CREATIVITY WORKSHOPS FOR VISUALIZATION DESIGN STUDIES

by

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A proposal submitted to the faculty of
The University of Utah
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

School of Computing
The University of Utah
May 2017

CONTENTS

CHAPTER 1

INTRODUCTION

This proposed dissertation is about jump-starting the visualization design process by fostering the creativity of designers and data analysts, and then harnessing that creativity to quickly find and explore opportunities for visualization research. Creativity is fostered through structured workshops that encourage, among other things, sharing ideas and exploring solutions [56]. Creativity workshops stem from the fields of advertising and business, where consultants collaborated to solve their client's problems [56]. Since then, software requirements engineers applied creativity workshops to understand the needs of diverse users [25]. Recently, visualization designers used creativity workshops to accelerate design studies, by quickly characterizing the problems faced by analysts and exploring designs to solve those problems [15]. Even with recent successes, there are no guidelines for visualization creativity workshops—to run one, designers must piece together creativity workshop research spanning many domains, the sparse descriptions of workshops in the visualization literature, and their own experience with the nuances of visualization design. We will change that. This proposed dissertation will contribute a framework that provides theoretical and practical guidance for using creativity workshops in visualization design studies, it synthesizes our experience conducting design studies both with and without creativity workshops, the collective reflection of seven visualization researchers who have also used creativity workshops, and creativity theory from the domains of psychology, business consulting, and software engineering.

1.1 Overview

As visualization designers, we aim to create useful visualizations for data analysts in design studies [68]. But creating useful visualizations is hard for a variety of reasons. Often, analysts cannot tell us what they want to do with visualization tools because humans struggle to communicate tacit knowledge [60]. This is further complicated by imperfect communication due to the specialized knowledge of both designers and analysts—we may not know their domain's vocabulary, and they may not know what is possible with visualization [77]. We also have to navigate the context where analysts work, accounting for the bureaucracy and political environment of their organizations [67]. And we have to do all this while remaining productive as analysts expect to see rewards, often in the form of useful visualizations, for committing their limited time and energy to working with us [67].

Visualization process models describe the steps of conducting a design study [35, 48, 52, 53, 67, 68, 72], and generalize the challenges we face early in the design process into three categories: intellectual, organization, and interpersonal. Intellectual challenges relate to finding real needs for analysts and whether fulfilling those needs is an interesting visualization problem [68], such as eliciting requirements based on analysts' tacit knowledge [60]. Organizational challenges include political, bureaucratic, and administrative constraints, such as the ability to share sensitive data [67] or the buy-in from management [29]. Interpersonal challenges focus on relationships or communication between individuals [68], for example, the amount of engagement that analysts have in the project [67]. If we fail to address any of these challenges early on, it can cripple the project as seemingly small errors cascade through the design process [52].

At the start of design studies, the typical methods for navigating these challenges require significant time commitment. The visualization community commonly uses a mix of contextual inquiry and interviews for finding interesting domain problems [68]. But these methods require the focused attention of analysts, potentially over multiple days [21]. This strains the collaboration as it requires a large time commitment before we can deliver useful visualizations. Large organizations complicate things further as we must work with a diverse set of analysts, requiring even more time and energy from them as we piece together the organization's goals from disparate perspectives [29].

In the formative work of this dissertation, we used creativity methods and workshops to effectively start two design studies. Creativity methods are participatory activities that bring together designers and analysts. They promote, among other things, interpersonal leveling, open communication, and repeated cycles of divergent and convergent thinking [56]. Creativity workshops are the structured use of one or more creativity methods, typically with about ten participants in sessions ranging from two hours to two days in length [25]. In our first design study, we used creativity methods with defense analysts to make use of limited meeting time, and gain trust and buy-in from analysts' management [29]. In our second design study, we used a creativity workshop to understand the diverse analysis needs of neuroscientists [30].

In both of our design studies, we based our methods on the visualization literature [11, 15, 35, 48, 75]. But, even though the literature gave us enough information to use the methods, we did not understand why they were successful. This is because visualization research often reported on *what* was done during creativity methods and workshops, leaving the reader to figure out practical considerations, *how* to use the them, and the underlying theory, *why* they were used.

In order to understand why the creativity methods and workshops were effective, we began a collaboration with fellow visualization designers to share best practices. Through this collaboration, we reflected on our collective experience to understand why creativity workshops are effective and how to best use them. We tested and improved our understanding by using them in two additional projects [34, 54].

The main contribution of this proposed dissertation aims to share our collective knowledge on visualization creativity workshops with the wider visualization community. In particular, we will provide guidance on their practical and theoretical aspects, answering questions that designers may have, including: Why should we care about creativity in visualization design? What does creativity mean in this context? What are creativity methods and workshops? How do we decide if a creativity workshop will help my project? How do we plan a creativity workshop? How do we run a creativity workshop? And, how do we use the workshop output during the visualization design process?

Some of these questions have been addressed by the domains of creative problem solving, software engineering, and psychology, yet, work from these domains fail to account for the nuances of visualization design. We will account for these nuances, including the use of specialized process models [72], the critical role of data early on in the design process [52], the sharing of knowledge between designers and analysts [77], the fuzzy nature of visualization software requirements [68], and the evolution of data and tasks that occurs throughout the project [47].

1.2 Contributions

This proposed dissertation's primary anticipated contribution is a *visualization creativity workshop framework* to provide practical and theoretical guidance on their use in design studies. It will be supported by three main pillars: 1) a literature review on creativity workshops spanning various domains, including, psychology [6, 12, 27, 65, 66], problem solving [5, 7, 17, 49, 50, 56], and software engineering [9, 24, 26, 38, 39, 41–43, 51, 63, 64, 69]; 2) collective reflection of six[1] creativity and visualization experts who have used creativity methods and workshops in twelve projects [9, 11, 15, 16, 22, 24, 26, 32, 34, 54, 62, 75]; and 3) our own experience conducting design studies both with and without the use of creativity methods and workshops [28–30].

This proposed dissertation's secondary contributions are design studies where we used creativity methods and workshops. First, in a design study for defense analysts, we used creativity methods to foster trust and engagement with analysts and their management. This project's contributions included task analysis, data abstraction, and a visualization tool for analyzing spatial and non-spatial data ballistic simulation data [18, 31]. Second, in a design study for neuroscientists, we used a full-day creativity workshop to expose shared needs and establish rapport with analysts. This project's contributions include a set of requirements for multivariate graph analysis software and a visualization technique for analyzing graph connectivity [30, 33].

The secondary contributions provide important grounding for the proposed creativity framework. Conversely, the creativity framework synthesizes our experience with that of our collaborators and an extensive creativity literature to propose best practices for using creativity in visualization design.

1.3 Structure of this Proposal

The remainder of this proposal includes related work, followed by a discussion of our three projects organized by time. Chapter 2 contains the background and related work to visualization creativity workshops. Chapter 3 reports the design study with defense analysts. Chapter 4 summarizes the design study with neuroscientists. Chapter 5 outlines

[1]If you are curious: Miriah Meyer, Jason Dykes, Sara Jones, Sarah Goodwin

the proposed remaining work, the visualization creativity workshop framework that will synthesize the prior chapters. Finally, Chapter 6 proposes a timeline for the remaining work.

CHAPTER 2

BACKGROUND AND RELATED WORK

This proposal is about using creativity workshops and methods to accelerate the visualization design process. This chapter focuses on work closely related to fostering creativity in this context. It first summarizes theoretical creativity research, including definitions, models, and research methods. It then describes the origin and evolution of creativity workshops in three diverse domains: problem solving, software engineering, and visualization.

2.1 Creativity Research

Creativity means different things to different people. Creativity research spans many domains, including philosophy [3, 19, 59], psychology [27, 58, 66], the arts [6, 8, 65], business [7, 56, 73], and computer science [3, 20, 70]. Across these domains, researchers agree that *creativity* is generating ideas that are new and useful, where both new and useful can be defined relative to an individual, to a group of people, or to all of humanity [46]. The creativity in visualization design involves designers creating a new understanding of a problem and creating designs to solve that problem.

Creativity occurs individually or in a group. *Individual creativity* refers to a single creator, though that creator is often in contact with others [66]. *Group creativity* emerges from a interactions between group members [65]. It is synergistic as the group creates ideas beyond what its members could do on their own. Individual and group creativity are complementary, as group creativity often relies on creativity of its individual members. We focus on fostering group creativity for visualization design.

The work related to both individual and group creativity fits roughly into two complementary categories: models and research. While creativity models provide a simplified view of creativity with a useful vocabulary for practitioners, creativity research tends to embrace the complexity of creative endeavors. The two are complementary, and there is a strong convergence of ideas between creativity models and creativity research. Next, we summarize common creativity models and research approaches.

Creativity Models

Creativity models provide a useful vocabulary, yet they oversimplify human thought. The *four stage model* describes a linear process of creativity [19, 59, 76], though in reality it is more likely a cyclical and iterative process [66]. First, creators *prepare*, learning domain concepts. Second, they *incubate* ideas, forming new mental associations. Third, they have an *insight*, generating a new idea. Finally, they *verify* the idea, expressing and elaborating it. By expressing an idea, creators start a feedback loop where their actions change the environment, and this, in turn, changes the creator's idea. For example, a painter's idea for a masterpiece evolves as they see the impact of their paint on a canvas [14]. The *action theory* of creativity [66] summarizes this feedback loop and emphasizes the importance of creators' actions. Both the four stage model and action theory emphasize that creativity involves both *thinking* and *doing*, often through many interconnected cycles.

Creativity models straddle philosophy and cognitive psychology as they distill human thought and interaction into logical processes. They are supported by various approaches of contextual creativity research, which studies creativity in the context where it occurs — the real word [46].

Research Methods

We focus on three broad types of contextual creativity research. Biographical researchers observe and interview creators to better understand their processes [6]. Although this approach is criticized because it lacks quantitative data and experimental control, it is ecologically valid and supported by a broad base of qualitative data [46]. While biographical researchers study individuals and small groups, organizational researchers study creativity in large groups, such as businesses [10]. This includes quantitative surveys to identify shared traits of creative organizations [23] and the collective reflection on how leaders can foster creativity in their organization [2]. Another contextual approach of creativity research is creativity support. Creativity support researchers synthesize the results of biographical, organizational, and other research, to understand how software can foster creativity, and make recommendations for software designers [70].

There are many other approaches to studying creativity that do not necessarily provide information about how to foster creativity. The quantitative study of creativity, such as the study of creative ideas in a group setting, often lack ecological validity and must be synthesized with contextual approaches to generate useful insight [66]. Additionally, biological [44] and individual personalty perspectives [58] attempt to explain creativity as an inherit feature of individuals, but have generally been unsuccessful [66]. Interestingly, historical [1] and cultural creativity research [36] explains the change of our socio-cultural perspective of creativity over time. They show that the notion of creativity is a relatively new concept, having evolved in the twentieth century.

From all these approaches to studying creativity, there is a general consensus on how creativity occurs [46]. More specifically, creativity results from hard work, open communication, and many series of small but interconnected insights [66]. The best practices for fostering creativity, however, have changed over time from the domains of problem solving, software engineering, and visualization.

2.2 Creativity for Problem Solving

The idea of harnessing creativity methods for problem solving started in the fields of business, advertising, and engineering. Although these techniques are based largely on personal experience, many of them are currently used by businesses [23, 55].

Explicitly using creativity to solve problems was first proposed by Osborn [56], where he coined the term *brainstorming* with a militaristic definition of "using the *brain* to *storm* a creative problem - and to do so in a commando fashion, with each stormer audaciously attacking the same objective." Effective brainstorming is the freewheeling generation of as many ideas as possible, followed by evaluation to identify the most promising ones. The Creative Problem Solving Group formalized these principles into a repeatable process that is used by consulting firms today [23].

Related to brainstorming is Synectics, which encourages problem solving through structured workshops consisting of three phases [17]. First, workshop participants explore a given problem, often in terms of needs or wishes. Next, participant use the ideas as *springboards* for in-depth discussion and elaboration. Third, participants evaluate the ideas and execute the more promising ones. The Synectics methodology has been adopted by various consulting and training companies [55].

Additionally, many other consultants have written books about their experience using creativity in business. Lateral Thinking [7] encourages exploration through suspending judgment and restructuring ideas. Similarly, von Oech [73, 74] encourages creators to use methods that encourage new perspectives on their problems. Miller [50] proposes that creators should balance analytic methods, such as listing assumptions, with intuitive methods,such as brainstorming.

Many aspects of creativity workshops for problem solving are still in use today, such as suspending judgment [56], encouraging the use of metaphors and analogies [17], and promoting reflection [7]. However, on their own these methods are not immediately applicable to visualization design as they assume the workshop participant's have sufficient knowledge to reach a valid solution whereas visualization designers recognize that they must establish shared knowledge of visualization and the domain for a successful project [68].

2.3 Creativity Workshops in Software Engineering

Software requirements engineers recognize that they must translate the specialized knowledge of project stakeholders into concrete requirements and that this is often a creative process [61]. To aid in this translation, software requirements engineers used creativity workshops as a form of participatory design [51], where requirements are elicited from stakeholders through structured methods. Software engineering research on creativity spans both the practical, reporting what happened, and the theoretical, explaining why certain things happened.

Jones [26] summarizes a range of software engineering creativity workshops and identifies common parameters, including duration (0.5 to 2 days), participants (8 to 24), and ideas generated (hundreds per workshop).

The first creativity workshop was reported by Maiden et al. [41], describing a two-day workshop to create requirements for aircraft scheduling software. It used methods to encourage analogical thinking and combine seemingly unrelated ideas — similar to Synectics [17]. Another two-day workshop run by Maiden et al. [42] used repeated applications of divergent and convergent thinking — similar to Creative Problem Solving [56] — to understand requirements for airspace management software. Similarly, Jones et al. [26] used of creativity workshops for e-learning software.

Workshops used in software requirements engineering are often part of larger requirements engineering methodologies [25]. Their outputs are used to create formal use cases and requirements for software engineers [43]. Additionally, researchers reflect on the experience of running workshops to understand best practices for future workshops, some of these best practices will be applied to visualization creativity workshops in Chapter 5.

There has also been theoretical work creativity workshops for software requirements engineering. Mahaux et al. [37, 39] describe and validate a set of factors that influence creativity among individuals and groups, but this work falls short of prescribing best practices for fostering creativity. Recently, Maiden et al. [40] mapped the use of creativity requirements workshops to those of creative problem solving to identify areas for future work.

2.4 Creativity Workshops for Visualization

Visualization is generally recognized as a creative problem, where creativity is needed to explore a consideration space before winnowing down to the more promising ideas [48, 52, 68]. The explicit use of creativity methods in the design process evolved independently but in parallel to their use in software engineering.

The early creativity workshops were seen more as structured participatory activities as the term creativity workshop had not yet been used in visualization. Dykes et al. [11] used full day workshops, following a diverge-converge pattern, to understand the visualization needs of geographic information systems visualization users. Walker et al. [75] also followed a diverge-converge pattern where defense analysts presented the state of their current technology and were then asked to identify aspects of it that were good, bad, or could be improved. As the day progressed, these ideas were synthesized into scenarios for the use of visualization. Kerzner et al. [29] used creativity methods to engage analysts and their managers in a large bureaucratic organization.

Goodwin et al. [15] applied software engineering creativity workshops [24] to visualization design for energy analysts, and introduced the term *creativity workshop* to visualization. Kerzner et al. [30] applied the same workshop structure to understand the needs of neuroscientists. Recently, Goodwin et al. [16] conducted a workshop to understand the needs of constraint programmers, with a focus on finding opportunities for visualization.

Different creativity workshop structures have also been used in visualization. Nobre et al [54] used a half-day workshop to understand the the needs of genealogists. Lisle et al. [34] used a two day creativity workshop to find opportunities for a collaboration with visualization and evolutionary biology researchers. Rogers et al. [62] brought together visualization designers to explore potential visualization designs for domain problems.

Despite these repeated success, understanding how to do creativity workshops requires that designers must piece together disparate information from literature of visualization, software engineering, business, and psychology. There are no guidelines nor best practices for applying creativity workshops for visualization design. This proposed dissertation will identify such best practices, based on the experiences of *every* visualization project mentioned in this section. Before getting to the proposed framework, we present our completed work that used creativity methods and workshops.

CHAPTER 3

COMPLETED WORK: VISUAL VULNERABILITY ANALYSIS

The first design study of this proposed dissertation is a 15-month collaboration with defense analysts who are trying to improve the safety of military vehicles. It was a remote collaboration. We worked with three analysts and one fellow tool builder two timezones away from us, in Maryland. The analysts' primary goal was to reason about the output of physics-based ballistic simulations in order to reduce the vulnerability of vehicles with respect to certain types of ballistic weapons. In this chapter, we describe the creativity methods that helped us make use of limited face-to-face meetings with analysts and summarize the project results and contributions, visualization tools for analyzing combined spatial and non-spatial data.

3.1 Creativity Methods

There were many challenges posed by working remotely with analysts in a large and highly secure organization. We met with analysts mostly through video conferences, and analysts had to leave their offices to video conference with us because of security constraints. In the beginning, analysts had to maintain their normal responsibilities as their management were not committed to our design study. Also, the analysts fulfilled different roles in the organization, each with different goals. For instance, one analysts worked to improve the safety of existing vehicles, while another worked on vehicles as they were being designed. When we visited analysts and spent a week on site, we used creativity methods to navigate these challenges.

We used creativity methods in three half-day meetings with analysts and their managers. During the meetings, we ran visualization awareness presentations [35] followed by brainstorming ideas for our work [56]. Using creativity methods with management exposed the organization's need for visualization. "[the current data] is intelligible to only a few people" said a manager, and "making sense of it is labor intensive." After the visualization awareness, the managers were excited about the potential of visualization and more likely to let analysts spend more time working with us. Moreover, the creativity methods exposed shared needs between analysts. Although analysts performed vastly different roles in the organization, we realized that they all use the same simulation software and that making sense of simulation outputs was tedious. Helping the analysts make sense of simulation results, regardless of their overall analysis goal, would fulfill many needs within the organization.

3.2 Contributions

The analysts were trying to understand the outputs of ballistic simulation software. The outputs of this software are best explained by looking at its origins: an optical ray tracer [4]. Ray tracers compute photon paths through an environment, shade surfaces using physically-based lighting models, and output pixel color based on primary visibility rays. Ballistic simulations replace photons with shots, a projectile being simulated, compute energy transfer using physically-based penetration models, and simulate the impact the shots on vehicle functionality using fault trees [71]. Historically, the simulations output statistical summaries such as the total vulnerable area of a vehicle, but these summaries have a relatively nebulous definition that make it almost impossible to reason about why a vehicle may be vulnerable [45]. We created visualizations to make sense of ballistic simulation output, allowing analysts to find and explain patterns in their data.

There were four main visualization contributions from this project, two addressed the visual vulnerability analysis, two focused on the methodology of design studies in large organizations: 1) a problem characterization, data abstraction, and task analysis for the vulnerability analysis domain; 2) Shotviewer, a carefully justified and validated software prototype for visual vulnerability analysis (shown in Figure 3.1); 3) a strategy for exploiting view-design parallelism while creating multiview visualizations based on a reflection of our work with multityped data; 4) four recommendations for conducting design studies in large organizations with sensitive data. As part of this work, we also developed a rendering algorithm that increased the computational efficiency of the underlying simulations. Please refer to the publications in the next section for a more detailed description.

3.3 Publications

This project resulted in two publications. These papers will form this Chapter in the proposed dissertation:

- design study paper in Computer Graphics Forum, presented at EuroVis 2015 [29]
- graphics technique paper in the Journal of Computer Graphics Techniques [18]

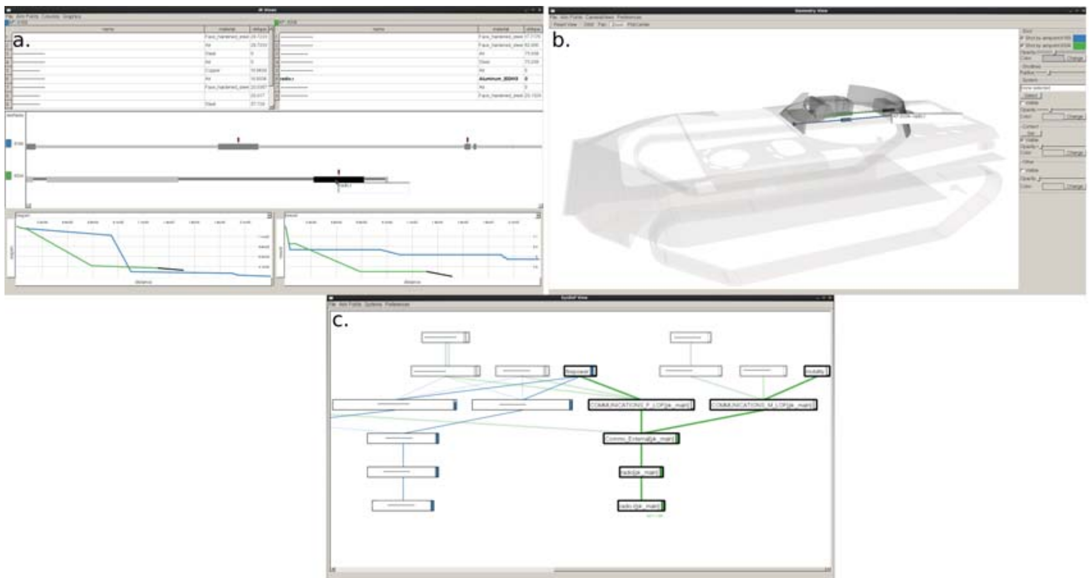

Figure 3.1: Shotviewer, software that supports visual analysis of spatial and nonspatial ballistic simulation data for vulnerability analysis. It consists of three linked views: a) the Shotline View displays an abstract representation of shots' paths through a vehicle; b) the Geometry View shows shots' 3D spatial context; and c) the System View visualizes the propagation of damage through a vehicle's systems. In this example, the green shot damages the vehicle's radio which impacts the vehicle's mobility and firepower capabilities.

CHAPTER 4

COMPLETED WORK: CONNECTOME VISUALIZATION

In the second design study of this proposed dissertation, we used creativity workshops to jump-start a two year collaboration with neuroscientists who are trying to reverse engineer the retina at a cellular level. In this chapter, we will describe the use of creativity workshops in the design study, followed by the project's visualization contributions: a set of tasks for analyzing paths in large multivariate graphs, two new visualization techniques to fulfill those tasks, and an open-source implementation of those techniques called Graffinity, shown in Figure 4.1.

4.1 Creativity Workshop

Early in this project we used unstructured interviews and contextual inquiry [21] to understand our collaborators analysis needs and domain goals, though the three limitations of these approaches motivated our use of creativity workshops. First, in analyst interviews we identified seemingly disparate needs. This is a common trait of working in large organizations [67]. Second, analysts had diverse goals as their research investigated different aspects of the retina. One researcher, for instance, studied the communication between cells, while another focused on classifying cells. Third, although we had established buy-in from a visualization champion [68], other analysts and support staff were not necessarily engaged in our collaboration.

Faced with these challenges, we decided to run a group-based workshop to understand the needs of many analysts simultaneously. We ran a workshop with the structure described by Goodwin et al. [15], though at the time we did not entirely understand the theory behind this structure. In retrospect, it followed a diverge-converge pattern, to explore a broad idea space and then to winnow the ideas and focus on the more interesting ones. Even though we did not understand why the it had worked, we were pleasantly surprised with the workshop results.

The workshop helped us establish trust with our collaborators and expose shared analysis needs. ′′The interpersonal leveling and intense re-visiting of concepts" said a senior member of the lab "made more team progress in a day than we make in a year of lab meetings." We estimated that the workshop generated ideas of about six months worth interviews and contextual inquiry. "The structured meeting" said the lab manager "created consensus by exposing shared user needs. " After analyzing the workshop output, we focused on supporting analysis of paths in large multivariate graphs, as this could fulfill the needs of many analysts, from understanding cellular circuitry and to classifying cells. A more detailed reflection on the creativity workshop will appear in Chapter 5.

4.2 Contributions

The contributions of this work focus on analyzing connectivity in multivariate graphs, motivated by the needs of our neuroscientist collaborators. Connectivity analysis involves reasoning about the direct and indirect connections between nodes, based on paths, and potentially considering node and edge attributes. For example, consider a graph of USA airports (nodes) connected by flights (edges). In this case, an analyst may be interested in how the airports of two regions are connected, allowing for one or more layovers. In the case of neuroscience, analysts wanted to understand how various neurons (nodes) were connected by synapses (edges). Our particular focus was on summarizing paths in a graph, providing a visual overview of connectivity.

Traditional graph and path visualization techniques do not provide effective overviews of connectivity. Node-link diagrams and adjacency matrices require that the analyst manually trace between nodes, or perform manual indirection between rows and columns of matrices [13]. Specialized path-based visualization techniques support browsing or ranking paths [57], but require that analysts manually aggregate paths to get an overview of connectivity. The contributions of this work focus on providing a scalable overview of connectivity that does not require manual tracing or aggregation.

There were three main visualization contributions: 1) a set of five requirements for visualization software to support connectivity analysis; 2) two new visualization techniques, the connectivity matrix and the intermediate node table, that summarize graph connectivity; and 3) prototype open source implementation of those techniques called Graffinity (Figure 4.1). Additionally, the tools that we created for this project enabled neuroscientists to discover various pathways that connect cells in the retina. Please refer to publications in the next section for details about these contributions.

4.3 Publications

This chapter will be formed from the following publications:

- technique paper in Computer Graphics Forum, presented at EuroVis 2017 [30]
- results paper in the Journal of Comparative Neurology [33]

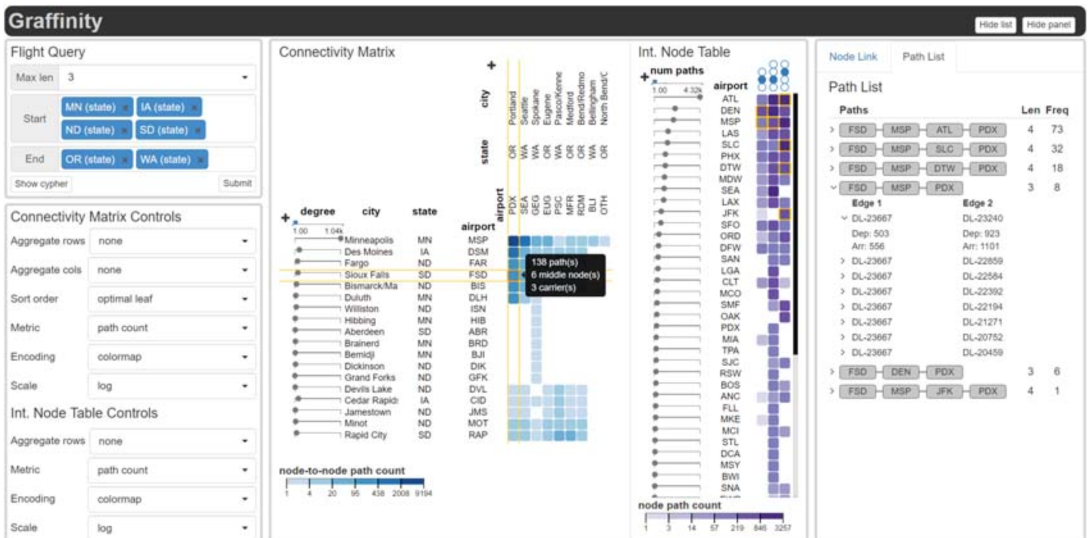

Figure 4.1: Graffinity visualizing 11727 flight paths with length $\leq$ 3 connecting states in the mid-western USA (Minnesota, Iowa, North Dakota and South Dakota) to states in the Pacific Northwest (Oregon and Washington). Graffinity consists of five views: the query interface, the connectivity matrix, the intermediate node table, and two views showing details about selected paths: the path list and the node-link view. The 138 paths connecting the airport FSD (Sioux Falls, SD) to PDX (Portland, OR) are selected and displayed in the path list view.

CHAPTER 5

PROPOSED WORK: VISUALIZATION CREATIVITY WORKSHOPS

In the previous two chapters, we described two design studies—in one, we used creativity methods to establish buy-in from defense analysts and their management, in the other, we ran a creativity workshop to expose the shared analysis needs of neuroscientists. We used these methods and workshops ad hoc, we read about methods in visualization literature, and tried them out, not necessarily knowing why they would succeed or not. To explain the theory behind creativity workshops, and provide practical recommendations based on our experiences, we propose creating a theoretical and practical *visualization creativity workshop framework*. In this chapter, we describe our research methods to generate and validate the framework. We also outline the proposed work as a set of 33 open question about workshops that we will address in our final project. Its anticipated result is a publication in IEEE Transactions on Visualization and Computer Graphics (IEEE TVCG).

5.1 Research Methods

We will create our framework through collective reflection with six collaborators who are also visualization designers and/or creativity experts. We will reflect on our experience completing design studies both with and without the use of creativity methods and workshops [28–30]. Our six collaborators will apply their visualization and creativity expertise to our framework, having used creativity methods and workshops in twelve projects [9, 11, 15, 16, 22, 24, 26, 32, 34, 54, 62, 75]. Our literature review grounds the proposed framework in theory spanning many domains, including psychology [6, 12, 27, 65, 66], problem solving [5, 7, 17, 49, 50, 56], and software engineering [9, 24, 26, 38, 39, 41–43, 51, 63, 64, 69].

<E: This section is missing something: what are the actual methods that we will use to create the workshop? Is 'collective reflection' a method?>

<E: This also needs an argument for validity.>

5.2 Contributions

This work's anticipated contribution is a framework describing how and why to use creativity workshops in design studies. It will consist of six stages, based roughly on the steps that a designer would use in planning, running, and evaluating a workshop. The stages are: 1) *motivate* the use of creativity workshops; 2) *scope* the workshop focus and goals 3) *plan* the workshop methods and logistics 4) *run* the workshop 5) *analyze* the workshop output and 6) *reflect* on the workshop efficacy.

For each of these stages, we describe its purpose, input, and output. We also propose a set of open questions that will be answered when this work is complete. The answers will be based on our collective experience and extensive literature review. The remainder of this section presents the six stages, followed by some general discussion questions that will need to be addressed in the final framework.

Motivate

The motivate phase is precondition to using creativity workshops. It is meant to convince designers that workshops are useful for design studies. The questions that a designer may have about this include:

1. *Why should I use a workshop? (Aren't interviews good enough?)*
2. *Why should my workshop be structured? (Can I just meet informally with my collaborators?)*
3. *What exactly does creativity mean in this context?*
4. *Why is it important that the workshops emphasize creativity?*
5. *Why do I need a* visualization *creativity workshop framework? (Isn't the existing literature good enough? What are the nuances of visualization design that I need to account for in my workshop?)*

Scope

In the scope phase, we evaluate whether a workshop would be useful for a design study. Input to this phase is a design study with domain experts. Outputs from it include a workshop focus (what role it will serve in the design process e.g., to understand or to ideate [48]) and goals (the stated reason for running the workshop). A designer may ask:

1. *Where is a good point in the design process to run a workshop? (Focus)*
2. *How much contextual knowledge do I need to run a workshop?*
3. *What can my collaborators and I expect to get from a workshop? (Goals)*
4. *Are my project constraints amenable to a workshop?*

Plan

In the plan phase, we assemble a workshop that fulfills the goals and focus while recruiting contributors. Input to this phase is a workshop scope — the focus and goals. Output from it are a list of contributors (including facilitators, scribes, and participants), logistics (such as venue and duration), and methods (the activities planned for the workshop). The open questions are:

1. *Who should I recruit as contributors?*
2. *What should I consider in my logistics — venue and duration?*
3. *What are the different kinds of methods available for workshops?*
4. *How should I select methods to use in the workshop?*
5. *Should I run a pilot workshop?*

Run

In the run phase, we execute the workshop and collect artifacts from it. Input to this phase is a workshop plan, including the contributors, logistics and methods. Output is a successfully executed workshop along with tangible and intangible results. A designer may ask:

1. *How should I prepare workshop contributors? (e.g., surveys of participants)*
2. *What are best practices for running the workshop?*
3. *How should I record ideas during the workshop?*
4. *How should I collect artifacts from the workshop?*
5. *How should I collect feedback from contributors?*

Analyze

In the analyze phase, we make sense of the tangible and intangible workshop results. Input to this phase are the results of a workshop that has recently been run. Output is actionable knowledge that fulfills the workshop focus and goals. The open questions are:

1. *What does the typical workshop output look like?*
2. *What are the different ways that I can make sense of workshop output?*
3. *How involved should workshop contributors be in analyzing output?*
4. *How can I use workshop output in generative design methods?*
5. *How can I use workshop output in evaluative design methods?*

Reflect

In the reflect phase, we evaluate the efficacy of the workshop. Input to this phase are the scope, plan, execution and analysis. Output are insights for the visualization community, potentially transferable to future design studies. The open questions are:

1. *How should I collect feedback from workshop contributors?*
2. *How should I evaluate the workshop with respect to the scope and plan?*
3. *When and how should I evaluate workshop effectiveness?*
4. *What is the role of quantitative/qualitative evaluation methods in our reflection?*
5. *What should I share about my workshop and reflection with the visualization community?*

Discussion

There are also interesting questions about creativity workshops that do not fit into the process of using them. These questions will be addressed in the discussion of our proposed work:

1. *What are the limitations of using creativity workshops?*
2. *How effective are creativity workshops with casual or non-expert analysts?*

3. *What is the relationship between visualization creativity workshops, participatory design, and co-design?*

4. *What is the relationship between visualization creativity workshops and agile development?*

5. *How do visualization creativity workshops apply to other areas of visualization research, such as technique or algorithm-driven work?*

5.3 Anticipated Publications

We anticipate that this project's outcomes will be published in IEEE TVCG. We will submit it for publication by September, 2017.

CHAPTER 6

CONCLUSION

In this chapter, we propose a timeline of remaining work and summarize this proposed dissertation.

6.1 Timeline

We present the timeline of completed and proposed work in terms of the projects. The three projects are:

- P1: Visual vulnerability analysis (completed)
  - design study published in Computer Graphics Forum (EuroVis 2015) [29]
  - technique published in Journal of Computer Graphics Techniques [18]
- Connectome visualization (completed)
  - technique published in Computer Graphics Forum (EuroVis 2017) [30]
  - biology results published in Journal of Comparative Neurology [33]
- Visualization creativity workshop framework (in-progress)
  - theory paper submitted to IEEE TVCG (anticipated, 2017)

The timeline of these projects is shown in Figure 6.1. Essentially, we will finish the visualization creativity workshop framework paper in the early Fall of 2017. This will provide time to write our dissertation and defend it in December, 2017.

6.2 Summary

This proposed work of this dissertation aims to establish a *visualization creativity workshop framework* that will provide practical and theoretical guidance on using creativity workshops in visualization design studies. The completed work of this proposal, two design studies, forms the foundation of experiential knowledge necessary to synthesize a visualization creativity workshop framework. In other words, the proposed work ties together experience from these projects into an actionable framework for using creativity workshops in visualization design.

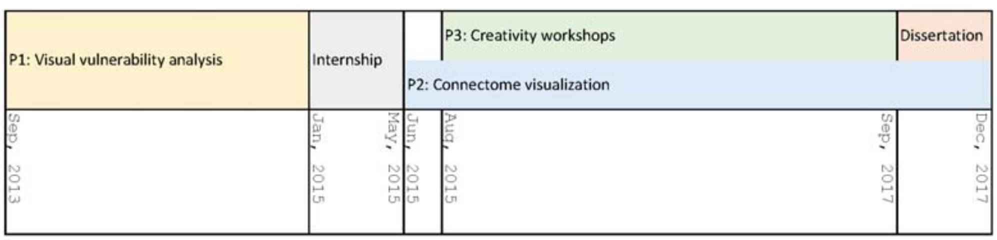

Figure 6.1: Timeline our completed and proposed work spanning the last four years. We propose completing the visualization creativity workshop framework by September, 2017.

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