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The Diagram of Information Visualization

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ABSTRACT
In the last ten years the area of Information Visualization has witnessed an exponential increase in its popularity. Diagrammatic reasoning and visual epistemology are becoming readily accepted methods of research in many academic domains. Concurrently, information graphics and Infovis have grabbed the attention of a larger mainstream audience.

This project communicates the history and development of Information Visualization discipline through an educational piece the audience can physically interact with. The visualized data are the results of an empirical work—the case study of 30 design projects developed in Information Visualization between 2005 and 2011—conducted in collaboration with the Austrian Institute of Technology. The resulting diagram has been transformed in an interactive three dimensional piece as part of an exhibition on diagrammatic reasoning.

The piece shows the story of Information Visualization, from past to future. It traces its expansion and features the projects that have had great influence on the discipline. It suggests potential directions where this field may develop in the near future. In the piece, each tin represents a project that participated in the development of Information Visualization. Each tin contains a description of the project, author, data, and a QR code linking the project website. The red circles diameters indicate the relative impact each project had on the field of Information Visualization. The right wall shows the subjects and disciplines where Information Visualization will have great influence in the future. Projects are grouped by subject and distributed chronologically within the groups.

INTRODUCTION

Twenty years ago the area of data and information visualization was primarily of interest to only a minor group of tech-obsessed individuals who shared a passion for data. In the last ten years however, we have witnessed an exponential increase in its popularity. Today, not only are diagrammatic reasoning and visual epistemology becoming readily accepted methods of research in many academic domains, at the same time information graphics and Infovis have grabbed the attention of a larger mainstream audience.

The recent forces that have been shaping this upturn in interest demonstrate how diagrammatic visualization is becoming more and more a necessary tool to explore and comprehend complex phenomena. The instrumental function of visualization has generated much attention; many disciplines have started to recognize the efficacy of visualization as an aid for research and these have begun to require the development of visual tools tailored for their disciplinary fields.

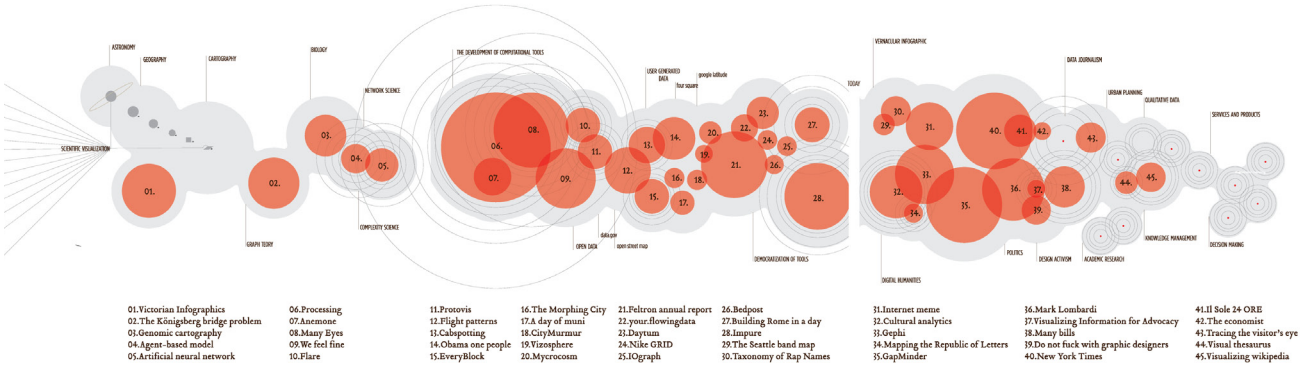

FIGURE 1: *The overall view of the diagram*

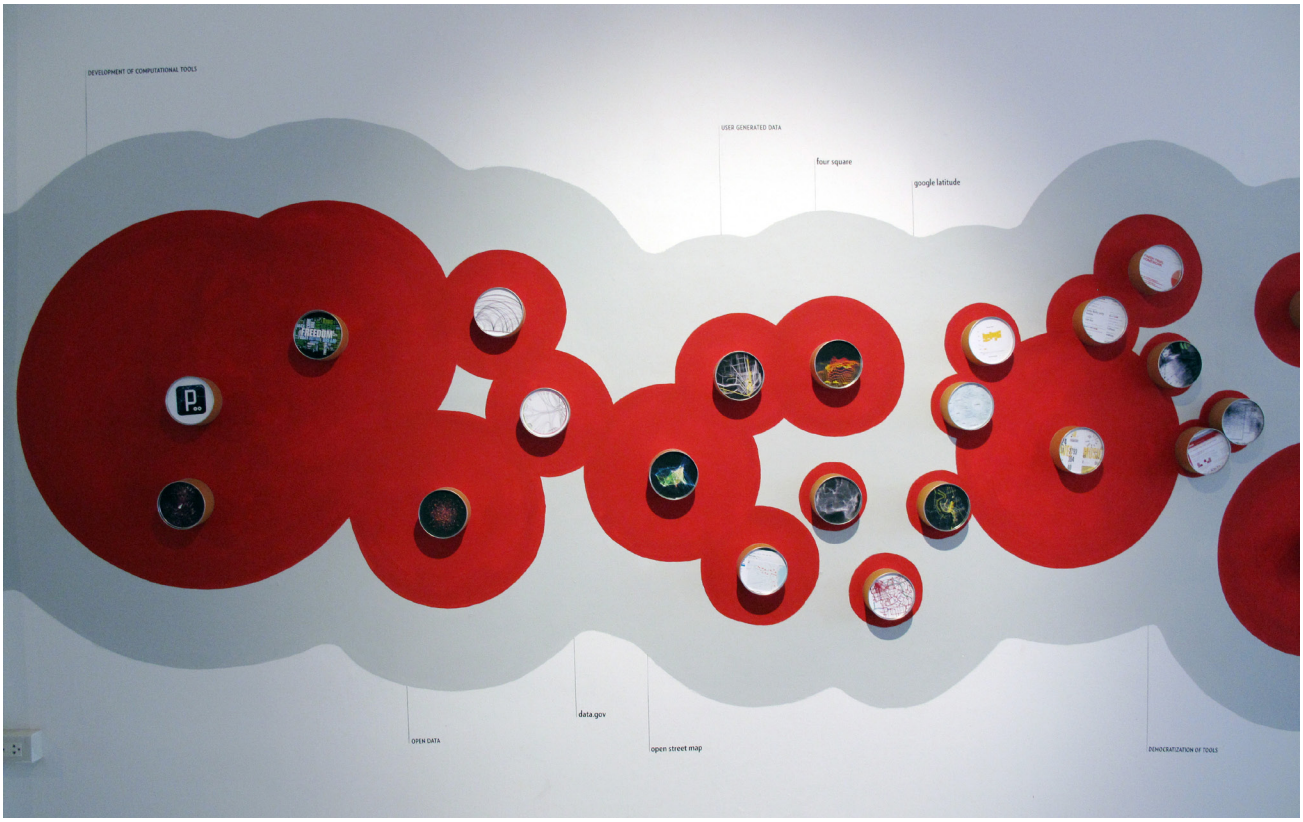

FIGURE 2: *Addiction to diagrams, the center part of the 12 meters installation*

Information visualization has been growing tremendously as a field of study and design. An ever increasing quantity of scientific research, dedicated journals, and papers have been published[1] but there is still a lack of historical research reflecting on the factors impacting the development of the topic and how they might reverberate in the future.

PROJECT

The diagram of Information Visualization is an ongoing research project started in 2009; the project consists of a research observatory on Information Visualization with the purpose of providing a systematic view on the discipline. The main issue addressed in the research concerns the nature of the design projects developed in the last decade, in order to understand their limits and opportunities and to delineate a research framework for future improvement. To accomplish this goal, two empirical works have been developed.

As a first step we identified and analyzed all the projects completed between 2003 and 2011 that have been published or reported within a pool of online and printed resources related to Information Visualization. Among those we selected 30 design projects for in-depth investigation. In the selection process we gave precedence to projects with a strong focus on visualization of agents' movements and emergence of patterns. The cases studies were selected and evaluated by 20 set criteria (clustered in User experience, Data, Content and Interaction). The methodology has been selected for its potential in explaining the complexity of causal links among events as suggested by Yin.[2] This study has been initially circulated in 2010 as a research report for the Mobility Department's Dynamic Transportation Systems Business Unit at the Austrian Institute of Technology with the objective of informing their ongoing projects.

The research result's significance for design and education persuaded us to design an interactive installation open to the general public. In 2011 we installed an educational exhibition piece aiming to communicate the research results to a broader audience. To design the exhibition *Addiction to Diagrams* which opened in Bangkok (Thailand) from September to November 2011 the results of the research-based empirical work was first

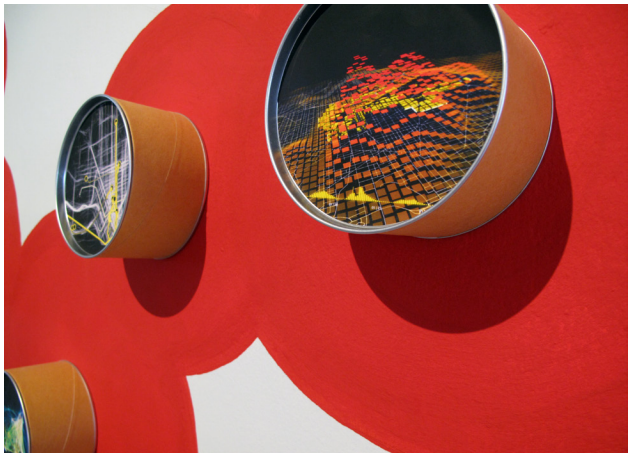

FIGURE 3: *Each tin represents a project developed in Information Visualization*

FIGURE 4: *Each tin contains a description of the project, author, data and a* QR *code linking the project website*

FIGURE 5: *The red circles diameters indicate the relative impact each project had on the field of Information Visualization*

arranged in a diagram. The diagram visually organizes the 30 projects analyzed in the case study, as well as highlighting computational tools, significant occurrences, or events. The elements are grouped by subject and their proximity indicates the presence of various similarities (e.g. intents, medium or concept).

The elements are distributed chronologically within their subject group; we did not prioritize the chronological order over the subject cluster—as the main purpose of the piece was to facilitate a deeper understanding of the relationships and interactions between different projects and their cohabitation in a specific trend of Information Visualization. A strict chronological order would not be able to provide much space for interpretation and reflection as it is a mere timeline of events. Each element has been inscribed in a circle; the circles diameters indicate the relative impact each project had on the field. On the right side of the diagram we visualized a possible future with a description of the disciplines we think will embrace Information Visualization tools and methods. The diagram has been transformed through an interactive three-dimensional piece as part of an exhibition on diagrammatic reasoning. In the piece, a series of metal and paper tins each represent one project that contributed to the development of the Information Visualization discipline. Each tin contains a description of the project, author, data, and a QR code linking the project to a website. The installation depicts the development of Information Visualization: highlighting forces, trends, and future developments. The key idea of this piece was to create a physical data representation that allows physical interaction using digital contents; the static quality of the installation was purposely designed to reduce the mesmerizing effect that most of information visualization pieces present when experienced in digital environments and media. After the initial impactful view of the whole 12 meter long piece, the visitors were engaged through the physical interaction with each element. In this manner visitors could discover more about each element. The QR code allowed the user to use their mobile devices to save a reference link for the project, or they could access the link and explore them online simultaneously (the use of smart mobile devices and data package in Bangkok is widespread).

THE GENERAL LAYOUT OF THE PROJECT

The lack of a historical view is addressed through the piece, and the explanatory framework for understanding the forces that are impacting the discipline are explored. The framework follows the three parts of the piece: displayed on the left side are the historical references

FIGURE 6: *The visitor could use their mobile devices to save reference of the projects or to explore them online simultaneously*

and the earliest projects, in the center part the projects developed in the last decade are presented; and on the right side the future development is projected.

THE LEFT SIDE OF THE DIAGRAM: THE ORIGIN

Representative visualization is an ancient human practice, yet in the last couple decades, it has seen a marked increase in interest from, as well as an increase of influence upon, various fields. The forces that shape these recent developments have been converging from different disciplines and to address different needs. Visualization has always been a useful tool for human sense-making; from the *Königsberg bridge problem* to images of *geographical spaces,* visual representations of knowledge have played a key role in human discoveries. What is called scientific imaginary has facilitated the understanding of scientific concept for centuries. The scientific imaginary has constituted of model and visual representation of the concepts under study. Even if the relationship between visualization and scientific discovery has been widely discussed[3] the recent changes in scientific research procedures has opened exciting new possibilities. The present development of scientific research procedures have dramatically increased the amount of data produced across fields. *Networks Science* and *Complexity Science* have demonstrated the necessity for new tools that could allow for the rendering and manipulating of massive quantities of data in real time. The same process has occurred in other scientific disciplines: as Ben Fry pointed out in his PhD thesis: "Biology has rapidly become a data-rich science, where the amount of data collected can outpace the speed with

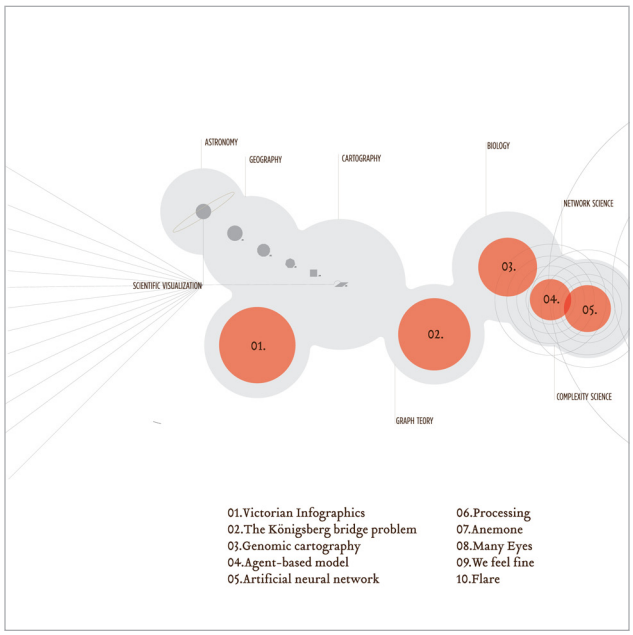

FIGURE 7: *The left side of the diagram*

which it can be analyzed and subsequently understood. Sequencing projects have made available billions of letters of genetic code, as analysis continues to add layers of annotation that describe known or predicted features along the linear sequence. Ten years ago, a few thousand letters, representing a few hundred genes, were known from a small number of 'model' organisms, where today this has become billions of letters representing tens of thousands of genes across a rapidly growing number of organisms."[4]

THE CENTER OF THE DIAGRAM: THE IMPACT OF TOOLS

The need to cope with such amounts of data has had a strong impact on the development of practical computational tools and technologies that are able to extract meaning and aid in understanding.

The development of *Processing* by Casey Reas and Ben Fry, *Many Eyes* by IBM, or other free tools such as *Flare* by the UC Berkeley Visualization Lab and *Protovis* by the Stanford Visualization Group demonstrates that the creation and application of new tools has been the first major force responsible for the Information Visualization bloom. For a long time, attention has been devoted to generate, test, and experiment with these tools, as well as to push the limits of what they can offer. The output of some of these activities became famous visualizations, reflecting focus and attention on the tool itself.[5] The devotion to develop new tools while experimenting with

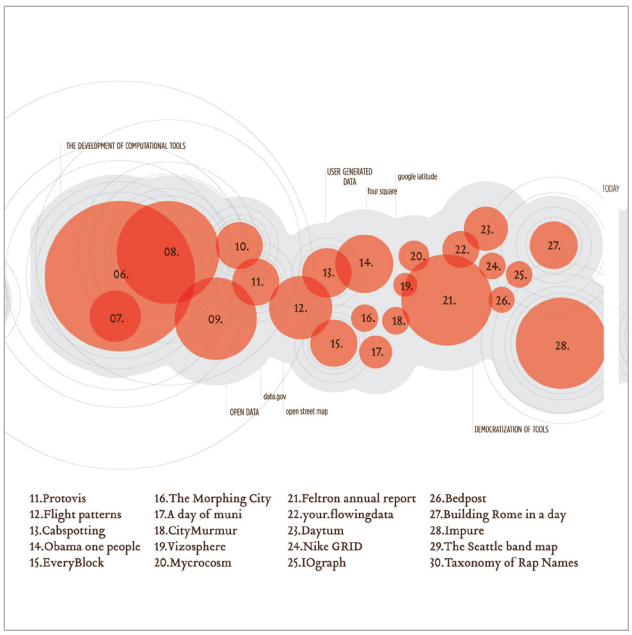

FIGURE 8: *The center of the diagram*

their possibilities has not been without consequences. The name "Information visualization" literally means the "visual representation of information," the definition commonly understood implies the use of computational tools for generating visual representation. The first dedicated page of Wikipedia written in 2005 used to define Information Visualization as a subject belonging to Computer Science, built on theory in information design, computer graphics, human-computer interaction, and cognitive science. I quote here the Michael Friendly definition, "Information visualization is the interdisciplinary study of the visual representation of large-scale collections of non-numerical information, such as files and lines of code in software systems, library and bibliographic databases, networks of relations on the internet, and so forth."[6] This definition seems to originate from the observation of a practice more than from an analysis of the core of the discipline. Even if computational tools have been extensively used and often required to deal with huge amounts of data throughout the process of generating an Infovis (acquire, parse, filter, mine, represent, refine, interact—to use the model Ben Fry[7] developed in his PhD thesis) it does not mean that Information Visualization is therefore a subject of Computer Science. Indeed the discussion among Wikipedia contributors has led to a definition that removes the direct reference to Computer Science, underling the different disciplinary contributions to the field: "Information Visualization has emerged from research in human-computer interaction, computer science, graphics, visual design, psychology, and business methods."[8]

The point I would like to make here is that Information Visualization has become a significant discipline in contemporary design discourse thanks both to, and because of, the availability of computational tools and technologies. It refers to the practice of making information visible *independently* of the tools we used to design it. Visualization can be considered as a technology, a collection of methods, techniques, as well as the tools developed and applied to satisfy a need.[9] As Marshall MacLuhan wisely stated "First we shape our tools and then they shape us"—the use and implementation of computational tools for information visualization has strongly impacted the discipline. For example, the use of *Processing* as a computational language for information and data visualization has shaped the majority of the projects developed after 2001, establishing a distinguishable approach to Infovis that prioritizes the transformation of data into visual spatial form over pattern recognition or knowledge inference. This kind of project has the ability to reinforce already established knowledge, representing it in a powerfully engaging form. "From the users perspective, a good representation will confirm what they already know, let them answer at once the question asked and show them several insights, leading to the so-called 'a-ha' moments when they feel like they understand the dataset."[10]

THE CENTER OF THE DIAGRAM: DEMOCRATIZATION OF TOOLS

The second main force that has been shaping the discipline of Information Visualization has been the growing interest in the Open Data philosophy, which has manifested in the increase of data made available by public institutions, such as governments, university, libraries etc. The trend of opening public access to existing databases has occurred in parallel to the implementation of new technologies (e.g. API) and the massive increase in content sharing. From ambitious projects such as *Open Street Map* to more mundane platforms as *DAYTUM* by Ryan Case and Nicholas Felton or *myflowingdata* by Nathan Yau, a large number of individuals have been responsible for producing content to be shared and visualized. This trend of personal data sharing has been supported by the development and diffusion of software such as *Google Latitude* and *Four-Square,* which provide quick and engaging platforms for sharing real time personal information. These two recent forces shaping Information Visualization—Open data and personal data sharing phenomena—can be interpreted as process of democratization of the tools and the concern

for user interaction. These conditions are a general indication that there is a breakdown of the gateways, this has led to diminishing the cognitive effort of managing and visualizing large datasets in order to simplify and extend access and participation to the broader public. The trend toward democratization of Information Visualization has involved mainly four areas: the *access* to existing data set, the *production* of data, the design of simple tools for managing data, and to *create* visualizations. Projects such as Impure by Bestiario are widening the accessibility to Information Visualization techniques previously limited to more technical and science-minded individuals, and opening them to a wider public. At the same time, various designers are pushing towards the improvement of designed interfaces in order to make visualizations more easily used and understood by a larger audience through a greater consideration of user engagement, and consequently, user interaction.

THE RIGHT SIDE OF THE DIAGRAM: FUTURE TRENDS

This research aimed not only to understand and describe the development of Information Visualization but to generate a hypothesis toward its future trends. Which disciplines would benefit more from this language? In which domains is information visualization becoming more relevant? The observed dynamics of the last years are seemingly linking Information Visualization with *computational arts,* not only because artists have more tools and visual models to experiment with, but also because the diffusion of information aesthetics and the culture of information design are increasing the sensibility of audiences while engaging a broader public. Art is where information visualization designers can experiment freely from issue of scientific methodology and validity. Projects expanding the conceptual horizon of Infovis as artistic practice in what has been called Informative art are becoming more and more present in the art scene.[11] Information and data visualization has been featured at institutions such as the Whitney Museum of American Art and the San Francisco Museum of Modern Art and have an increasingly relevant presence at Ars Electronica.

At the same time, this increased interest of the public is having a strong impact on the use of Information Visualization as a political tool for persuasion. The power of visualization as a medium to communicate and convince of the validity of represented information has been widely demonstrated.[12] Michael Camille[13] states: "Representations, then as now, are not only vehicles of pleasure and reflection, they are also agencies of power and control. They are wondrous objects of human production and attention,

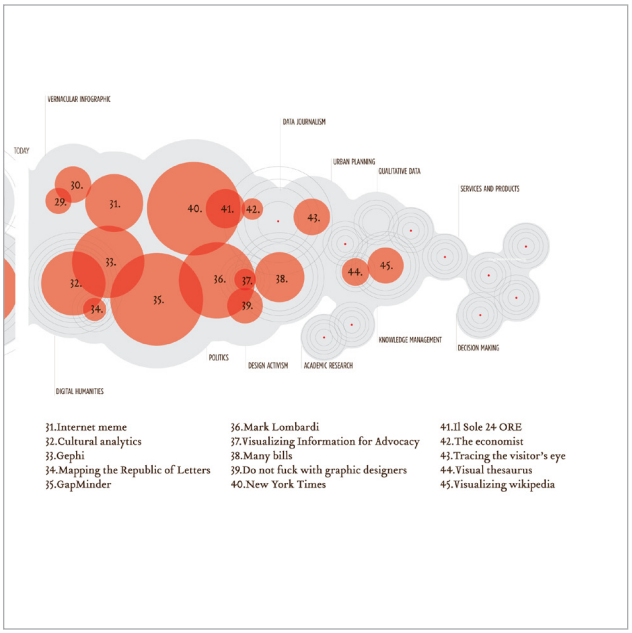

FIGURE 8: *The right side of the diagram*

and this very made-ness gives them special power and instrumentality." The revealing ability of visualization has attracted the attention of the broader public always captivated by the idea of uncovering hidden relations, confidential links, networks of power and secret connections. The work of *Mark Lombardi* as an example overall was fundamental not only for its artistic value but also as an inspiration for many other projects aiming to reveal hidden networks of power between different entities as corporations, countries, institution etc.

Visualizations will also play an increasingly central role in the future of journalism, a field which is going to rely more and more on Infovis for surviving the digital turnout. The first conference on *data driven journalism* was organized in Amsterdam in 2010 with the aim of "Developing the know-how to use the available data more effectively, to understand it, communicate and generate stories based on it, could be a huge opportunity to breathe new life into journalism. Reporters can find new roles as 'sense-makers' by digging deep into data, in turn making journalism more socially relevant."[14]

The main strengths of Information Visualization which lie in making visible what is invisible and revealing patterns will be exploited in various fields from business models and services, to social science, and to scientific planning. The New York City *cabspotting* visualization designed by the *New York Times* has been already translated into an iPhone application able to accurately suggest where to

catch a cab in real time, a clear example of how the advantages of an interactive visualization can be used to design a public service. The disciplines of planning and decision-making are increasingly showing interest in the benefit coming from visualizing real-time information about cities such as traffic, pollution, movements, and other factors.

Within social sciences there is an increasing interest in applying the potential for creating interactive platforms that can be used for humanities research, platforms which will able to take into account both the quantitative and qualitative features of social data. Many research projects in the social sciences are relying more and more on visualization as a tool for understanding and analyzing cultural artifacts. Lev Manovich calls them *Visual analytics*,[15] Bruno Latour refers to Mapping of controversies,[16] and the Stanford Humanities Center is researching on how to visualize the Electronic Enlightenment in a project called *Mapping the Republic of Letters*[17]; these are only some examples of ongoing research projects that are promoting the use of Information Visualization creating the need for more extensive research and development.

As Wrigth stated, "In the study of complex phenomena many problems can be answered only by direct simulation or collections of data far beyond the scale of human assimilation. These activities can often be expressed only in terms of imagery. Furthermore, in the inexact sciences that attempt to model highly contingent events, a form of 'pure' simulation is emerging that seeks only to reproduce the behaviour of phenomena without any pretence to a theoretical understanding. In these cases the generation of visualisation imagery could assume the status of a common epistemological currency - the creation of a visual knowledge."[18]

BEYOND THE DIAGRAM

From the analyzed cases and the research results we can infer some common necessities that should be addressed for future Information Visualization projects. Projects that make the most use of visual representation are targeting a non-technical public; it seems that there is a consensus that visualizations may be engaging and visually appealing, but not scientific. The visual implementation phase of the research process has often been seen of secondary importance. A common pattern seems to emerge: the quality of the aesthetics of a project is inversely proportional with the technical level of its context i.e., the more technical the audience, the less visually appealing visualization. There have been few interests in experimenting, researching, and understanding the epistemological issue beyond a visual representation. Designing visualizations that work as tools should take in account this final objective of the visualization. Furthermore, it requires a distinctive comprehension on how we generate and justify knowledge through the interrogation of visualizations, in other words a visual epistemology. Defining a visual epistemology is of primary importance for the future of the Information Visualization discipline.

There is an increasing level of interaction within Information Visualization projects even if the access to the data is often restricted, along with accuracy in declaring the data sources and data treatment. Transparency should be addressed as a critical value in future projects. Most importantly, the future of this discipline depends on our ability to design visualizations that can facilitate the acquisition of new information and knowledge. Visualizations should not only be considered as communication devices, but should work as tools to explore and investigate phenomena. A phenomenon, especially when complex, can be better analyzed, observed, and understood through the development of visual constructs.[19] Most of the analyzed projects did not take complete advantage of the inductive potentials of generating new insights and ideas that makers of visualizations often claim they possess. They generally show something that is already known and presumable but deeper insight may be gained by "interrogating" the visualization. This, however, is a normal phase of a discipline that is relatively new and that is not entirely consolidated in its methods, or in its applicability. Information Visualization at this point is still experimenting with data and borrowing research methods, approaches, and procedures from other disciplines while challenging them in completely different contexts and research objectives. I believe that this problem will be solved by the deeper interdisciplinary collaboration with other domains and by the application of the discipline to scientific research. Personally, I deeply believe in the power of Information Visualization as a construct for better changes: not only because visualizations are synthetic and are able to make complex phenomena more understandable; not only because they are highly engaging and enlightening—visualization has a revealing power and the future of this discipline depends on our ability to design and develop visualizations that are able to show us the unknown.

BIOGRAPHY

Dr. Gaia Scagnetti is an expert in visual epistemology for decision making and strategic planning as well as information visualization and mapping. Her current research investigates the impact of Information Visualization on design discourse with a focus on design education. Her complete portfolio at namedgaia.com

NOTES

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