure 4) that could be applicable to the visualization of dynamic data from the review of definitions and characterizations of mental models in various domains such as cognitive science, visual analytics, human-computer interaction, and visual languages.

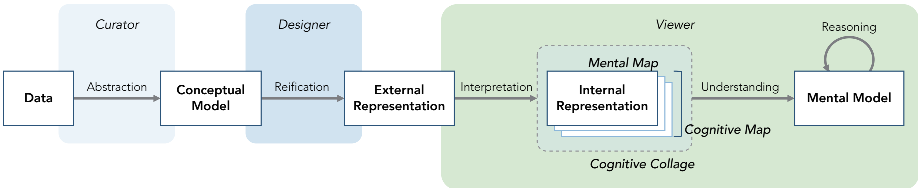


Figure 4: Key concepts and terminology along with roles of mental model

"**Data**" is reality and exists in the world. A *curator* selects a relevant subset of the data to create a "**conceptual model**" [Nor14], also called the 'represented world' [Pal78]). This process is called "**abstraction**."

The process of *reification* is one that is performed by a *designer* who creates an "**external representation**" (ER [LS10], also called a 'system image' [Nor14], or the 'representing world' [Pal78]) of the conceptual model. The ER, which we interpret as 'what is perceived.' It may be one object or a collection of objects, which may be visual, aural, text, or multimedia.

The process of *interpretation* is a perceptual process where a *viewer* perceives the ER and creates an "**internal representation**" (IR) [LS10], which is a static representation in working memory [Mun14, War12, Mac86, CM85]. One ER may result in several different IRs. A "cognitive map" [Tve91, ARW98, Spi98] is a meta-IR that links a set of IRs together. These IRs can be of different forms [JL80]; e.g., sentential, spatial, temporal. A "mental map" is a particular type of IR that represents spatial relationships.

The process of *understanding* is a cognitive process where the viewer interprets the IR so as to create a "**mental model**" of reality [Nor14]. Several IRs (which may form a 'cognitive collage' [Tve91]) may contribute to building up this mental model. Several mental models might be created from the same IR [JL80], thus creating a set of possibilities for a viewer to choose from.

Each ER is implicitly associated with a set of processing operations that are invoked automatically - both at the perceptual [War12] and the cognitive level [Pal78]. Gibson calls these processing operations 'affordances' [Gib14]. Activating these processing steps strengthens the mental model; that is, makes it closer to the conceptual model.

Reasoning is the process of developing this mental model further. The nature of the model will be influenced by prior knowledge and expertise, as well as personal characteristics.

Further *interaction* with the ER may also develop the mental model. In particular, if the mental model is incorrect, or contradicts prior knowledge (or just seems a bit odd), then further perception of the ER may result in a change in the IR and hence a change in the mental model.

Mental Model for Visualizing Dynamic Data

With regards dynamic graph drawing, the ER is the evolving graph. It does not matter whether the change comes about naturally (as a result of change in the conceptual model) or as a result of interaction. What is important is that the ER has changed from one perceived visual form to another. Perceiving this ER results in a change in the IR (which, in this case, has the special term 'mental map'). The viewer can then update their mental model as a result of this change in their mental map.

There are two implications of this. First, there is a perceptual load in translating the ER to the IR/mental map. In a dynamic environment, this load can be reduced by ensuring minimal perceptual change in the ER (i.e., 'preserving the mental map'). Second, there is a cognitive load in translating the IR to the mental model. In a dynamic environment, this load can be reduced firstly by giving the viewer time to process the IR, and secondly by taking advantage of the viewers' existing mental models where possible (these may be based on prior knowledge/expertise or personal characteristics).

5 Overview of Talks

There were three invited talks, giving rather broad overviews on different aspects of the visual analytics challenges. Moreover, one additional talk was given.

Towards Perceptual Optimization of the Visual Design of Scatterplots

Luana Micallef, University of Copenhagen

Designing a good scatterplot can be difficult for non-experts in visualization, because they need to decide on many parameters, such as marker size and opacity, aspect ratio, color, and rendering order. This paper contributes to research exploring the use of perceptual models and quality metrics to set such parameters automatically for enhanced visual quality of a scatterplot. A key consideration in this paper is the construction of a cost function to capture several relevant aspects of the human visual system, examining a scatterplot design for some data analysis task. We show how the cost function can be used in an optimizer to search for the optimal visual design for a user's dataset and task objectives (e.g., "reliable linear correlation estimation is more important than class separation"). The approach is extensible to different analysis tasks. To test its performance in a realistic setting, we pre-calibrated it for correlation estimation, class separation, and outlier detection. The optimizer was able to produce designs that achieved a level of speed and success comparable to that of those using human-designed presets (e.g., in R or MATLAB). Case studies demonstrate that the approach can adapt a design to the data, to reveal patterns without user intervention.

https://userinterfaces.aalto.fi/scatterplot_optimization/

Layout Adjustment and the Mental Map, 1995

Peter Eades, University of Sydney

This talk discussed classical and old-fashioned models of the preservation of the 'mental map' of the diagram: orthogonal ordering, proximity, and topology.

Algorithmic Stability Analysis

Wouter Meulemans, Eindhoven University of Technology

Visualization of time-varying data often asks for stability – small changes in the data should lead to small changes in the visualization. This implies a trade-off between the quality of each frame in isolation and the amount or speed of change between frames. This trade-off has, for example, been investigated for time-varying treemaps [SSV18]. However, algorithmic analysis of such problems is difficult has it creates a convoluted set of questions, such as: (1) when should the visualization structurally change; (2) what is the effect of requiring transitions between frames to be smoothly interpolated; and (3) what is the effect of limiting the speed at which the visualization may actually change? In this talk, I described our framework [MSVW18] for dealing with such questions by splitting the analysis in three steps: event stability (1), topological stability (2) and Lipschitz stability (3). The focus in the talk was with topological stability as being an intermediate analysis step which is often easier to analyze than the complete question with bounded speed. Even with infinite speed but continuous change, we gain insight into the difficulties introduced by continuity that will also affect any further results with bounded speed. I illustrated this via recent and ongoing work on the stability of typical kinetic computational-geometry problems that often provide underlying structures for visualizations.

What we look at in the MRC/CSO Social and Public Health Sciences Unit

Mark McCann, University of Glasgow

Dr Mark McCann gave a presentation at Shonan meeting 127 outlining the work of the Medical Research Council / Chief Scientist Office Social and Public Health Sciences Unit at the University of Glasgow - and how information visualisation could make an important contribution to the Unit's work. The Unit's mission is Improving Health and reducing inequalities through the study of social influences on health and wellbeing. Dr McCann gave examples of the Unit's work: studying the co-evolution of friendship networks and alcohol use frequency over adolescence, the formation of coalitions around health policy debates such as minimum pricing for alcohol units, the use of node edge diagrams to represent complex causal processes underpinning health inequalities, and to develop interventions to improve health. There was a fruitful discussion about a range of methods within information visualisation that could help support this work, and suggestions for future ways to develop the use of information visualisation in health improvement.

6 List of Participants

- Daniel Archambault, Swansea University
- Karsten Klein, University of Konstanz
- Kazuo Misue, University of Tsukuba
- Lyn Bartram, Simon Frasier University
- Markus Chimani, Osnabrueck University
- Walter Didimo, University of Perugia
- Emilio Di Giacomo, University of Perugia
- Peter Eades, University of Sydney
- Michael Kaufmann, University of Tubingen
- Jessie Kennedy, Edinburgh Napier University
- Stephen Kobourov, University of Arizona
- Andreas Kerren, Linnaeus University
- Bongshin Lee, Microsoft Research
- Giuseppe Liotta, University of Perugia
- Kwan-Liu Ma, University of California-Davis
- Mark McCann, University of Glasgow
- Fintan McGee, Luxembourg Institute of Science and Technology
- Wouter Meulemans, Eindhoven University of Technology
- Luana Micallef, University of Copenhagen
- Martin Nöellenburg, TU Wien
- Jaakko Peltonen, University of Tampere
- Helen C. Purchase, University of Glasgow
- Benjamin Renoust, Osaka University
- Falk Schreiber, Universität Konstanz
- Tatiana von Landesberger, Technische Universität Darmstadt
- Hsiang-Yun Wu, TU Wien

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