

Innovations in Visualization

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ABSTRACT

While information is a crucial part of people's everyday lives, many people find that access to information via today's technologies is awkward, stressful, and overly intrusive in their lives. The problem is not with the information itself, but rather with its volume and the unwieldy ways currently provided for interacting with digital content. My research focus is to create interactive information visualizations so that they support people's everyday work and social practices as they interact with information. In this paper I will provide an eclectic overview of my research, particularly featuring the research done by my PhD students.

Keywords: information visualization, observational studies.

Index Terms: H5.2 [Information interfaces and presentation]: User Interfaces - Interaction styles, Input devices and strategies.

1 INTRODUCTION

I am amazed and deeply honoured to receive the Canadian Human-Computer Communication Society award. This is definitely a paper of thanks, and I have many people to thank – so many that it will not be possible to name them all here. For example, while academia is reportedly quite competitive, my experience has been that they have been welcoming and supportive. This has particularly included my home department, Computer Science at the University of Calgary, and the three nationwide research collectives I have been privileged to be a part of: NECTAR, GRAND, and Surfnet. It is also true of wonderful support and research exchange with SMART Technologies – particularly Gerald Morrison, David Martin and Nancy Knowlton. However, even though these have been tremendously important, I would like to make this brief paper a celebration of those to whom I owe the most – my students.

In the next section I will outline the research I have conducted with my research group – Innovations in Visualization (InnoVis). I will keep the words brief, and the images as plentiful as possible. In a paper of this length, I cannot possibly cover all the research we have conducted, nor mention all of my students. I have had to choose and have made eclectic selection. I have chosen some projects because they show our beginnings and others because they are more recent. Some projects were chosen because they represent what InnoVis is known for and others were chosen because they are less well known. Within this selection there is at least one project of all graduated PhD students. The students involved are featured with images and are named in captions. Post-doctoral fellows will be identified with PD and collaborators who are not my students will simply be listed as collaborators.

2 INNOVIS RESEARCH

My research goal has always been to make information more accessible, more comprehensible, and more possible to make use

of in our everyday lives. To this end, my research has encompassed new visual representations, and new explorations into interaction techniques. However, all of this has been grounded in careful, ethnographically-inspired observational studies. Since these studies have in many ways provided the foundations for my research and have perhaps provided my most significant research contributions, they have figured prominently in this overview.

While information visualization has always been my overarching goal, I have often found my research leading me towards investigations of interaction basics, particularly when it comes to tabletop and wall displays. After all, working with information often requires some means of spreading the information out to get an overview and the increasing availability of various types of pen and touch interaction make the possibility of letting people *get their hands in their data* worth pursuing. In this research overview I will touch upon: tabletop interaction; paying attention to real world data; the possibilities of supporting use of visualizations during collaboration; the extension of tabletop interaction in 3D; initial investigations into using visualization to support alternate search methods; the use of visualizations in public spaces; a look at a recent contribution to elastic presentations; new ideas in visual representation; and finally a look at a new direction – visualization to empower us in our everyday lives. Due to space, in this paper there are no in depth explanations, simply a research statement, an image, acknowledgements and references.

2.1 Tabletop Interaction

To better understand tabletop interaction fundamentals, we started by conducting several observational studies. Notably these include our research into item orientation as a collaborative communication aid (Fig. 1, [22]) and into understanding tabletop territoriality (Fig. 2, [31]). Interface item orientation is a significant issue, at least in part, because individuals sitting around the display have different views of the workspace.



Figure 2: Discovering that the orientation of items is a method of collaboration communication (with Russell Kruger, Stacey Scott and collaborator S. Greenberg).

From our studies on territoriality as manifested on tabletops, we showed that people establish three types of tabletop territories when sharing a tabletop workspace: personal, group, and storage territories (Fig. 2, [31]).

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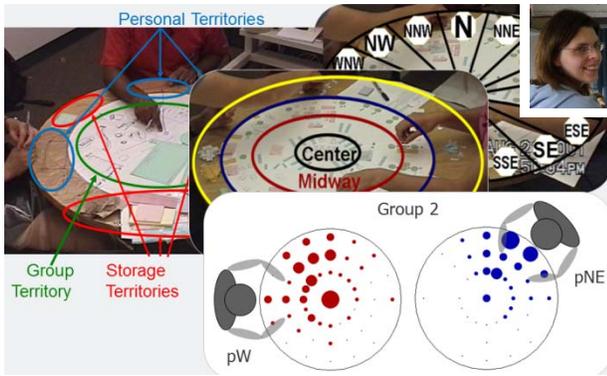


Figure 2: Studying tabletop territoriality. These images show part of the process of analyzing which parts of the table members of small groups used during collaboration. (with Stacey Scott and co-supervisor K. Inkpen).

A primary factor about tabletop territoriality is that people readily adjust territories according to immediate needs, making tabletop territories flexible and mobile. These tabletop territories facilitate collaborative interactions on a table by providing commonly understood social protocols that help people organize and share the tabletop workspace. These social protocols help clarify which workspace regions are being used for joint task work, for assisting others, for independent activities, and for storing task resources.



Figure 3: Two initial tabletop interactions. On the left: Storage Bins (with Stacey Scott) – mobile flexible tabletop storage territories. On the Right: Interface Currents – items in adjustable controllable motion within flexible containers (with Uta Hinrichs, Stacey Scott, Eric Pattison).



Figure 4: Finger painting with individual brush strokes (with Martin Schwarz, Katherine Mason, PD Tobias Isenberg).

In combination, these orientation and territoriality tabletop theories have led to new interaction paradigms for tabletops that better support the organization and sharing of digital information during collaboration. These include integration of orientation and translation [22], flexible mobile storage bins in tabletop territoriality support (Fig. 3 left, [30]), use of adjustable flow for interface items (Fig. 3 right, [16]), including extending this to digital touch-based finger painting (Fig. 4 [23, 29]), and more recently extending Stacked Graphs [4] functionality with touch interactions to create TouchWave (Fig. 5, [2]). These required the development of an interaction buffer to provide smooth fluid interaction [20].

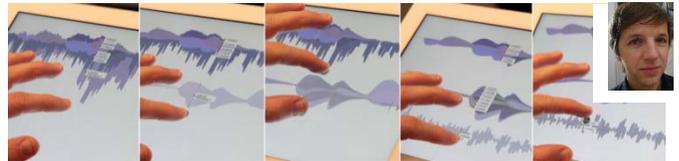


Figure 5: TouchWave is a recent tabletop interaction, where we used touch interaction to extend the functionality of Stacked Graphs (with PD Dominikus Baur and MSR collaborator B. Lee).

2.2 Real World Data

An important factor in my information visualization research is grounding my research in real world data. I will illustrate this with four projects: visualizing uncertainty in medical diagnosis, studying information exchange between nurses, looking at flow visualization for weather data, and visualizing linguistic data.

Visualizing uncertainty is frequently discussed as one of the grand challenges in visualization research [33]. All data has some degree of uncertainty, which may arise due to human error, during data acquisition, from instrument limitations, or may develop during processing. While uncertainty can be a crucial factor in decision processes, integrating uncertainty into a visualization is not straightforward. Visualizing an abstract concept like uncertainty is hard; visualizing it in conjunction with its data and maintaining readability of both the data and its uncertainty is harder still. Our investigation of decision processes when diagnosing pulmonary embolism, was conducted in collaboration with physicians (Ghali, Baylis, Altabaa at Foothills Hospital). From an observational study and contextual interviews of the diagnostic process, a model that relates uncertainty in reasoning to uncertainty in data was developed and used to create a set of visualizations, which were then evaluated with a focus group of physicians (Fig. 6, [42]).

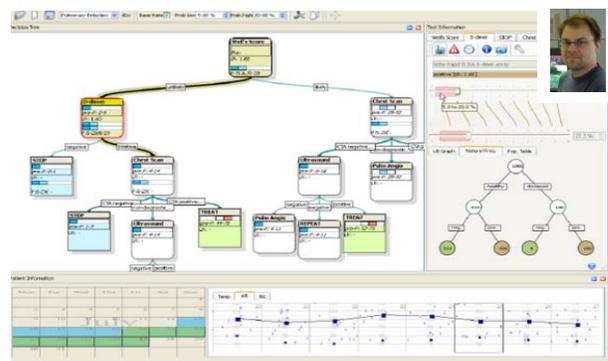


Figure 6: Working with surgeons to develop a tool to support diagnosis of pulmonary embolism (with Torre Zuk and medical collaborators Drs W. Ghali and G. Altabaa).

From an observational study and contextual interviews of the diagnostic process, a model that relates uncertainty in reasoning to uncertainty in data was developed and used to create a set of visualizations, which were then evaluated with a focus group of physicians (Fig. 6, [42]). This collaborative approach reduced the interdisciplinary separation and provided an understanding of the problem space that is reflected in the visualizations, which are now moving forward towards clinic trials. The same approach of starting with in depth observational studies was used in our research into the information flow between nurses (see Fig. 7, [32]).

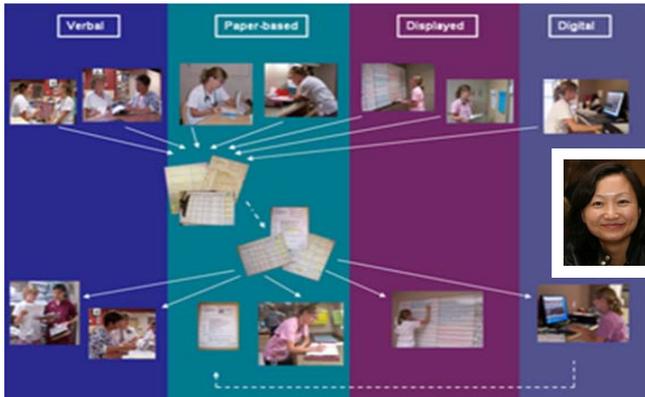


Figure 7: Discovering that nurses’ information flow involves a process of assembly (top of diagram) and disassembly (bottom of diagram) that involves verbal, written, displayed and digital data. (with Charlotte Tang – here it was necessary to put Charlotte’s image in the middle of the right hand side to avoid the diagram).

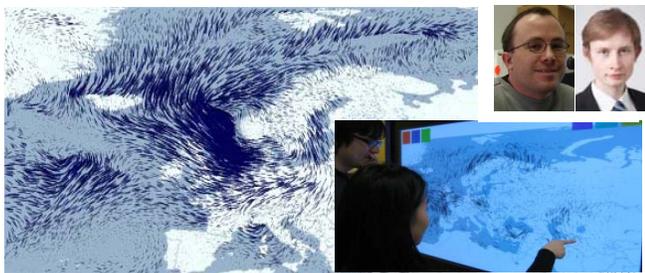


Figure 8: Interactive Exploratory Visualization of 2D Vector Fields. Here a set of simple hand postures let individuals custom-design their glyphs, making their own shapes such as arrows, lines, etc., in order to best reveal patterns of the underlying dataset. There is freedom of glyph placement, control of glyph density and animation. (with PD Tobias Isenberg, Jens Grubert and collaborator M. Evert).

To provide possible personalization of the representation of flow data, we explored the use of individually created glyphs coupled with flexible placement to create data flow visualizations (e.g. the wind data shown in Fig. 8, [19]). The intention here was to support viewers developing their own understanding of the data.

The complexity of linguistic data led to the development of VisLink (Fig. 9, [9]). VisLink is a fundamentally new approach for exploring the relationships between representations of different aspects of data sets. VisLink makes it possible to reveal relationships, to show connections between two or more primary visualizations, and to enable inter-visualization queries. VisLink

presents a new visualization structure that generalizes to all 2D visualizations. Essentially it provides for the display of multiple 2D visualizations in a single 3D environment and supports the propagation of queries from one visualization to another visualization. The VisLink environment allows the viewer to query a given visualization in terms of a second visualization, using the structure in the second visualization to reveal new patterns within the first. For example, starting from a similarity-based word visualization, the viewer can propagate edges from a chosen word into WordNet [25] visualization and back again to reveal synonyms of the selected word in the similarity-based word visualization.

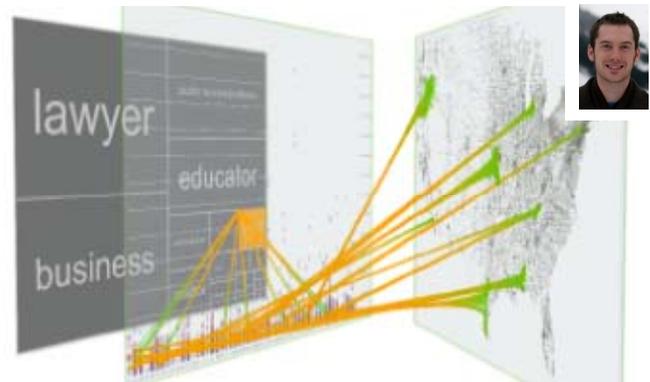


Figure 9: VisLink lets you display multiple 2D visualizations and use them to query each other. In this image VisLink shows a treemap of professions of congress candidates on the left with the profession journalist selected. The central scatterplot shows that the journalists were not particularly good fund raisers and this in turn is linked to the locations where they ran for office. (with Christopher Collins).

2.3 Collaborative Visualization

Practical use of information visualizations often involves teams working together over their visualized data to discover possible insights. Yet while there has been a strong call for collaborative visualization tools [33], there is still comparatively little research into collaborative visualization. Some exceptions include: some tabletop display research [1, 21]; Comotion [24] which offers some visualization support for collaborators; and web-based visualization tools [37]. We started with observational methodologies to increase our understanding of collaborative information analysis processes and thus to better inform design of information exploration environments that are specifically designed for co-located collaborators. To avoid the constraints imposed by existing software, our initial study on small team collaborative use of visualizations was paper based (Fig. 10, [18]).

We discovered that while most of the basic activities such as browse, select, parse, clarify, operate and validate had been previously discussed, people also spent considerable time strategizing and planning the nature of their collaborative activities. However, the most interesting discovery was that the temporal patterns were always varying. That is that when actually involved in problem solving people did not follow any set order of activities. In fact, abrupt changes were usually triggered by moments of insight, where the teams might have an idea of a solution and jump to validating it or might realize that their direction was not likely to reach a solution and change directions.

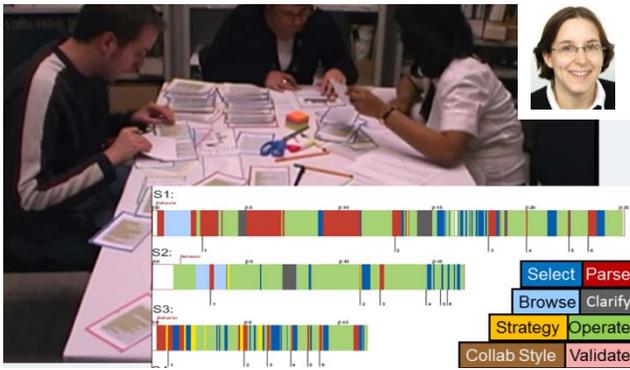


Figure 10: Studying paper-based information analysis led to the realization that unconstrained information analysis is atemporal (with Petra Isenberg, Tony Tang).

Two practical implementations resulting from this study are collaborative tree comparisons (Fig. 11, [17]) and Lark, which was developed for exploring clustering hierarchies in biological data (Fig. 12, [36])

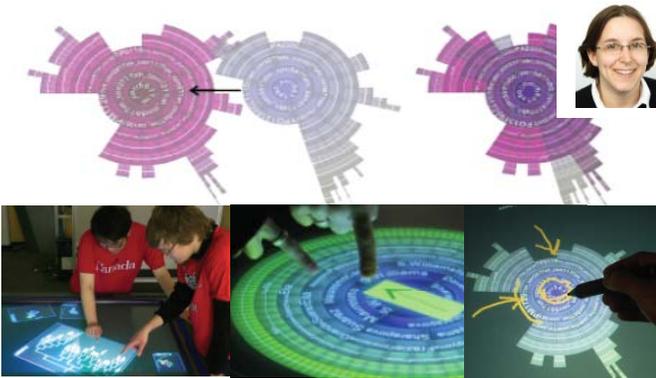


Figure 11: Collaborative Tree Comparisons. Top: transparent trees can be overlaid for comparison; bottom left: adjacent windows can be linked; bottom center and right annotation capabilities are included. (with Petra Isenberg).



Figure 12: Lark: links visualizations with a meta-visualization that shows how individual images relate. (with Matthew Tobiasz, Petra Isenberg).

2.4 3D on Tabletops

On traditional tables, people frequently use the third dimension to pile, sort and store objects. The goal of this research project is to

leverage the freedoms afforded on traditional tables by the use of 3D on digital tables. However, the fact that people view a table from all sides raises new perceptual issues for 3D displays. In studying how people perceive 3D on tabletops, (Fig. 13, [12]), we discovered that as the size of angle between a person's viewpoint and the projection's center of projection increases so does the interaction error rate. However, for parallel projections, the case when the center of projection is directly above the table is a special case and reduces this problem. Fig. 13 shows the setup for this study. Fig. 14 shows sticky finger interactions [13, 14] for 3D objects on tabletop displays. Fig. 15 illustrates applying this type of 3D touch interaction to VisLinks [38].

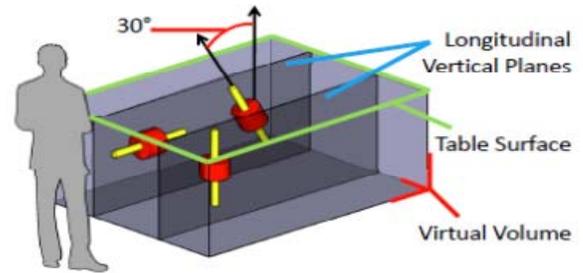


Figure 13: Studying the perception of 3D on tabletops led to the realization that parallel projection with a viewpoint above the table provides reasonable 3D understanding (with Mark Hancock, PD Miguel Nacenta, and collaborator C. Gutwin).

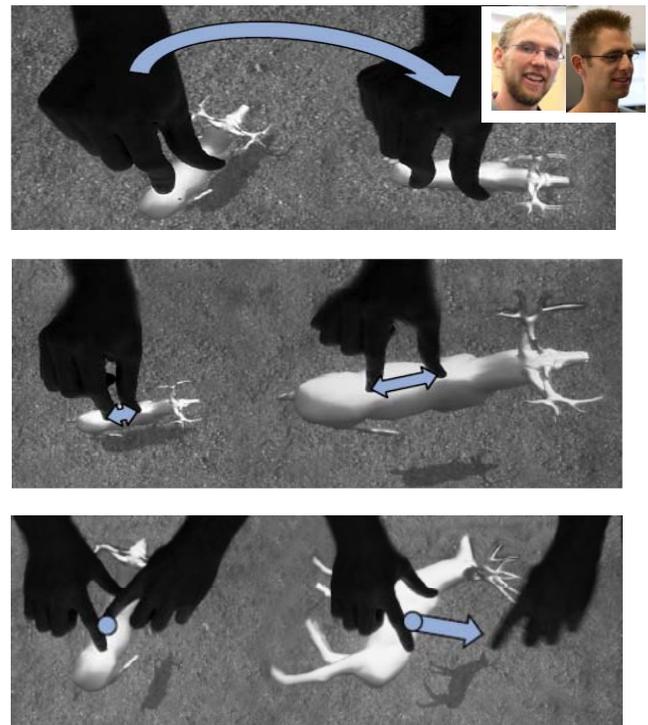


Figure 14: Sticky fingers touch interaction for 3D items on tabletop displays (with Mark Hancock, Thomas ten Cate and collaborator A. Cockburn).

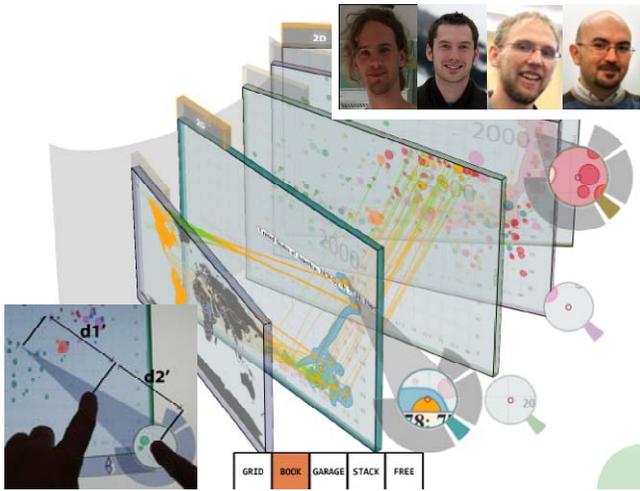


Figure 15: To create touch-based interaction for VisLinks we made most interactions (selection, adjustment of visualization planes, etc.) simple touch and added a virtual mouse, *rizzo* (inset), to offer pantograph pointing and selection of fine details. With *rizzo* the relationship of the distances between the cursor and cone touch (d1) and the cone touch and lens touch (d2) are preserved. (with Luc Vlaming, Christopher Collins, Mark Hancock, PD Miguel Nacenta and collaborator Tobias Isenberg).

2.5 Alternate Approaches to Search

As the search capabilities have expanded to the point where in much of our work and social activities we make frequent use of search, the general attitude in search has remained surprisingly deficit focused. That is, it depends on identifying what is missing and asking for it. We have begun an exploration into the use of visualization in search to support a more open and playful approach to search [8]. Fig. 16 shows Visgets (Visualization Widgets) [7] where we use visualization to ease the specification of some types of search parameters such as specifying a temporal range and to filter the number of hits. Fig. 17, [6] shows an example of a simple graph-based search for incoming and outgoing influences made explicit by using edge curvature to indicate direction of influence.

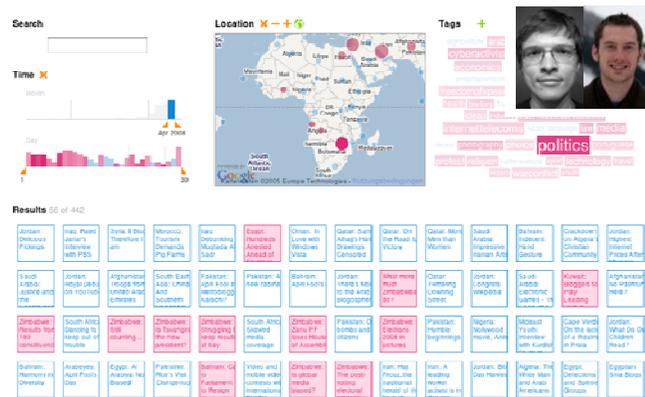


Figure 16: Alternate approaches to search. Across the top three Visgets, time, map and word-based. The intensity of the pink colour shows brushed highlights (with Marian Dörk, Christopher Collins and co-supervisor C. Williamson).

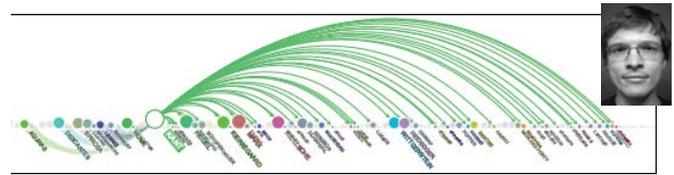


Figure 17: The philosophers that influenced Kant are shown with downward curves and those that he influenced are shown with upward curves (with Marian Dörk and co-supervisor C. Williamson).

2.6 Large displays in Public Spaces

Our observational studies of use of large displays in public spaces revealed the importance of temporal and social context in gesture sequences (Fig. 19, [15]). Our most recent example of information visualization for a public display (Fig. 20), the Bohemian Bookshelf [35], explores incorporating serendipity in search.



Figure 18: Studying gestures in public installations (Vancouver Aquarium) led to a deeper understanding of the impact of social and sequential context of gestures (with Uta Hinrichs).

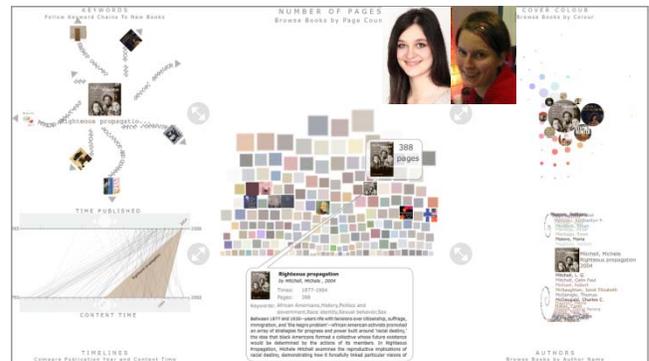


Figure 19: The Bohemian Bookshelf combines possible search through five visualizations: keyword chains (top left), a dual timeline showing publication date and content date (bottom left), a page pile where smaller books trickle down (middle), the cover colour circle (upper right) where books can be selected by the predominate cover colour, and an alphabetical author spiral (lower right) (with Alice Thudt, Uta Hinrichs).

2.7 Learning from Sketch Practices

While traditionally information visualization has focused on developing ideas for new visualizations by focusing on either the data or the tasks to be accomplished, as an alternative direction we have noted how many people use sketches and quickly created visuals to help them in their thinking processes [11]. To understand this better and to inspire new ideas for visualization,

we are exploring how people use sketches and diagrams to support thinking (Fig. 20, [40]). As part of this direction we are also looking at how people would use a ‘*what-you-sketch-is-what-you-get*’ interface. To this end we have conducted a Wizard of Oz study where we learned that people have definite ideas about when to use pen and when to use touch and that, as well as transferability from the physical world, people readily transferred interaction paradigms from within the system (Fig. 21, [39]).

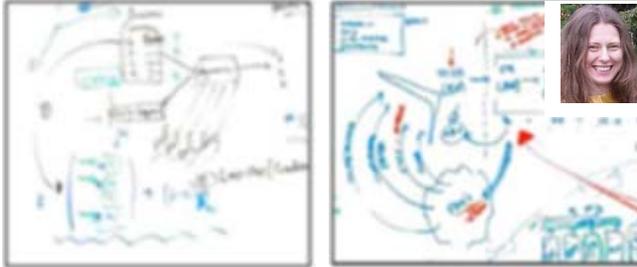


Figure 20: Studying whiteboard usage from an information visualization perspective provides insight into use of diagrams for thinking (with Jagoda Walny and MSR collaborators N. Henry-Riche, G. Venolia, P. Fawcett).

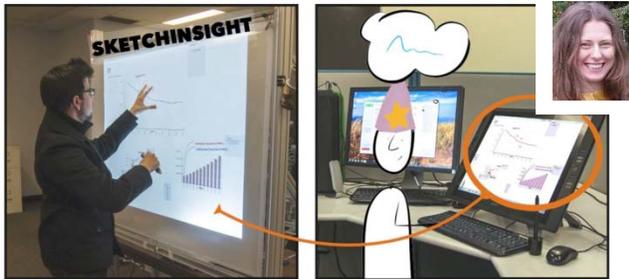


Figure 21: Wizard of Oz pen and touch interaction study (with Jagoda Walny and MSR collaborators B. Lee, N. Henry-Riche, P. Jones).

2.8 Elastic Presentation

One of my research themes that I started during my own PhD is to look for ways to cope with the fact that our screens are too small for the amount of information we need to display – to look for solutions to the screen real estate problem. This shortage of display space may be due the numbers of applications you need available for your work or to the sheer size of the images you work with. In fact, while our displays have increased in size and pixel count, we are still losing ground to the size and volume of data we wish to display. I initially explored elastic presentation [5], which offered a variety of variant magnification methods to support detail-in-context views. This type of approach to the screen real estate problem usually resulted in some accompanying distortion and compression. Whether or not some use of distortion is a viable approach has been much debated. Recently, to this stream of research we have added the Undistort Lens (see Fig. 22, [3]). The Undistort Lens can remove distortion from selected regions. Since Undistort is an image-based algorithm, it can be used with any geometry based distortion viewing approach.



Figure 22: Showing a couple of Undistort Lens on a cartographic projection. These two Undistort Lenses transform Baffin Island and Europe from a sinusoidal projection to a Mercator projection (with PD John Broz, PD Miguel Nacenta).

2.9 Visual Representation

One of the challenges of information visualization is that the data must be represented visually. Often this entails developing a visual spatial mapping from the data to the display. As a result this is always part of our research. For example, we have a series of specialized tree layouts: ArcTrees [28] (Fig. 23, Top); PhylloTrees [27] (Fig. 23, Left); and Docuburst [10] (Fig. 23, Right). A recent example of a new approach to representation is to embed the data in the ink. That is, instead of merely dithering to indicate data intensities, the actual numbers of the data can be used – if the fonts are designed in such a manner to make the ink proportional to the numbers. For example: the digit nine contains nine times as much ink as the digit one. We have called this idea FatFonts [26]. These FatFonts are particularly well suited for large high-pixel count displays (see Fig. 24). Here from across the room the FatFonts will work as dithering, but from a close distance the actual numbers of the data can be read.

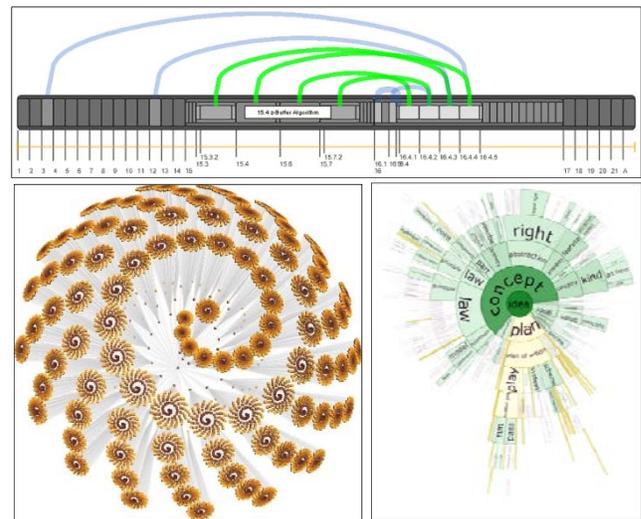


Figure 23: Top: ArcTrees showing hierarchical structure of a book with content relationship links (with Petra Isenberg and collaborator S. Schlechtweg). Left: PhylloTrees using phyllotactic patterns to create layouts for large trees (with Petra Isenberg, Anand Agrawala). Right: Docuburst uses radial space filling layout and Wordnet to show semantic structure of books and documents (with Christopher Collins and co-supervisor G. Penn).



Figure 23: FatFonts on a large wall display (with PD Miguel Nacenta, Uta Hinrichs).

2.10 Visualization in Everyday Life

People are now accessing information in a wide variety of situations such as in social situations, while travelling, while shopping, or while looking for a restaurant. It seems to make sense to make use of what we have learned in visualization to empower us in our everyday lives. Taking visualization out of the workplace and into everyday situations will also introduce new challenges in developing appropriate interactions in a social context. We are starting to approach this from a domain-specific perspective, focusing on specific data that people need and use, identifying the important features of their information, understanding the specific nature of their tasks, and looking for factors that arise from their everyday social context and routines. One example of this new direction is the Visits project. Visits makes use of the spatial and temporal data generated by most smart phones. However, it takes these two types of data and combines them to make a map-timeline (see Fig 25, [34]). Visits pays attention to dwell-time to present this map-timeline in terms of places visited and diminishes the travel time between places.

3 CONCLUSIONS

While these projects just discussed have made real progress, many of the research questions asked or exposed via our observational studies remain open. For example to mention just a few:

- While it is increasingly clear that territoriality is an interface and interaction issue, there is still more to understand about how to best leverage this.
- The need for atemporal interaction for information analysis will mean re-thinking our underlying basic interface systems.



Figure 24: Visits (with Alice Thudt, PD Dominikus Baur)

- If the right representation can make solving a problem comparatively simple, there is a great deal of work to be done creating matching representations for a given data set and its tasks.
- Since people use their gestures simultaneously for social and interface needs, we need to re-think how interfaces can be set up to handle this. Gestures may need to be thought of as sequences similarly to dance.
- We live in a sea of data that we are gathering, creating or is being gathered about us. How can we use visualization to empower us in our everyday lives?

Establishing an excellent research environment has also been joint work. Together with Saul Greenberg, Ehud Sharlin and Anthony Tang, we have managed to create an exciting lab full of collaborations and on-going exchanges. It has been a privilege to be part of this group. It has also been a real privilege over the years to work with SMART Technologies. I think it is particularly unusual to have a close relationship with an industrial partner – SMART employees are frequent visitors to the lab – where the industry partners understand the importance of curiosity driven research and fully supported it.

This brief overview has focused on projects by my PhD graduates, presenting at least one project for each of them. With these projects most of my Post-Doctoral Fellows have also been included. Unfortunately there is not space to list projects for all current graduate students, masters students, research assistants, undergraduate research assistants, interns and exchange students, except for when they were involved with one of these projects. I would have very much liked to mention projects for all my students, but that simply is not possible since to date they number over fifty. Current students not mentioned above include: Lawrence Fyfe, Katayoon Etemad, Jonathan Haber, Marjan Eggermont, Laurel Johannesson, Lindsay MacDonald, Ovo Adagha, Kyle Hall, Aura Pon, Bon Adriel Aseniero, and Gerry Straathof.

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