What is Knowledge Visualization? Perspectives on an Emerging Discipline

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Abstract

This paper collates eight expert opinions about Knowledge Visualization; what it is and what it should be. An average of 581 words long, topics span from representation, storytelling and criticizing the lack of theory, to communication, analytics for the masses and reasoning, to trendy Visual Thinking and creativity beyond PowerPoint. These individual views provide a picture of the present and the future of a discipline that could not be more timely, aiming for a common understanding of the visualization of knowledge.

Knowledge Visualization is…

The International Symposium on Knowledge Visualization and Visual Thinking is now in its seventh year, and it is about time to assemble a selection of expert opinions on where we are today and where the discipline should be heading.

Therefore, members of the Advisory and Review Committee were invited to participate in a joint paper, and seven co-authors have accepted the invitation. The requirements were: to contribute a personal view of no more than 625 words, with no illustrations allowed, using a few references if needed. The topical requirement stated that these personal opinions had to reflect on the current and/or future state of what the authors consider to be Knowledge Visualization.

The result is a set of individual vistas on a multifaceted discipline. Each view sheds a different perspective on the notion of knowledge visualization and highlights specific theoretical or practical aspects. As a whole, they lead beyond the diversity of visualization.

Stefan Bertschi

…about communication – fundamentally (Tom Crawford)

While classically, the word communication implies that it is from one person to at least one other, it can also be communicating to yourself as a way of understanding and remembering what you have learned.

The process of Knowledge Visualization contains steps such as gathering, interpreting, developing an understanding, organizing, designing, and communicating the information. While the previous sentence implies a linear flow, it is hardly a linear process. In fact, any step can link to any other step in any number of iterations until a "final" representation is created. Of course, it never is quite final. Even if we were able to come up with the perfect visualization, our knowledge changes and with it changes the visual. In fact the visual often provides so much insight that our knowledge changes and thus the visual needs to change creating a fascinating recursive loop.

Strangely, while we have learned much about Knowledge Visualization over the last 100 years, we still have yet to re-think and redesign some of the most common forms of communication. For example, the lowly recipe, which has been around and largely unchanged for over 3,600 years, is a form of communication from one person to another. The original assumption of the recipe designer was that anyone who needed to read it shared a specialized language and process, which often now is learned either as an apprentice or in culinary school. However, that language breaks down when the same information design goes from chef to home cook. The assumptions of terminology and process break down when the home cook has not had the same education or experience as the professional chef.

So, what would happen if we were to re-think the design of the recipe and apply Knowledge Visualization techniques to the problem?

During the early stages of Knowledge Visualization we would conclude that the recipe contains four basic types of information: ingredients, process, and equipment which are combined in particular ways via a series of techniques. In analyzing the current recipes, we would find that the design mixes the four types of information somewhat randomly which leads to the possibility of mistakes.

For example, the list of ingredients also contains process steps (e.g. 200 grams onion, diced). These are two different pieces of information. An ingredient list is essential for making sure that what is needed to make the recipe is present. However, what you do with those ingredients should all be handled in one place. It becomes even more complex when understanding that "dicing" an onion is not one but actually five steps (cut in half, top, peel, plus at least two cuts).

Knowledge Visualization would not only make it clear what kind of onion, but also what then needs to be done with it. No longer would cloves be confused with garlic cloves because they look nothing alike. Photos could be used to show what a ripe banana looks like in comparison to one that is past its prime to help the home cook choose not only the right ingredient, but the freshest and best ingredients. The same idea could be applied to the equipment which is rarely, if ever, shown in a recipe. Food mills, reamers, mandolines and many other infrequent, but valuable tools could not only be shown, but demonstrated directly in the context of the recipe.

The recipe is only one of the common forms of communication that could use a much closer look. By using the tools and process of Knowledge Visualization, we can begin looking deeply at the recipe's components, who it is used by, and what they are using it for, and therefore create more effective tools that reduce errors and increase satisfaction. That is Knowledge Visualization.

…storytelling (Andrew Vande Moere)

Knowledge is information that has been made part of a specific context. In order for information to transform into knowledge, one must share some context, some meaning, in order to become encoded and connected to preexisting experience. In that sense, Knowledge Visualization can be considered as data visualization "in context". While Knowledge Visualization facilitates people to explore trends, patterns and outliers in data, it does not necessarily aim to discover them, but rather attempts to unravel the driving principles that influence these data phenomena. With such knowledge, data trends can be explained, rather than simply discerned. Knowledge, therefore, is not about knowing the facts, but knowing the causal factors and context in which the facts have come about.

Stories are a powerful means of providing context. Not surprisingly, knowledge is often shared and communicated through the process of storytelling [1]. Storytelling tends to place information (e.g. activities, events, facts) within a commonly accepted contextual framework, often by exploiting the qualities of internalization and socialization. While a story aims to convey a series of specific truths, it is the narrative that provides a context in interpreting the overarching meaning, which potentially transforms it into actionable knowledge.

While Knowledge Visualization is recognized as an independent scientific discipline [2], the relevance of storytelling towards its scientific goals is still relatively unexplored. Early research proposed some simple "actions" like animation, mood and place as particularly effective storytelling techniques in data visualization [3]. A more recent study has investigated several design dimensions like genre and visual or narrative structure to categorize the existing methods of visual storytelling in the domains of online journalism, graphic design, comics, business, art, and visualization research [4]. In the context of Knowledge Visualization research, the emerging popularity of online visual storytelling [5] presents at least two new challenges.

First, the use of storytelling in visualization has been primarily considered on a phenomenological level, as a set of design techniques that have the ability to direct a viewer's attention through a sequential narrative, or a series of visual transitions. This experiential viewpoint seems to miss the role of context in the visualization practice, and how providing rich context can augment the visual sense-making process from observing eventual data patterns and trends into reasoning about the meaning of their occurrence. If context drives data-driven knowledge acquisition, then how is it best represented? Second, it might be equally revealing to analyze visual storytelling techniques in the context of Knowledge Visualization, or vice versa, investigate Knowledge Visualization design methods. Such wide analysis should at least provide a better understanding in successful design strategies. Alternatively, one might discover promising but under-explored approaches to Knowledge Visualization.

While Knowledge Visualization might be less entertaining and eye-catching than most popular forms of currently existing visual storytelling, both approaches focus on conveying context, and therefore a form of knowledge, to an increasingly information-hungry audience. What might make data visualization different from other types of visual storytelling is the complexi-

ty and scale of the content that needs to be communicated [3]. However, with the emerging popularity of data visualization in current online media, expectations will inevitably shift from simply delivering information to conveying the causally influencing factors that drive the events in our world today.

…inductive transformation from data to visual space (Randy Goebel)

Current – The current state of the art in Knowledge Visualization is pretty well represented by the distribution of papers in [6], which I claim shows a healthy diversity of ideas on how to transform data into pictures. There is balance between the development of new ideas for rendering objects in a visual space, and on the application of existing methods to a variety of application specific data, including health, bioinformatics, geography, and a broad spectrum of web data. There remains opportunity for the articulation of insight into visualization semantics and the role of cognitive science in drawing inferences from pictures; I suggest these aspects should be stronger, because, after all, visualization is about how the human visual system can be inferentially amplified by rendering data in appropriate visual spaces.

The overall scientific interest in visualization is also growing, for example, by the seven years of the Science Visualization Challenge [7, 8], which has brought the role of visualization into the scientific mainstream. The continued problem here, however, is that while the Science challenge raises awareness and interest in visualization, it still has the flavor of a kind of "beauty contest," instead of a disciplined assessment of the quality of visualization techniques. The question should always be about *how well* a particular visualization technique supports visual inference.

Future – With respect to the future of visualization, I think an appropriate approach is captured by Alan Kay's assertion that "The best way to predict the future is to invent it." [9] One strong personal motivation for inventing the future of visualization arises from an assertion I recently read in a paper I was refereeing, which wrote "…as the theory of visualization tells us…." I balked, as there is no theory of visualization. But there should be.

To invent the future of visualization is not to abandon the current state in pursuit of some fundamentally different paradigm, but just to bring a little more scientific thinking to what a theory of visualization should be? If the simply stated goal of visualization is to amplify the human visual system's ability to draw inference from complex data, then we need much more work on *what kinds* of inferences can be made, and *how well* they can be made.

Again from my own viewpoint, not uniformly shared, I believe that it is scientifically useful to view pictures as inductive inferences about the data and data relationships from which they arose. Within that framework, we can not only design experiments that evaluate the quality of inference that a visualization method provides, but can also reflect on how easy it is for humans to reach conclusions intended by visualization methods application.

So, take Alan Kay's generic advice to heart, and invent the future of visualization. This requires a stronger role for good scientific reasoning to guide the connection of visualization research components: clever graphics, scientifically justified "art," innovative multi-dimensional rendering, all *coupled* with evaluation with respect to the efficacy of making insightful inferences.

Prognosis – Perhaps Knowledge Visualization is a kind of maturing teenager, slowly emerging out of the eclectic chaos of graphics cleverness, scientific modeling art, and overly specific multi-dimensional rendering? I think the best evidence is the continued diversity of visualization ideas, coupled with an increasing volume of work on visualization evaluation. After all, if the goal of visualization is to amplify our visual systems' ability to draw inferences from visual representation of data, then we need to develop scientific discipline about how to assess alternative visualization methods. From that will emerge aspects of a theory of visualization, and the future will be invented.

…expressing concepts through meaningful graphical mapping (Sabrina Bresciani)

Visualizing knowledge means mapping concepts graphically, by structuring text and visuals in a meaningful way. Visual representations are used to organize information and concepts in order to convey knowledge, to amplify cognition and to enhance communication. Examples include conceptual diagrams, knowledge maps, visual metaphors and sketches.

Knowledge Visualization can overcome the limitations of textual/verbal communication and of visual representations alone. Through the use of spatial distribution, it leverages on both the textual and the visual abilities of the brain to express meaning (Dual Coding Theory [10]). Knowledge Visualization can provide the big picture, give an overview and show the relationships between concepts. It structures conceptual knowledge [11, p. 7] and provides salience, thereby facilitating the focus on certain information at the expense of other. Images have an impact also on the emotional attitude of the user, by providing engagement and motivation. Visualizing knowledge is useful for collabora-

tive work: mapping the group dialogue can facilitate the integration of knowledge and it can surface misunderstandings more prominently than text.

A relevant aspect is the relationship between Knowledge Visualization and Information Visualization. The two concepts overlap in their common aim to offer insights to the user [12]: "Knowledge visualization […] designates all graphic means that can be used to construct and convey complex insights." [13, p. 551] Yet the uniqueness of Knowledge Visualization lies in the content that is being mapped, posing a stronger emphasis on knowledge and experiences rather than on numerical information. Adopting the definition of Chaomei Chen, "[t]he term *information visualization* refers to computer generated interactive graphical representations of information." [12, p. 387] By contrast, Knowledge Visualization is not necessarily computer generated, nor interactive. A mind map drawn with pen and paper is a common example of Knowledge Visualization which is not computer generated. However, recent developments in Information and Communication Technology (ICT) enable a widespread use of Knowledge Visualization by empowering any user with limited drawing skills to easily create conceptual visualizations.

Visualizing knowledge is not without risks. Typical challenges and mistakes committed while creating or using knowledge visualizations include, for example, oversimplification and ambiguity of meaning.

In recent years, reflecting a trend in society, we witness a growing number of case studies and theoretical conceptualization, and thus the emergence of Knowledge Visualization as a new discipline. Yet, the lack of a solid theoretical background is a significant limitation for the development of this particular field.

Future directions of development for Knowledge Visualization and its potentials are seen along the following three main paths. Firstly, the discipline would benefit from rigorously studying and measuring the impact of visualizations, especially in emerging forms of collaborative interactions, including visual groupware, Group Support Systems and social media. Secondly, the diffusion of innovative input devices such as (multi-)touch screens is enabling new ways of interaction with software and particularly in groups. The field of Knowledge Visualization could benefit from understanding the implications of these fluid forms of interaction. Finally, it could expand its horizon of applications by introducing and testing knowledge visualizations in new domains, including for instance intercultural communication, a context where visual representations can be particularly useful to overcome linguistic and cultural barriers.

…the link between visualization and information overload (Wolfgang Kienreich)

Knowledge Visualization is the missing link between the expert tools developed in the thriving field of Visual Analytics and the frantic demand of the general public for intuitive ways to cope with increasingly large and complex personal digital universes.

Visual Analytics, the science of analytical reasoning facilitated by interactive visual interfaces, combines automated analysis, visual representation and user interaction in a closed loop intended to provide users with new insights [14]. This approach has been successfully applied in domains like business intelligence or genetics. Visual Analytics emphasizes the use of visual abstractions to represent aggregated information and facilitate the formulation and validation of hypothesis by expert analysts.

Knowledge Visualization utilizes visual representations to foster the communication of knowledge between two or more people. Clear benefits of this approach have been demonstrated for common situations like presentations and discussions [15]. Knowledge Visualization emphasizes the use of visual metaphors to represent relevant information and facilitates collaborative dissemination and decision making by domain experts.

Phenomena like the advent of social and consumer generated media or the prevalence of personal imaging devices have vastly increased the size and complexity of personal digital universes. As a consequence, many analytical tasks which have traditionally been performed by experts have become a concern for the general public: When a private photo collection is comprised of many gigabytes of image data, locating relevant images requires facetted multimedia search and retrieval techniques. When a personal social network is comprised of hundreds of individuals, identifying who could contribute to a problem or benefit from a piece of information requires methods of social network analysis. A plethora of services and applications enables users to share content and media and to build networks. However, simple, accessible means for analyzing, evaluating and, ultimately, utilizing the wealth of knowledge thus created are sadly lacking.

We propose that Visual Analytics and Knowledge Visualization join forces in order to tackle this problem. Visual Analytics could contribute techniques for the automated analysis of large amounts of information and the closed loop approach which integrates analysis, visualization and interaction. For instance, consumer-generated media could automatically be analyzed for sentiment and quality. User feedback provided through a visual interface could adapt the model of what constitutes sentiment and quality on a personal level.

Knowledge Visualization could contribute the practices and methods required to design domain and user specific visual representations. Such representations would be comprehensible for users with limited visual literacy. For instance, media analysis results could be presented using a map, meter or aquarium metaphor. Appropriate knowledge visualizations have already been proposed for supporting discussions. In the outlined scenario, they would be backed by aggregated information computed from massive repositories.

Multi-touch surfaces could turn out to be a driving technological factor for a closer integration of Visual Analytics and Knowledge Visualization. Recent applications of Visual Analytics acknowledge the benefits of collaborative approaches and utilize multi-touch tables to support joint analysis of complex problems by groups of experts [16]. Knowledge Visualization already has accumulated a wealth of experiences and findings on how to visually support such group situations. Both disciplines could only benefit from a closer exchange of ideas and of an integration of approaches in applications to solve real world problems.

...the crucial stage in knowledge processes (Vedran Sabol)

To define Knowledge Visualization, it is important to agree on a definition of knowledge: knowledge is an acquired, established set of facts, recognized to be valid and valuable within a specific domain. It can be represented by a formal model consisting of concepts, relationships and logical conditions. Knowledge Visualization deals with creating and applying visual representations with the purpose of constructing and communicating useful knowledge [17]. Knowledge Visualization includes both static visual representations, such as panels or posters, as well as interactive visualizations, offering possibilities for exploration of visualized knowledge depending on users' needs. Knowledge in visual form not only facilitates remembering and transfer, it also provides the fuel for reasoning processes where new knowledge is derived and created from previously acquired knowledge.

Knowledge Visualization is contrasted by the fields of Information Visualization and, more recently, Visual Analytics. Both disciplines operate at a lower level of abstraction than Knowledge Visualization, focusing mainly on raw data and information. In this context, data is understood as sequences of numbers or characters, representing qualitative or quantitative attributes of specific variables. To obtain information data is processed and brought into a context within which it gains a specific meaning and becomes understandable to users. Information Visualization makes use of human visual perception capabilities for recognition of patterns and extraction of knowledge from raw data and information. Visual Analytics builds upon Information Visualization to facilitate analytical reasoning by combining automated discovery and interactive visualization [18, 19].

While Visual Analytics focuses on discovery of new knowledge from raw data and information, and targets analysts in application domains such as business intelligence, Knowledge Visualization deals with expression and creation of knowledge, targeting areas such as knowledge management and strategic management in general. Although different in their conception and areas of application, both fields share several common properties: they breed new knowledge, deliver support for decision making, and provide a common basis for collaboration.

Knowledge Visualization is a powerful resource which could be used outside of its traditional application domains. Knowledge Discovery is a data processing chain consisting of, roughly speaking, data selection, transformation, and mining and presentation steps, where at the end of the process new knowledge arises from raw data [20]. Visual Analytics has been successfully applied in the context of Knowledge Discovery, where it serves as the final stage of the process chain, supporting users in visually identifying patterns and extracting new knowledge. Because knowledge is the final product of the process, it appears as a compelling idea to integrate Knowledge Visualization as the final stage of the Knowledge Discovery process chain. Moreover, in this final stage Knowledge Visualization could build upon and be combined with Visual Analytics. Therefore, a unified process would be created where visual interfaces are used for discovery, creation and communication of knowledge. Management support, which is provided by Knowledge Visualization, would now be closely integrated with analysts' output, which is supported by Visual Analytics.

Many questions remain open though, for example: How could findings provided by Visual Analytics be incorporated in Knowledge Visualization representations? How could Knowledge Visualization and Visual Analytics be combined to generate synergies in a Knowledge Discovery process which not only provides means for unveiling hidden facts, but also delivers knowledge as its final product including all its accompanying facets such as experiences, attitudes, perspectives and opinions?

…the doodle revolution (Martin Lindner)

Visual Thinking is a big trend, particularly in the age of the "micro-web". Its main exponents are Dave Gray (CEO of consulting firm XPLANE, co-author of "Gamestorming" [21]), Dan Roam (author of "Back of

the Napkin" [22]), Lee LeFever (creator of the simple explanation videos "…in Plain English" that became popular via YouTube) or Sunni Brown who coined the term "Doodle Revolution" (book forthcoming, cf. [23]). "Enterprise 2.0" consultancies like XPLANE or the more mainstream Root Learning use visualizations collaboratively created by workshop participants for change management processes [24].

The wider context, I think, is a new wave of visualizations and Visual Thinking that was started in the 1990s. Of course we had revolutions in visual language before: Otto Neurath invented modern "infographics" around 1930, and Quentin Fiore, who collaborated with Marshall McLuhan in the 1960s, may also stand for early revolutions. However, this wave reached new heights in the 1990s: digital data, Apple-driven graphic engines and, finally, the Web 2.0 have changed the game.

We have discovered whole new possibilities to collect, organize and manipulate digital data, but this has opened the view on new abstract facts, new complex realities. Meanwhile, human understanding is still stuck in the primary world of physical objects, face-to-face communication and people doing things to each other in direct ways. In a world of massively mediated interaction and communication this cognitive model must fail. As mass "macro-media" become grassroots "micro-media", they reach beyond entertainment and pop culture. What we see emerging is a new mode for new ways of collective thinking, networked conversations and knowledge creation.

Certainly, there are a lot of trends in visualization that run back to the "Big Bang" caused by personal computing and digital networking. A presentation by designer Peter Morville gives a good and visual overview of Visual Thinking [25]. On the "richer" side, we have Hans Rosling's famous performances explaining the world through statistical visualizations (see the stunning BBC Four video "200 Countries, 200 Years, 4 Minutes"). This is in line with Al Gore's effort to visualize the ungraspable reality of Global Warming in his "illustrated talk" that was finally turned into a movie.

Back in 2000, Al Gore was basically using PowerPoint as visualization tool, which then was criticized by Edward Tufte in 2003 for its inherent tendency towards "Stalinist" visual New Speak: corporate salespeople silencing their audience with a power play of curves, bullets and pies. But at the same time, artist David Byrne introduced new ways of using PowerPoint. In the last five years, this has become the mainstream: A bunch of Web 2.0 pioneers has developed a new style of well-designed Visual Thinking (although most are using Keynote, the presentation software for Macs).

All in all, new visual languages and new cognitive styles are emerging. This has many facets. I am especially interested in new formats that can be discovered and observed in the World Wide Web: simple visual objects that can be produced with little effort by almost anyone, like a doodle or a napkin sketch. They are part of what Lev Manovich called "micro-media" in 2000, and what is now the evolving trend towards "micro-media convergence". Because they only require a small attention span to get their ideas and messages, these simple user-generated objects can be easily circulated in the cloud: in blogs, via flickr, SlideShare or YouTube.

This is part of a paradigm shift from "published ideas" to "circulating ideas". What people formerly did on their desks is now part of collaborative thinking processes enabled by the Web 2.0 ecosystem. It was web intellectual Steven Johnson who described this ecosystem in some detail. He even made a fascinating animated "graphic recording"-video to promote his book quite successfully [26]. It is 4:07 minutes, the length of a pop song. Possibly, this is not mere coincidence. It just may be the natural format for the hive mind.

…visualization beyond PowerPoint (Stefan Bertschi)

The roots of Knowledge Visualization, as it is presented annually at the International Conference Information Visualization, are in business and management. Therefore, we learn from research into visualization that strategic and operational processes rely on communication and interaction. Visualization of any kind significantly improves communication and therefore business processes. Knowledge Visualization caters for refined and aggregated information commonly used in planning and implementation practices as well as projects and change processes [2]. Though not solely confined to business, Knowledge Visualization aims to understand how the sender's intended meaning can be transferred in such a way that it is not distorted in the recipient's perception, therefore allowing effective and efficient communication to take place.

The human mind is a strange thing, however, for most people we may state that complex dependencies and interactions can more easily be understood when illustrated: an intelligent process flow chart makes more sense than a numbered list describing the same process in words, a project (Gantt) chart showing timelines and interdependencies allows for better understanding than a project scope, even if structured. The difficulties are to be found in how to make best use of the understanding of others, their intentions and perceptions, simply because there is no direct way to look

inside their heads. Visualization and Visual Thinking subsequently allow us to reveal these "understandings" because they provoke discussion, allowing the alignment of opinions and arguments.

If organizations in need of successful transfer of knowledge are to ensure they benefit most from current knowledge, then the single most important advice would be: "listen", but also "listen with your eyes". Think of illustrations and visualizations beyond PowerPoint and Project; think why "pencil selling" just using pen and paper is so much more effective than words alone in selling anything, ranging from goods to projects. Do not be afraid to draw and sketch in front of a live audience, or even better, sketch collaboratively and experience how much better ideas are being generated, ideas that stick in all participants' heads.

Speaking and listening with your eyes also means making full use of the available methods (see the Periodic Table of Visualization Methods [27]). Knowledge that can be seen can be used effectively and efficiently. It is important to keep a critical mind, if used incorrectly visualizations can be risky [28]. Furthermore, the activities of knowledge workers (like attorneys, marketers, scientists and senior executives) are "too variable or even idiosyncratic to be modeled or structured with a defined process". Basically, their need for access to knowledge sources, ranging from online databases and social media to spreadsheets, presentation tools and business intelligence analytics "is presumed to be equally eclectic and unpredictable." [29, p. 90f.] The range of tools used does not ease the knowledge process.

Does this mean the complexity of some of the tools and software available is a barrier to creating visuals? I would not necessarily blame the complexity of software but the lack of complexity or willingness for creativity in creating these visuals. I have personally had great experiences with visual co-creation both in strategy and in operational processes. Visuals stimulate discussion, and discussion creates knowledge. Arguing this way, full use of methods does not mean to use them all at once, but to use and combine them as necessary. Less is many times more because the average human brain can process far less information than we anticipate: four complex arguments in one go are too many, rather make your three points, but make them right and sustainably. Transparency and simplicity are the answer – visibly and visualized for business purposes and far beyond.

What is Knowledge Visualization?

By reading "only" eight opinions on Knowledge Visualization, it seems difficult to find a unifying definition that says it all about Knowledge Visualization and Visual Thinking. The aim of this joint paper was to span the discipline by provoking a range of individual vistas. Therefore, let us revisit what we can learn through the eyes of others.

Tom Crawford highlights the communicative function of Knowledge Visualization; in his opinion, the non-linear process of representing knowledge is a recipe for success, if handled correctly and by using visuals as an effective tool.

Andrew Vande Moere identifies the importance of storytelling and meaning. In his opinion, Knowledge Visualization allows to explore patterns by putting them close to their context. The "story" is the perfect visual carrier for knowledge, rendering it actionable.

Randy Goebel offers a reflection on the theoretical and methodological foundation of visualization. In his opinion, the strength is in the diversity to achieve insightful inferences. He criticizes the lack of a theory of visualization and argues for inventing the future.

Sabrina Bresciani organizes her insights around the need to amplify cognition and to enhance communication; visuals should also consider emotions and experiences. Knowledge Visualization has to question the actual impact of visualizations across all methods.

Wolfgang Kienreich promotes Visual Analytics as a way of managing the complex digital universe of today's knowledge and network society. Driven by the closed loop of representation and interaction, he pleads for analytical means for the masses.

Vedran Sabol sees Knowledge Visualization as the most important stage of knowledge processes. In his opinion, it not only provides fuel for reasoning but operates at the highest level of abstraction, allowing sound perspectives, effective decisions and valuable synergies.

Martin Lindner introduces Visual Thinking as the main trend of Enterprise 2.0. Whilst visual revolutions are nothing new, we see new efforts to overcome the failing cognitive model of objects and physical interaction, promoting collective thinking in the cloud.

What can be learned from all contributions is that visualization improves communication, in particular the interaction around cognitive processes. Knowledge Visualization and Visual Thinking fabricate the necessary understanding of these processes because knowledge needs to be "seen". If there is one common truth contained in all eight perspectives, then it would be: without successful and sustainable transfer, knowledge is meaningless.

Beyond the diversity of visualization and of these views, it becomes apparent how all eight contributions (at least implicitly) emphasize a process-driven concept of visualization. The act of visualizing is more important than the image itself: medium > message.

Stefan Bertschi

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