Looking for Betsy:
A Critical Theory Approach to Visibility and Pluralism in Design

by

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Abstract

Drawing on previous research on Critical Design (Dunne and Raby), Feminist HCI (Bardzell and Bardzell & Bardzell), and Rich-Prospect Browsing Theory (Ruecker), this dissertation strengthens the theoretical basis for further research into the development and application of a critical and reflective approach, emergent from the humanities, to the design of graphical user interfaces.

Specifically, critical and feminist engagement with GUIs produced as part of an interdisciplinary project to design interfaces aimed at facilitating human decision-making within a manufacturing context resulted in three contributions. The first contribution is a conceptual framework for the interrogation of existing and the construction of new HCIs that includes the following six principles: challenge existing practices, aim towards an actionable ideal future; look for what has been made invisible or under represented; consider the micro, meso, and macro; privilege transparency and accountability; and expect and welcome being subjected to rigorous critique. Second, I provide an extension to RPB theory in the form of four new principles and three new tools: Principle of Participation, Principle of Association, Principle of Contexuality, and Principle of Pluralism; and the Connections Tool, the Structure Tool, and the Pluralist Tool. Finally, I challenge the current ontology of constraints and offer an expansion of the constraint category to include not just parts and materials, but also people (individuals, groups, and communities), environments (machines, working spaces, surrounding spaces, and electronic spaces), and processes (steps, time, decisions, upsets, consequences, factors, communications, relationships, and dependencies).

Keywords

Critical Design, Feminist HCI, Rich-Prospect Browsing, Human-Computer Interfaces, Decision Support Systems

Preface

Some of the research conducted for this dissertation forms part of a research collaboration, led by Dr. Fraser Forbes at the University of Alberta. The academic team and industry partner contributed by framing the *Oil Sands Project,* providing the formula that would drive the solution-generation aspects of the interface, and engaging in feedback on the three designs produced as part of this research.

The three designs discussed in Chapter 5 of this dissertation – A+1, B, and Z – were published as the following:

Radzikowska, Milena, Stan Ruecker, Chung Ta, Walter F. Bischof, and Fraser Forbes. "Human Decisions for a Machine World: Designing Experimental Interface Alternatives that Support Decision Making." *International Conference on Interaction Design*. 9–11 Nov. 2011, Hongkong, CN. Presentation.

---, Stan Ruecker, and Chung Ta. "So, Why Is This a Digital Humanities Project: An Interdisciplinary Case Study in Connecting DH, Engineering and Industry." *Society for Digital Humanities / Société pour l'étude des médias interactifs* (*SDH/SEMI*) *Annual Conference*. 30 May–1 June 2011, Fredericton, NB. Presentation.

---, Stan Ruecker, Walter F. Bischof, Michelle Annett, and Fraser Forbes. "Geared Decisions: Experimenting with Decision Support Visualizations." *Seventh International Conference on Design and Emotion*. 4–7 Oct. 2010, Chicago, IL. Presentation.

---, Stan Ruecker, Walter F. Bischof, Michelle Annett, and Fraser Forbes. "Sprockets for Gears: Interactive Decision Support Visualization for Multi-Modal Industries." *Chicago Colloquium on Digital Humanities and Computer Science* (*DHCS*). 14–16 Nov. 2009, Chicago, IL. Poster.

Dedication

To Olivia, for being a part of me from the day this work started and for getting me through its toughest parts.

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Chapter 1: Introduction

> "I always thought of myself as a humanities person as a kid but I liked electronics. Then I read something that one of my heroes, Edwin Land of Polaroid, said about the importance of people who could stand at the intersection of humanities and sciences and I decided that's what I wanted to do."
>
> Steve Jobs (qtd. in Isaacson xix)

Through this dissertation I aim to apply theories emergent from the humanities and visual communication design to the design of graphical computer interfaces in general (henceforth GUIs) and, more specifically, to those interfaces aimed at facilitating human decision-making within a manufacturing context. My approach to this body of work is deliberately interdisciplinary in nature, and draws on published work from comparative literature, humanities computing, computing science, and design.

I propose that we treat GUIs as a kind of cultural object, or in Derrida's terms a "text" that can be read and analyzed from the perspective of comparative literary studies. Such reading and rereading can provide us with valuable insights into how these graphical interfaces may, subsequently, be read and understood by their users – a critical concern to the design of effective user interfaces. The reading and rereading of interfaces would be somewhat similar to the practice of critique, which is fairly common to design. Arguments can and have been made, however, that human-computer interface design (HCI) can benefit from a more rigorous engagement with design criticism (Cockton et al., ff.). Criticism, or critique, in design most often takes place within the process of creation, partnered with the practice of design iteration. In iteration, designers cycle through making-thinking-remaking until either they become reasonably satisfied with the emergent result or they, simply, run out of the time that has been allocated for the project (hopefully the former). Too often, however, critique and iteration are used to make incremental adjustments to existing artefacts, too narrowly focused on the functionality or the aesthetics of the object, rather than to enable substantial challenges to or shifts away from the status quo.

In the place of design critique, I therefore propose the use of critical design theory, which provokes designers to reflect on and critique existing cultural values, mores, and practices. Critical design emerges out of constructive design research, positioning design activity as a form of research (Bardzell et al. "Critical Design and Critical Theory", 289). Popularized by Dunne and Raby, critical design looks beyond issues of usability and functionality, beyond "how users interact with the designed product on a day-to-day basis"(Kannabiran and Petersen, n.pag.), instead using "speculative design proposals" (Dunne and Raby Critical Design FAQ) to challenge our assumptions about design, asking us to reconsider the positive and negative roles it plays in our daily lives. Design is seen as opportunity for provocation rather than an exercise in "rearranging surface features according to the latest fashion while obfuscating the norms and conventions inscribed in the designs and their use" (Bardzell et al. "Critical Design and Critical Theory", 289), a particularly important, weakly addressed, point in HCI. In constructive design research, or research through design, "design experience in the form of designers' judgments is equally important to the analysis and reasoning activities that are common to all kinds of research" (ibid. 288). A design research activity "can start with just imagining future states, and in HCI, how technology can improve the current state of human existence" (ibid. 288).

In his 1973 edition of "Design for the Real World", Papanek calls out industrial design for being one of the most harmful professions, and advertising for its lack of authenticity. He states that, while advertising designers persuade "people to buy things they don't need, with money they don't have", industrial designers create unsafe, unnecessary, "tawdry idiocies" to be "hawked by advertisers"(Papanek, 14). Papanek's judgment on these areas of design goes even further. He calls design in the age of mass production "the most powerful tool with which man shapes his tools and environment (and by extension, society and himself)" (ibid. 14), then accuses it of putting "murder on the level of mass production" (ibid. 14). As evidence he points to the industrial process and product-use that create exorbitant waste material, pollute our air and water, and are capable of causing injury and harm to a cross-global population. HCI-emergent artefacts straddle both categories: some have the tangibility of industrial design, while others the promotional qualities of advertising. And some, I would argue, embody the negative aspects of both, as described by Papanek. Though most web sites are not the outcome nor the mass producer of industrial design, many enable mass production, distribution, purchasing, and obsolescence on a scale that does not have its equal in a physical counterpart. Take amazon.com as an example. In 2014 they reported almost 89 billion in net sales (Statista), with almost 114,000 total office and warehouse units, 181.12 million unique monthly visitors, and 305,258,547 unique products (ibid). While Amazon is not responsible for manufacturing all these products, the company and its web site do provide unprecedented access to them in terms of availability and lower cost, with little substantial information regarding the products' origin or value. If I wanted to know which specific sheep helped to make my sweater, I would be out of luck.

Central to this dissertation is the notion of design as an inherently (whether or not consciously or intentionally) political activity: "[d]esign is political because it has consequences, and sometimes serious ones" (Winhall). With the development and implementation of user-centred design methods and tools, HCI designers have made the statement that not only are we responsible (and can be held accountable) for the consequences of our design efforts, but that the power of design is in the potential for making things to have consequences that are – intentionally – different from the status quo.

Background

Some of the work described in this dissertation was part of a large, multi-disciplinary research initiative (completed in January 2012), titled *Decision Support for Multi-Mode Oil Sands Operations*, with the goal to develop a framework for plant-wide decision making. My role on the *Oil Sands Project* was that of the design researcher, building on previous work in human-machine interfaces for use in industrial plant operations, graphical outputs for decision support, and information visualizations for large text collections. My aim was to propose novel approaches to interface design for manufacturing decision support by extending Rich Prospect Browsing Theory towards the visualization of data associated with distributed decision-making. More precisely, I was interested in contributing to the existing discourse about what design strategies help to make an effective human-computer interface for use in manufacturing decision support, while including not just the quantitative, but also the qualitative experiences of the decision-makers within the design. The three human-computer interface (HCI) designs that I completed as part of the *Oil Sands Project* are introduced in this chapter, then discussed in greater detail within Chapter 5.

The *Oil Sands Project* benefited from a collaboration with several engineering departments and the Computing Science Department at the University of Alberta, and an industry partner, Syncrude Ltd. – partnerships that, I hope, will contribute to the broad field of HCI and, more specifically, the design of future manufacturing interfaces that aim to support human decision making.

The engineers and computing scientists on our team pursued interests rooted within their particular domains, while I was able to consider HCI design through the lens of humanities theories and reflect on the applicability (and potential extendibility) of these theories to a problem outside the humanities. My work with Syncrude is a significant part of this dissertation because it provided an opportunity to construct specific examples of prototypical interfaces designed to address questions about the applicability of theories emergent out of the humanities to the design of HCIs. Syncrude also represents an actual area of domain knowledge, constructed through a well-defined set of formulas and processes, and delivered to a reasonably well-defined community of users. Furthermore, it is a domain that I believe can benefit from a critical engagement with design that goes beyond discussions of functionality, usability, or aesthetics. The humanities, generally, and the specific theories that have become central to this dissertation, function as atypical lenses onto HCI and decision support system design thus, hopefully, revealing new challenges to and opportunities for these domains.

My work as the design researcher on the Syncrude visualization project began in January 2009. The primary objective of the project was to explore experimental alternatives for the design of an interactive environment for manufacturing decision support, and the design of the graphical representations of the linear formula developed by the Engineering PhD students also on the project. I was instructed to push the boundaries of the existing discourse surrounding interface design for decision support and for manufacturing, while also helping future users make effective manufacturing decisions. I was asked to conceptually develop several unique HCI designs that would provide decision makers with all of the information they needed to make effective choices, including identification of optimal operating variable values and the sensitivity of these optimal values with respect to assumed process parameters. This project was a continuation and expansion of a previous project entitled “Optimization-Based Decision Support for Integrated Mining Operations”, which focused primarily on the visualization of truck allocation problems and analysis of vector optimization problems (Ta et al. 2005).

Much of the actual data we were dealing with was proprietary to our manufacturing partner. Therefore, we chose an ice-cream manufacturing scenario as a working model in place of an oil extraction, processing, and distribution scenario. Ice-cream manufacturing was an appropriate alternative because it is a multi-modal system that contains sufficient complexity in the processes to be generalized to many other kinds of manufacturing operations. While I reference literature related to human-machine interface (HMI) design, located within the manufacturing domain, the term HMI is no longer in wide use, HMIs being considered as located within the broader HCI discipline. My sketches specifically reference the ice cream scenario.

While my focus was on the design aspects of an HCI for manufacturing decision making, in the context of the *Oil Sands Project,* "design" became defined, primarily, in terms of function. Aesthetics played a secondary, supportive role by helping to define a hierarchy of information and clearly labelling the different parts of the formula. The HCI's design was meant to support the answering of the following user questions:

- What is the current status of the manufacturing process overall, as well as those specific components that are my responsibility?
- Where are my resources (people and dollars) currently being allocated? What does this mean? How many resources do I have left? How best could they be used?
- In what phase or product area do I have the highest or lowest sunk costs, value, or competitive advantage?
- Is my distribution of resources aligned with value?
- At what point in the future might there be a gap in activity or revenues?

Fig. 1.01: The 2008 design concept by Carlos Fiorentino (Paredes-Olea et al. 2008).

In 2008, the team that worked on the project ran a study which identified several types of information that the design of that time was not supporting (see Fig. 1.01): [1]

- decisions in various environments were routinely connected to the time of day, as well as the calendar;
- interconnections were required, both between different decision factors and the thresholds at which they would be active; and
- the interface needed to accommodate different types of variables which we have categorized as continuous (such as flow of water), and discrete (such as containers).

Subsequent to the 2008 user study, the design direction from the team remained focused on functionality. Additionally, the team encouraged me to explore experimental alternatives of the kind that may be implemented by Syncrude ten years in the future, and that were as

[1] Please note: I was not yet engaged on this project at that time, my involvement beginning in May 2009.

different as possible from those discussed in existing literature on HMI design (see Fig. 2.03) (Hollifield et al. 115).

As well, our team developed a set of sample tasks for use in the designs, meant to show that decisions do not occur in isolation, but are connected to numerous other factors:

1. The manufacturer must make the best amounts of its three ice-cream flavours given a restricted supply of basic ingredients. The user wants to determine the best production solution including the production of each flavour, consumption of each ingredient, profit, and active constraints;
2. The user wants to determine how increasing each of the following would affect the profit – chocolate production, vanilla production, banana production, milk availability, sugar availability, cream availability; and
3. The user wants to determine the most effective way to increase profit.

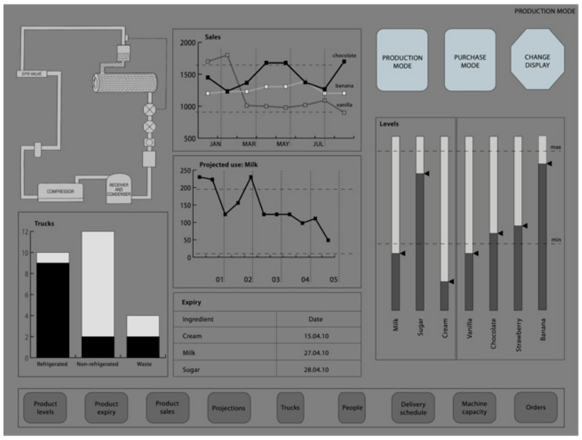
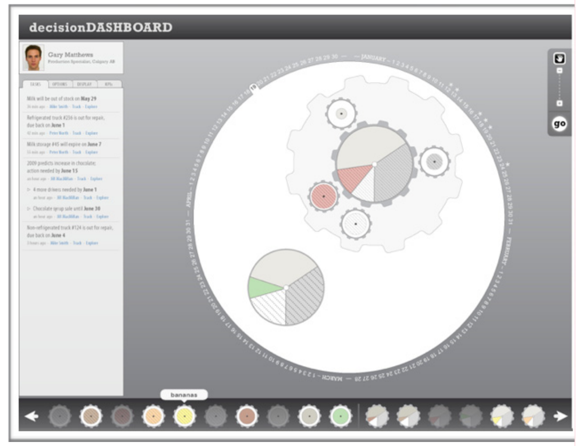
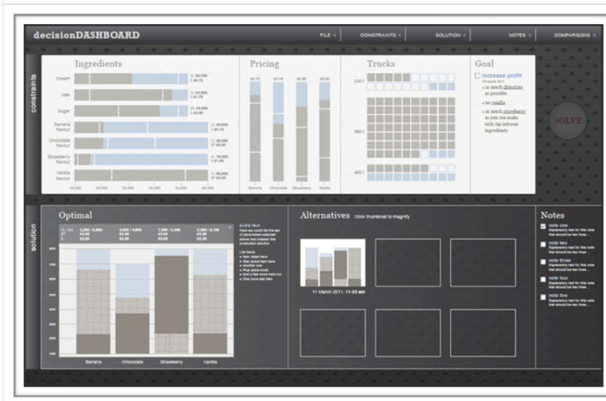
Design A	**Design Z**
Design A is based on a traditional HMI design, and utilizes sliders, line graphs, and bar graphs.	Design Z s made up of gears representing parts of the linear equation are constrained by a circular calendar.
	
Design A+1	**Design B**
Design A+1 is based on a traditional HMI design, utilizing sliders and bar graphs, but has been re-designed to address issues with look-and-feel and functionality.	Design B is an alternative that has been stripped down to basic lines and dots, structured in a layout that is similar to Design A+1 but provides a less familiar visualization approach.
	

Table 1.01: Four designs proposed as part of the *Oil Sands Project*. Originally published in Radzikowska et al. 2011; and Radzikowska, Ruecker, and Ta, 2011.

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Based on the team's call for a radical alternative, I designed the first of three concept HCIs for decision support in manufacturing: Design Z (the Gear design). Design Z was based on *Bradford Paley's TextArc Calendar* (Paley) and a gear metaphor (see Table 1.01) – intentionally unlike the designs discussed in existing HMI literature. The design still aimed to address the functional requirements established by the 2008 user study, while enabling user experimentation with different decisions. The user can directly manipulate each nested gear in the process of addressing a particular decision. For every decision a new set of gears appears, displaying the relevant variables and their relationships to one another. Both the nesting and the gear metaphor represent the relationship which exists between the different variables within the decision making process. For example, a decision of whether or not to increase the production of one of the ice-cream flavours does not occur in isolation, but is connected to numerous other factors.

Since I was interested in accommodating the human aspect of the decision making process – the work experiences and knowledge that have been gathered over the years by those working in the field – users can simultaneously choose to display similar decisions that had been made in the past, together with their implementation and consequences (or lack thereof), and the contact information of the decision makers. Finally, users can run several decision experiments and compare their projected outcomes.

Design Z reflects a new set of system affordances I developed for the design of interfaces for decision support in manufacturing (Radzikowska et al., "Gearing Up", 2012):

- Experimenting with different decisions: gears enable the user to compare multiple decisions that have been made in the past and experiment with different decision scenarios;
- Choosing a starting point: the user can choose a decision, a variable, or time/date as a starting point for experimenting with or reviewing decision;

- Displaying and managing decision variables: the interface presents a prospect view of the decision space which can be organized by either time/ date or type of decision;
- Recognizing different variable types: I created a system of gear design that uses the size, amount, shape, transparency, and colour to represent the type of decision being made and the nature of individual variables; and
- Connecting decisions to time: the user can select days/hours as a sequence or independently, display a micro and/or a macro system view, and review past, present, and future (experimental) decisions.

Design Z was met with fierce criticism – a common occurrence when working on collaborative and cross disciplinary HCI teams. From these experiences, my colleagues in the Digital Humanities and I have developed an approach to interface design based on the notion that the process of change is most successful when it can be managed as part of a slowly shifting sense of identity (Paulsen et al. ff.). We first became aware of the challenges of introducing radically different (or experimental) interface design alternatives while working on research teams as designers and digital humanists with computer scientists working as programmers (Ruecker, Radzikowska, and Liepert, 2008). While both groups are equal contributors in these types of projects, issues surrounding communication and expectations seem to routinely arise (Blandford et al. 2014; Mehta et al. 2009). Designers have tended to imagine systems that initially strike programmers as too difficult or too unusual, negotiating implementation then becomes challenging, with the resulting HCI less than useful as a contribution towards innovation in design research. The process has tended to look something like this (see Fig.1.02).

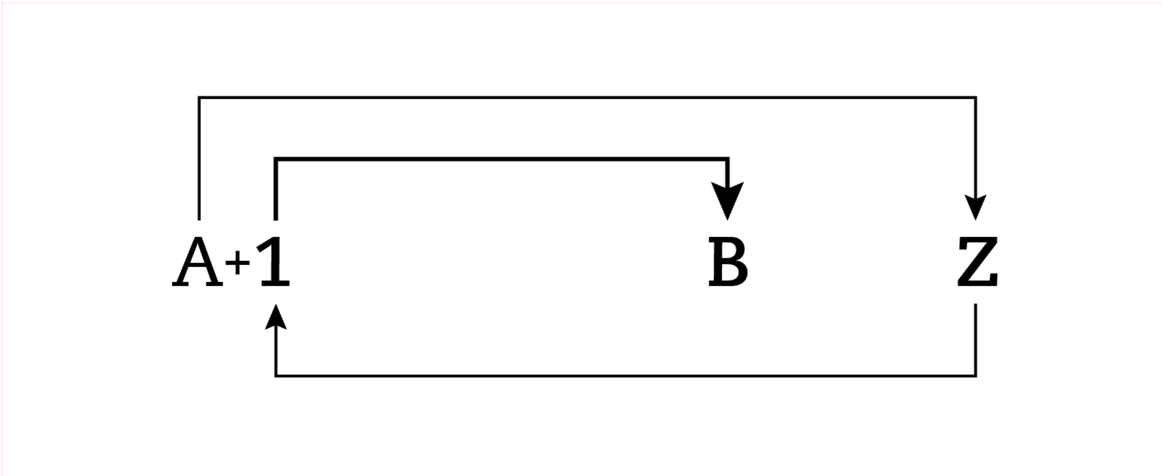

Fig. 1.02: Proposed system for managing the change process (Radzikowska, Ruecker, and Sinclair, 2015).

The researcher interested in an experimental system consults potential users of the system in order to understand their current best practices (Design A). An interesting set of research questions might be addressed by inventing a new system that involves a significant degree of change – a departure away from A that we called Design B. However, B is seldom the ideal for current users, as it is too far removed to be useful under present circumstances. Instead, they imagine a position of A+1 (current best practice with a very minor degree of change). While A+1 can be reasonably justified from every perspective – it will cost less time and effort, involve fewer risks, and can have immediate benefits – it is incremental change and will not produce significant research nor disruptive innovation in the area of experimental systems (Radzikowska, Ruecker, and Sinclair, "From A to B"). Therefore, in an attempt to sufficiently shift the relationship between identity and current best practices, we have tended to provide Design Z: a design radical enough to be as far as possible outside the current bounds of discourse. In the process of considering Z, the scholarly community of humanists and digital humanists alike has tended to shy back to A+1, spend some time in beginning to recognize its limitations, then asking instead for research in the area of position B.

The designs for the Syncrude project followed a similar path. After I proposed Design Z, and it was discarded for a large number of very valid reasons, I designed A+1 (the Bar design): a moderate shift away from the designs discussed in HMI literature (see Fig. 2.03).

I constructed Design A+1 using the same traditional components as appeared in the Hollifield et al. design; however, I added a persistent navigational structure in the form of a top horizontal menu bar, and separated the constraints portion of the interface from the subsequent solution results, placing the constraints at the top, with the solution appearing only subsequent to user action. The re-design was meant to encourage linear exploration: the user customizes the constraints panel, and then sets the constraint values. Once the constraint parameters have been set, the user clicks on "Solve" to generate a solution recommendation. The user can go back and change any or all of the constraint parameters, and re-solve, generating another solution recommendation. Solution recommendations – or alternatives – are stored in a separate panel, allowing for subsequent review and comparison. Existing systems only allow for a single optimal solution – there is no easy way to get at alternatives and compare them. A+1 also aimed to encourage the storage, sharing and recall of relevant qualitative experience. Users could set weekly, monthly, or quarterly manufacturing goals. They could prioritize these goals, and share or assign them to others. Users could also attach notes to solution alternatives discussing, for example, their reasons behind a particular solution implementation.

As in past projects, our team spent some time considering the strengths of A+1. As an unexpected side benefit, the design also sparked much discussion about the system's functionality and the linear formula that would produce solution alternatives. The design appears to have become clear and well structured to the point that the visual design faded into the background, allowing the thinking underlying the design to come first into view, then into question. After much consideration, it also became clear that Design A+1, despite its clarity and functionality, was not a far enough departure from current best practice to contribute meaningfully to its discourse.

The third and final concept design (Design B – the Line Design) emerged as a negotiated point between the highly graphical, experimental nature of Design Z and the more traditional, graph-based solution demonstrated through Design A+1 (see Fig. 2). Our team was able to question what was, in fact, essential information, and just how much ink was required to communicate that essential information in each information graphic. What emerged was a design stripped down to basic lines and dots, with a structure similar to Design A+1 – constraint panels appearing across the top half of the screen and the solution visualization occupying the bottom half. Constraints were given one type of graphical treatment, and solutions another.

In the process of designing and iterating from Design Z to Design B, additional system affordances emerged that were not incorporated into the designs, but which are worthy of mention:

- Tracking consequences: the user can review the impact of previous decisions on stages of operation and consequences of inaction;
- File export: decision experiments, implemented decisions, and/or decision outcomes may need to be exported for use in other systems;
- Decision reporting: a decision summary based on date range, decision type, or manufacturing cycle may need to be generated; a playback function may be useful for training purposes; reporting should support numeric values and visuals; and
- Access control and collaboration: some decisions may depend on one user's input, while other decisions may require cross-departmental or even cross-site collaboration; multiple work areas may be required to control the type

of information displayed to visitors or trainees, for example, versus plant managers.

All three HCIs discussed above – Design Z, Design A+1, and Design B – are designed using the principles defined by Rich Prospect Browsing Theory. For example, the display of ingredient and flavour gears within the circular calendar, as well as their relationships, is meant to provide the user with a meaningful representation of decision components, as are the sliders and solution alternatives in Designs A+1 and B. The gear palette and left-hand navigation are meant to offer controls for manipulating these items. These tools change depending on the items currently displayed. An RPB for decision support would require one consistent set of tools for the manipulation of constraints and another consistent set of tools for the manipulation of result scenarios. More work is needed in this area, particularly in reflecting the last three RPB principles in the designs: multiple item representations, links to related data, and the ability to mark items. If possible, more than one representation of an item should be made available. In an HCI for DSS, the RPB would provide an alternate, graphical representation of amounts; and allow for both a macro and a micro view on the equation. Each item would then link to more – related – data, for example, allowing users to view the computational results of decision models. Finally, users should be provided with the ability to mark items in some way, for example, to annotate solution alternatives. The ability to mark solution alternatives would allow for the capture and retention of not just the quantitative solutions, but also the qualitative experience of the decision makers: a user could experiment with multiple solution alternatives, and then choose to implement one of them. S/he could note the rationale behind the choice, as well as track it for potential, future consequences.

Incorporating these affordances into a design for decision support may help leverage human knowledge and experience in the decision-making process.[2] For example, a repository of decision experience will be created by giving decision makers the ability to experiment with several decisions, compare them to one another as well as to similar decisions that have been implemented in the past, and track the consequences of those decisions chosen for implementation. Such a repository can be used for employee training, policy review and public accountability. In addition, our system connects decisions to decision makers, and facilitates communication between relevant individuals (department managers who may be impacted by a particular decision, for example).

Though my involvement with the *Oil Sands Project* officially ended in 2012 with a report to the industry partner, the presentation of the three interface concepts described above, and a more focused set of functional requirements, I chose to continue engaging with the problem, this time from a hermeneutic position. While certain alternatives are meant to propose incremental improvements over pre-existing design (see the designs showcased in Hollifield et al., 115, for example); other alternatives are deliberate attempts at a major departure – radical change – from existing designs (Ruecker, Radzikowska, and Liepert). The radical change approach to interface design contributes unique alternatives that hold the purpose of diversifying the pre-existing gene pool of valid ideas (Ruecker, "The Perennial and Particular Challenges", 124).

Contributions of Dissertation: a Chapter by Chapter Outline

Fuller argues for an increased welcoming of contributions from a much broader spectrum of disciplines than are typically concerned with technology design and development, implementation, and critique: "artists, computer scientists, designers, philosophers, cultural theorists, programmers, historians, media archaeologists, mathematicians,

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2 The concept of affordance was first developed by Gibson (127–140) and is defined as all possible actions that exist within an environment. See much more on affordances in Chapters 4 and 5.

curators, feminists, musicians, educators, radio hams", plus those who cross multiple disciplines. Software's design complexity, its vast and varied implementation, and the numerous roles it plays in our lives intersects all these disciplines, suggesting that it "makes more sense [when] understood transversally" (Fuller, 10). I fully support Fuller's position, and argue that interface design and, specifically, interface design for decision support in manufacturing benefits when considered through lenses emergent out of non-neighbouring disciplines. By challenging its traditions, design has the opportunity to also challenge its own assumptions and practices that have, perhaps, become unquestionably entrenched over time.

This dissertation attempts to make a theoretical contribution to the humanities, to design, and to computing science, and an applied contribution to interface design practice. I attempt to build upon existing theoretical foundations established by Critical Theory, Critical Design, and Feminist HCI, in order to strengthen a case for considering these particular lenses both in the creation process of new artefacts and in acts of rigorous interpretation of existing artefacts. My experience with the *Oil Sands Project* has provided me with an opportunity to challenge established practices for the design of decision-support interfaces in manufacturing; however, I hope that subsequent work outside this dissertation will prove this work useful, applicable, and extendible to other HCI concerns.[3] The structure of this document reflects the multi-disciplinarity of this PhD. I was deliberate and intentional in involving diverse academic disciplines and professional specializations in considering the problem of DSS design for manufacturing. Rather than duplicating existing knowledge, I hope to define an intersectional space for the future consideration of similar problems in HCI.

Human decision-making does not occur in a vacuum. In fact, it often occurs in times of acute stress and severe time constraints, with consequences that can range from the mundane to

3 Please see more regarding extendability in the concluding (Chapter 6) of this dissertation.

the disastrous (Hollifield et al. 19–24). The kinds of choices people make and how they manage the day-to-day manufacturing operations can have profound consequences for other people and other processes. Thus, the ultimate goal of this dissertation is to propose a critical approach to the design of HCIs for manufacturing in order to disrupt the current way of approaching the design of such interfaces and open up opportunities for their future innovation.

Chapter 2: Visualizing Information

While Chapter 1 introduces the dissertation, Chapter 2 provides an overview of existing approaches to the graphical representation of information, and how those manifest in the various disciplines under discussion. Within relevant literature, it is possible to identify several threads dealing with proposed conceptual structure for decision support system design, the benefits of a well-designed system, and various functionality, visual design, design process, and aesthetic recommendations. While some recommendations appear to align well with relevant visual design literature, many of them make sense in theory but require specialized expertise to successfully put into practice. Chapter 2 begins with a historical overview of literature relevant to interface design for manufacturing and decision support: interfaces for decision support (DS), information dashboards, and human-machine interfaces (HMIs). I conclude this section with a review of design recommendations emergent from these fields, combined with design discussion rooted in information design. The next section of the chapter provides an overview of graphical data representation and visualization tools, and reviews the types of graphical objects that most often make up interfaces for decision support: charts and graphs, information graphics, and data visualization.

Chapter 2 exists for two reasons. First, it attempts to provide a territorial overview in order to answer the following questions: how is visual design discussed within DSS literature; what has been included as part of the discourse; and what has been omitted? This synopsis is a macro view. Second, a micro discussion of the graphical display of information that crosses disciplines, with visual examples, aims to broaden our understanding of what may be possible in terms of interface design for decision support. Through Chapter 2 I argue that we should consider the visual design of an interface at a leaf, or micro level: by looking at the lines, shapes, and colours that make up its surface; the tree, or meso level: the graphical objects, such as charts and graphs, that are meant to communicate data; and at the forest, or macro level, where we observe the totality of the artefact where "the whole is other than the sum of the parts" (qtd. in Dewey).

Chapter 3: Critical HCI

The word *design* is used throughout this dissertation, therefore I would be reticent if I did not attempt to provide its definition. Chapter 3 begins with a wide brushstrokes overview of how the word design tends to be interpreted by members of the general public. I contrast these perceptions with definitions provided by theorists, practitioners, and educators from the design discipline. I conclude this section with an attempt at my own, coalescent definition of design.

The chapter continues with a shift in focus from the field of design to a summary of the existing work in Critical Theory, Critical Design, and Feminist HCI. The chapter culminates in an argument for considering decision support system design through the lenses provided by Critical Design and Feminist HCI.

Chapter 3 has two goals. The first goal is to consider Critical Theory and Critical Design as appropriate and useful fits for contemporary HCI research. Sumner argues, more generally, for more critical engagement in interdisciplinary research, stating that doing so "opens up the critique that interdisciplinarity begins, allowing research to move beyond the bounds not only of disciplines, but also of the status quo." Furthermore, through the suspicion that emerges out of a critical attitude, "researchers [can] begin to address complex contemporary issues such as globalization and sustainability" (Sumner, 1). Currently, the uptake by designers of approaches emergent out of Critical Theory has been limited, and there is ongoing argument as to the ways these theories can be most beneficial, not only as theories but in practical application. Part of the problem, it has been argued, is lack of clarity, examples, and directions that would enable someone new to the field to hit the ground running. Another challenge lies in the fact that the definition of Critical Design is still (understandably) under way, as is the discussion of what is the "critical" in critical design.

The second goal is to consider the value of a direct engagement between feminist thinking and human computer interaction. Bardzell argues towards the development of an alliance between feminism and interaction design, and "proposes the design and evaluation of interactive systems that are imbued with sensitivity to the central commitments of feminism – agency, fulfillment, identity and the self, equity, empowerment, diversity, and social justice (Bardzell, "Feminist HCI", ff.).

Approaching HCI through the lens of Critical Design and Feminist HCI may lead us to challenge the design notions and expectations that have been established within HCI, as well as within the specific domains it attempts to serve (for example, the design of decision support systems), thus provoking new ways of thinking about these objects, their use, and how they impact the surrounding environment.

Chapter 4: A Case for Critical Design in Practice

Chapter 4 is a continuation of Chapter 3, with a shift towards a discussion of work that has taken place, thus far, on critical design frameworks, rigorous critique, and the application of critical design: Agonism, Design Fiction, Speculative Design, Slow Design, and Satirical Design. I conclude this chapter with a proposal of a new framework for critical design, with six corresponding parts: Challenge existing methods, beliefs, systems, and processes; Focus on an actionable ideal future; Look for what has been made invisible or under represented;

Consider the micro, meso, and macro; Privilege transparency and accountability; and Expect and welcome being subjected to rigorous critique. I conclude with a reflection on designer accountability.

Chapter 5: Paths Are Made by Walking

Rich-Prospect Browsing (RPB) theory proposed a category of interactive displays that are composed of well-designed visual representations of all items in a particular collection. Central to the theory is the notion that a browsing display will be better at supporting someone who is seeking to understand, interpret, or systematize information, than a display that attempts to artificially or arbitrarily restrict the amount of information provided, especially if certain features of the visual display can be easily user controlled (Ruecker, "Affordances of Prospect", ff.).

RPB theory was first developed in association with the Orlando Project – one of the biggest feminist digital humanities projects to date (Brown, Clements, and Grundy, ff.). Orlando is an online cultural history currently featuring 1012 British women writers. Subsequent to the work on Orlando, Ruecker et al. have made a compelling case for the use of RPB in interfaces that display numerous other large text collections (Ruecker, Radzikowska, and Sinclair, "Visual Interface Design", ff.). However, although RPB was designed in conjunction with a feminist project, it was not originally, explicitly feminist. Additionally, RPB was not intended for use, specifically, in the design of interfaces for decision support nor manufacturing. It is also not, explicitly, critical. Therefore, several questions remain: has RPB met its potential as a Feminist HCI theory; do the existing RPB principles foster a critical look at HCI; and how is RPB affected (its principles extended or modified) when viewed through Critical Design or when it attempts to live up to its feminist origins?

In Chapter 5, I first attempt to interrogate the questions posed above. I also propose a contribution in the form of an extension of RPB theory to interfaces designed for decision support through the addition of 4 new principles to the original 7 as set out by Ruecker and three new tools to the original nine (Ruecker, Affordances of Prospect, ff.). I also attempt descriptive, analytical, and critical readings of the three design alternatives – Z, A+1, and B – produced as part of the *Oil Sands Project*. I close Chapter 5 with a critical challenge to the power embedded in the concepts of prospect and refuge that underpin RPB Theory.

Chapter 6: Summary & Conclusions

Chapter 6 acts as a summary of this work's contributions to the fields of interface design and decision support. I also attempt to build on the notion of meaningful item representation as discussed by Ruecker et al. (Visual Interface Design", 95–110), by focusing it through the lens of Feminist HCI.

Chapter 7: Future Research

In Chapter 7 I imagine opportunities for future projects in critical design thinking, making, and evaluation that would extend the contributions proposed in this dissertation, including to areas outside manufacturing.

Process

The need for HCI design and development that is iterative – involving steady refinement of the design based on user testing and other evaluation methods – has long been recognized (e.g., Bury, ff.; Buxton and Sniderman, ff.; Gould and Lewis, ff.). As Nielsen so aptly put, "[e]ven the best usability experts cannot design perfect user interfaces in a single attempt, so a usability engineering lifecycle should be built around the concept of iteration" (Nielsen, 32). Similarly, we can iteratively apply rigorous interpretive analysis throughout the HCI design process, thus providing systemic, concrete, and evidence-based discussions of what is present (and what is absent) within a given design. As Rockwell suggests, we will "learn not by thinking in isolation but by building and looking and rebuilding and looking again" (Rockwell, 7).

This dissertation was built by looking, then looking again. I began the *Oil Sands Project* as I had previous projects on designing interfaces for large text collections, by considering how best to apply RPB theory and push, as far as was possible, away from established norms thus, hopefully, diversifying the gene pool of available ideas. With each unique iteration, new questions arose as to the core functionality of the DSS, and the algorithm that would govern the solution. Functionality became more specific, and the visual design eliminated decorative detail.

Once the industry-partnered project had come to an end, I began critiquing established DSS practices, then revisiting the three iterations I designed. New questions arose as to the purpose of a DSS, what was made visible and represented, what remained hidden, and how context impacted (or did not) a computer-supported decision process. These are important questions that would have been hard to expose without a push past functional requirements, user-defined interface processes, or aesthetic preferences – without considering that there is great value to design that challenges the established status quo, or that engages critically with economic, political, and cultural issues.

As I moved through the chapters, first re-reading the literature review in DSS design, HMIs, and information dashboards, then considering designs A+1, B, and Z through the traditions and disciplinary practices it defined, I was able to ask myself "What would 'better' look like here?" Critical Design and Feminist HCI provided not the answers, but questions that helped me examine my work on the *Oil Sands Project* even more deeply. What emerged was a challenge to rethink how we engage in the iterative process of design. As I looked more and more critically, the higher the bar rose for what a user could expect from an interface of the type I was investigating. The Critical Action Design framework proposed in Chapter 4 and the extensions to RPB Theory described in Chapter 5, while the culmination of my efforts here, are hopefully the start of future critically-engaged work, not only in interface design for decision support but in other HCI applications.

Researcher Positionality

I write as a feminist and practicing design researcher; I aim to be a mentor and community builder. My work in human-computer interaction is reciprocally informed by my passion for creating safer, more inclusive, and compelling spaces, both digital and analog. My design and research work is interdisciplinary and collaborative, marked by a passion to work in the service to others. Over the past ten years I've worked on over a dozen projects designing human-computer interfaces with researchers working within the digital humanities, primarily exploring large text collections; an online support environment for breast cancer survivors; and a wildlife tracking system for provincial parks. I have had the great privilege to work on large, medium, and small, national and international research teams. My work has been iterative and experimental – meant to challenge existing interface design conventions and explore unique alternatives to complex visualization problems. My work on the Oil Sands Project began in January 2009. All the original design work described in this dissertation has benefitted from this collaboration.

Chapter 2: Visualizing Information

> "When designers replaced the command line interface with the graphical user interface, billions of people who are not programmers could make use of the computer technology."
>
> Howard Rheingold (qtd. in Kosner)

GUIs are a type of human-computer interface that allows users to interact with an electronic device (its computational capability and collection of data) through only graphics or a combination of graphics and text, as opposed to text-only interfaces or typed commands. A GUI may be made up of numerous graphics, collected within and across multiple, individual screens. In some GUIs, the individual screens are identifiable, distinct entities, while in other GUIs individual screens are more difficult to identify as distinct entities, and act more as a set of user actions and graphical responses. Users can interact with (manipulate or modify) some graphics, while some graphics remain static. Each graphic serves a purpose within the interface and attempts to communicate with its users. A graphic may be singular or constructed from multiple graphical objects. Some graphics are combinations of shapes and colours, while others are images or photographs. For the purpose of this discussion, I will be using the word "graphic" to mean all pictorial representation of data, including typeforms, since text may be added to some or all graphics within an interface.

There are many ways to think about or (formally) evaluate a GUI. Most often an interface is considered in terms of its function (what it does), its visual design (how it looks), and its usability (how easy/quick/effective it is in performing its function). In all three cases the push, over the past two decades, has been to use a combination of expert knowledge and information gathered about and from a pre-defined group of users (real and distilled or prototypical) as a basis for making decisions regarding the functionality, visual design, and usability of the GUI, with visual design often considered much lower in terms of priority and importance than functionality and usability. Within HCI, discussions about the role of visual design appear primarily focused around meeting users' pre-established physical, emotional, and psychological needs or characteristics;[4] the purpose of a design; the users' physical environment (such as lighting, number of screens they monitor, distance to the screens) (Haley and Keuhel, 110); and the types and number of tasks users are asked to accomplish. Detailed recommendations regarding the characteristics of an effective visual structure for interfaces, including guidelines on typography sizing and selection, colour/background contrast, graphical treatment, and animation use have also appeared (Hollifield et al. ff.; Few, *Information Dashboard Design*, ff.). Within GUI design for manufacturing and decision support, visual design is considered primarily in its role of supporting the operator's understanding of information, prioritization of tasks, and focus (Hollifield et al. ff.). Miner et al. (1981) for example, outline a set of general characteristics that are meant to help create an effective decision support system. Their guidelines focus exclusively on making recommendations regarding the usability of an interface in reference to how well it supports users as they move through the interface to accomplish a task. In contrast, Yu's recommendations focus on functionality rather than user support (2004). Specific design recommendations are also common within the decision support literature: some are meant to apply to the design of singular graphical objects (how to design better bar graphs, for example); others focus on multiple graphical objects forming clusters or units (menu systems, for example), still others focus on the screen composition in its entirety. While some of the recommendations that emerge out of these domains appear to align well with relevant visual design literature, many of these recommendations are easy to agree with, but

4 See Hambidge (1919); Birkho (1933); Eysenk (1941); Hambidge (1968); Maquet (1986); Maniere (1992); Alexander (1997); Iwamiya and Takaoka (2000).

hard to implement and require a substantial amount of resources and expertise to implement well.

While in Chapter three I focus on theories emergent out of the humanities and their potential application to the design of decision support interfaces in manufacturing, the goal of this chapter is to frame my discussion of GUI in terms of visual communication design as relevant to the two domains that underpin this dissertation: interface design for decision support in manufacturing and interface design within the digital humanities.

Chapter two is subdivided into two sections. I begin with a historical overview of literature relevant to interface design for manufacturing and decision support: interfaces for decision support(DS), information dashboards, and human-machine interfaces (HMIs). I conclude this section with a review of design recommendations emergent from these fields, combined with design discussion rooted in information design. The second section aims to provide an overview of graphical data representation and visualization tools, and a summary of the types of graphical objects that most often make up interfaces for decision support: charts and graphs, information graphics, and data visualization.

Interface Design for Manufacturing & Decision Support

The history of decision support can be traced back to work conducted on management information systems (MISs) in the early 1960s (Tolliver, ff), theoretical studies of organizational decision making at the Carnegie Institute of Technology during the late 1950s and early 1960s, and technical work on interactive computer systems, mainly carried out at the Massachusetts Institute of Technology in the 1960s (Keen, ff.). Early DSSs were interactive IT-based environments for human decision makers – the information system provided assistance to the human dealing with the complex unstructured parts of the problem by automating the structured elements of the decision situation (Ackoff, ff.). The purpose of this process was to improve the effectiveness of, not replace, the decision maker.

Few MISs achieved any form of success – the systems were large and inflexible and the reports generated for the managers, while extensive, contained very little useful information (Bhargava, Power, and Sun, 1084).

During the mid 1970s the concept of DSSs evolved into an area of research; during the 1980s research activity in the area gained intensity. The single user and model-oriented DSS evolved into executive information systems (EISs), group decision support systems (GDSSs), and organizational decision support systems (ODSSs). By the mid-1990s, researchers were exploring the possibilities of using the World Wide Web and Internet technologies for building and deploying decision support systems, and by the end of the 1990s, several software firms were working on new Web-based analytical applications (ibid. 1085). In early 2000, Bhargava et al. envisioned going beyond Web-based individual DSSs to a collection of systems from multiple providers sold on a pay-per-use basis via an electronic library (ibid. 1086). Work continues in this area.

Decision support systems come in many shapes and sizes depending on the context of their implementation – the scale and complexity of the domain, organization, and/or the decision making process. One basic example of DSS use would be if an on-line book seller wanted to determine if selling her products internationally would be a wise business decision. A DSS could collect, analyze, and present data from internal and external sources in order to help the seller determine if there is demand for such an expansion and if the company has the ability or potential ability to expand its business. In a more complex example, a DSS could be developed for plant-wide decision-making, with a view of improving knowledge of the global impact of individual decisions. For example, what is the impact on water, gas, and oil consumption if ten more trucks are added to the system?

Domain-specific and notable work in DSS design and development has taken place in business, medicine, defence, manufacturing, transportation, forestry, and law. One such system, PROMIS (the Problem-Oriented Medical Information System) stands as one of the major breakthroughs in interface design for decision support (from the standpoint of functionality). It included on-demand access to patient, symptom, and laboratory information as well as epidemiological studies and other research endeavours. PROMIS also allowed for medical and business audits to aid organization and efficiency in the management of common medical and surgical disorders (CBR).

Advancements have also been made in simulation and visualization of air traffic control, where effective decision-making requires the support of multiple actors with different views on the system and the possible outcomes of the decision process (Chin, van Houten, and Verbraeck, ff.). One such system, completed in 1987 by United Airlines (UA) and Texas Instruments, was designed to reduce flight delays related to ground operations by increasing the effectiveness of United's gate controllers in assigning aircraft to the series of available gates. The Gate Assignment System used an artificial intelligence program to capture the experience of United operations experts, who rely on memory and a wall-sized scheduling board full of magnetic aircraft symbols. The system was phased in through a user-centred implementation process. The interface provided minute-by-minute aerial views of all UA gates, the location of UA aircraft and status information on each flight. Gate controllers could update flight information when changes occurred. The Gate Assignment System is credited with significantly reducing travel delays by aiding the management of ground operations at various airports, beginning with two major international airports: O'Hare International Airport in Chicago and Stapleton Airport in Denver.

Research conducted by Chin et al. on air traffic control for the Port of Rotterdam found that interface design for this system type needed to provide two views on decision making: one on the system under investigation; and one on the decision making process. The authors suggest developing a simulation and visualization portal for use by multiple decision makers in mainports (ibid. ff.).

Modern DSSs aim to provide business managers with decision support for tasks such as information gathering, model building, sensitivity analysis, collaboration, alternative evaluation, and decision implementation (Bhargava, Power, and Sun, 1083). Within the business domain, decision support falls under the broad category of Business Intelligence (BI). BI is used to gather, store, analyze, and provide access to data, in order to help enterprise users make better business decisions. Within the business domain, DSSs are seen primarily as providing opportunities to improve the effectiveness and productivity of managers and professionals, in order to strengthen the organization and rationalize the decision making process (Shen-Hsieh and Schindl, ff.). Successful DSS applications have tackled decision problems in a broad range of managerial and policy environments, at both the operational and strategic levels.

Shen-Hsieh and Schindler describe a project conducted by Visual I/O on a decision support system designed for a pharmaceutical company to address their key strategic decisions. The DSS interface utilized visual metaphors for data, including a visualization of time, collaboration, and modelling scenarios (ibid. 3). The Visual I/O interface also demonstrated different approaches to visualizing abstract constructs into DSS interfaces, such as decision theory, statistical analysis, and competitive advantage (ibid. 3). The Visual I/O system was designed around the fundamental concept of making an informed stop and go decision, and used a baseball metaphor as a way to illustrate the decision making process. Information relevant to the decision was pooled into a simple pie chart, and further detail was attached by lines. Detailed review and customization was made possible through an expanded Current Pitcher/Batter History section. Users could tailor the statistics and rearrange the visual hierarchy on the screen to meet their needs.

Visual I/O designed the interface so that the decision making process mirrored the way the decisions were being made within the company. In particular, they were interested in accommodating not just the quantitative data but also the qualitative human aspects of the decision making process (the experience, intuition, collaboration, negotiation, etc.) behind any complex decision. In order to leverage human knowledge and experience, questions were analyzed by polling the opinions of those involved in making major decisions. The interface still provided access to statistical data, however information was filtered through the views of those who most intricately understood the problem. Human opinions could be compared to statistical models in order to form a more comprehensive image of the problem.

Over the last thirty years a number of different approaches to DSS have been developed and, during that time, each approach has had a period of popularity in both research and practice. These different approaches to decision support represent differences in the scope and scale of project, potential impact on the organization, type of technology, and managerial structure. Personal decision support systems are small-scale systems, developed for one manager, or a small number of independent managers to work on one decision task. In contrast, group support systems are created where responsibility for decisions is shared by a number of managers and where groups of managers need to be involved in the decision-making process. More task-specific support systems have also been developed. According to Antunes and Costa, there are seven types of DSS, including the following four most relevant to the manufacturing domain under discussion:

- negotiation support systems are used within group contexts to facilitate negotiations;
- intelligent decision support systems aim to replace the human decision makers;
- executive information systems and business intelligence provide organizational reporting to managers; and

- knowledge management-based DSS provide knowledge storage, retrieval, transfer and application to support the use of individual and organizational memory in decision making (Antunes and Costa, 2015).

Executive Information Systems (EIS) evolved into information dashboards, first found primarily in the offices of executives, and featuring key financial measures (Few, *Information Dashboard Design,* 6). In the 1990s, Kaplan and Norton introduced the concept of a *Balanced Scorecard* (Few, *Information Dashboard Design,* 7), that later became an approach to management that involved the identification of key performance indicators (KPIs). This idea, combined with advances in data warehousing and processing capacities, increased interest in management through the use of metrics that remains to this day. According to Few, the Enron scandal in 2001 "put new pressure on corporations to demonstrate their ability to closely monitor what was going on in their midst and to thereby assure stakeholders that they were in control." (Few, *Information Dashboard Design,* 7). In the past decade, numerous vendors have began offering dashboard products; however seldom offering new, custom solutions to unique design problems. Few defines information dashboards as

> a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance (ibid. 34–35).

Dashboards combine data from different sources, with the goal of supporting users in identifying data trends, recognizing problem areas, and pinpointing changes and exceptions. Information dashboards can be used to monitor information in real time, from one or more sources. There are dashboards to monitor and manage business operations, crime statistics, financial market information, blogging activity, time, on-line radio, and many others.

One of the primary strengths of the dashboard design is its ability to present a large amount of information on one screen, often without scrolling. When designed well, dashboards can provide both a macro and a micro view on the data. They can provide high-level summaries of the data, then provide users with the ability to drill down into the most pertinent details. Since dashboards are used to present large amounts of data on single screens, information organization into meaningful groups while maintaining a low data-ink ratio becomes critical. Simplicity, and restraint in colour and non-data ink use is particularly important when dashboards are used to highlight and signal unusual changes in the data. Data is represented using text, information graphics, mind maps, icons, images, and tables. Small multiples can be used to signal to users links to related data, or to data that may be used for comparison. Few classifies dashboards into one of the following three roles: strategic, analytical, and operational. Strategic dashboards provide a quick overview that decision makers need to monitor all levels of their organization. Information presented is static (not changing from moment to moment), typically focusing on high level measures of performance and forecasts. Analytical dashboards often include more context, data comparisons, and subtler performance evaluators. They typically support interactions with the data. Operational dashboards are used for monitoring rapidly changing activities and events that may require immediate attention (ibid. 42). The dashboards described by Few are meant to facilitate users engaging in data retrieval, comparison, and understanding; they are meant to tell users what is happening, not why it is happening (see Fig. 2.01).

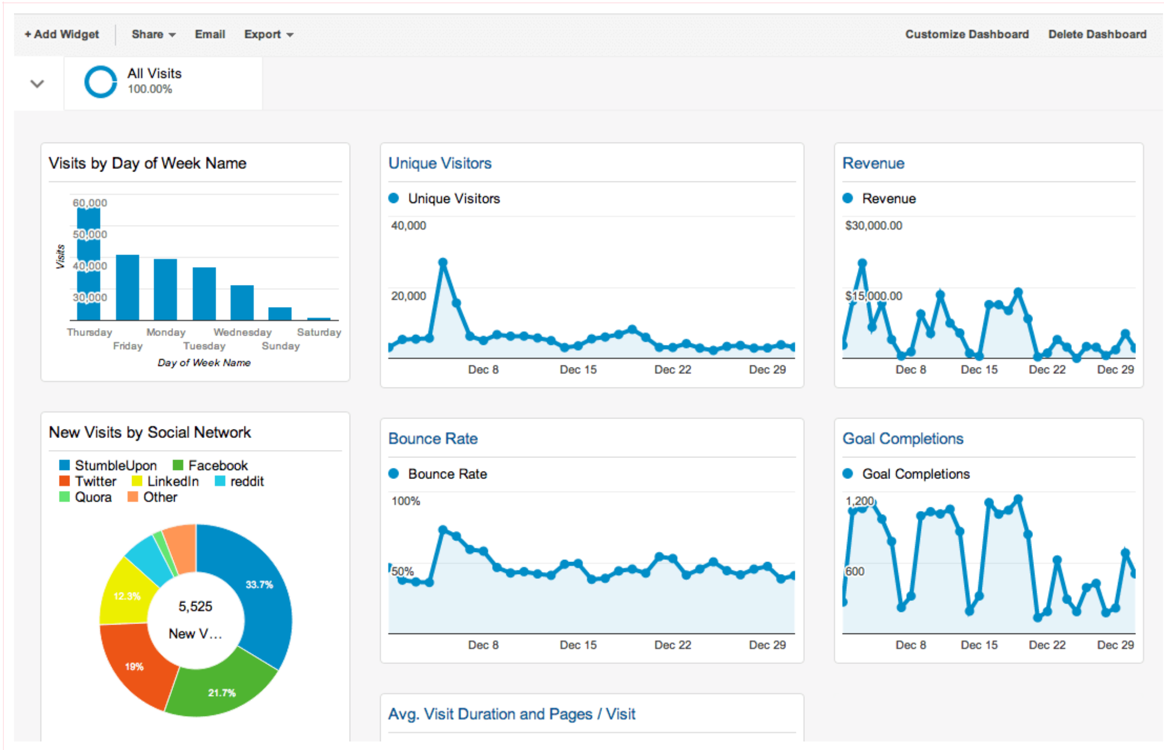

Fig. 2.01: Sample dashboard design, featuring Google analytics (Kissmetrics).

Once a DSS has been implemented, in what ever form, it has to meet the needs of different types of users. A system for the military, for example, is fundamentally different from one designed for business, and the users will vary in terms of their needs, expertise, strategies for knowledge management, and managerial hierarchy. However, most DSSs will, at minimum, attempt to serve the following four groups of stakeholders: developers and maintainers, model builders, operators, and managers. For developers, the system has to enable and accelerate the development process and streamline the maintenance process. For model builders (or decision implementers), the system must provide ways to create process models, decision scenario models, and analytic tool models. Operators need the tools for manipulating the required data (and, possibly, related machine components) and creating useful outputs, while managers require regular outputs in the form of system reports. In addition to these stakeholder groups, a manufacturing DSS may be used for training and public relations purposes. Visitors to the manufacturing site may be invited to view selected parts of the system, in which case certain processes and/or decisions may need to become hidden from view.

A well-designed DSS has many potential benefits. For example, it may improve personal and organizational efficiency by expediting problem solving within an organization. A DSS can also facilitate interpersonal communication and promote employee development through training. Through a DSS, organizations may increase their level of control over the decision-making process as well as internal and external accountability via an increase in the amount of evidence in support of a decision and automation of the managerial process. Quicker and smarter decisions may mean a competitive advantage over other companies and an increase in innovation and discovery.

Furthermore, in certain critical instances a DSS can mean the difference between successful crisis resolution or, and this is the unwelcome scenario, an industrial disaster. One such example, the largest petrochemical plant disaster in U.S. history that was not due to natural causes, took place at a petrochemical plant in 1989, at a cost of $1.6 billion. According to the Abnormal Situation Management Consortium (ASM), the cost of lost production due to industrial accidents is at least $10 billion annually in the U.S.A.; costs of equipment repair, replacement, environmental fines, compensation for human casualties, investigation, and litigation represent another $10 billion (ASM Consortium). These monetary costs do not take into account the vast emotional impact such disasters have on industry employees and their families, as well as the communities within which the disaster takes place.

Similarly to decision support systems, industrial plant operations have an over sixty-year interface design history, beginning with the design of control rooms and control panels. In the 1930s, and up until the 1970s, most manufacturing plants had a room where most of the control instruments were housed. Instruments were logically grouped, alarms carefully selected and placed together in separate lightbox panels and, sometimes, a pictorial representation of the plant was used behind the appropriate instruments (Hollifield et al.

10). There were several disadvantages to the control room. When a new instrument or alarm needed to be added, other instruments or alarms would have to be moved, to keep with the logical arrangement. This was expensive, thus seldom allowed change, resulting, over time, in a breakdown of the logical relationship between pictorials and controls. An additional downside of the control room was its size: instruments took up a lot of physical room, creating a cramped space (see Fig. 2.02).

Fig. 2.02: Instrument panel in the control room of the PUREX Plant, 1988
(Roger Ressmeyer).

In the 1970s, Distributed Control Systems (DCSs) began to replace the control panels. Physical instruments were replaced with software displays, and signals began to be monitored by computers. The primary advantage to the DCS over the control room was that almost everything in the system was changeable with relative ease. The earliest DCSs did not allow for graphic customization. Groups of control elements would be shown together on one display, and hundreds of these groups would be configured and used to display all the controls and measurements needed by an operator. Operators lacked a big picture view of the entire process. Thus, operators needed an ever-greater number of alarms to notify them of a change in conditions in parts of the system that they were not currently viewing. Unfortunately, the graphical representation components of the DCS that were developed at that time have seen only marginal advancement since (ibid. 12).

Design Recommendations Emergent from HMI & DSS Literature

Over time, creation of custom graphics, with a limited number of colours, schematic-type illustrations, and changeable screen elements became possible. The Human Machine Interface (HMI) began to be used to describe the graphical display that governs the interaction between a user and a machine. Though the term is very broad, and has also included interfaces for cell phones, industrial computers, household appliances, and office equipment, an HMI has most often referred to interfaces specific to manufacturing and process control systems. An HMI provides a visual representation of a control system and offers the acquisition and the graphical, textual and numeric display of real time data. Every HMI implementation is unique and customized. The category includes built-in displays provided by a manufacturer, custom graphic displays designed and used by owner/operators, navigation methods to access the information, plus several other software and hardware items (ibid. 2008). There has been no one standard HMI developed to represent or administer every manufacturing process; therefore, great variability exists in both HMI design and level of quality. According to Hollifield et al., the ability to develop and manufacture new HMI products and functionality has come faster than the ability to understand how to do so effectively. HMI displays can now be designed with three-dimensional graphics, a multitude of colours, animation, and digital photography of different parts of the process, but the "basic principles of effective displays are often not known or followed"(ibid. 12). According to McDonald (ff.), specific, engineering-related research concerning interface design methods (for machines or in manufacturing) focuses on the technical details of building particular user interfaces, not on visual design theories and methods. With the exception of a handbook by Hollifield et al., design standards that exist for human machine interfaces were either developed for government-sponsored systems, and include those for the Department of Defence and NASA, or produced as guidelines (and marketing materials) by companies in the business of manufacturing, selling, and implementing human-machine interfaces.

The guidelines and recommendations regarding best practices for the design of an effective HMI that do exist fall into two broad categories: design process recommendations; and aesthetic recommendations. The Hollifield et al. text, for example, offers a micro-level critique of HMI design and aims to provide direction regarding HMI aesthetics, though recommendations about content and functionality are also included amidst discussions of visual design (see Fig. 2.03). Authors warn HMI designers against excessive detail, illegible or lacking content, inconsistency, and improper alarm depictions. One potential outcome of dealing with a design at a micro level, without considering the impact of such decisions on the unit or the macro level, is that they may affect the visual experience of the interface as a whole in unintended, unexpected ways. It is the equivalent of carefully constructing a sentence without considering that it will, in the end, belong to a paragraph that will belong as part of the climax to a short story. Conversely, some of the recommendations emergent out of DSS and HMI design literature are too vague to be useful. Haley and Kuehel (110), for example, recommend the following: remembering your audience, sticking to the point, avoiding unknown jargon, and using a template. *Remembering your audience* is a key component to user-centred design, where the needs, preferences, limitations, and characteristics of users are given a priority when making design decisions. Qualitative and/or quantitative research methods, such as persona and scenario building, focus group testing, usability testing, and many others, can be utilized in order to keep the design user-centred. Thus, to remember your audience is a noble endeavour; however, to actually put "remembering your audience" into professional practice references a substantial and highly specialized domain. Similarly, while templates can be helpful in establishing consistency across multiple, similar design components or compositions, any template has to be carefully and intentionally designed before it can be successfully implemented. Such recommendations, while in principle aligning well with relevant visual design literature, are very challenging to implement.

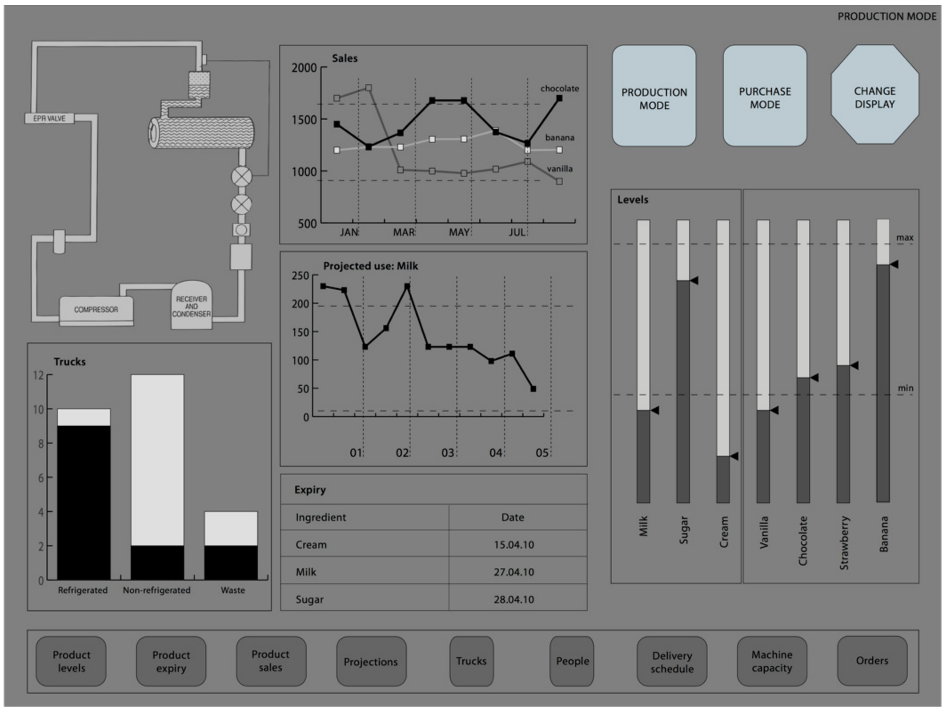

Fig. 2.03: Sample HMI interface (design by Radzikowska, adapted from Hollifield et al., ff).

In terms used by two dimensional visual arts – in particular painting, visual design, and photography – any graphical composition is constructed by, first, carefully choosing lines, shapes, tones, textures, colours, and the space these will occupy (*the elements* that are placed within a composition), then manipulating and arranging them within the space according to a set of *principles* (pattern, contrast, emphasis, balance, scale, harmony, rhythm, unity and variety). Design elements describe the fundamental structure of any visual composition, while design principles govern the relationships created between the elements used within a design: “The principles of design . . . affect the arrangement of objects within a composition. By comparison, the elements of design are the components of design themselves, the objects to be arranged”(McClurg-Genevese). Principles are used to visually group elements and units, differentiate elements and units from one another, establish a hierarchy of importance or priority, focus attention, direct the viewer's eye across the composition, create order and stability, and eliminate redundant elements.

Each element can be selected, manipulated, structured, or organized well or poorly using some combination of the principles. Each element has both an internal quality – one that is inherent to it – and an external quality – one that is created by its interaction with other elements. How the relationship between elements and principles is constructed is dependent on numerous factors, and schools of thought regarding their application differ both across disciplines and between individual practicing designers. Elements can be manipulated, for example, in reference to and accordance with a particular art movement, or they can be manipulated according to the stylistic preferences of or feedback from a client or user.

Elements can be selected, combined, and manipulated independently from the subject of the composition. However, there are two co-dependent goals, functional and interpretive, to the selections of elements, their manipulation and construction into units, and organization within a composition. Functional goals are most often related to the usability of the object as a whole, and to performance measures. Interpretative goals are most often related to establishing an intellectual and emotional connection with the user, a community or culture, the subject matter or domain, and/or the organization or company, while framing the composition as distinct or unique from its environment.

Discussing the building blocks of visual form is relevant to the design of interfaces for decision support and this dissertation since, whether deliberately addressed or not, designers make choices regarding said building blocks the moment their pencil makes contact with paper. Furthermore, the type of graphical objects that make up an interface, and the visual quality that these objects have been given, impacts how we interpret, use or avoid, and are affected by our interaction with that interface. Karvonen (86) argues that “beauty may be the decisive factor when wondering whether or not to trust a service enough to conduct business online.” Frascara (3–32) supports this position, stating that visual design affects the user’s immediate response of attraction or rejection of an artefact, the effectiveness of its communication, the length of perceptual time commitment, memorization of its message, the active life of the design, and how it impacts the quality of the environment within which it exists. Finally, since literature related to design for decision support already references (and provides advice with regards to) both the building blocks of visual design and the selection and manipulation of graphical objects, a critical review of this literature must examine and, potentially, challenge such references.

Some of the recommendations emergent from HMI and DS literature are in contrast to existing visual design literature. For example, two recommendations for “producing HMIs that are clear, easy to use and legible across a control desk” developed by Hexatec: shadowing as a recommended method for subdividing a display; and using black outlines to highlight objects, can result in an overly cluttered display that has less hierarchy and is harder to read (Hexatec Consulting). I say *can* because both these written recommendations can result in a myriad of visual solutions, some of which (as can be seen in Fig. 2.04) provide little benefit on the interface as an aesthetic object, are harder to interpret (due to their generic nature), and can result in reduced functionality.

Some lists for the design of an effective GUI for manufacturing provide three distinct types of recommendations combined into one, without differentiation that they do, in fact, aim to address the visual experience of an interface at vastly different levels of granularity, with significantly different consequences. The de-contextualized, micro-level recommendations fail to consider the designed object as an entity that is greater than the sum of its individual parts. Fig. 2.04 illustrates four pieces of literature on HMI and dashboard design. Each set of authors tackles concerns over design quality at a different level: the interface, which makes macro-level recommendations; the screen, which considers each bounded instance of the interface; the item, such as a diagram, a menu, or a table that is located on a screen; and the element, the lines, shapes, and colours, manipulated through the principles of design, that make up the items.

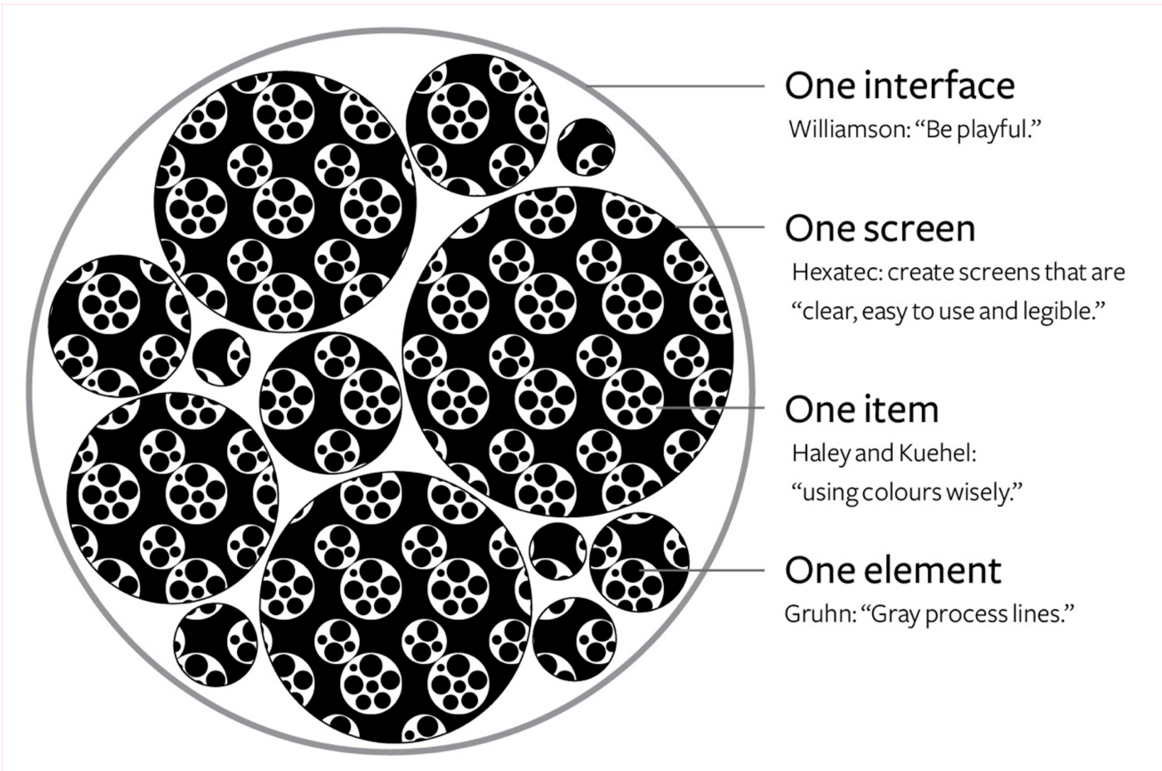

Fig. 2.04: The four levels of recommendations common to HMI design.

Recommendations found within these lists also, at times, contradict one another without providing enough context or evidence to support the difference in opinion. For example, Haley and Kuehel (110) recommend "using colours wisely" to give primary data a higher contrast than secondary or support data. Williamson (ff.), on the other hand, suggests a more playful, rich use of colour that engages users and encourages interaction, and Hexatec recommends the use of "muted tones" while avoiding "alarm colours" (Hexatec Consulting).

Charts & Graphs in HMI / DSS

All HMIs, interfaces for decision support, and information dashboards use some amount and variety of charts and graphs. In Fig. 2.03, for example, we see a combination of bar graphs, line graphs, plus a variety of buttons and a process flow diagram (the graphical item on the top left-hand side). Outside of literature related to HMI, DSS, and dashboard design, much has been written on how to construct an appropriate visual language for these types of graphical data representations.

According to Few (*Visual Pattern Recognition,* ff), charts enable pattern perception and, through pattern perception, charts empower the construction of broad statements, of the kind "ice cream sales increased from 2009 to 2011". The individual variables are less important than the overall understanding of the content, which can take place relatively quickly within cultures where such data representations are commonplace. Charts also enable the display and reading of specific details, for example: overall, sales increased from 2009 to 2011, but the last quarter of each 2009, 2010, and 2011 saw a downward sales dip. Here the user is focusing on a sub-set of the data and its relationship to the rest of the information.

Line graphs contain at least one line which connects data points in a series. They work best when the data is continuous and where the order of values is important. Bar charts have the ability to easily display more than two variables, one on the horizontal axis and one on the vertical. They display discreet values, where the order of values may or may not be important. Area graphs are usually a series of stacked line graphs, with the space below each line is filled with a pattern, shade, or colour. A pie chart can represent only relative values, since the total area must add up to 100%. Its strengths lie in showing distribution of parts of a whole (Camoes). Scatter plots are useful in revealing relationships between the amounts of independent values. A scatter plot is similar to a line graph, but having the goal to communicate the concept of a best-fit line.

Graphs most often represent numerical values through abstract forms (or, in Peirce's terms, through indexes [Chandler, n.pag.]). A bar chart, for example, converts numerical values into horizontal or vertical rectangular bars with lengths proportional to the values that it represents. A wide variety of other graphical objects may be used for numerical representation. Common options include geometric shapes, but more complex (or iconic) graphics have also been used.

Several authors have proposed recommendations for how to achieve well-designed, information-rich charts. Tufte, for example, proposed the idea of the Data–Ink Ratio, advocating the use of only as much ink as is needed to convey the data (93). Though most charts and graphs have a data–ink ratio below 1:1, meaning that some of the ink is used for non-data information, the idea is to maximize data ink and question how much unnecessary ink is being used to convey the information.

Visocky O'Grady and Visocky O'Grady (105) call for the use of hierarchy in data displays: when certain data needs to be highlighted within a chart, thus placing emphasis on a portion of the display. There are several ways – drawn from the principles and elements of design – to call out specific parts of a diagram without drastically increasing the 1:1 Data–Ink ratio. Changing the colour, weight, position, shape, texture, or movement of one part of a diagram while maintaining or even de-emphasizing the others will place emphasis on the one that appears different. Such changes must be dramatic enough to be easily noticeable. They also need to be carefully localized to the area meant for emphasis – too much change to too many parts of a design will, in fact, lower the emphasis and increase noise.

Since capacity for short term memory varies among individuals, Miller (ff.) suggests chunking the data. Specific design decisions will determine the success or failure of a user's ability to quickly scan a chart, understand the big picture and identify specific components, and create relationships between information. Poor design can result in a misrepresentation of information, skewing of facts and altering of user's interpretation.

While many of the micro, unit, and macro level recommendations referenced above can result in more effective GUI designs – supporting users through their tasks, appropriate functionality, and clear, well-structured visuals – and that specific directions on the design of all aspects of an interface are also helpful, there is much potential for more in-depth, critical work in this area. Some of the questions that are not answered through the exploration and application of such recommendations, for example, are: what are the consequences of the practical implementation of these recommendations; what kinds of interface objects, to what effect, do they help us create; and what kinds of interfaces are made impossible or invisible by only looking at design through measures of performance or preference?

Graphical Data Representation

I propose that looking at the lines, shapes, and colours that make up an interface, together with how those are combined and organized, considers the interface at a leaf, or micro level. As discussed above, all graphical artefacts contain these pieces, and multiple factors are at play as to whether their selection and manipulation will result in a successful visual design. In the case of the majority of current GUI design for decision support, human-machine interfaces and dashboards, principles and elements are used to construct a specific sub-set of graphical objects (graphical data representation): charts and graphs, information graphics, or data visualizations. In such GUIs, graphical data representation(s) are often combined with textual or graphical content, navigational items, identity signifiers, or numerical values to create an appropriate, unified, and functional composition.

The goal of graphical data representation is to aid our understanding of information by leveraging the human visual system's highly tuned ability to see patterns, spot trends, and identify outliers. Well-designed visual representations can replace cognitive calculations with simple perceptual inferences and improve comprehension, memory, and decision making (Suda, 117). By making data more accessible and appealing, visual representations may also help engage more diverse audiences in exploration and analysis. The challenge is to create effective and engaging visualizations that are appropriate to the data, and that leverage past experience with similar graphical objects. The limited set of visualization examples described below are meant to illustrate the ways graphical data representation can help us filter information according to relevance, and to discover patterns and connections among items. Lima (123) argues that visualization will soon become indispensable, with technological advancements offering increased opportunity to collect, store, connect and access data on an ever more massive scale. Not only are we becoming increasingly inundated with information, but we also need a support "mechanism to the various political, economic, cultural, sociological, and technological advances shaping the coming years" (Lima, 123). How do we enable the discovery of relevance; How is subsequent, relevant information communicated in ways that are heard above the din? These have become key questions for the future designers of data visualizations.

Graphical representations of data can be, themselves, complex and powerful visual objects. Tufte, for example, describes a map drawn in 1869 by the French engineer, Charles Joseph Minard, as "*War and Peace* as told by a visual Tolstoy" (qtd. in Yaffa). This info graphic, roughly the size of a car window, depicts the fate of Napoleon's Grand Army in the tragic 1812 campaign into Russia (see Fig. 2.05). The map is read from left to right, then back to left again. A thick tan bar begins on the banks of the Niemen River, representing the initial invading force of 420,000 French soldiers. As the army marches east, toward Moscow, the tan bar narrows – the soldiers begin to die. The graphic is constructed from geometric shapes and sharp angles. Due to this restraint and a lack of literal depiction of the subject matter, the story of this sprawling, bloody horror takes a moment to sink in. As the French army turns back and the tan (now) line turns to black, we realize we are following the path of whatever French soldiers the Russians haven't killed in battle, as they die from cold and hunger. On November 28, half of the retreating army, 22,000 men, drowns as they attempt to cross the icy waters of the Berezina River – the already thinned, black line is suddenly reduced by half. The entire journey – there and back – takes a mere six months, with only one in forty-two soldiers returning home.

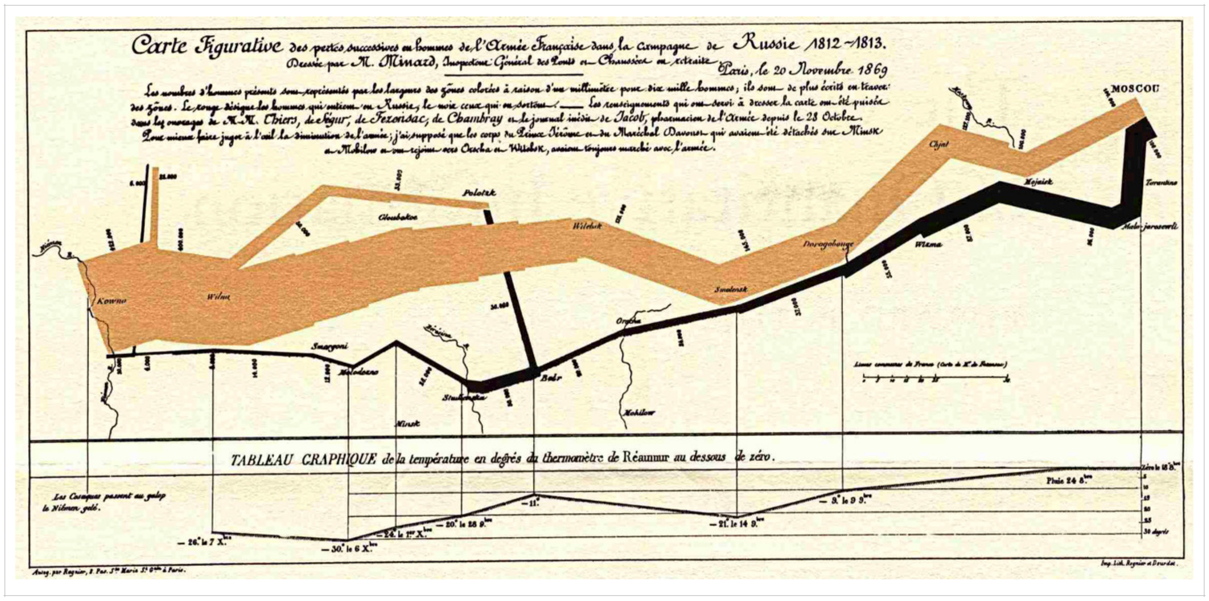

Fig. 2.05: Charles Minard's map of Napoleon's Russian campaign of 1812 (Minard).

While Minard's map is a rich, multi-layered representation of a fairly constrained time and space, Emma Willard's immensely ambitious *Picture of Nations* attempts to trace the advent of human civilization across an expansive time and space (see Fig. 2.06) (Willard). Her chart visualizes the progress of nations and empires from the time of the Christian creation story through to Ancient, Middle, and Modern periods. The purpose of this image was to help students understand a more complex version of history and to, hopefully, understand that history is contextually dependent on both space and time. Willard's map is multivariate in its attempt at showing a universal history through a graphical representation of such variables as cause and effect, connections between nations, connections between events and beginnings of historical eras, and connections between events, nations and their leaders.[5]

5 DataViz. *Picture of Nations, 1854*. The Face of Visual Rhetoric, Spring 2012, 3 November 2014 <http://web.ics.purdue.edu/~salvo/dataviz/?page_id=107.>

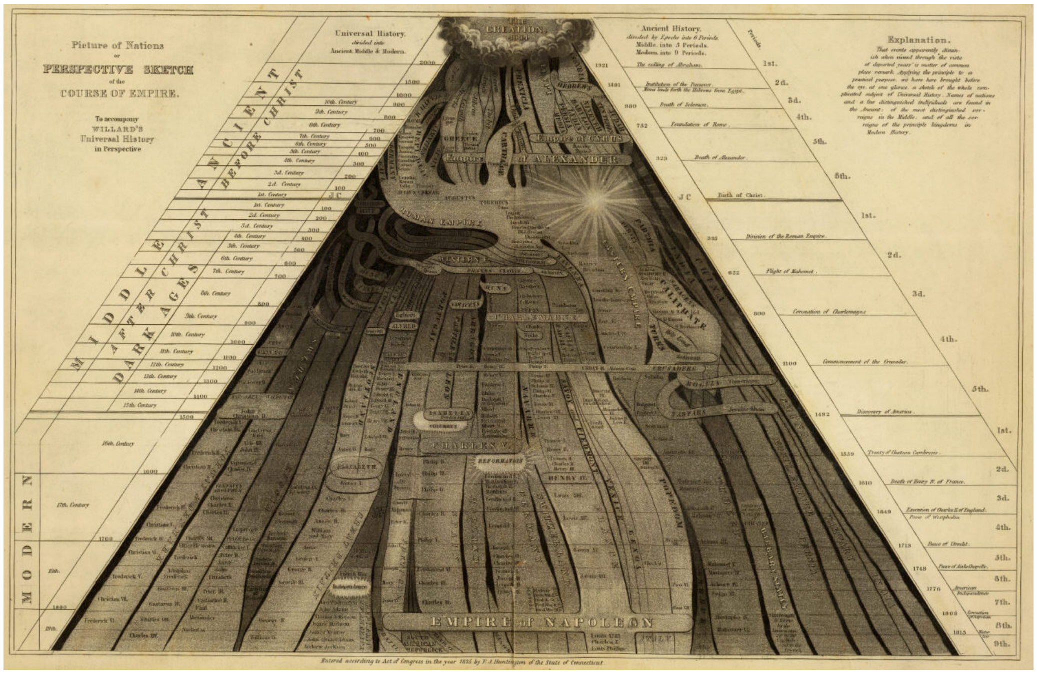

Fig. 2.06: Emma Willard's *Picture of Nations*, 1835 (Willard).

While it may be argued that Minard's diagram is an attempt to build a case against future attempts to invade Russia (a case that has, since the 19th century, become both historically reinforced and entrenched in pop culture), the diagram itself was, even during its time, a visual historical record. In its position as a historical account it bares much similarity to Willard's diagram. John Snow's *Cholera Map* stands in sharp contrast as design for social change (see Fig. 2.07). In 1854, a cholera epidemic swept through the city of London, killing thousands. Snow went door-to-door asking local residents about cholera deaths, then marking the location of each death on a map. He used the gathered data to trace the source of contamination to the neighbourhood water pump. He then used his map as an argument and ordered the pump's handle removed, preventing the further spread of the disease. Snow's map is a combination of two chart methods to form a more complex, early visualization (Pearce).

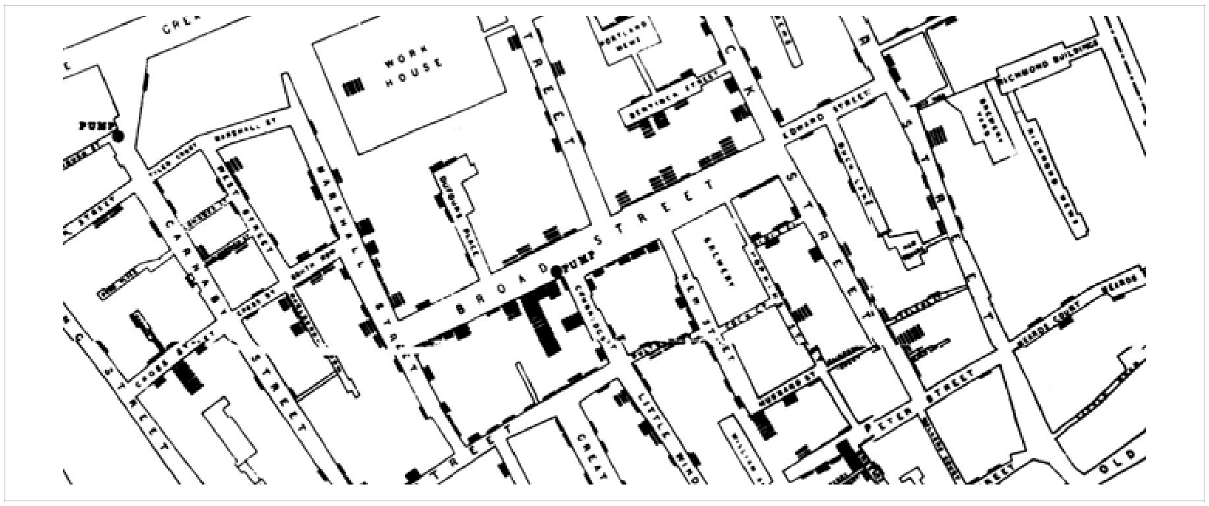

Fig. 2.07: 1854 John Snow's *Cholera Map of London* (Snow and Cheffens, n.pag.).

The polar-area diagram (or Nightingale's Rose diagram) invented by Florence Nightingale, is similarly functional in its intent (see Fig. 2.08). Illustrating the extent and sources of patient mortality during the Crimean War, Nightingale wanted a way to communicate more effectively with Members of Parliament and civil servants on the conditions of medical care in British military hospitals as a call for sanitary reform and change in medical practices of the time. Small, in his work on Nightingale's legacy, argues that depicting variation of death rates due to hygiene conditions, as can be inferred from her diagrams, was very important to reformers like Nightingale because it suggested a possible way to improve health conditions in the population as a whole (Small).

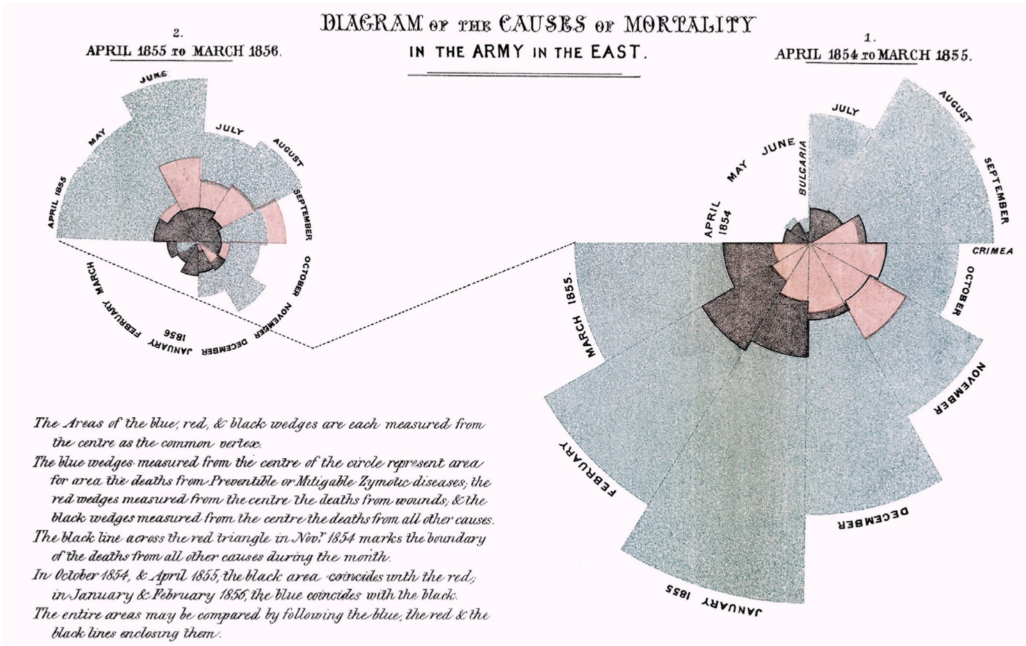

Fig. 2.08: *Diagram of the Causes of Mortality in the Army in the East* by Florence Nightingale (n.pag.)

In the past ten years, our vocabulary for classifying the vast array of graphical objects associated with data representation has become substantially expanded and, currently, there is little consensus regarding the definitions for the categories that have been developed. Determining what type of graphical object falls under the category of chart or graph, information graphic, information visualization, and data visualization is particularly challenging, with little agreement among multi-disciplinary practitioners and academics.

Suda defines a chart or a graph as "a clean and simple atomic piece", and a visualization as containing "sometimes complex graphics or several layers of charts and graphs"(10). Charts and graphs tend to describe a category of graphical objects that are self-contained and, within the spectrum of graphical data representation, contain a subset that tends to be more often taught as part of a K-12 curriculum, thus more easily read and understood by the general public. Line and area graphs, bar and pie charts, scatter plots, geographic maps, and rudimentary timelines tend to fall into this category; while radar plots, multi scalar plots, and polar area diagrams (to name just a few) have, thus far, gained marginal popularity (ibid.

171). Few describes tables and graphs as the "two primary means to structure and communicate quantitative information," and argues that we "now thoroughly understand which works best for what type of information and why" (Few, *Show Me the Numbers*, 4).

A chart organizes and represents a set of numerical or qualitative values. Charts are often used to help communicate large quantities of data and the relationships between parts of the data. A chart can take a large variety of forms, however there are common features that provide the chart with its ability to extract meaning from data. Typically, a chart will have a title (often placed at the top of the main graphic). A horizontal (x-axis) and a vertical (y-axis) axis may be used to communicate dimensions. Each axis will have a scale, denoted by periodic graduations and usually accompanied by numerical or categorical indications, as well as a label placed outside, but close to, the body of the chart, describing the dimension represented. A grid of lines, placed either in regular intervals or at significant graduations, may be used to visually align the data. Chart data may be rendered using dots, shapes, lines, in a wide variety of colours and patterns. A chart may include a legend containing a list of the variables appearing in the chart and an example of their appearance.

Information graphics or infographics are most often defined as graphic visual representations of information, data or knowledge – a definition that could easily be applied to charts and graphs. However, while charts and graphs tend to be fairly simple graphical translations of quantitative information, information graphics are either (1) innovations or modifications on pre-existing models; or (2) collections of tables, graphs and textual content into one, pre-defined space. Both categories of objects are meant to enable the telling of more complex stories through data, and support the filtering of information, establishing of relationships, discerning patterns and representing them in ways that support the construction of meaningful knowledge (Rajamanickam). They may include complex diagrams, timelines, maps, or schematics. Qualitative or textual data may also be visualized either via a graphical metaphor or through a more direct representation, by using the data itself as the visualization. In its innovative combination of timeline, line graph, and geographical map, Minard's *March to Russia* could be defined as an early example of a category one info graphic, innovating on pre-existing data representation models. However, some may categorize it as a data visualization for the same reason. Fig. 2.09 is an example of a second category info graphic, exploring health care spending in the U.S., Jones uses a collection of numerical values, area graphs, bar charts, and tables to display costs associated with hospitalization, procedures, and medications, contextualizing the display within a theory on health care reform proposed by businessman, Steven Brill (Jones).

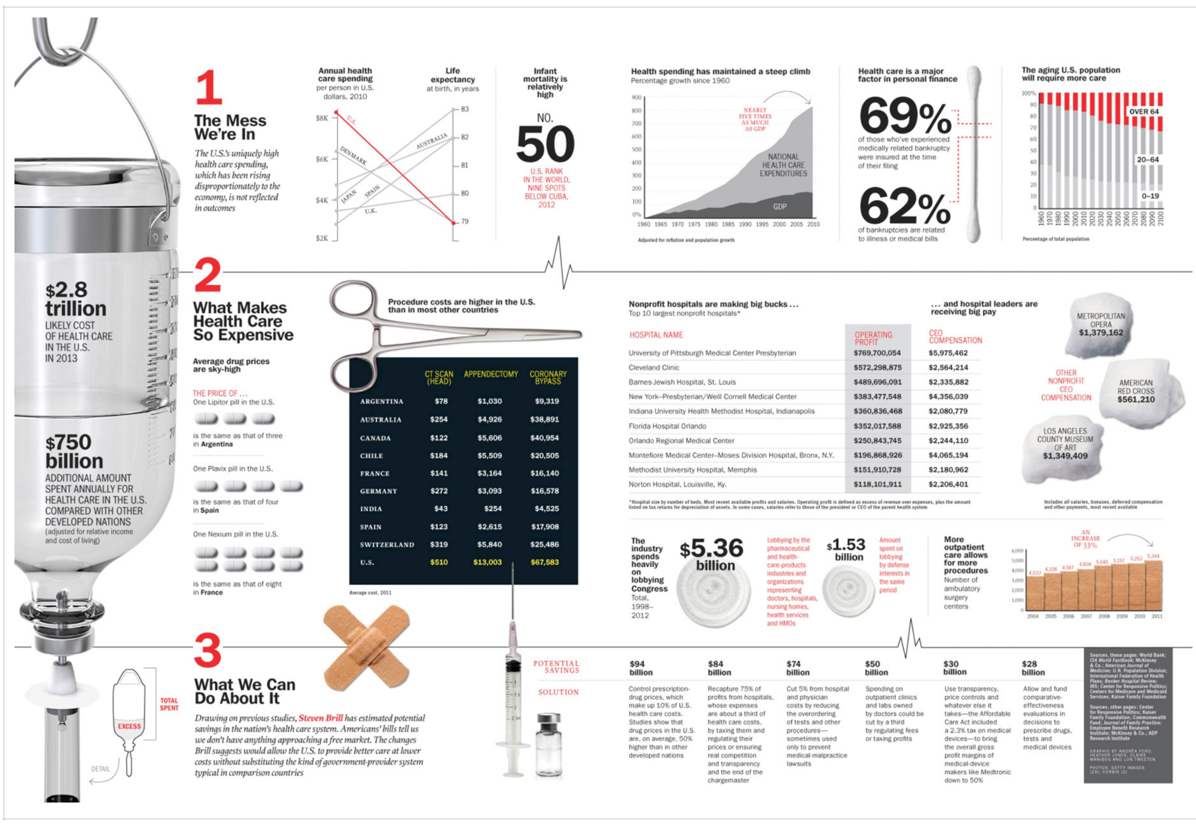

Fig. 2.09: *Why Health Care is So Expensive* by Heather Jones (Jones).

Data visualizations most often tend to be comprised of one, very complex graphical representation of data, sometimes displayed with smaller supporting statistics in the form of charts or graphs. Fig. 2.10 is an example of a data visualization exploring the story of Nobel winners between 1901 and 2012. Within the primary graphic (the award timeline) are displayed the six prize categories (colour coded according to discipline), the average age of the recipients, recipient's gender, grade level, and University affiliation. Each dot placed on the timeline stands for one prize recipient, positioned according to the year the prize was awarded and the age of the person at the time of the award (Lupi et al.). A legend and a support graphic have been included, but the bulk of the display is made up of the one, multi-layered visualization.

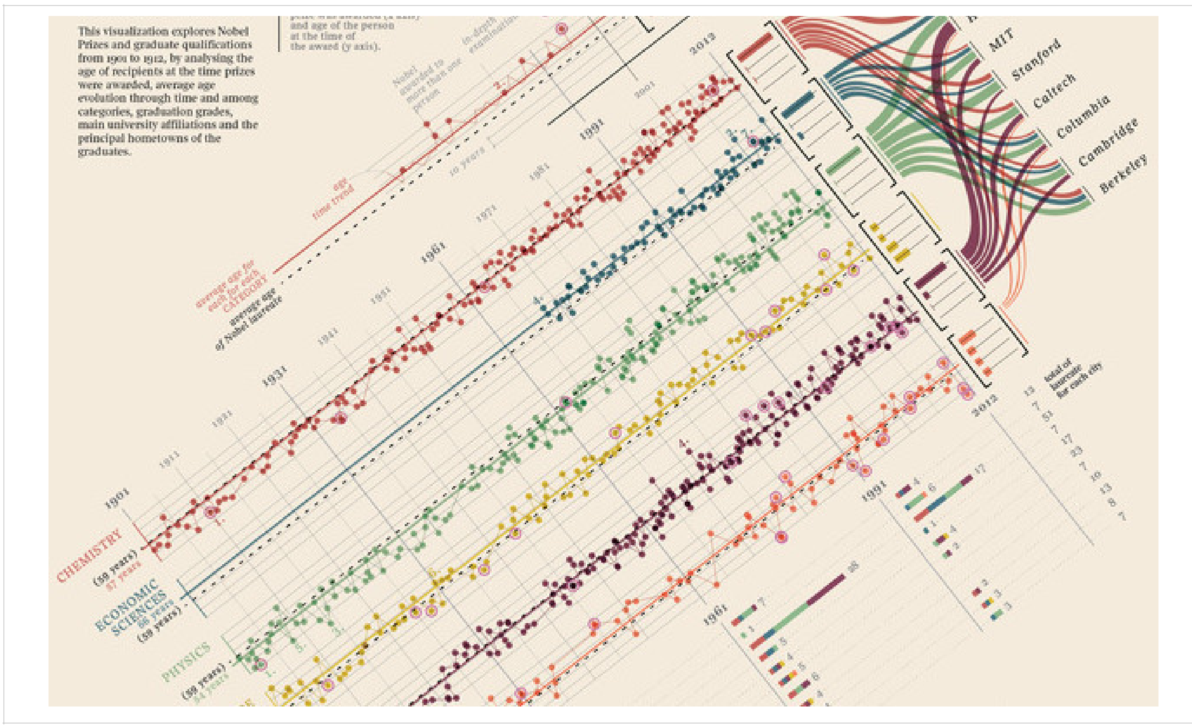

Fig. 2.10: Exploring Nobel Prize Recipients (Lupi et al.)

Circos stands at the far end of static data visualization. In one graphic it shows the entirety of the human genome: 22 pairs of chromosomes 1-22 and the pair of sex chromosomes X,Y (see Fig. 2.11) (Krsywinski et al.). Chromosomes are shown as wedges and arranged in a circular orientation. Their length is marked with a scale. This data is supplemented on the outer ring with tracks representing genomic variation between individuals and populations. Data within the grey ring highlights positions of genes implicated in cancer, diabetes, and glaucoma. Grey links inside the circle illustrate disease-related genes found in the same biochemical pathway, whole colored links connect those genomic region pairs that are highly similar, illustrating the deep level of similarity between genomic regions (Circos). This is an incredibly complex visual display, requiring not only a high degree of familiarity and comfort with the act of reading graphical objects that are of similar complexity, but also discipline-specific knowledge in genetics. At the same time, however it is, perhaps accidentally, aesthetically compelling – suggesting the vastness and beautiful complexity that is the human existence.

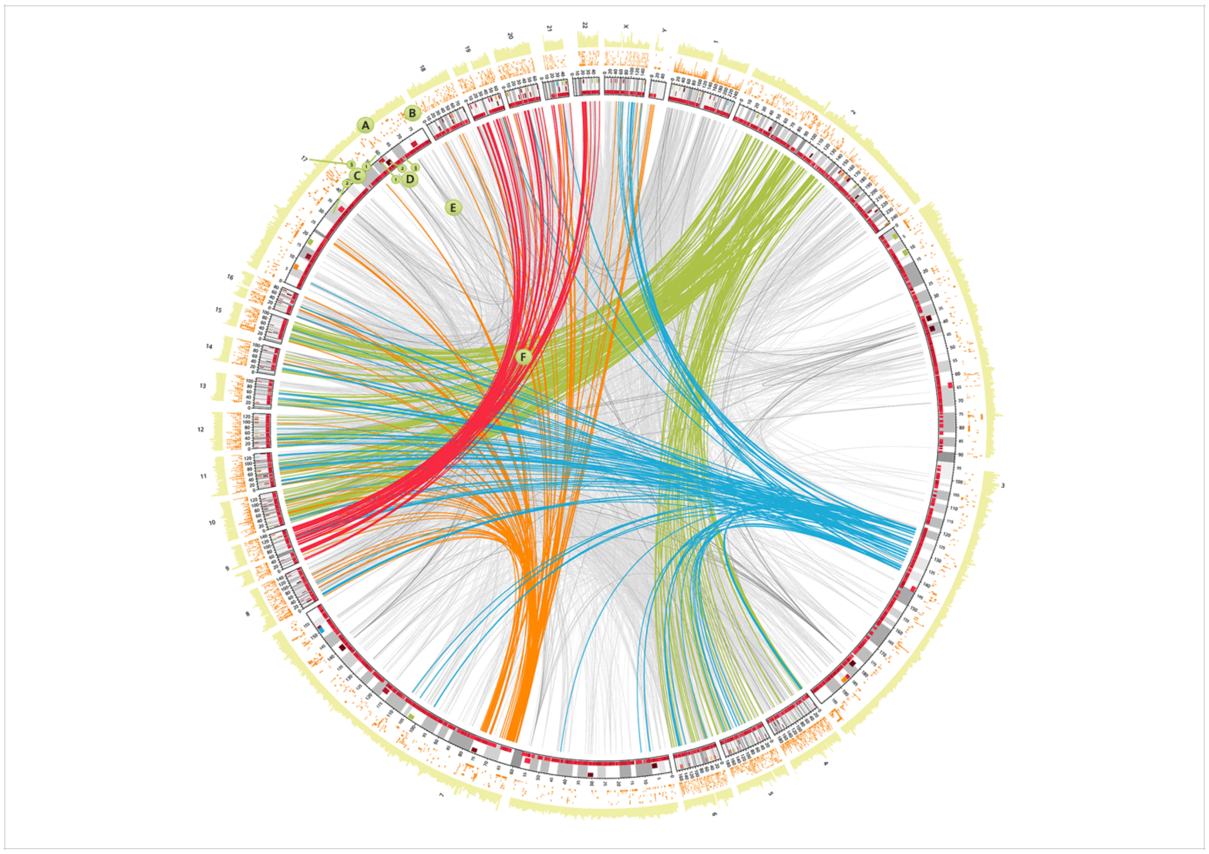

Fig. 2.11: A static data visualization of the human genome (Krzywinski).

Information graphics can appear in either static or kinetic form. Minard's diagram, Nightingale's Rose and Willard's *Picture of Nations* are all examples of static displays. Static displays produce no sound, show no movement, and offer no opportunity for change through interaction: they are, essentially, for-print posters, even if displayed on an electronic screen. In contrast, kinetic displays (motion graphics) show movement in the form of video or animation. Sound is sometimes added to kinetic displays. Fig. 2.12 is an example of a motion graphic that takes the viewer through a one hour, one day, and one year period, at the end of which New York City adds 54 million metric tons of carbon dioxide to the atmosphere. Neiman argues that this terrific number for atmospheric pollution is meaningless to most people since few of us have a sense of scale when it comes to such large values. Using 3-D modelling, Nieman gives the collective New York emissions physicality, by turning them into giant, blue balls. By the end of the short movie (and the end of one year), most of New York is buried under a mountain of these carbon balls. Specific numbers are less important in this graphic; what is important is the emotional impact provided through the contrast of emissions to the city scape (Niemen and Dickinson).

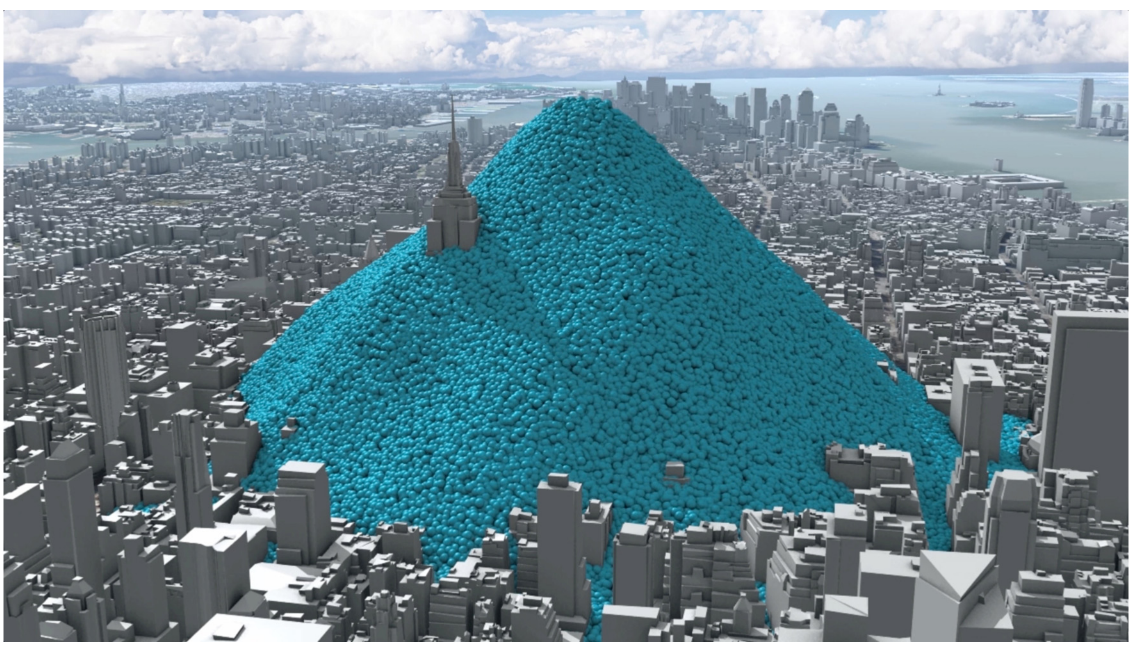

Fig. 2.12: Still from a motion graphic (Niemen and Dickinson).

More recently, some data visualizations are intended not just as reference or argumentation objects, but as tools for analysis, discovery, or research. In literary studies, data visualization tools have been used for exploring single or multiple texts, as well as text and image collections. In the field of Digital Humanities, researchers have built, modified, and used tools for the analysis of large text collections in order to gain relevant insights or propose new arguments regarding narrative structure, style, or associations within and across texts. *TextArc*, for example, (see Fig. 2.13) is a "combination of an index, concordance, and summary", mapping word frequency and associations in Lewis Carroll's *Alice's Adventures in Wonderland* (Paley). Upon launch, the tool first draws the entire text of the novel, sentence by sentence, in the shape of an ellipse. Every word is then repeated according to its sequence within the book, and positioned next to the sentence in which it appears. Words that are in proximity to one another in the book are brighter and share a similar colour. Users can select any word and view where it occurs in the book (Lima, 123).

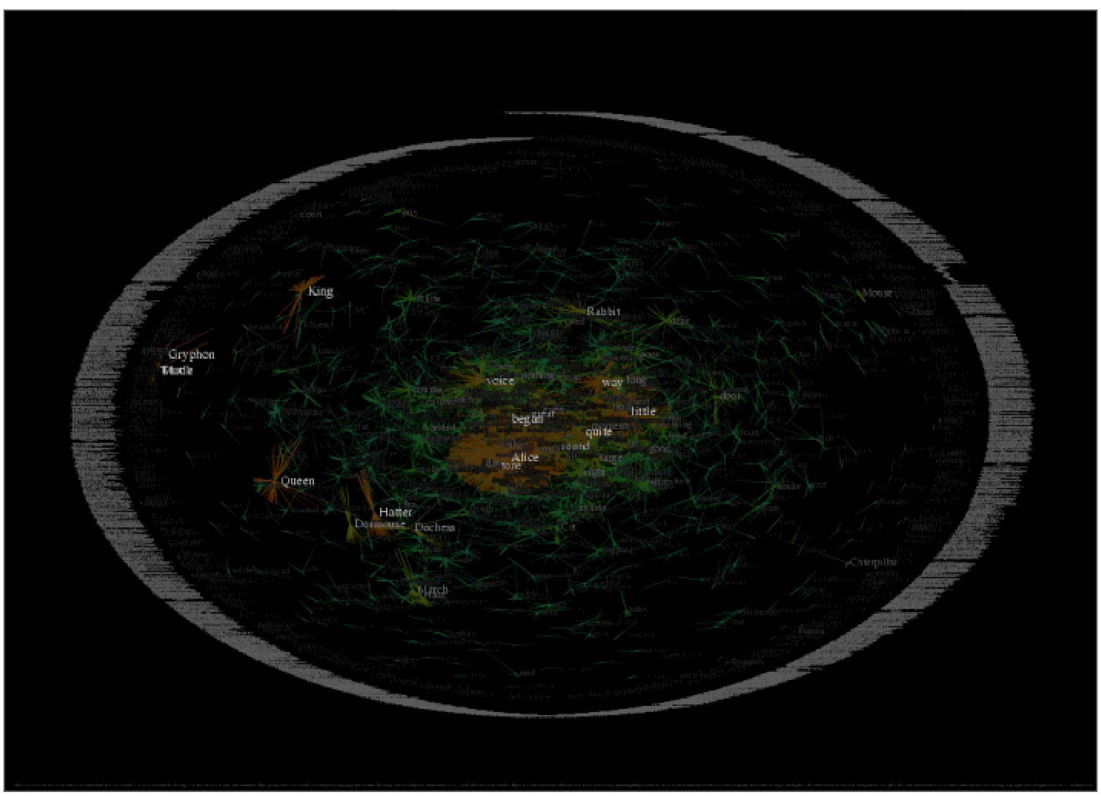

Fig. 2.13: *TextArc,* illustrating relationships between words found in *Alice in Wonderland* (Paley).

The TAPoR 2.0 gateway provides a good snapshot to the kinds of tools (and their sheer volume) that are currently available for humanities-emergent scholarship. It lists 463 tools for text manipulation, analysis, and visualization, and describes itself as

> a place for Humanities scholars, students and others interested in applying digital tools to their textual research to find the tools they need, contribute their experience and share new tools they have developed or used with others (Rockwell et al.).

In its 2.0 iteration, users can discover historic tools, read tool reviews and recommendations, learn about papers, articles and other sources referencing specific tools, and collaboratively tag, comment, rate and review tools.

Numerous such gateways or collections of data visualization tools currently exist, outside of those specific to the DH community. datavisualization.ch, for example, short lists 55 tools: libraries for plotting data on maps, frameworks for creating charts, graphs and diagrams and tools to simplify the handling of data (datavisualization.ch). Visual Complexity is a multi-disciplinary resource for anyone interested in the visualization of complex networks, providing an access point to 777 data visualization projects with "one trait in common: the whole is always more than the sum of its parts" (ibid.).

Similar to TAPoR, Visual Complexity offers encyclopedic-like entries for every tool, with a title, screen shots of the interface, author attribution, date of creation, url, and a short description. Users can add their own experiences or observations in the form of comments, to any tool (Lima, visualcomplexity.com). Visual Complexity, unlike TAPoR, provides access primarily to interactive data visualizations that aid in data exploration, not tools for research or work-task completion. For example, the *Health InfoScape* project, designed by the team at MIT SENSEable City Lab, visualizes 7.2 million patient records from General Electric's proprietary database. It aims to foster an exploration of connections between health conditions found in American patients in order to answer such questions as, for example, “When you have heartburn, do you also feel nauseous? Or if you're experiencing insomnia, do you tend to put on a few pounds, or more?” (MIT SENSEable City Lab). Users can select conditions from 16 ailment categories. Conditions are then associated with gender prevalence and correlated with other, relevant, conditions (see Fig. 2.14). It may be argued that interfaces such as *Health InfoScape* help users in preliminary research towards self-diagnosis or subsequent discussions with their healthcare provider; they are primarily intended as, what I would term, education-light, similar to Web MD.

Notable about *Health InfoScape* is its visualization-navigational model. The interface consists of one visualization space. Within this space is located the navigation system (through which users can explore the data) as a side category menu, and the data visualization itself, which is also interactive. There are, in fact, two visualization layouts made available to us, and switching between does not change the data, just its display. All exploration is contained within this one space.

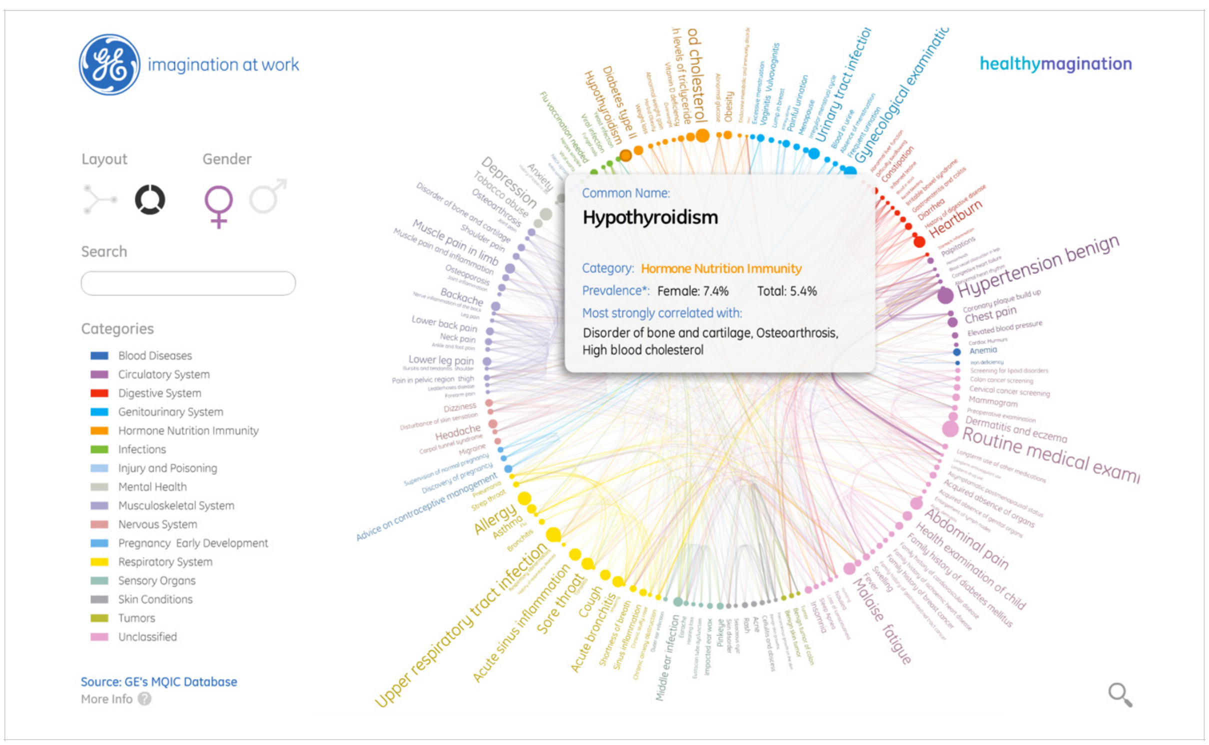

Fig. 2.14: The *Health InfoScape* project (MIT SENSEable City Lab).

While both the *Health InfoScape* and the *TextArc* projects are highly graphical and display substantial data sets, they are limited in terms of user interaction and contribution. In contrast, the *The Johnny Cash* Project supports user engagement through navigation, and contribution of content into the collection, both on a micro and a macro level (Milk). Working within the original music video for the song "Ain't No Grave", users are invited to draw their own versions of a frame from the video. That frame is then combined with frames by other users from around the world, and integrated into a collective reconstruction of the video. This interface provides a prospect view on all the user-created frames, with the added functionality of switching the view between frames that received the highest user rating, those that were selected by the site's curator, or those that were defined by a particular artistic style (pointillism vs. abstract, for example). Each representation of an item in the collection (video frame) becomes the means of accessing further information on that item. When a user selects one of the frames, an information panel appears to the right of the frame listing such details as the frame number, artist's name and location, drawing time, and number of brush strokes (see Fig. 2.15). Users can easily navigate between frames using the prospect view below the video playback or, when in the detailed frame view, by using the previous and next frame buttons.

Fig. 2.15: The *Johnny Cash Project* (Milk).

The *Health InfoScape* project relies on a pre-existing dataset that is made available for exploration to its users. The *Johnny Cash Project* relies on two sources of data: the original video, made available by the project's designers, and frame and rating contributions, made by users. Thus, the dataset grows as the community of user-contributors grows (as of 5 November 2014, they have had 52,609 submissions) (Gilbert). In contrast, the *We Feel Fine* project is based primarily on user created content from numerous, continuously and independently generated datasets (see Fig. 2.16) (Kamvar and Harris, n.pag.). Its search engine continuously crawls blogs, microblogs, and social networking sites looking for sentences that include the words *I feel* or *I am feeling*. It extracts these statements, as well as the gender, age, and location of the people authoring them, and displays them within an ever-changing and interactive art installation.The *We Feel Fine* interface allows users to search, browse, or ask specific questions such as "How did young people in Ohio feel when Obama was elected?" It is an interface for qualitative exploration of emotional data, and its flexible data collection system enables the continual growth of the dataset. The result is a database of over 14 million expressions of emotion, increasing by 15,000 – 20,000 new feelings per day. Notable about the *We Feel Fine* interface is the complexity of its interaction model. It enables users to perform sentence-level analysis: sentences are the canonical documents in the dataset. Each sentence is combined with, and can be searched and sorted by, contextual information: time of the emotion, and location, age and gender of the speaker. *We Feel Fine* uses the sentiments themselves as the primary organizing principle – they are the underpinning of its interaction model – and, based on the principle that feelings are never wrong, there is no statement ranking in the interface. Instead, the interface emphasizes browsing and summarization, thus enabling users to shift between macro and micro views of the data. The visual form of the interface is meant to reflect their human origin as well as the diversity inherent to emotional states, while providing functional and direct access to the data.

Fig. 2.16: The *We Feel Fine* interface (Harris and Kamvar).

Treemaps stand in sharp contrast to the delicate and organic display of *We Feel Fine*. Invented by Ben Shneiderman in 1992, treemaps are a way to visualize tree structures within a contained space (Shneiderman). Each branch of a tree is given a rectangle, then tiled with smaller rectangles that represent the sub-branches of the tree. The size of the rectangle is proportional to the size of the others: think of cutting up a rectangular pan of brownies amongst a room-full of relatives, each one with a differently-sized appetite. Colour is often used to separate dimension or to create categories. *Newsmap* (Weskamp) is one of many examples of treemaps currently in use. It is a news aggregator that displays stories, organized by popularity and volume of reporting. World, National, Business, Technology, Sports, Entertainment, and Health categories help users subset the data. Users can also toggle their view based on the country from which the feed has originated. Fig. 2.17, for example, shows news stories emergent out of New Zealand, related to technology. Mousing over a square reveals a small pop-up summary of the story, and clicking on the square directs you to the story's origin, where you can read the entire text. What stories are displayed and how often the display updates with new content depends on the type and level of news activity that is occurring at any given moment.

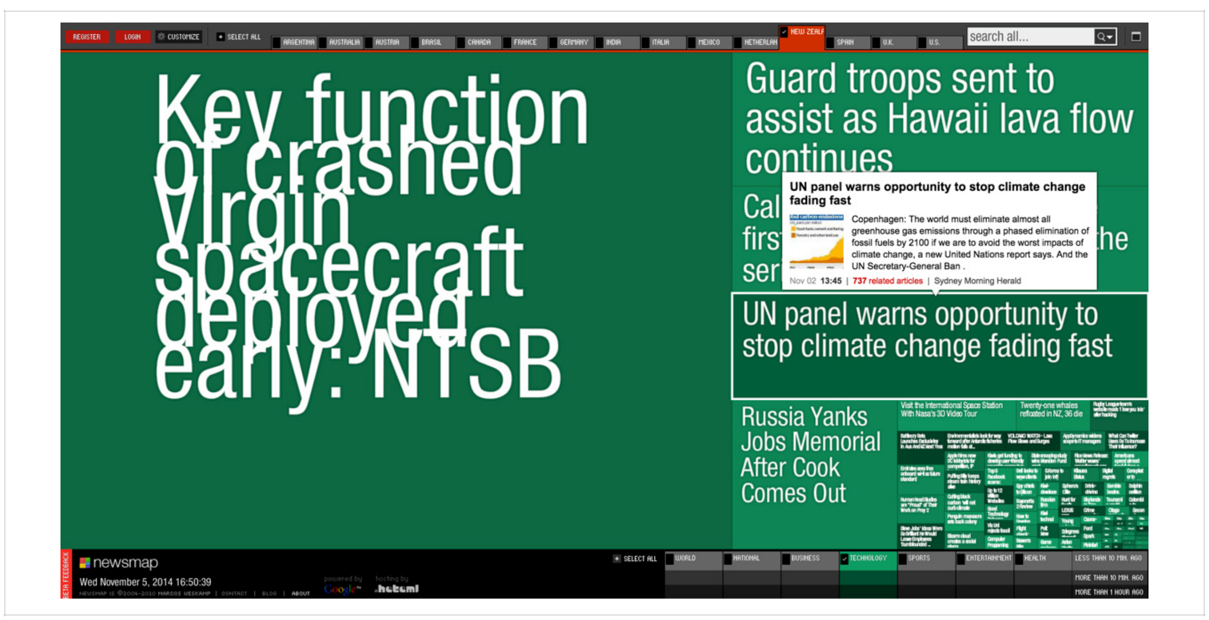

Fig. 2.17: Newsmap (Weskamp).

While *We Feel Fine* continuously grows its dataset through its emotional search engine and Newsmap updates according to changes in news feeds, the *Bubblelines* tool provides users with two options for the origins of their dataset: using a set that has been preloaded into the tool, or uploading their own set (see Fig. 2.18). *Bubblelines* visualizes the frequency and repetition of words in a crops (Rockwell and Sinclair). Documents are represented as horizontal lines, divided into equal segments. Users can search for words in the documents; words are presented as bubbles with their size indicating the word's frequency within a particular text segment. The larger the bubble, the more frequently that word occurs in a segment. Users can view all words on the same line, with overlapping bubbles, or on separate lines. The tool is significant to this discussion in the way it enables users to upload their own corpus, however large, containing any number of documents. These documents can then be displayed in parallel to one another, enabling comparison and juxtaposition.

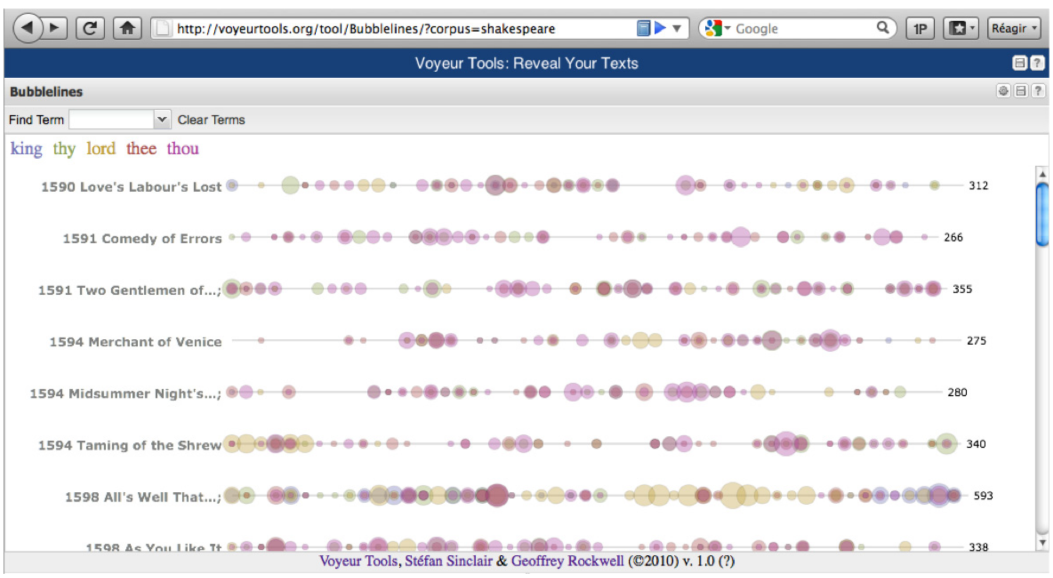

Fig. 2.18: The *Bubblelines* tool with a pre-loaded corpus (Rockwell and Sinclair).

Wicked Problems in Design

Fundamental to my concerns over design recommendations that occur at the interface, the screen, the item, or the element levels is that they fail to consider HMI, GUI, dashboard, information graphic, or visualization design as *wicked* problems – complex and multidimensional. In the 1960s, Rittel and Webber proposed the idea of wicked problems in design to challenge the notion that design problems are linear, with the proposed solution following a process of research and investigation. In contrast, he described a class of social system problems common to designers, which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing (Rittel and Webber, ff.). Not only are some design projects wicked from beginning to end but, I propose, the visual design of an artefacts is also a wicked problem. This is evident in the ten properties of wicked problems identified by Rittel and Webber (161 – 167):

1. Wicked problems have no definitive formulation, but every formulation of a wicked problem corresponds to the formulation of a solution.
2. Wicked problems have no stopping rules.
3. Solutions to wicked problems can not be true or false, only good or bad.
4. In solving wicked problems there is no exhaustive list of admissible operations.
5. For every wicked problem there is always more than one possible explanation, with explanations depending on the *Weltanschauung* of the designer.[6]
6. Every wicked problem is a symptom of another, "higher level," problem."
7. No formulation and solution of a wicked problem has a definitive test.
8. Solving a wicked problem is a "one shot" operation, with no room for trial and error.

[6] Buchanan defines *Weltanschauung* as "the intellectual perspective of the designer as an integral part of the design process" (16).

9. Every wicked problem is unique.
10. The wicked problem solver has no right to be wrong-they are fully responsible for their actions.

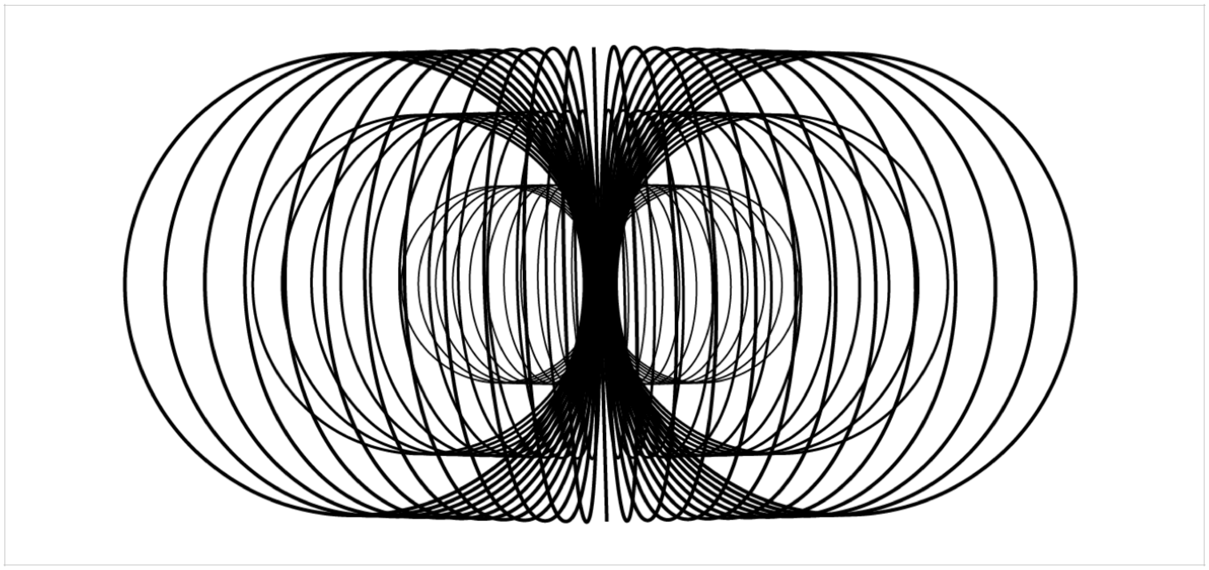

Fig. 2.19: Diagram illustrating the connectedness of all aspects of visual design.

Fig. 2.19 demonstrates the interdependence, nestedness, and connectedness of interface, screen, object, and element. Designers make choices at each of these levels, and those choices are both informed by the objectives they have established for the whole, and impact the whole's eventual manifestation. When we change the form that some segment of information takes, we not only impact the aesthetics and functionality of the entire design, but also how it will be, subsequently, interpreted.

Chapter 3: Critical HCI

> "The urge to design – to consider a situation, imagine a better situation, and act to create that improved situation – goes back to our prehuman ancestors. Making tools helped us to become what we are, and design helped to make us human."
>
> Carl DiSalvo (ix)

Cockton et al. argue that human-computer interface (HCI) design should look to disciplines outside of itself, identifying literary and cultural studies as a particular appropriate fit. They position HCI artefacts as amalgams to text, suggesting that HCI would benefit from borrowing from established practices in textual reading (Cockton et al. ff.). In this Chapter, I attempt to contribute to this position by proposing that HCI design generally, as well as interfaces designed to support human decision making within manufacturing, should engage with theories emergent out of the intersection of humanities and visual design, specifically with Critical Design and Feminist HCI.

As discussed at some length in Chapter two, the design of graphical user interfaces for manufacturing and GUIs designed to support decision making is of particular concern because these types of interfaces have not seen significant design advancement in the past twenty years (Hollifield et al. 12). Though some notable work in decision support system design and, particularly, in dashboard design, has taken place, more work remains to be done. Critical engagement with human computer interfaces represents an opportunity to both diversify the pool of available design alternatives and diversify the ways that we approach the act of designing such interfaces.

But First, Views on Design

In Chapter two I discussed specific designed artefacts (graphical user interfaces, human-machine interfaces, decisions support systems, and dashboards); the data-rich graphical objects that, most often, occupy such artefacts (charts and graphs, information graphics and data visualizations); and the elements and principles used to construct and manipulate all graphical objects. Now, I would like to take a moment to step back and talk about the disciplinary umbrella under which all the above-mentioned discussion takes place: *Design*. Given the focus of this chapter: critical design, design criticism, and feminist design for interaction (Feminist HCI), such a pull back is an important grounding step.

Unfortunately for many people, design is synonymous with ornament, style, decoration, or pattern. In this way, the shadows made by leaves on a wall are sometimes, erroneously, described as a design instead of a beautiful pattern in light and dark. Identifying naturally-occurring phenomena as design places nature or the divine in the role of active creator, with the potential consequences that all perceived entities then become design. Designers attempt to construct an initial, substantial narrowing of the field by defining design as the physical result of some kind of planned *human* activity, thus positioning naturally or non-intentionally occurring phenomena (independent of their aesthetic value or perceived intentionality) outside the design field.

Sometimes, design is described as pretty pictures, relegating its value solely in terms of the quality of its form (or its aesthetics). Though form quality is an important concern to designers, most would argue that aesthetics are not the primary focus of their work but are, in fact, subservient to a wide range of other factors (the functionality or usability of the artefact, for example). Most late 20th century designers (and many of the 21st) would argue that concerns over form should follow concerns over function. This discussion – of form vs. function – has its origins in the tensions that emerged out of industrial manufacturing. As mass manufactured products became more widely and more cheaply available, their visual and production quality came under increased critique. Many considered such products to be overly decorated in an attempt to make them appear more familiar and mask their manufactured origin. In a counter movement, Morris, Image, Macmurdo, Ruskin, and others argued for a celebration of natural forms, a truth to materials, and a return of the artisan (both designer and creator) (Meggs, 162). Two schools of thought emerged: one that argued for a revival of classical forms and one that argued for a return to agrarian regional design. The idea that form follows function emerged, based on Sullivan's "Form ever follows function" (16). While forms follows function promotes form's subservience to its use and purpose, Weitz proposes that when we consider "Form *ever* follows function", neither come first but both exist in a delicate balance, created through equal emphasis (n.pag.). *Form ever follows function* allows designers to begin the design process with a random connection, emotion, or experience – imagine the seemingly impossible – then figure out how to make it functional (n.pag.).

In an attempt to extend Weitz's argument, I propose that aesthetics have function: that form and functionality are so intricately intertwined that it is impossible to speak of one independent of the other. While Sullivan's (and Weitz's) statements suggest a positive value to both form and function (*good* form follows *good* function), my argument relies on the notion that when form exists, so does some kind of function, and vice versa. Whether they exist for good, and what kind of good they exist for, calls for further interrogation.

Returning to the central theme, it is more accurate to describe design as a series of sub-disciplines and professions, all with a diverse set of practices, tools, and traditions. Most design fields have a rich history, with ongoing theoretical developments and debates. Most offer and require extensive and specialized training, either institutionalized or through practicum. Some design fields have an extensive academic underpinning and have made valuable multi and cross disciplinary partnerships, while others are squarely grounded in industry practice.

Fig. 3.01: This sentence, developed by John Heskett explains the four ways design can manifest: as the field or discipline, the process(es) used to achieve an outcome, the physical plan, and the finished product. (Diagram by Windsor).

With its close relationship to drawing, design has also been described, more simply, as the plan or sketch for something to be created or constructed at a later date, as well as to "plan out in the mind"(Mirriam-Webster). Frascara's definition of design focuses on it as action – the product as a final step of a journey (often called *design process*):

> to invent, to project, to program, to coordinate a long list of human and technical factors, to translate the invisible into the visible, and to communicate (Frascara, 2).

Rand's definition highlights a view of design as a discipline in service to the needs of others, a view that has gained much prominence and buy-in over the past twenty years:

> Graphic design – which fulfills aesthetic needs, complies with the laws of form and the exigencies of two-dimensional space; which speaks in semiotics, sans-serifs, and geometrics; which abstracts, transforms, translates, notates, dilates, repeats, mirrors, groups, and regroups – is not good design if it is irrelevant (Rand, 9).

Simon's definition attempts to encompass all the above-mentioned definitions: to design is to "[devise a] course of action aimed at changing existing situations into preferred ones" (111). While for Simon design is a science and the pursuit of design a scientific activity, Buchanan roots design in the humanities: a contemporary form of rhetoric. The scientific perspective focuses on the empirical study of the effects of design activities and artefacts on people. The rhetorical perspective sees design products as "vivid arguments about how we should lead our lives" ("Design and the New Rhetoric", 194). Thus, design practice and scholarship, according to Buchanan, should act as facilitators who "organize conversations and debates about the values of a community and how those values may be implemented with productive results." Simon's position on design stands in contrast to that of Buchanan, together offering a useful snapshot on contemporary design. Cross (ff.) argues that design is neither science nor humanities, but its own category, with its own, designerly, ways of knowing.

DiSalvo argues that design possesses three characteristics, regardless of whether you support Simon's, Buchanan's, or Cross' views (15–16). Design's first characteristic is that its practice extends the professions of design, independent of whether that practice is defined as design or enacted by a designer (though it still remains a human activity). An activity becomes design when a deliberate and intentional approach has been taken to the creation of a product or service that shapes the environment. DiSalvo's second characteristic for design is that its practice is normative: "design attempts to produce new conditions or the tools by which to understand and act on current conditions" (16). Thus, design acts have an ethical, moral, and political dimension, whether practicing designers recognize or position it as such. Finally, the practice of design provides an experiential (tangible) accessibility to human ideas, beliefs, and capacities for action. Even though the process and materials may be different depending on the specific design sub-field, the end result – accessible tangibility – remains constant.

It strikes me that DiSalvo's characteristics pose a number of critical questions for designers, those who think about design, and those who engage designed artefacts. How do we determine whether a design is intentional? Is this a binary characteristic, based solely on whether it is a deliberate, human act? Or, can the level and type of intentionality vary, be subsequently discussed or evaluated? Do characteristics act upon one another? If we agree with DiSalvo that all design has a political, moral, and ethical dimension, is there an – assumed – connection between it and intentionality? Do we question designers about the political, moral, or ethical position held, demonstrated, or supported through their design? Or should we? Furthermore, as design has "accessible tangibility", should as well the positionality of its intention?

Is design – like literature – relative, subjective, or agnostic? Are there no value distinctions in design; can anything be called good design, as long as it is intentionally created by human beings, it is normative, and tangible? Or is design value subjective; is its evaluation a purely personal matter? Is there a greater truth about good design that, while exists, our subjective value systems prevent us from knowing it? Is good based on usefulness or functionality; and are usefulness and functionality only valuable through tangible, measurable outcomes? Are all opinions on design created equal, or are some more valuable than others? Ones, for example, emergent out of a designerly expertise and capable of building a *valid* case for an evaluation?

There is a value judgement – sometimes unspoken and at times transparent – placed within the definitions of design outlined at the start of this chapter. Consider in Frascara, for example, a designer does not merely invent, translate, and communicate, she must do so well. Rand, Simon, and Buchanan are more direct, describing good design as one that is "relevant" (Rand, 9), that creates "preferred" states (Simon, 111), and that argues for better ways to "lead our lives" (Buchanan, 194). Rams believed that design could not be measured in a finite way; instead of a quantifiable metric, he proposed ten features of good (product) design: innovation, usefulness, aesthetic value, understanding, unobtrusiveness, honesty, endurance, thoroughness, environmental friendliness, and simplicity (Lovell, Kemp, and Ive ff.).

Building on these definitions I propose not only that good design does exist, but that we should consider two additional characteristics to the three outlined by DiSalvo and ten developed by Rams: good design as nourishing and good design as veracious.

Nourishing design leaves a mark in our memories and hearts: it plants a seed, then grows. It is "not an expression of my beautiful soul" (a phrase sometimes used by University of Alberta's Professor Gary Kelly). It challenges, but through that challenge it is of use. Design at its best is transformative; it combines aesthetics, emotional engagement, and functionality to spur metamorphosis and growth.

Veracious design is transparent about its origins, positionality, and privilege. It acknowledges that all design is iterative – it can always be subject to critique, contextual development and change. Thus, through its welcoming of iteration, veracious design becomes accountable.

Having dedicated several pages to defining *good* design, permit me to end this section by describing its opposite. Bad design at its best is merely frustrating, dull, or unpleasant. It is the itch at the back of your throat. It is an obstacle instead of an enabler; it is useless and self serving. At its worst, bad design causes harm; it creates negative outcomes or situations. It obscures or deceives. Consider the following example: the painting of pink fracking drill bits as a breast cancer fundraiser. In 2014, Susan G. Komen partnered with Baker Hughes, a leader in hydraulic fracturing equipment, to raise breast cancer awareness among (mostly male) oil field workers. Baker Hughes donated $100,000 to the Foundation, then painted 1000 drill bits used in fracking the specific shade of pink trademarked by Susan G. Komen (Levine). Given the carcinogenic nature of fracking chemicals, the cost involved in painting pink these many drill bits, and the cost of the Baker Hughes' marketing campaign (versus the monetary benefit to breast cancer awareness and research), this becomes silly, if not ethically questionable.

Why Design Matters

That design matters – that it exists, that it will have an impact, and that this impact can be for the positive – has, more recently, entered the multi-disciplinary discourse. Fuller acknowledges that "objects, devices, and other material entities have a politic – that they engage in the arrangement and composition of energies, allow, encourage or block certain kinds of actions" and writes that "these concerns have also more recently been scrutinized by the interdisciplinary area of science and technology studies" (7). In 2007, my colleagues and I argued that "research interests in graphic design and presentation find a new relevance and weight, not only as a contributing factor in the design of computer interfaces and visualization systems, but also as an area of study in their own right." The contributions possible by design are increasingly being recognized as valuable, the "significance of the visual is sufficiently evident … that aesthetic factors become intrinsically woven with issues of functionality"(Ruecker, Sinclair, and Radzikowska, "Confidence, Visual Research"). For the humanities, Brown champions design's cause, arguing that "an algorithm has no impact without an interface" ("Remediating the Editor", 81), adding that design's importance to the digital humanities, while an "uncomfortable truth for many digital humanists" will, according to Cohen, determine whether a "resource will be useful and used" (Cohen). Particularly the critical analysis of design, argue Galey and Ruecker, "positions us in a potent space between the past and the future. Failing to recognize design as a hermeneutic process means failing to understand how our inherited cultural record actually works" (421).

Critical Design

In the late 1960s, Sottsass declared that design "is a way of discussing society, politics, eroticism, food and even design. At the end, it is a way of building up a possible figurative utopia or metaphor about life" (qtd. in Dormer 10). Antonelli traces the history of Critical Design to predating the Radical Design defined by the Italian movement of the 1960s. He argues that architecture and design have, at different points in the past, "raised red (never white!) flags and creatively proposed corrections under different manifesto umbrellas" (Antonelli). The 1964 *First Things First Manifesto,* for example, published by Ken Garland and 20 other designers, photographers and students, was a reaction against trivial production and mainstream advertising. It called on designers to "focus efforts of design on education and public service tasks that promoted the betterment of society" (Garland et al.). Forty five years earlier, Walter Gropius called for a unification of the arts with craft through an artistic revolution of a sort,

> Let us therefore create a new guild of craftsmen without the class-distinctions that raise an arrogant barrier between craftsmen and artists! Let us desire, conceive, and create the new building of the future together. It will combine architecture, sculpture, and painting in a single form, and will one day rise towards the heavens from the hands of a million workers as the crystalline symbol of a new and coming faith. (Gropius)

In 2000, the *First Things First Manifesto* was rewritten and republished, once again encouraging designers to seek "pursuits more worthy of our problem-solving skills." The manifesto singles out "cultural interventions, social marketing campaigns, books, magazines, exhibitions, educational tools, television programs, films, charitable causes and other information design projects" dealing with the environment, and social and cultural crisis as particularly deserving of design attention (Garland et al.). In the 1990s, Colors, a Benetton magazine launched by Tibor Kalman and Oliviero Toscani, featured thematic, multi-language issues on topics ranging from AIDS and victims, to touch, water, and prayer.

It was powerful, well crafted, antagonistic design, though also called opportunistic by its critics (e.g., Giroux, ff.). Adbusters, a Canadian-based not-for-profit organization founded in 1989 has launched numerous international campaigns, including Buy Nothing Day, TV Turnoff Week, and Occupy Wall Street (Adbusters; Yardley). Its anti-consumerist and pro-environment publications are known for their subvertisements (spoofs of popular ads).

The term "critical design" first appears in Dunne's *Hertzian Tales: Electronic Products, Aesthetic Experience and Critical Design,* then in Dunne and Raby's *Design Noir: The Secret Life of Electronic Objects*. In *Hertzian Tales,* Dunne's interest lies in using design research to draw our critical attention to the "hidden social and psychological mechanisms" of designed artefacts (xvi). Dunne builds on work by Ezio Manzini in which he envisions two roles for the future designer: the designer using her or his skills to imagine alternative futures in ways that can be communicated with the public, and the designer as strategist, directing industry to work towards achieving these futures (ibid. xvii). The goal becomes to look beyond commercial and marketing activities, and construct opportunities for democratic conversation about what kinds of future people really want since design (Dunne and Raby. "Design for Debate"). For Dunne, design cannot [spelling] be divorced from people, and people's mental lives (Dunne, *Hertzian Tales* 148), making our conversations about technological developments essential for an informed debate about design's possible implications (Dunne, "Design for Debate").

Some of those who advocate for critical design have turned to critical theory to support their approach (Bardzell, Bardzell, Forlizzi, Zimmerman, and Antanitis, ff.). Critical theory is a massive tradition (Adams, ff.), with both "a narrow and a broad meaning in philosophy and in the history of the social sciences" (Bohman). According to the Frankfurt School, "a theory is *critical* to the extent that it seeks human emancipation" (Horkheimer, 246).[7] Numerous critical theories have been developed, in connection to various social movements. In both its

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7 Max Horkheimer. *Critical Theory,* 1992 (New York: Seabury Press).

broad and its narrow definition, critical theory has as its aim to "explain and transform *all* the circumstances that enslave human beings" (Bohman). Critical theorists have intentionally sought to distinguish their approaches to those practiced by the natural and social sciences and combine the differences found in the poles of philosophy and the social sciences to seek human emancipation (Horkheimer, 244). Since critical theory no longer concerns itself, solely, with the fine arts and literature, but also with current popular and consumer culture, there is much potential in appropriating (or re-thinking) a critical theory vocabulary to explore relationships between an artifact's features and qualities, the structures of users' experiences, and the contexts within which the relationships between artifact and users are created, experienced, and maintained. All the while, it is argued, designers can preserve their commitment "to socially good and richly fulfilling aesthetic experiences" (Bardzell, Bardzell, Forlizzi, Zimmerman, and Antanitis, 289). Critical theory is seen as offering resources designers can use to create artifacts that engage the public in challenging existing socio-cultural norms and structures. The body of work produced by Bardzell, Bardzell and colleagues in Feminist HCI, interactive criticism, and critical HCI (extensively cited in this dissertation) is notable in this area. HCI, when seen as an interventionary field in particular, when we do more than react to inventions or empirically derived user needs, when we are "proactive to imagine and support lifeworlds in which technologies play positive social and cultural roles" (Jeffrey Bardzell, Shaowen Bardzell, Carl DiSalvo, WIlliam Gaver, and Phoebe Sengers, 1136), appears a natural fit with critical theory.

Dunne and Raby, however, argue that critical design is not related to critical theory or the Frankfurt School but is, instead, critical thinking, "not taking things for granted, being skeptical, and always questioning what is given" ("Critical Design FAQ"). While critical design often deals with larger and more complex issues, all good design is in fact critical design because "designers start by identifying shortcomings in the thing they are redesigning and offer a better version" (*Speculative Everything,* 35).

Design practice that aims to *improve the current state of human existence* appears to share much in common with Critical Theory. Both appear to agree that social transformation can be achieved "only through interdisciplinary research that includes psychological, cultural, and social dimensions, as well as institutional forms of domination" (Bohman). For Dunne, critical design is a "synthesis between theory and practice, where neither practice nor theory leads" (Hertzian Tales xvii). It is an opportunity for designers to engage in the social, cultural, and ethical implications of the artefacts they help create. Balsamo supports such engagement, arguing that "[d]esigners serve as cultural mediators by translating among languages, materials, and people to produce – among other things – taste, meaning, desire, and coherence" (11). Thus, design work can be profound when designers embrace the notion that "[t]hrough the practices of designing, cultural beliefs are materially reproduced, identities are established, and social relations are codified. Culture is both a resource for, and an outcome of, the designing process" (11) Thus, approaching the study of interfaces for DS, specifically, through the lens of critical design may lead us to challenge the design notions and expectations that have been established within these domains, and provoke new ways of thinking about these objects, their use, and how they impact the surrounding environment. This may be in the form of imagining desirable future states for such systems, or through imagining the "undesirable things – cautionary tales that highlight what might happen if we carelessly introduce new technologies into society" (Dunne and Raby).

In many ways, by being seen as having coined the term "critical design", Dunne and, subsequently, Raby have come to stand for it. Malpass, in his doctoral work, challenges the idea that Dunne and Raby are critical design and poses, instead, that the Dunne and Raby Critical Design exists within a much broader context of critical design practice that can be traced back to the Radical Design in the Italian tradition, mentioned earlier, Anti-Design, New Design and Conceptual design, and critical practice in HCI (20). Malpass is concerned that critical design is seen as a novelty or as quasi art:

> the danger is that critical design becomes overly self-reflexive and introverted. As it gathers in popularity, there is a risk of it becoming a parody of itself and its usefulness as part of a larger disciplinary project is undermined. There are already utterances of critical design being, 'design for designs sake', 'design for designers' or perhaps more appropriately 'design for critical designers.' (Malpass, 6)

Critical design is subject to iterative design like any other intentioned artefact. Aside from Malpass' proposal of a taxonomy for critical practice in product design (further discussed in Chapter 4), work has also taken place on challenging both Speculative and Critical Design's perceived lack of political accountability. Prado and Oliveira question the validity of a (critical) discipline "that consistently dismisses and willingly ignores struggles other than those that concern the intellectual white middle classes – precisely the environment where SCD comes from" (Prado and Oliveira). In their harsh and deeply important criticism they call out critical designers for depicting "a dystopian universe where technology comes to paint a world in which their own privileges of their own reality are at stake, while at the same time failing to properly acknowledge that design is a strong contributor to the complete denial of basic human rights to minorities, right here, right now." They accurately, to my mind, describe CD as primarily focused on white, middle class, cisgendered, and heterosexual needs (and possible futures). When imagining either utopian or dystopian technological futures, do we consider that those future artefacts "will most probably be manufactured in China, Indonesia or Bangladesh"? The work in Feminist HCI comes closest to considering issues of race, gender, and privilege; however, even this area – more thoroughly discussed below – fails to adequately acknowledge its own, narrow position. Prado and Oliveira still believe that design's powerful language "is perfectly positioned to provide relevant social and cultural critique", but to achieve such relevance it must be "held accountable for its political and social positions" and "escape its narrow northern european middle class confines" (Prado and Oliveira). The only way it can gain relevant accountability is by being accountable and by diversifying beyond its limited, privileged starting points.

Feminist Theories

Martin has argued that "synergies between critical theory and feminist theory could and should be explored" (1). While earlier in this chapter I considered the position that HCI design can benefit from engagement with theories emergent out of the humanities, specifically with Critical Theory, in this section I explore feminist theories, in an effort to map out any connections between them and Critical Theory, Critical Design Theory, and HCI. Bardzell and others have proposed the development of an alliance between feminism and interaction design, and argued that "feminism is a natural ally to interaction design, due to its central commitments to issues such as agency, fulfillment, identity, equity, empowerment, and social justice" (Bardzell, "Feminist HCI", 1301).

Feminism, as both a cultural and political movement, has been an important and controversial issue in many Western countries since at least the 18th century (Hannam, 2); while as an academic discipline, feminism has been prominent for over half a century. The feminism movement is comprised of a wide range of attitudes, concerns, and strategies – a plurality that reflects the diversity of motivations, methods, and experiences among feminist scholars, as well as its commitment to and acknowledgment of diversity within its community (Kemp and Squires). Any working definition of feminism, though both useful as an anchor and reasonable given that certain concerns do fall outside the boundary, must acknowledge the complexity of what it is attempting to constrain. Hannam defines feminism, with such an acknowledgment, as "a set of ideas that recognize in an explicit way that women are subordinate to men and seek to address imbalances of power between the sexes" (3 – 4). The author states the belief that "women's voices should be heard" is central to feminism. Feminism is considered in terms of its history, in terms of a broad spectrum of beliefs and ideas, and as a political movement. Some authors now speak of feminisms instead of feminism, in an effort to capture its diversity and dynamism (Kemp and Squires).

Hodgson-Wright identifies three types of early feminist activity, prior to the First Wave (3 – 14). Early "feminist" writers attempted to combat negative views of women emergent out of Judeo-Christian writing. They challenged the prevailing attitudes towards women as inferior to men, with some early feminists calling for the creation of female support networks.

These early efforts preceded the ″three waves″ that are conventionally thought to represent the evolution of contemporary feminism. The First Wave began in the 1860s–1880s, with the forming of several European organizations for the improvement in women's social and political positions. Between the 1900–1920s, women's suffrage became the focus of feminist activity in Europe and North America, and is now often cited as the defining characteristic of First Wave feminism. It focused on women's rights to be legally recognized as persons, to vote, and to participate in democratic government. At the same time, it maintained that being born a woman meant having characteristics that are uniquely feminine. Those included physical attributes, such as breasts and uterus; and moral and psychological attributes, such as mothering, closeness to nature, heightened empathy, and devotion to others. The First Wave relied on essentialism to explain what the term "woman" means, and used it as a political tool, not only in the fight against the subjugation of women, but against slavery as well (Dictionary of American History).

The post world war period saw growth in education opportunities for women, entry into previously all-male professions, legislation on abortion and equal pay, and increase of birth control availability. First Wave feminists were active in politics, and became organizers, fundraisers, and public speakers. Simone de Beauvoir's *The Second Sex*, the defining volume of this period, argued that whatever essentially female characteristics a woman may possess, her most important trait is that she is not a man. The idea that women are not born but made drew a critical dividing line between women's sex and their gender (ff.).

The Second Wave began subsequent to the publication of Betty Friedman's *The Feminine Mystique* in the 1960s, and broadened the discussion to both practical and legal issues concerning sexuality, reproduction, family, and the workplace. The Second Wave includes liberal feminism, radical feminism, and black feminism among others. In North America, the Second Wave strongly opposed the idea that women are defined by their biology; however, this opposition did not come with full rejection of First Wave essentialism. Women were not inferior, but they were different. Carol Gilligan, for example, argued for the recognition that women's moral development has a distinct focus, with more emphasis on human relationships than on abstract ethics (ff). Female differences became important tools for political change, addressing issues such as sexual assault, domestic violence, and need for maternity leave, as well as supporting solidarity, and reinforcing an image of a universal sisterhood.

While the 1960s–1980s feminist theory was predominately Western, white, and heterosexual, more recent feminist writing has tended towards the recognition and celebration of difference, and an acknowledgment of multiplicity (see Tong), challenging the Second Wave notion of the universal woman. The realization that women have differences in race, ethnicity, religion, and sexual orientation has led to a transition into the Third Wave, and began in the mid 1980s–1990s, continuing to the present day (Hannam, 159). Similar to the Second Wave, the Third Wave includes concerns around gender stereotypes, sex-positivity, media portrayal, and language. The Third Wave is marked by a lack of an all-encompassing single feminist idea, and considers gender as a construction rather than a given fact (biological or otherwise) (Bardzell, "Feminist HCI"). The Third Wave rejects essentialism in all of its forms. Butler, for example, argues that gender is a learned performance, and without its formal acts, gender would not exist (ff). Further, Haraway proposes a new cyborg body that "can be dispersed and interfaced in nearly infinite, polymorphous ways" ("Cybord Manifesto", 130). In the 1990s, some began to argue that postmodern identity politics could not be effectively used as a political tool to, for example, argue for better maternity leave, because they were too sharply divorced from the experience of living in a female body (Liepert). Some also argue for reconciliation between feminist critical theory and the empirical sciences (Poovey, ff.).

It is important to note that the Third Wave emerged as a response to the perceived failures and lack of relevance of the Second Wave, and became "reinforced by the popular media which used the term post-feminism – not to describe something that occurred after feminism, but to imply that there was an active rejection of second-wave feminism and its outmoded ideas" (Hannam, ch. 7). The Third Wave rejected both a universal female identity (that over-emphasizes the experiences of upper-middle-class white women), and a single, all-encompassing feminist idea. Instead, it embraced diversity and grassroots activism: "the inclusion of persons of various genders, sexualities, nationalities, and classes [are] a top priority" (Heywood and Drake, 8). It encourages women to define both themselves and feminism for themselves. Third Wave ideology focuses on a more post-structuralist interpretation of gender and sexuality, for example, seeing the male-female binary as artificial and a tool for the creation and enforcement of power. Lastly (for this brief discussion), some feminists do not separate women's issues from human issues, and join in campaigns concerned with environmentalism, anti-capitalism, anti-corporate activities, cultural production, and human rights (Hannam, ch. 7).

Currently, there appears to exist a plurality of feminist approaches, each carrying with it a different perception of what constitutes and creates the ideal world. Liberal feminism is the most mainstream approach to feminism. It focuses on the attainment of social and legal equality for women and men, and views the sexes as, essentially, the same. The characteristics described by Bardzell as the central commitments to feminism "agency, fulfillment, identity and the self, equity, empowerment, diversity, and social justice" ("Feminist HCI") emerge out of the liberal feminist approach. Alternative (non-liberal) feminisms, on the other hand, are cultural, relational or care-focused feminist approaches that stress the non-rational, natural, intuitive, and collective. They place emphasis on, and argue for increased valuing of those characteristics considered traditionally female. The multicultural approach argues that identities are complex and proposes that women do not always share a common experience of the world simply by the fact that they are women.

For Kaplan, the lack of one, "monolithic feminism is a good, if at times uncomfortable, fact", meaning that "feminism is alive and well, and always changing in accord with larger social, historical and political changes" (47).

Some have challenged the usefulness of considering the history of feminism in terms of waves, thus making it reductive of the complexities involved in actual history. Nicholson, for example, argues not only that "the wave metaphor has outlived its usefulness" but that, as a metaphor, it is "historically misleading and not helpful politically" (n.pag.).

Intersecting Feminism(s) with HCI

An understanding of the multi-dimensional nature of feminism is critical, since as argued by Kotamraju, any exploration of Feminist HCI needs to consider the kind of feminist lens being used, given that each approach has a different interpretation of usability and a different approach to engagement with HCI (440).

The author continues, arguing that certain issues appear more distant from the core work of HCI while others, those more closely associated with the work environment and the role of care, more central. Though concerns related to the work place deserve consideration, I would argue against constructing a hierarchy of relevance when discussing potential points of engagement between feminism and HCI, especially in the light that the above-mentioned list appears to reinforce stereotypes around value in work-related activity. HCI-work related to reproductive control, motherhood, domestic labour, and violence deserves equal opportunity and consideration.

Winchester reflects on the implications and consequences of Churchill's assertion that product/technology designers – most often male – design objects with "implicit or explicit assumptions about how products will be used and by whom" (14). Winchester adds that "these males are most often white, most likely are members of a higher socioeconomic status, and to further provoke, identify as heterosexual. Thus … design decisions, while I am sure well intended, will most likely be made through 'planes' aligned and reflective of this characterization – male, white, heterosexual, etc." (15). Though this, in many ways, singular and filtered perspective, has resulted in much design innovation, it cannot be expected to consistently and unquestionably address, reflect, and affect neither the whole of society, nor the vast majority of "other" groups within it. Winchester concludes by echoing Bardzell and Bardzell to consider "matters of aesthetics and enlightenment, social justice and oppression, self-actualization, and wisdom" ("Problems in the Appropriation of Critical Strategies" 2), and engage with the "messiness of the lives of real people – from cradle to grave"(ibid. 19). Critical Design has the potential to act as the lens through which designers consider previously unchallenged perspectives. Popularized by Dunne and Raby, critical design goes beyond "how users interact with the designed product on a day-to-day basis" (Kannabiran and Petersen, n.pag.), instead using "speculative design proposals to challenge narrow assumptions, preconceptions and givens about the role products play in everyday life" (Dunne and Raby, Critical Design FAQ). Design is seen as opportunity for provocation rather than an exercise in "rearranging surface features according to the latest fashion while obfuscating the norms and conventions inscribed in the designs and their use", and design research activity as a way to consider "how technology can improve the current state of human existence" (Bardzell, Bardzell, Forlizzi, Zimmerman, and Antanitis, 288).

Common misconceptions about feminism are that it is entirely concerned with opposing (or resisting) the subjugation of women, or that its primary focus is issues of gender. While questioning gender categories is an important feminist concern, Suchman adds a questioning and examination of other interest categories for feminism, such as subject and object, nature and culture, and people and technology (n.pag.).

Similarly, many definitions of gender exist, and the discussion of gender and its relationship with technology is complex and multidisciplinary. The term sex has, increasingly, been used to describe "the distinction between women and men as a result of their biological, physical and genetic differences" (Esplen and Jolly), while the term gender as "a set of ideas about maleness and femaleness and the shifting boundaries between them" (Lerman et al., 5). However, even these definitions are beginning to undergo scrutiny and critique since they fail to acknowledge the existence and interests of intersex and transgender individuals, transsexual people, and hijras – those who do not fit into the biological or social categories of women and men. Therefore, sex is now also seen as a social and cultural construct not, simply, as a biological destiny. Lerman et al. describe gender as individual: shifting based on identity, expression, and performance; symbolic: a set of meanings attached to actions, things, and people; analytical: for making sense of culture; and relational: capable of shifting and redefinition based on social interaction. They go on to describe technology in similar terms, as a "construction situated firmly in cultural context" (3).

In the last six years, HCI has witnessed a call towards an integration of a feminist agenda into interaction design research and practice (Bardzell, "Feminist HCI"). One reason may be, as noted by Kemp and Squires, that feminist theory is traditionally characterized by its interdisciplinarity: "its transgression of the usual subject divides (e.g. literary, historical, philosophical, psychological, anthropological, and sociological)" (4). In a useful parallel, Blythe et al. call HCI a "magpie discipline" for its tendency of appropriating cognitive psychology, sociology, or engineering methods into its practice (183–184). The authors challenge us to consider perspectives from Critical Theory in our HCI work, in addition to more traditional concerns of usability and efficiency, which they deem "no longer sufficient scopes of inquiry" (183). Muller offers that, in HCI, feminism challenged our notions of scientific accuracy and social justice, helped us to think about how to hear "the voice of the user," and contributed to innovations in qualitative research and analysis (447–449). Muller adds that feminist ideas have helped us to "re-orient our thinking away from an authority-given set of objectives, to a more polyvocal way to describe needs and goals" (448). The term polyvocal refers to the consideration of multiple perspectives while, specifically, adding volume to those diverse voices that are typically silenced. Suchman identifies feminist research in HCI as being "distinguished by the joining of rigorous critique with a commitment to transformative engagement" and considers "how capacities for action are configured at the human-machine interface, informed by developments in feminist science and technology studies " (1).

At the same time, however, HCI work that appears to embody feminist principles, has shown a reluctance to explicitly engage with feminism, or possesses a complex and ambivalent attitude towards issues of gender (it is either considered irrelevant to HCI, its relevance is overlooked, or it is considered with hostility due to the belief that women are lesser creatures) (Bardzell and Churchill, ff.). Rode theorizes that the ignoring of gender may be neither sloppiness on the part of the researchers, nor a failure to take a theoretical stance on the subject. It may, in fact, be an expression of Liberal Feminism and an intentional denial of gender differences. Through the lens of Liberal Feminism, gender does not matter in general, thus should not matter in HCI (Rode, ff.).

In discussing the history of HCI, Harrison et al. describe two major intellectual waves that have formed the field (ff.). While first-wave HCI emerged from engineering and focused on the machine, the second wave stemmed from cognitive science and focused on the user.

During the second-wave, formal methods and systematic testing made way for qualitative approaches (such as participatory design, contextual inquiries, and others) (Bødker 1–2).

Bødker and others have suggested a third-wave for HCI that has, with a few exceptions, moved away from a commitment to users. Bødker proposes that third-wave HCI attempts to consider a more complex view of the human life, including issues of culture, emotion, and life experience. Focus is on the "non-work, non-purposeful, non-rational" (1–2). The role of technology in issues of social justice – health, the environment, international development, and the experiences of marginalized communities – is beginning to be examined (Dimond, 1). Technologies, such as ubiquitous computing, visualization, affective and educational technology; and approaches, such as embodiment, situated meaning, values, and social issues, with prior poor fit in the second-wave, now find home in the third-wave: "all action, interaction, and knowledge is seen as embodied in situated human actors" (Harrison, Tatar and Sengers, 7). Third-wave HCI recognizes that we no longer design single, monolithic systems, but technology that must be seen and used in relation to many other devices, applications, and systems (Bødker 1–2). It also recognizes the complexity of work-life, and that technology, applications, and systems traverse out of home spaces and into work spaces, and vice versa. Considerations of context(s) have become more complex as the ways that we cross-integrate technology into our lives has gained ubiquity. Discussions of emotion in HCI are not new (cf. Norman, Emotional Design) and were present in the second-wave; however, those discussions have expanded to include considerations of social and cultural interactions (Bødker 1–2). Participants are encouraged to engage in the design process (that is not a new approach) as "whole" individuals not just in the singular roles most closely related to the design's objectives. Questions remain about how best to engage with marginalized individuals in the design process, not just those who are easy to access (and who, often, already hold substantial representation in HCI projects.) Considering that topics outside of the workplace (such as emotion and aesthetics) are relatively new in HCI, but have long traditions of scholarship in the humanities and social sciences, Blythe et al.

propose that “a constructive dialogue between critical theory and experience in questions of design and evaluation” (4521) can be of great benefit to HCI.

The work of Jeffrey and Shaowen Bardzell and their colleagues stands out in the area of Liberal Feminist HCI, though in their literature these authors prefer to describe it more simply as Feminist HCI. Bardzell describes her work as “the reflective integration of feminist strategies as a resource for interaction design” (Bardzell, “Feminist HCI” 1301), and proposes four types of contributions that can be made by feminism to HCI: in theory, methodology, user research, and evaluation (Bardzell, “Feminist HCI” 1305). Feminism is proposed as a critical lens through which we can question core concepts, assumptions, and epistemologies of HCI. A Feminist HCI methodology is one that is clearly connected to some aspect of feminist theory. While maintaining a commitment to the epistemic values of traditional science, Feminist HCI would also be guided by moral values. Heterogeneity through transdisciplinary and the use of diverse and mixed-methods is encouraged. When methods are chosen, those choices come with assumptions, commitments, and goals which would be disclosed as part of the methodology; the researcher’s own position in the world is also made transparent. Researchers are focused on building empathic relationships with research participants, and make the effort to understand them and their experiences. Co-construction and collaboration are encouraged, as much as is possible, between researchers and participants. Finally, Bardzell asks researchers to continually self-question “about whether the research is delivering on its ambitions to be feminist, improve human quality of life, and undermine rather than reinforce oppressive social structures, etc.” (“Towards a Feminist HCI Methodology” 682).

Bardzell borrows from the notion of “qualities,” introduced by Löwgren and Stolterman (ff.), in an effort to transform the set of general principles described above, into a set of qualities for feminist interaction design. While she acknowledges that the qualities she proposes are not unique to (most notably third-wave) HCI, she argues that a “constellation of qualities" would characterizes feminist interaction ("Feminist HCI" 1305). The six qualities proposed by Bardzell (and discussed in detail below) are pluralism, participation, advocacy, ecology, embodiment, and self-disclosure.

In feminism, the quality of pluralism investigates and even nurtures the marginal ("Feminist HCI" 1302). Pluralism, as applied to design, would resist any single or universal point of view: "there are many users, many needs, many voices" (Muller 447–449). Efforts have been made in investigating the design of gender-pluralist software and in the ways that men and women engage with technology. By being sensitive to marginal or marginalized users, designers have the opportunity to produce artifacts that are, both, more inclusive (Burnett et al., 450), and more representative of a particular user community. In addition, pluralism recognizes the value of the marginal as a source of design innovation. The opposition to the quality of pluralism in HCI have been the concepts of "Universal Usability" or "Universal Accessibility", and in design the concepts of "universal design" in USA and "inclusive design" in the UK and Europe.

The second quality proposed by Bardzell, participation, warns us about "the problem of speaking for others" (Muller 447–449), and encourages us to actively seek out and listen to the voices we are describing or discussing, especially if those are the individuals who are conventionally silenced. In design, the quality of participation means engaging in participatory processes during the creation and evaluation of design alternatives. It is not an argument against the scientific method (consisting of systematic observation, measurement, and experiment; formulation, testing, and modification of hypothesis) which values replicability, nor of usability testing or other scientific strategies, but a call to complement quantitative approaches with participatory processes.

The quality of advocacy in feminism means supporting or recommending the taking of a position or course of action. This quality is counter to the view that the researchers' role is that of a neutral observer and reporter (Muller 447–449). Feminist design, on the other hand, seeks to not only engage, but also actively initiate social or political change. It also asks designers to continually question their own point of view (lens) and the position(s) they aim to assert in society.

The fourth quality, ecology, connects the exploitation and domination of women with that of the environment. In design, the quality of ecology considers how design artifacts affect (and are affected by) the "world" and the stakeholders within it: the ways that an artifact exists in relationships with other artifacts, and how these relationships determine its meaning. In HCI, there is a rising interest in the concept of ecology (systems theory; and sustainable interaction design). Additional considerations in terms of gender, race, social class, developing countries, etc. are needed (Bardzell, "Feminist HCI", 1307).

The quality of embodiment states that how we understand the world and ourselves is strongly influenced (even constructed) by the various physical and social situations we find ourselves in (Haraway, "Situated Knowledges", ff.). In design, embodiment means that the agency of interaction is focused not on the interface, the technology, or the designer, but on its users. Third-wave HCI proposes that how we "come to understand the world, ourselves, and interaction derives crucially from our location in a physical and social world as embodied actors" (Harrison, Tatar and Sengers, 6). Further to that point would be the recognition that the designer's position in the world is likely to hold, potentially substantial and unacknowledged privilege. Privilege, in this context, refers to the position that some groups benefit from unearned advantages that increase their power relative to that of others, thereby perpetuating social inequality (Twine 8–10).

The sixth quality described by Bardzell is self-disclosure. Bardzell cites the quality as based on the work by Haraway, who calls the scientific "universal, disembodied objectivity" a myth, and advocates that researchers should disclose the perspective they bring to a question, as well as any relevant aspects of their background and identity (Haraway, "Situated Knowledges", ff.). In feminism, an individual's position in the world, goals, and (potentially) political, or other relevant, beliefs need to be disclosed (Bardzell and Bardzell, "Towards a Feminist HCI Methodology", ff.). In addition, a design that considers the quality of self-disclosure renders visible the ways that it affects its users. It calls to attention what the design is trying to make of its user, introduces a critical distance between itself and the user, and creates opportunities for users to define themselves.

Feminism(s) can contribute to HCI through studies that use some part of a feminist lens (after the fact): user research, design critique, or design evaluation emergent out of or incorporating some aspect of feminist theory, methodology, or an updated notion of the "user" that more accurately reflects gender. It can also directly influence design judgments (before and during the fact): an action-based agenda incorporated into all stages of the design process.

Several views opposing Bardzell's work exist. Rode outlines prior treatments of gender in HCI: those that parameterize gender; those that focus on the creation of gender-specific technology; and those that argue that gender is irrelevant (Rode 393–400). She calls for a more direct engagement with gender in HCI, and is concerned with how gender roles are enacted and performed in everyday life. Rode proposes a third contribution, beyond those offered by Bardzell: a socio-technical theory of gender. While the values selected as a point of focus by Bardzell are grounded in Liberal Feminism, Rode lists numerous additional feminist theories as potential contributors to HCI: Technology as Masculine Culture; Gender Positionality; Lived Body Experience; Radical Feminism; Marxist and Socialist Feminism; Psychoanalytic Feminism; Multicultural, Global, and Postcolonial Feminism; Ecofeminism; and Postmodern and Third Wave Feminism, in an effort to overturn present assumptions and treatment of gender in HCI.

A noteworthy question has also been raised by Burnett: while Bardzell and colleagues suggest that a constellation of qualities will characterize Feminist HCI, they do not address how large a constellation would need to be in order to qualify for that label (1–4). A too narrow set of criteria (one that, for example, requires all six qualities to be present) may exclude work that has a pertinent and worthwhile contribution; while a too broad application may result in the dilution and invalidation of the field. For example, if a project labels itself as Feminist HCI because it has incorporated the quality of pluralism – design that resists "any single, totalizing, or universal point of view" – it could, potentially, be considered as aligning with certain "feminist" principles. Considering gender differences in software usage clearly reflects some important aspects of feminist practice; however, "taking into account gender differences in software usage so as to be inclusive of women as well as men" may be, in fact, replacing one limiting view of gender with another (that of the singular user with that of a binary), neither of which is, in fact, truly sensitive to marginalized communities (Burnett 1–4). Therefore the question of how many Feminist HCI qualities are needed to form a constellation, remains.

Intersecting Feminist HCI with Critical Theory[8]

Efforts continue towards improving our understanding of the relationships between gender and technology; and how gender is impacted by and affects technology, its use, and its design (and vice versa). Work also continues in exploring how feminism(s) can support legitimate and intellectually rigorous creative activity and novel problem solving. In support of the work that has been done to date in Feminist HCI, as well as Rode's critique of said efforts, I propose that there is now room in Feminist HCI to do bolder work. Obrist and Fuchs, for example, advocate for HCI's engagement with critical theory, specifically for a more dialectical thinking in HCI, where we view technology as having "multiple, contradictory effects on society" and society as having "multiple, contradictory effects on technology" (Obrist and Fuchs). Therefore, new interaction technologies can equally have

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8 Intersectionality is a term coined by Kimberle Crenshaw. It is a "prism from which to view a range of social problems to better ensure inclusiveness of remedies, and to identify opportunities for greater collaboration between and across social movements" (Crenshaw).

negative as positive consequences on society, and those consequences need to be considered by designers. Furthermore, Obrist and Fuchs propose that interaction design is, in fact, the design of society and should, therefore, consider societal structures (economic, political, and cultural) that shape and are shaped by technology. The authors intersect technology with societal structures, proposing a set of societal and individual design principles. Societal principles include ecological preservation, human-centered technology, economic equity, political freedom, and cultural wisdom. Social design principles include openness, participatory decision-making and community-formation, while individual design principles, proposed by Obrist and Fuchs, include efficiency, freedom of involvement, and mental user capacities.

Adding to this argument is Martin's position that critical and feminist theory, though having developed independently and with little intellectual exchange, differ in terms of emphasis not in terms of commonalities, which are many and important (3). Martin concludes that critical theorists and feminist theorists should work together on problems of change, turning "away from seeking society-wide transformation, to focus on a critique of the status quo", towards "effectively, ... reduc[ing] or eradicat[ing] those inequalities" (33). This view aligns well with the notion of Critical Design, as it challenges designers to use a critical theory based approach to reflect and critique existing cultural values, mores, and practices (Bardzell, Bardzell, Forlizzi, Zimmerman, and Antanitis, 288).

What kind of space is co-created by the intersection of feminism(s) and Critical Design? What does feminist design thinking, critical design making and critical design evaluation (that are also feminist) look like? Simply applying a constellation of feminism(s)-emergent principles to design does not guarantee a design that challenges the established status quo, or that engages critically with economic, political, and cultural issues. The need for HCI design and development that is iterative – involving steady refinement of the design based on user testing and other evaluation methods – has long been recognized (Bury, 743–748;

Buxton and Shneiderman, 72–81; Gould and Lewis 300–311). As Nielsen so aptly put it, "[e]ven the best usability experts cannot design perfect user interfaces in a single attempt, so a usability engineering lifecycle should be built around the concept of iteration" (Nielsen 32–41). Though the idea of a perfect user interface is problematic if we consider HCI design as wicked problem, if we agree in spirit with Nielsen's statement, we can consider iteratively applying rigorous interpretive analysis throughout the HCI design process, thus providing systemic, concrete, and evidence-based discussions of what is present (and what is absent) within a given design. One way to interpret Rockwell's point: we will "learn not by thinking in isolation but by building and looking and rebuilding and looking again" (Rockwell, 7), is to consider no design, no artefact, and no approach whole beyond the exact moment in which it is made. Another, is to consider it never whole – each instance existing within an ever present process of re-creation as various constraints allow.

Chapter 4: A Case for Critical Design in Practice

> "When designers replaced the command line interface with the graphical user interface, billions of people who are not programmers could make use of the computer technology."
>
> Howard Rheingold (qtd. in Kosner)

If we agree, for a moment, with Cockton et al., Martin, Bardzell et al. and others that Critical Theory, Critical Design, and Feminist HCI are valuable for design and make design more valuable, then how can these theories translate into an approach (or, more likely, a set of approaches) that is useful to design? What does Critical Design or Feminist HCI *thinking* look like? How do we *do* it? How do we *evaluate* our efforts?

Through Chapter 4 I focus on, first, the *making* and, second, the *thinking* aspects of Critical Design. The chapter is subdivided into three major sections. I begin by discussing Critical Design through five type of existing practice: Agonism, Design Fiction, Speculative Design, Slow Design, and Satirical Design. I continue by describing past work on Critical Design frameworks, with a focus on design criticism and rigorous critique. In the third section I attempt to contribute to the call put out by Bardzell et al. in the form of a new framework for critical action design, with six corresponding parts: Challenges existing practices; Aims towards an actionable ideal future; Looks for what has been made invisible or under represented; Considers the micro, meso and macro; Privileges transparency and accountability; and Includes, expects, and welcomes being subjected to rigorous critique.

Bardzell et al. note four primary difficulties in making the fit between design and Critical Theory. First, "Critical Theory offers little insight about how to make things…while design is an embodied making tradition, where both processes and outcomes happen with and through design materials" (Bardzell, Bardzell, Forlizzi, Zimmerman and Antanitis, 290). I agree that design's primary focus has been on various parts of the design process: questions such as how do we define a problem; how do we engage stakeholders or co-create with community members; how do we evaluate our ideas, concepts, and prototypes, are typical in design research and practice. As I will attempt to argue later on in this chapter, however, Critical Theory can serve as a useful model for how we can think about the things we are making and the things that have been made. Additionally, in design the creation of an artefact can be, in of itself, a way to formulate an argument about designing similar artefacts. This idea, proposed by Galey and Ruecker, is based on what they see as theoretical affinities between design and book history scholarship, experimental interface design sharing much in common with the emerging practice of peer-reviewing digital objects in scholarly contexts (ff.). Both design and book history engage in interpretation and in making and both, according to Galey and Ruecker, "can contribute to a theoretical framework for new questions facing humanists" (406). In short, critical theory may not tell us how to make new objects, but it has much to offer in terms of thinking about what has been made. Similar to the work by Galey and Ruecker, Bardzell argues that a design can function as a form of research. He builds on work in aesthetic cognitivism, and asserts that design, in its ability to tell us something about reality, contributes to human knowledge ("Design as Inquiry"). I fully support Galey's, Ruecker's, and Bardzell's positions, and welcome the opportunity to interrogate designed artefacts at their macro, meta, and micro levels. Such interrogation of an artefact would consider its existence as both a collection of multiple, designed parts, and a totality that is something far more complex than the additive nature of its individual components. It would also consider the inherently context-dependent nature of design.

The second challenge in fitting design and Critical Theory, according to Bardzell et al., is that Critical Theory tends to be anti-method, and considered elitist and obscure. A similar line of criticism has been offered to Agonism, Design Fiction, and Speculative Design. I would argue that CT's "tendency to resist stating explicitly its own processes" ("Critical Design and Critical Theory", 290), while going against some design ideals – such as methodological democratization and user engagement – is only an issue if we think of approaches that may emerge out of CT as a *replacement* to those that have been appropriated by design from the social sciences. I can not imagine that ever being the case, and have not seen any arguments for it. Contributions by CT can be additive and enriching to existing design methods. Additionally, as anyone who has attempted to engage an unfamiliar discipline would be likely to attest, there is a great challenge in learning its customs and language. This does not mean it is not a worthwhile activity.

Third, Critical Theory emphasizes the affect of cultural artifacts on the world,[9] once they have been released into it, while design is looking for methods that engage with the process of creation: "the work of a designer is done before the critic typically gets started" (Bardzell, Bardzell, Forlizzi, Zimmerman and Antanitis, 290). Part of my objective for this chapter is to argue that design needs more engagement with already-existing artefacts in the form of responsibility-taking through transparency and ongoing, post-release criticism.[10] What happens to the designs we are responsible (at least in part) for bringing into this world, once they have entered it? What are their impacts and consequences on human physical, mental, and emotional existence, on history, on culture, or on the environment? While Sless, through the Communications Research Institute of Australia, developed a six-part re-design process for health information that included scoping, benchmarking (as steps one and two) and monitoring (as the final step in the process), designers continue to primarily engage in

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[9] In this chapter I use the term *world* to mean the relevant environment (physical, emotional, cultural, and social).

[10] See more on this in the second half of this Chapter.

evaluation either during the design process or as the first step of a re-design (Sless). What about all the other times that a design exists in the world? By eschewing it from evaluation or ongoing criticism, are we (1) assuming it is only capable of positive impact on the world, hence we do not worry about it until a negative impact comes to light; or (2) assuming it has no impact on the world at all, which places a very low opinion on the potential influence of design.

Finally, according to Bardzell et al., Critical Theory generally rejects the creative intention of the author, while design places much focus on the designer's intention (Bardzell, Bardzell, Forlizzi, Zimmerman and Antanitis, 290). During the design process there is much effort to align a designer's intent with the outcome of users' interpretation or action; however, once the artefact makes its appearance in the world, the designer's intent becomes completely detached from the artefact's interpretative use. An extreme example of this process of detachment is the *Upcycle Movement*. Upcycling is turning an artefact that is no longer in use into something else, with some new function. The re-made artefact is meant to be "more functional, valuable, and beautiful than what it previously was" (Karsten and Rom). Some upcycles become functional objects and some become art objects. Example include old tires turned into flip flops' outsoles (GomaVial Solutions), old rotary phones turned into doorbells (Pipitone), and old vinyl banners turned into bags (Karsten and Rom). The repurposed object gains a new designedly intent; however, once it reenters the world in its new form it becomes, once again, detached from the designer. Those flip flops mentioned earlier can be a complex socio-political statement against tire yards or, simply, cheap footwear.

While there is much excitement in re-imagining Critical Theory in terms that may be useful to design, Cockton et al. argue that we must be wary of any attempts at feeble borrowing of (as opposed to a deep dive into) methods and approaches emergent out of the humanities, particularly those from philosophy and the history of ideas (3163–3166). Any such efforts must also demonstrate genuine engagement with the humanities by evaluating any subsequent work according to their unique and appropriate methodological and theoretical standards, and not those that have become customary within our own disciplines. An additional problem of adoption or thoughtful appropriation, is that the language used to discuss Critical Theory (Bardzell and Bardzell, "Problems in the appropriation of critical strategies in HCI", n.pag.) fails to bridge the disciplinary gap between Critical Theory and design, thus doing little (so far) to help designers imagine what a re-appropriation of critical tools by design would look like. Given that there is little understanding in the design community of Critical Theory (Bardzell and Bardzell, "Problems in the appropriation of critical strategies in HCI", n.pag.), more effort will be needed in bridging vocabulary and scaffolding foundational knowledge.

There is also a strong argument for Critical Design as an appropriate and useful fit for contemporary HCI research. Currently, its uptake by designers has been limited, and there is ongoing argument as to the ways it can be most beneficial, not only as theory but approach. Part of the problem, it has been argued, is lack of clarity, examples, and directions that would enable someone new to the field to hit the ground running. Another challenge lies in the fact that the definition of critical design is still (understandably) under way, as is the discussion of what is the "critical" in Critical Design. Bardzell et al. also propose that the main challenge for more mainstream adoption of CD is the existing perception of it as only a concept or theory, or the domain of agitators and gallery-designers. The authors suggest building a loose framework "that can help design researchers select and sequence methods that support the specific question, issue, or phenomena at the focus of their inquiry" instead of pushing for formal methodologies, similar to those common in the sciences (Bardzell et al., "Critical Design and Critical Theory", 289). Given all these challenges, Sterling and others continue to argue towards a diverse and enthusiastic embrace of Critical Design by the design community:

> Nobody is ever going to crisply buy a kilogram of "critical design." It's precarious – but that problem is far from unique to "critical design" as a modern practice. It will shake out somehow, because the sun is shining and the topsoil is fertile. We may not see many golden, corporate GMO crops, but we're about to see a whole lot of weeds (Sterling).

Critical Design can serve as an approach on three fronts: critical design thinking, critical design making, and critical design evaluation (Bardzell, "Interaction Criticism", ff.). Critical design thinking would act as a mode of inquiry into designed artifacts as they currently exist, and the ways in which they affect the world they occupy. HCI in particular would benefit from a practice of interaction criticism: "rigorous interpretive analysis that explicates how elements of the interface, through their relationships to each other, produce certain meanings, affects, moods, and intuitions in the people that interact with them" (ibid. 2). The required rigour would offer systemic, evidence-based analyses of what is *present* and what is absent within the design. Though designers tend to already practice criticism (I would call it critique and point out that it is taught in many if not all design curricula) it may lack the kind of rigour and consistency that can be subjected to discussion and review. Additionally, designers' and design researchers' judgments are often hidden from view, once again making it difficult to subject such judgements to rigorous inquiry (ibid. 2). Critical essays have been cited as one, specific, example of a method for critical design thinking, with a particular form of the critical essay – epistemological analysis – used to study and evaluate what has been said, what was not said, and what may need to be rethought in published HCI research (Bardzell, Bardzell, DiSalvo, Gaver, and Sengers, 1136).

Critical Design Making

Critical Design practice shares space – vocabulary and ideology – with several other movements: Agonism, Design Fiction, Speculative Design, and Slow Design. In fact there is some debate whether critical design should be used as an umbrella term for all these movements, with each becoming a manifestation of it, or where their differences are significant enough to warrant their own, unique title.

Agonism

DiSalvo provides a valuable discussion regarding the cultural production – the conceptualization and making of products and services – aspects of critical design. Agonism (adversarial design or tactical media) uses designedly means and forms to "evoke and engage political issues" (DiSalvo, 2). These practices do not limit themselves to the profession of design, often engaging art, engineering, and computer science. He argues that we need another way to talk about those manifestations of design that are about political expression and action, and proposes agonism as the means through which we can make sense of and engage in these types of projects. DiSalvo distinguishes agonism as political design from design for politics. Where design for politics works, most often, to improve access to politically or socially-related information or access to political action and expression, political design is inherently contestational and strives to investigate and raise questions about an issue.

The Million Dollar Blocks project, for example, asks the question "Where does the prison population come from?", with the answer resulting in a series of maps of four American cities that depict the distribution of home residences of prison inmates (see Fig. 4.01). This project is a political design activity since, through its exploration, we learn that certain single city blocks are costing the U.S. government over a million dollars a year in incarceration fees of their residents (Kurgan and Cadora). What is particularly compelling about *Million Dollar Blocks* is its potential impact on the world: since it provides access to real, relevant, and pertinent data, it could be used for exploration, hypothesis formulation, and decision making.

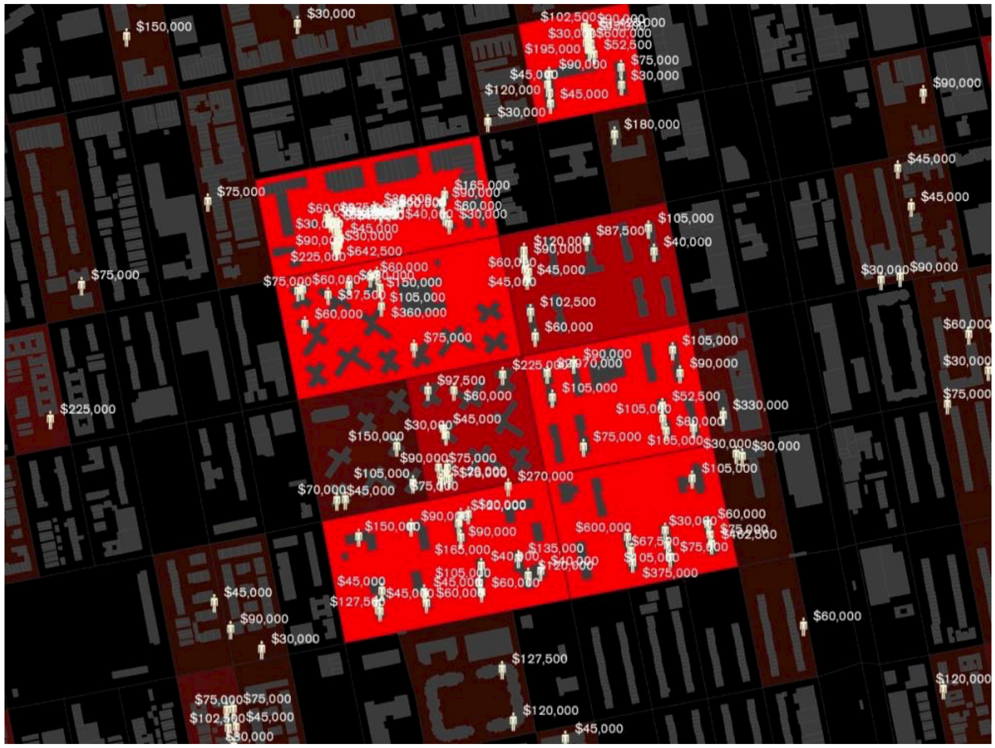

Fig. 4.01: *Million Dollar Blocks* by the Spatial Information Design Lab and the Justice Mapping Center (Kurgan and Cadora).

Design Fiction

In his *Hertzian Tales,* Dunne presents five projects as "material tales" for provoking questioning and stimulating discussion about design's complicated relationship to people and their mental lives (similar to those offered by some film and fiction writing). He explores ways to present conceptual yet realistic technological design as investigation and process rather than production-ready prototypes. Each tale provides us with opportunities for reflection on the different forms of realism: technological, functional, social, and psychological. All five projects centre around a common theme: a re-imagining of the radio and its associated technology, and it is time well spent to reflect on each one (xvii).

For the sake of this document, I will describe only one: the *Faraday Chair* (see Fig. 4.02). Dunne and Raby re-imagine a conventional chair, typically offering support and some degree of physical comfort, into an object also offering psychological comfort and respite. The chair has been turned into a tank, large enough to allow a person to lie inside it in a fetal position. Encased within this transparent, womb-like structure, the person becomes protected from the magnetic fields and electrical currents emitted by everyday appliances, and the effects these may have upon her. The *Faraday Chair* is proposed as a retreat; however, it is also restrictive, like a sarcophagus, intentionally conjuring both positive and negative aspects of shelter and prison. This is an object open to interpretation, inviting emotional engagement with potential for strong argument. It raises questions about security, solitude, and the purpose and function of furniture. Its transparency and mobility-restrictions place its inhabitants on display – person becomes exhibit object – creating an uncomfortable interplay between the private and the public (*Hertzian Tales,* 144).

Fig. 4.02: Dunne & Raby, *Hertzian Tales, Faraday Chair,* 1997–98 (Hammoud).

These design objects are meant to be viewed within controlled exhibit spaces. Gallery patrons tend to engage with gallery exhibits in particular ways: to consider the potential complexity of displayed artefacts; to be challenged by them; for them to exist for their own sake, rather than in functional, accountable service. Such tightly controlled exhibition acts as both a benefit and a limitation. Gallery patrons may be more likely to engage critically with these objects; however, the objects' scope of influence is limited to those who frequent gallery spaces.

What is particularly fascinating about the *Faraday Chair* is that it has a consumer-based counterpart in the Floatation (also called Isolation) Tank: a small, light and sound proof enclosure, partially filled with salt water (see Fig. 4.03 as example). Developed by John C. Lilly in 1954, floatation tanks are now used for meditation and relaxation. Users float with their face above the water. Sensory stimulation is reduced through a complete lack of light and sound. Skin sensation is reduced since the air and water are set to the user's skin-temperature. The goal of the tank is to produce a feeling of weightlessness and the disappearance of boundary between the self and its physical environment (Gonzalez).

Fig. 4.03: Float Tank (Mark van Manen).

The difference between the Faraday Chair and the Floatation Tank appears to be primarily contextual. In the case of the chair, the user is placed on public display in an environment primed for critical engagement. In the case of the floatation tank the user occupies a much more private space for the purpose of self care. Even though the use of the tank is far more intimate since users are nude and deprived of most if not all sensory experiences, the users of the chair occupy a much more vulnerable space. Here we have two objects, both designed for isolation and protection, with the primary difference in their meaning resting in the object's availability for critical engagement. The floatation tank could, in a different context, become a statement on the Western over-scheduled, over-worked, and over-stressed lifestyle.

Speculative Design

Design Fiction closely overlaps with Speculative Design, with some notable differences. Design Fiction places strong emphasis on technological futures, with Sterling defining it as artefacts of the future (Bosch and Sterling), and Johnson as “sci-fi prototyping” (n.pag.). Thus, Design Fiction asks us to suspend our disbelief about some aspect of our technological future. It tends towards the positive, celebrating rather than critiquing technological progress. In contrast, Speculative Design, according to Dunne and Raby, tends towards darker visions of our futures (Bosch and Sterling). It is often “glitchy, strange, and disruptive, and hint[s] at other places, times, and values” (*Speculative Everything,* 100). Speculative Design steps away from the pressures of the marketplace (arguably also present in social and humanitarian design) into design that privileges the construction of novel ideas (*Speculative Everything,* 11).

The *Communo-Nuclearist Train* is one part experiment from the *United Micro Kingdoms* project, commissioned by the Design Museum in London. The entire project speculates on a possible fictional future for the UK. The train, for example, exists as one of four self-contained and self-governed counties, each with a unique set of structural benefits and downsides. The Communo-nuclearist society has a limited population and controls growth through a one in and one out policy (see Fig. 4.04). Its citizens use nuclear power to harness near limitless energy, and all their needs are satisfied by the state. At the same time, no one wants to live near them, and they live under the constant threat of attack or accident. They are heavily isolated and tightly contained.

Fig. 4.04: Dunne & Raby, Communo-Nuclearist Train, 2013 (Dunne and Raby, *United Micro Kingdoms*).

Each society in the *United Micro Kingdoms* project is a laboratory that attempts to provide us with the opportunity to question the ways that future technology may influence the way we live. We are meant to be challenged with questions about potential cultural and ethical impacts. In some respects, the train is a way for us to experiment with future decisions we may have to make. Through it, we can imagine and interrogate possible technological scenarios then contemplate, more preferable, alternatives.

Slow Design

Slow Design is a fairly recent movement that aims to address positive behavioural change (see Fuad-Luke; Strauss; Mojoli; Manzini et al.).[11] Developed by Fuad-Luke on the concept and principles found in the Slow Movement, Slow Design aims to slow down the metabolism of people, resources, and flows, proposing an approach to design that integrates material and social functions, and considers design's short and long-term impacts of design. Designers

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11 See, for example, Alastair Fuad-Luke, "Slow Design" (*Design Dictionary: Perspectives on Design Terminology*. Basel, CH: Birkhäuser, 2008, 361–363); Carolyn Strauss and Alastair Fuad-Luke, "The Slow Design Principles: A New Interrogative and Reflexive Tool for Design Research and Practice" (*slowLab*. slowLab Inc., n.d.); Ezio Manzini and Anna Meroni, "The Slow Model: A Strategic Design

are encouraged to accept the idea that time is infinite, thus the potential for their influence, within their thinking system (Strauss and Fuad-Luke).

Fuad-Luke proposed six Principles of Slow Design: reveal, expand, reflect, engage, participate, and evolve (ff.). *Reveal* considers the missed or forgotten aspects of every day experience, including an artefact's materials and process of creation. For example, Lohmann's work explores a product's origins and reimagines their use: sheep stomachs become lights, seaweed becomes a replacement for plastics and leather (see Fig. 4.05) ("Design Resident: Julia Lohmann").

Fig. 4.05: *Ruminant Bloom* (2004). Lights made of preserved cow stomachs (Lohmann).

Expand reminds us that objects have both real and possible expressions beyond their immediate or intended functionalities, affordances, and lifespans. In this way, the expand principle is similar to the Upcycle Movement described earlier; however, its manifestations have also included explorations of intimacy and how we live with our objects.[12]

[12] See, for example, Monika Hoinkis' work at http://www.livingwiththings.org/03-5.html.

Reflective consumption aims to induce intentional contemplation of an artefact's attributes and presence, including ideas of preciousness and instability. In this way, reflect is intently personal. Engage, however, is focused on the open-source and collaborative. Similarly, participate encourages us to actively and communally engage in the design process. Finally, evolve asks designers to look beyond today's needs and circumstances.

For example, the *Slow Ways of Knowing* project uses an urban design tool to "capture local knowledge and public imaginings about the evolving identity of the neighborhood or surrounding area". Community members are encouraged to participate by sharing their thoughts, memories, drawings, and fantasies (Strauss and Fuad-Luke). Such a project has the potential to consider not just the physical and quantitative aspects of urban planning, but also the qualitative experience of its community with, hopefully, an increase in visibility for the community's uniqueness and the diversity of its members.

Satirical Design

Some designers are using satire to challenge their own profession: practice, artefacts, and roles within consumer society. Whether these are conscious manifestations of critical design or more simply attempts at making fun of design's role in capitalist and consumerist culture, the end results provoke a much needed critique of contemporary design practice and a community that tends to take itself very seriously even when co-creating frivolous and disposable artefacts. The fake advertisements produced by Adbusters are an early example of satirical design, spoofing political candidates, products, and corporations (see Fig. 4.06) (MacLeod; Adbusters, "Spoof Ads").

Fig. 4.06: An example of an Adbusters' subvertisement – Absolut Impotence (IOGT-NTO).

The *Droog Design* collective aims to 'do normal' design while critically investigating what they are doing and why they are doing it. Droog's emphasis is on proposing products that, while challenging, could be marketed and sold. For example, the *Do Hit Chair* by Marijn van der Poll, available in the Droog shop for € 7,930.00, is a hammer and a metal box. Upon purchase, you use the hammer and your own resources to shape the box into whatever you want it to be, thus becoming the product's co-designer (see Fig. 4.07). [13]

[13] Marijn van der Poll. "Do Hit Chair." *Droog Design* <http://www.droog.com/webshop/furniture/do-hit-chair---hit-by-van-der-poll/>

Fig. 4.07: Do Hit Chair (van der Poll).

Human Beans aims to challenge assumptions around healthy living and the roles of assistive technology by hacking existing products, then re-imagining them in new, more provocative ways: “Zapparolla” is a stun gun mobile phone; “Mr Germy” (see Fig. 4.08) is a bacteria-infused chewing toy to boost infants’ immune systems; and “U” is a simulation PC game where you clone and change your life (Charbonnel and Vanstone).

Fig. 4.08: Mr. Germy (Charbonnel and Vanstone).

What is particularly interesting about satirical design – its digestabilibty – is also its potential biggest downside. While it does appear to make visible a critique of the outcomes of design and their affects on the world, they do not appear to contribute much depth in terms of critical discourse. They are, for the most part, one liners: clever and memorable but more likely to end up on a t-shirt than to incite meaningful change.

Critical Design Thinking

Though Critical Design processes are still under-represented in design literature, some worthwhile work in approaches for critical design engagement and in frameworks for design criticism has taken place. Bardzell and colleagues have attempted to use Critical Design "to provoke, disrupt, or transgress existing social and cultural norms", while at the same time providing a useful reflection on the effectiveness of their particular approach. One of their projects, the *Significant Screwdriver,* used Critical Design to explore the gendered nature of spaces with a goal to, more effectively, imagine how design can intervene in the form of forced reflection or decision making regarding gender roles in such spaces (Bardzell et al., 288). Researchers created a stereotypically-masculine power tool, with an additional function for expressing intimacy that is stereotypically feminine. The masculine-feminine conflict was aimed at provoking a reaction in the tool's users that would help future tool designers better understand the role played by design in establishing or reinforcing gendered divisions of domestic labor. This work sheds some interesting light on challenges in transforming a theory into an "object in the world" and in engaging users in the critical design process. For example, the *Significant Screwdriver* did not garner expected reactions from study participants. They tended to focus on the product rather than the provocative nature of its concept (Bardzell et al., 288). Additionally, during the course of the study, participants became more and more engaged with the study design itself, not just with their own participation. Bardzell et al. reflect that perhaps in a critical design study, "not only does the research destabilize the topics of inquiry, but it also destabilizes the relationship between researchers and research participants. The whole study seems open to negotiation." Study participants were empowered and researchers disempowered – destabilizing the power dynamic – with the project becoming much more feminist (Bardzell et al., 288).

Bowen uses critical reflection as part of a human-centred design process to engage participants in imagining future possibilities. Critical artefacts become "creative probes to explore novel problem contexts" (Bowen 11–13). He describes one project where participants are asked to consider new ways of using digital photograph collections. The *Forget Me Not Frame* has a lever that descends over time and needs user intervention to prevent the photograph from disappearing. This prototype prompted participants to reflect, first, on the concept of "wiping someone out [as] horrible", then on the effects of changing family structures, and the consequences of photo editing on memory keeping (Chamberlain and Bowen, 8). The *Forget Me Not Frame* inspires further questions regarding emotional attachment and the role it does or does not play in inspiring – repetitious – action. Is the familiar, positively-associated representation an incentive? Does the incentive ever run out? These kinds of questions are significant when we consider the meaningful representation of objects, as further discussed in Chapter 6 of this dissertation.

Frameworks for Design Criticism

In contrast to the provocation intended by the *Significant Screwdriver* and the *Forget Me Not Frame,* frameworks developed by Bertelsen & Pold, Löwgren and Stolterman, and Bardzell aim to generate insight and reflection, not to validate or prove claims. Rather than strategies for better design such as those developed to evaluate the effectiveness of a menu system, for example, these frameworks are attempts at supporting more critical understanding of HCI (Bardzell and Bardzell, "Interaction Criticism", n.pag.).

Bertelsen & Pold offer an 8-part framework for the study of the aesthetic quality of interfaces (Bertelsen and Pold). The first part of their framework looks at the stylistic references that appear to be present in the interface, for example whether the interface borrows from the visual language of Mac OS or Microsoft Windows; renaissance or baroque. The second part looks at what standards are being used and whether the visual design conforms to any pre-existing graphical tradition. The third part of the framework considers the materiality of the interface and how it draws on the materiality of other, non digital, media. Similar to the concept of literary traditions that set certain expectations in readers selecting a "novel" versus a "biography", interface design will tend to reflect one of several possible genres that, once stated, govern user expectations. Games will tend to have a different visual appearance (and functionality) than banking web sites, for example. The fifth dimension – Hybridity – considers the functional versus cultural dimensions of an interface (how much of each is present). *Representations* aims to identify different graphical techniques that have been used, then analyze how they work (e.g. realistic and naturalistic representations vs. symbolic and allegorical representations). The seventh and eighth parts of the framework look at whether the design challenges user expectations and if it has the potential for expansion and for supporting unanticipated use. Bertelsen & Pold's work is important because it argues for the value of aesthetic analysis for their own sake, independent of their service to functionality. They separate "statements of measure or quantity" from "statements of value or quality", then consider aesthetics as important to the overall quality of the interface object. Further work in the area of frameworks for discussing aesthetics, however, is needed. What is unclear in the current Bertelsen & Pold framework is how it can be used to evaluate instead of simply describing and how is *good* determined? For example, when an interface has a clear stylistic reference, is that good in of itself? Or, does the critic propose an argument where the appropriateness of the stylistic reference is challenged against the interface's purpose, content, or user group? A critical engagement with aesthetics requires a questioning aspect that goes beyond *What is present?* and into *What* *it 'does'?* and *How well it appears to be executed?* Any aesthetic analysis needs to clarify "relationships among elements of an interface and the meanings, affects, moods, and intuitions they produce in the people that interact with them" (Bardzell and Bardzell, "Interaction Criticism", n.pag.) with the goal the creation of a "generation of innovative design insights" (Bardzell and Bardzell, "Interaction Criticism", n.pag.).

The focus of work by Löwgren and Stolterman is on original thinking in design. They propose four strategies for better design practice – strategies that are meant to increase creativity by "liberat[ing] the designer from preconceived notions" (8). Their strategy combines increased awareness and sensibility regarding what is present in a design and the processes that were engaged in achieving it, with a more robust technical analytic vocabulary, reflective thinking, and retrospective reflection. The authors draw on Donald Schön's reflective practitioner, and argue that designers have a responsibility for the functional, ethical, and aesthetic qualities of design (8). Thus, they attempt to address the knowledge that is required of an interaction designer in terms of design process, interaction methods and techniques, and the conditions for design. Design knowledge is created, then articulated so it can be shared, debated, challenged, extended, rejected, and used.

Bardzells' work on a four-part interaction criticism framework aims at addressing general level critical concerns in HCI: Interaction Designer as Creator, Interface as Cultural Artifact, User as Reader/Viewer, and the Social Context of HCI. The author's goal is to bridge and, hopefully, enable cross-pollination of "two hitherto separated discourses – HCI (including psychology and engineering) and criticism (including design and the liberal arts)" (Bardzell and Bardzell, "Interaction Criticism", n.pag.). This framework is still in its infancy (a point admitted to by Bardzell), and serves well for reflection on a set of concern categories in the development of future frameworks for interaction criticism, not as a set of actionable points for the reading of current interfaces. *Interaction Designer as Creator* speaks to the problem of authorship and the role of the designer's intent in the subsequent interpretation of her work. Bardzell argues that HCI, at least, has embraced the "death of the author" (Barthes ff); with few, notable, exceptions the user matters more than the designer, with the designer's hand often said to be best when invisible.[14] The author appears to support this view, privileging the meaning-giving onto the user-reader. It is unclear whether he supports Löwgren and Stolterman's position that designers should cultivate skills for self-criticism and self-reflection (a framework that speaks to a designer's process). Most designed artefacts do not come with artist's statements, but must stand on their own, open (and functional under) a multitude of interpretations. Thus, Bardzell argues for that very position: interfaces won't have a single meaning, but the potential for many, equally-valid interpretations by their user-readers. Furthermore, in interaction design, the reading is in fact an event that is constructed by user-readers over time. HCI as performance challenges the widely-accepted notion that user interpretation is a "problem whose solution is typically either for designers to do a better job of anticipating user mental models, or for users to change their mental models to accommodate the system" (Bardzell and Bardzell, "Interaction Criticism", n.pag.). In contrast, use becomes meaning-making, with user in the role of creator.

As discussed previous, however, the challenge remains as to whether those who do not have training in aesthetics and critical traditions can engage in interaction criticism – how does one become a good reader – and what kind of criticism will emerge when such training is not present. Additionally, and perhaps more importantly, even in interpretative approaches that accept the existence of varied, even contradicting interpretation, any such discussion is still expected to be evidence-based.

In the *Interface as Cultural Artifact* part of his framework, Bardzell argues for our engagement with three text-based theories as we explore meaning and signification, form and content, and texts (interactive objects) as part of a tradition: formalism, semiotics, and

[14] One exception would be the god-like status given to Apple's Design Chief, Jonathan Ive.

intertextuality (n.pag.). Finally, through the *Social Context of HCI* category, we are meant to question how users' participation in interactive technology, and the social networks it helps them co-create, shapes their activities, interpretations, and relations with other people. The author points to several, emerging theories that may help us explore this issue.

Bertelsen & Pold acknowledge the inherent difficulty in performing the kind of criticism proposed through their framework without foundational knowledge in aesthetics and critical traditions. Thus, their framework can only be used by those with a very particular kind of training. That in itself is not necessarily a weakness: insights into the aesthetic, emotional, intellectual, and sensual qualities of an artifact, provided by those who are capable of speaking thoughtfully and rigorously about design and have the appropriate background(s) and vocabulary, are desperately needed. Much work would be needed to modify these frameworks for use by those without critical or aesthetics backgrounds. Additionally, Bertelsen & Pold suggest future work into addressing relations between aesthetics and the temporal dynamics of the interface since, currently, the framework appears to treat an interface as a collection of individual, independent screens, and not to deal with the connectivity, fluidity, and morphability of its parts. All of these frameworks offer critical strategies for designers to use when critiquing interactions, while each appears to have its own point of focus and particular blind spots: Bertelsen & Pold focus on the nature of the artifact, and Löwgren and Stolterman are the most designer and process focused.

Sengers et al. propose a systematic approach of critical reflection to help identify "unconscious assumptions in HCI that might result in negative impacts on our quality of life" (49). The authors ground their perspectives on reflection in the Western tradition of critical theory and on a foundation of participatory design, value-sensitive design, ludic design, critical design, critical technical practice, and reflection-in-action. Out of these foundations emerge the following principles for use by a designer to engage in critical reflection. First, reflection as a tool to uncover the unconscious values and assumptions of their practice as a whole; to centralize what is typically marginalized by HCI; and to stimulate further debate on the activities and values that should be supported by HCI. Second, reflection as a tool to understand the designer's own values and judgements. Third, reflection as a tool to support users in reflecting on their own lives. Fourth, reflection as a tool to encourage skepticism about technology and the role it plays in our lives. Fifth, Sengers et al. argue for reflection as part of a holistic experience – a tool in action. Finally, reflection as a dialogue, a collaboration through conversation between designer and users, with the possibility of an iterative improvement on the reflective process. The framework for critical reflection provided by Sengers et al. is particularly powerful because they have also articulated several strategies for practicing reflective design – a list they acknowledge will continue to grow. Their list is multi-spectral in their consideration of all agents of the design process as unique and as fallible: the designer as practitioner, the designer as individual, the technology, users as individuals, and users and designers as collaborators.

On Reflection

In considering – reflecting on – the work of Sengers et al., it struck me that reflection, critical or otherwise, is multi-dimensional and provides a challenge to critical interpretation. For example, what does it mean to use reflection "to understand the limitations of the field as a whole?" How do we reach an understanding of the "values and experiences [we are] bringing to the table"? What do we do once we have gained such understanding?

Much valuable work has taken place on reflection, particularly in pedagogy. Schön defined the notion of reflection-in-action by differentiating tacit from explicit knowledge. Reflection is used as a way to turn explicit knowledge into tacit knowledge. Learning is seen as an opportunity to internalize any knowledge that can be gained through an experience for future use (ff). Reflection can take on three forms: descriptive, analytical, and critical. In descriptive reflection, we consider what has taken place and our general reactions to it.

Analytical reflection aims for meaningful reactions emergent out of our consideration of existing assumptions, beliefs, feelings, and our attempt to imagine alternate points of view. Finally, critical reflection attempts to discover new meaning by seeking the root causes of our knowledge, particularly in an effort to inform future actions (Brookfield, *Becoming a Critically Reflective Teacher*, ff; *Using Critical Incidents,* ff). Thus, in design, critical reflection goes beyond the observation of an artefact (descriptive), beyond the reactions we may have with regards to the artefact (analytical), and into a questioning state, where we challenge both our perceptions and reactions, with a goal of expanding our field of vision for the betterment of future practice.

I close this section on frameworks by suggesting the following as points for future consideration of critical reflective practice – a practice that I consider to have great potential for critical design practice. As in Sengers et al., this is not an everyday life, self improvement type of reflection, but reflection that is contextualized within a specific design problem or challenge.

1. Time: We can reflect on ourselves, our discipline, our experiences and actions (technological and otherwise) by considering how those looked and felt in the past. What was positive or negative about each one? Our goal of such reflection is to make sense of it: what can we see now that we were not able to consider then? We can contrast those with a reflection of the same in the present, and our desires, fantasies, and fears for the future.
2. Context: Reflecting contextually means standing back to consider a wider view of the problem. What are the consequences of actions or inactions, thoughts or decisions, on the self and within a larger community or environmental contexts? What is the context of use and its potential impacts?

3. The Unseen: Through reflection, we can reveal what we find difficult to admit, for example, we can consider the role we have in the marginalization of others, and our own blindspots, privileges, or biases.
4. Understanding: Reflection can encourage us to pursue a deeper knowing. We can engage in "yes, and" activities, seeking informed understanding and questioning what we consider as knowably stable.

Critical reflection can result in doing or making, but it can also result in observing, then in releasing without action or change. Reflection can involve drawing conclusions in order to move on, change or develop an approach, strategy or activity. A reflective act can result in further questioning or probing. It can also result in self empowerment or desire for transformation. Reflection can shift perception of relationships with the self and with others. It can be intimate and personal, or playful and collaborative. Reflection can reveal past traumas or triggers. Since reflection can be so diversely interpreted, it becomes important to contextualize it within the design activity, clarifying the outcomes that will mean its success, while leaving room for the unexpected.

A New Framework for Critical Design Practice

One of my particular concerns is how design can better serve real world problems, in particular those that are constructed by and exist within rigid structures, institutions and corporations, for example, and that impose authority onto others with limited power. Bardzell phrased it well when she asked: "How do we simultaneously serve real-world computing needs and avoid perpetuating the marginalization of women and indeed any group in technology?" ("Feminist HCI", 1304). I agree with her position that serving existing needs – as those defined by Syncrude – would reinforce the status quo, in particular when defined by those in upper management positions. An activist stance, as defined by design fiction or speculative design, is also problematic not only because it privileges the values of the designer, but because it limits its audience to a particular class of artist-intellectuals, and its display to gallery spaces.

How do we conduct critical, feminist design that is also practical, and that stands a chance to be implemented in the world it aims to address? I propose the following as a preliminary conceptual framework for the practice of critical design. The framework consists of six parts and can become integrated into every aspect of the design process: during user research, prototype iteration or ideation, and during artefact evaluation (within a design process or in critiquing existing designs.) It is a proposed model for a holistic reading and design of interfaces for DS. The six part framework is built on Sengers et al. work (ff), thus, I encourage critical reflection while considering all of its principles.

Designers who engage in the practice of critical design while developing HCIs,

1. Challenge existing methods, beliefs, systems, and processes;
2. Focus on an actionable ideal future;
3. Look for what has been made invisible or under represented;
4. Consider the micro, meso, and macro;
5. Privilege transparency and accountability; and
6. Expect and welcome being subjected to rigorous critique.

1. Challenge existing methods, beliefs, systems, and processes

The concept of environmental scanning, well covered in business and management literature, is defined as strategic, purposeful, and organized information gathering, focused around a particular interest or critical decision being faced by an organization (Choo, 21). Designers utilize a form of environmental scan when they review what exists as part of the visual culture most relevant to a particular project. They may conduct an environmental scan based on the pre-defined user group(s), the subject matter, and the content. For example, if the task was the re-design of a web site for an Alberta-based oil company, a designer would conduct an environmental scan of local, national, and international competitors' sites, as well as companies of any related or relevant subject matter. If the client had, as one of its objectives, better communication around its commitment to environmental sustainability, then a review of sites related to the environment may also be useful. One of the goals of the resulting re-design would then be to utilize a visual language that would be appropriate for (and familiar to) oil companies, while also communicating, for example, its local affiliation and leveraging a visual quality that suggests a link to the natural environment. This is a time-honoured and useful strategy, similar to the literature review conducted as part of this dissertation.

Unfortunately, without an intentional focus on diversifying the pool of existing design ideas (Ruecker, "The Perennial and Particular Challenges", ff), the tendency when using environmental scans as part of the design process is towards moderate shifts (A+1) rather than extreme design departures. User-centred design is meant to challenge the unquestioned repetition of established practices for that which would tangibly benefit an artefact's actual users. In terms of rejecting the status quo, however, these methods, though very valuable, do not always challenge existing mental models, or unnecessary social or cultural constraints. If we approach user-centred design methods with the lens offered by critical design, we have the opportunity to challenge and then redefine those qualities of an artefact that will be considered useful, usable, functional, and appropriate. We will also, hopefully, question more closely the needs and characteristics of those who will affect and be affected by the design. I will call this type of artefact Z+1. To repurpose Jarod Lanier's statement, we can consider that the computer should be like a musical instrument: "a device where you can explore a huge range of possibilities through an interface that connects your mind and your body, allowing you to be emotionally authentic and expressive."[15] The more instrument types, musical genres, and melodies at our disposal, the richer the results.

2. Focus on an actionable ideal future

Z+1, while extreme, will still aim to either be or be able to become implemented. While not always geared for industry, Z+1 is not meant to be designed as either an art object or as an activist stance. It is design that is meant to enact positive change on its world by imagining actionable, ideal futures. Such imaginings can be either implied or implementable. Implied futures direct us towards change by demonstrating what requires it. *The Million Dollar Blocks* project is a good example of a kind of design that implies an actionable future: as we begin to question and challenge our views on incarceration and the American criminal justice system, we will hopefully work towards effective and tangible social change.

The *Mighty Mom* shows us the potential for an imagined but implementable future. The challenge was to create a breast pump that would replace bulky, difficult to use, expensive, and dehumanizing models. Current models remain little changed from the one that was first patented in the 1920s, providing ample opportunity for radical departure. The MIT Breast Pump Hackathon brought together "150 parents, engineers, health care providers, lactation specialists, designers, and educators … for two days of non-stop brainstorming, collaboration, deconstructing, and re-inventing" with the goal to not only make a better breast pump, but to "help fuel a culture of innovation in the space of maternal and neonatal health, a space that typically lags behind other fields in technological innovation" (Dizon). *Mighty Mom* won the competition for its breast pumping utility belt that combines discreet, comfortable, and hands-free pumping with record keeping on a mobile device.

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15 "If there's any object in human experience that's a precedent for what a computer should be like, it's a musical instrument: a device where you can explore a huge range of possibilities through an interface that connects your mind and your body, allowing you to be emotionally authentic and expressive." (qtd. in Burkeman).

3. Look for what has been made invisible or under represented

Usability, "the user", and universality remain at the centre of HCI. Universality is a value that has been traditionally associated with masculinity; and the user prototype, it has been argued, is male, white, and heterosexual. This narrow approach to perceiving, defining, and serving the human population continues to dominate usability and design evaluation. Design Z+1 is intentional in its search for what exists outside the bounds of typical discourse. This includes populations that are not or under considered and vulnerable populations. It imagines "what if" scenarios that question what is present and considers its reversal.

The Personal Space Dress and *The Auto Filter* are interesting examples of increased visibility, through design, of important social and environmental issues. The *Dress* uses proximity sensors to identify when someone gets physically too close to the wearer, then expands to increase the wearer's personal space (McDermott). It is the second in a series of projects called *Urban Armor*, which consist of "playful pieces that help women assert control over their personal/public space" (McDermott). While the dress may not seriously impact the harassment women experience in public and, in fact, would be likely to receive some warranted criticism if it actually went into production (similar to those experienced by the creators of the nail polish that detects date rape drugs (Dusenbery)), it does make an important, and very visible statement about the non-negotiated, gender-dependent ownership over public and personal space. *The Auto Filter*, also part of the *Urban Armor* project, is a scarf with a built-in urban pollution sensor. It automatically covers a wearer's face when it senses alcohol, cigarettes, or car exhaust (McDermott). Both these projects use changes to an artefact's structure and appearance to signal the existence of something significant in the environment that may, otherwise, be hard to perceive. While in both projects physical changes do nothing to increase the wearer's knowledge and do not, actually, modify the environment, they do have the potential to communicate discomfort and desires to those within its proximity. The *Dress* signals the wearer's lack of personal space to others occupying the metro; the *Filter* may communicate the wearer's dislike of or allergy to excessive perfume or cigarette smoke.

4. Consider the micro, meso and macro

The value of the micro and the macro has been considered by numerous, diverse disciplines. In sociological study, macro-level looks at large-scale social processes, for example, social stability, change, law, bureaucracy, and technology; while micro-level considers small-scale interactions between individuals, for example, conversation, patterns of behaviour, and group dynamics (Boundless). In philosophy of engineering, macro examines the level of individual actors within organizations, meso the intermediate level of organizations, and macro the level of social institutions (Li, 23). In business innovation, problems in decision-making are considered at the micro (individual firm) and macro (aggregate) levels (Bridges, Coughlan, and Kalish, ff). In the digital humanities, Moretti's call for distant reading (ff) continues to be hotly debated. While Manovich calls databases and narratives "natural enemies" (n.pag.) and Whitley assumes that literary critics "value close reading . . . over the broad brushstrokes of information visualization"(188), Hoover criticizes the "marginalization of textual analysis and other text-centered approaches" (n.pag.). Ross in her review of *Distant Reading,* on the other hand, writes that surface reading, distant reading, and DH are not inherently in opposition to close reading – it is the potential for the development of bad *reading* habits that are the concern. Thus, she argues for considering "new forms of analysis" and suggests that "moving back and forth between the microscopy of close reading and the wide-angle lens of distant reading would enrich both methods, creating a dual perspective that boasts both specificity and significance" (Ross).

It may be argued that Rich Prospect Browsing Theory, in some ways, supports macro and micro views through its simultaneous display of every item in a collection and the availability of information on individual items. For example, the *Mandala Browser* (see Fig. 4.09) shows a macro view on the entirety of *Romeo and Juliet,* with each speech in the play displayed as one dot. When a user clicks on a dot, she can read the corresponding speech in a text frame located to the right of the browser, receiving the micro, textual view on the speech. However, the visualization itself – the graphical display – does not offer multiple views. A design that supports macro, meso, and micro views would shift between these views, revealing new, detailed information as it did.

Fig. 4.09: The Mandala Browser displaying an analysis of "love" in Shakespeare's *Romeo and Juliet* (Mandala Application).

If we accept that the meaningful display of all items in a collection, fundamental to rich prospect browsers, positions the display at the meso layer – that the meso layer is the starting point for the browsing of all RP displays – then we can begin questioning what would be revealed by zooming out to the macro view and zooming in to a micro view of a display. We can also consider whether the change between views would function as a binary switch or a gradation.

5. Privilege transparency and accountability

Since every design is founded on certain assumptions about its future users, Bardzell argues for self disclosure in Feminist HCI design: for software to make visible how it perceives its users and what it is trying to make of them (Bardzell and Bardzell, "Towards a Feminist HCI Methodology", 682). I propose to push that point even further by more fully engaging with Feminist Standpoint Theory (Harding, ff). Thus, if we suppose that all knowledge is socially situated, and all knowledge production inevitably enmeshed in acts of power, I argue that every design should self disclose not only about its perception of users, but the positionality of its designers. Furthermore, transparency and accountability would become inherent to any interface where its systems or processes have consequences on others. This notion supports Illich's idea of conviviality: tools that are playful and encourage openness with oneself and others. Illich considered conviviality "to be individual freedom realized in personal interdependence and, as such, an intrinsic ethical value" (11).

6. Expect and welcome being subjected to rigorous critique

In an effort to further extend the fifth principle – privileging transparency and accountability – I suggest that we consider every instance of critical design as an iteration, thus subject to interpretation, questioning, and rigorous critique. Bardzell makes a similar point for HCI, when he argues for the "rigorous interpretive interrogations of the complex relationships between (a) the interface, including its material and perceptual qualities as well as its broader situatedness in visual languages and culture and (b) the user experience, including the meanings, behaviours, perceptions, affects, insights, and social sensibilities that arise in the context of interaction and its outcomes" ("An Introduction to the Practice", 604). Models for serious, expert-led critique abound in philosophy, film, literature, architecture, even culinary studies. Graphic design has tended to shy away from public critique not because, according to Heller, "it is inherently uncriticizable, but because designers have neither a critical vocabulary, nor the means to address work in a public forum" (Heller). He calls for practical and theoretical criticism, so that designers can better understand what is good, what has failed, and why either has taken place.

I would like to call upon designers to set a higher bar for our discipline. Not only should the artefacts we have a hand at creating be held subject to rigorous critique, but we should as well. Too often designers become invisible, standing behind the companies who employ them, the clients who pay for their work, or the marketing team. When the work is considered successful, it may receive awards or accolades in design annuals; when it is bad, the work may be shamed, but the designer can simply move onto another client or project. Yes, a designer's reputation may suffer, and we are still primarily employed on the basis of the strengths demonstrated through our portfolios, but the judgment we receive comes from a very small, specialized community, with little actual recognition for the origin of truly harmful work.

There are many potential benefits to such accountability. To add to the benefits of rigorous critique listed by Bardzell – "informing a particular design process, critiquing and innovating on design processes and methods more generally, developing original theory beneficial to interaction design, and exposing more robustly the long-term and even unintended consequences of designs" ("An Introduction to the Practice", 604) – we have the opportunity to add much needed credibility to our discipline by genuinely and justifiably celebrating the good and condemning the harmful.

Parts of the Framework: How many is enough?

Each component of the framework requires exploration for the framework's effectiveness to be demonstrated. Unlike feminism, where a full, complete immersion is not required for membership (a 10% feminist is still a feminist), to encourage the fullest possible exploration of critical action design, attention must be given to all of its six principles.

Reflection on Accountability

When considering the exhibition *Strangely Familiar: Design and Everyday Life,* Blauvelt writes that those outside of the design field – most people – are unfamiliar with design's practices, intricacies, and processes: "[Design outputs] tend to conceal rather than reveal the process of their making" (14–15). Blauvelt suggests that design's invisibility is a matter of human survival, since novel, every-changing design has the potential of becoming an overwhelming "visual cacophony". According to Dieter Ram "good design means as little design as possible." Similarly, Jared Spool instructs HCI designers that "Good design, when it's done well, becomes invisible. It's only when it's done poorly that we notice it." It is outside the scope of this dissertation to trace the origins of this (to designers) ubiquitous directive, though the rebellion against Victorian tendency for over decoration, and the late 19th-century European separation of graphic design from fine art, might be a good place to start (see Meggs' *A History of Graphic Design*). The 20th century marked an increased disappearance of the designer and the design process from the public eye, cemented by the invention of desktop publishing in 1985 (Meggs, 455). With few notable exceptions per design sub-discipline – Paul Rand, Jonathan Ive, Philip Stark, David Carson, to name a few – we are surrounded by invisible products with vastly more invisible creators.

Such invisibility has benefited design practice. The separation of artefact from creator has meant that greater emphasis has been placed on an artefact's use and its users, instead of seeing the artefact as an opportunity for the designer's self expression. However, there are also several consequences to the separation of creator from her design. First, design is unclear about the location of meaning. Does how an artefact is interpreted rest in the intent of the designer, the experience of the user, or as viewed through any of a series of available cultural or theoretical lenses? Since designers have become invisible, so has their intent and the process that they undertook to reach the end result. With a lack of intent, so goes the potential for accountability. If I purchase a can opener, and it breaks after a few uses, I will blame the company with its logo on the box. If it does not work for the size of my hands, or if it fails to open cans, my blame will rest in the same place. While it may be argued that the blame for a failure in materials may be placed at the feet of the manufacturer, the failure for the functionality should rest at the feet of the one who designed it. At least in equal part to those who paid the bill. If we can not blame designers for their failures, we are unlikely to celebrate them for their successes. When we do, we have the benefit of an entirely new layer of discourse regarding what a successful design processes, of the kind undertaken by Apple Inc. for example, look like.[16]

The projects described as illustrating Critical Design, Agonism, Speculative Design, Design Fiction, and Slow Design benefit us, in part, because of the critical context in which they appear – a physical or virtual gallery space – which welcomes statements of designerly intent. Thus, we can reflect on this work, challenge it, and call it out for intended or unintended marginalization (if appropriate). We can debate with their creators because the creators and their artefacts remain connected. While meaning does not rest solely in their intent, we are able to consider a fuller scope of an artefact's meaning. We can build on our knowledge by challenging one another's interpretative arguments, finding new evidence, and reading deeper. Critical design demands the creation of an engaged and public conversational space between intended meaning and multiple points of interpretation.

Designed artefacts should undergo an iterative process of evaluation and interpretation of the kind that takes place during their creation and development. When an artefact enters the world, our critical engagement with it should continue, as we hold it to an appropriate level of social, ethical, and political accountability. That is the difference between critical design

[16] See, for example, William Buxton's *Sketching User Experiences: Getting the Design Right and the Right Design* (San Francisco: Morgan Kaufmann-Elsevier, 2007).

that is reactive to stylistic trends or crisis in functionality, versus one that considers all artefacts as meaningful, situated iterations.

Chapter 5: Paths Are Made by Walking[17]

> "In the case of rich-prospect interfaces, the benefits are that the combination of meaningful representation of items with emergent tools for manipulating the display potentially results in an intuitive way for users to understand an entire collection and how its designers conceived of it. People are also able to see information that can remind them of things they've forgotten, or suggest to them things that they never knew. They can be reassured about what is included in a collection and what is not there."
>
> Visual Interface Design for Digital Cultural Heritage
> (Ruecker, Radzikowska, and Sinclair, 171)

Rich-Prospect Browsing (RPB) Theory builds on work by Appleton on prospect and by Gibson on affordances, proposing a new category of interactive displays for visually exploring digital collections. Appleton first introduced the concept of *prospect* in order to answer the question: "what is it that we like about landscape, and why do we like it?" (Appleton 1). His data consisted of responses by critics to landscape paintings, through which he identified two features of landscape that are directly related to survival for people and animals in a natural environment: prospect and refuge. *Prospect* refers to the human and

17 "Caminante, son tus huellas el camino, y nada más; caminante, no hay camino, se hace camino al andar" (Machado, 77).

animal desire to see without obstruction; and *refuge* refers to the human and animal desire to hide from view (73). The term *affordance* has been defined by Gibson as possible actions that exist within an environment (127–140), and by Norman as the perceived and actual properties of an object, particularly in terms of how it may be most obviously used: for example, “a chair affords (‘is for’) support, and, therefore, affords sitting” (Norman, Psychology 9). Affordances can be objectively measured; though they exist independently of the individual′s ability to recognize them, they are dependent on the individual’s ability to act on them. That ability to act is unique to each individual.

RPB aims to challenge one of the fundamental tenets of information retrieval, such as exemplified by the Google search box: that users are not able to handle large amounts of information; that they need to be protected from it; and guided by various sorting and filtering strategies, devised for them by information-handling specialists (information architects, programmers, usability specialists, etc.) It proposes an alternative model for collections that contain thousands or fewer entries, where people are offered the opportunity to browse the entire contents. In proposing RPB, Ruecker argues that the “two technologies are not mutually exclusive”, however combining retrieval and retrieval results within one browsing space provides certain perceptual advantages and new opportunities for action (“Visual Interface Design for Digital Cultural Heritage”, 28). Thus, in a browsing interface every item in a collection is assigned a visual representation. All items are displayed at once, and users are provided with a set of tools for manipulating – organizing, sorting, filtering – the items in the display. Ruecker posits that RPB interfaces provide affordances – opportunities for action – that are not found in other kinds of interfaces, communicating information about the size of a collection, the kinds of items that make up its contents, how those items are organized, and whether the collection includes any significant features (ibid. 153).

In the ten years since its initial proposal, RPB has been applied to a wide range of projects, including, but not limited to, the to the design of human-computer interfaces for browsing books, conference delegates, pills, research faculty, environmental sustainability projects, medieval woodcuts, heritage buildings, and electron microscope images of wasp wings. These projects have dealt with the design of interfaces for collections that consisted of hundreds, thousands, or sometimes tens of thousands of items, either represented textually, graphically, or both. Most aimed to propose a radical departure from existing browsing models. The *Faces of Innovation* browser, for example, enables users to explore the research community at Mount Royal University by selecting a researcher, then viewing their corresponding CV (Mount Royal University). Researchers are represented through a gridded series of photographs. Users can filter their results using a right-hand panel to view researchers by Faculty or Department (see Fig. 5.01).

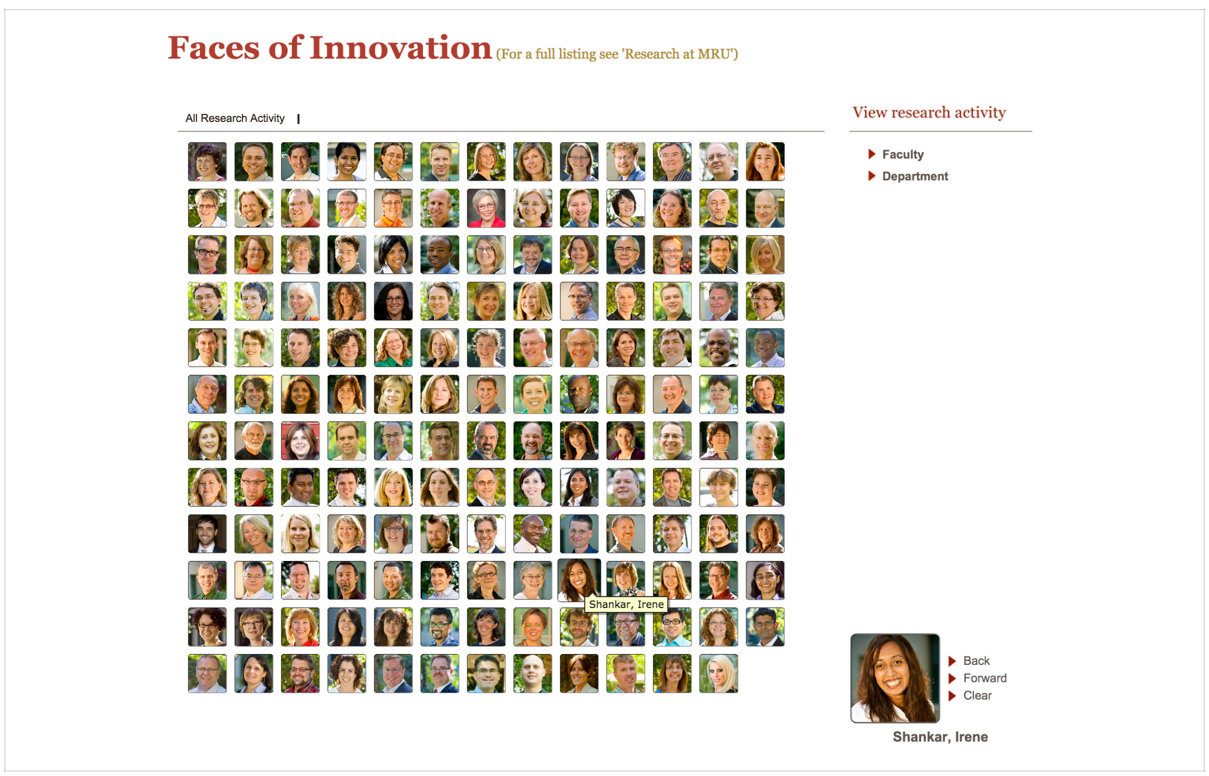

Fig. 5.01: Faces of Innovation displays all researchers at MRU with tools for sorting by Faculty and Department (Mount Royal University).

Browsing interfaces stand in sharp contrast to methods typically used for decision support in manufacturing and to those used for solving resource allocation problems. Linear programming (LP) has become the standard tool for many businesses and organizations for such tasks, and numerous software packages dedicated to solving linear problems have been developed (MacDonald). Most recently, several standard business packages (Microsoft Excel, for example) include an LP solver (see Fig. 5.02).

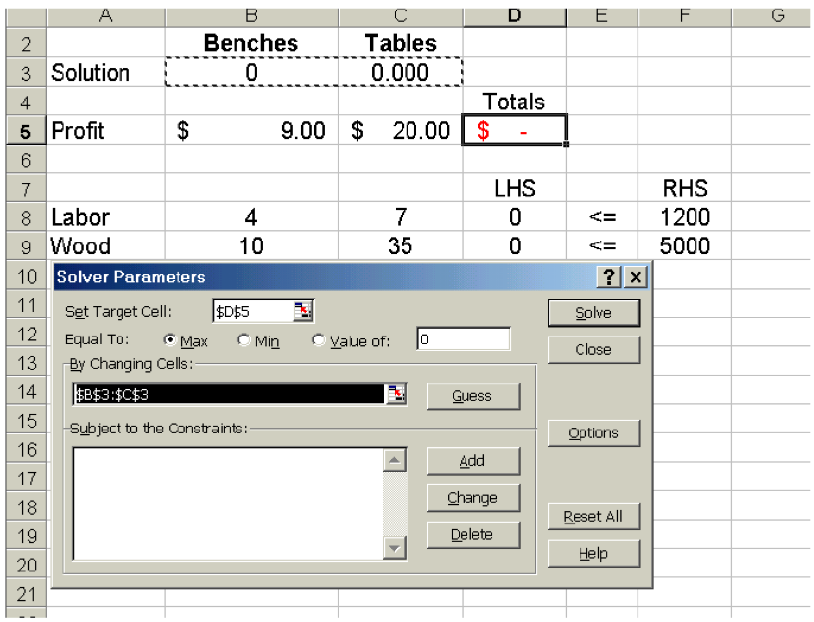

Fig. 5.02: An example of the Microsoft Excel Solver (Microsoft).

Plug-ins such as the one for Excel shown in Figure 5.02 and applications such as LP Solve are limited to computing the minimum or maximum of a linear objective function within user-defined linear constraints. New solutions require the adjustment of numerical values and re-solving (re-calculating) the formula. Thus, unlike Rich-Prospect Browsers, Solver, LP Solve, and others are limited in their ability to support data exploration, knowledge discovery, and hypothesis formulation, leaving ample room for critical innovation within this domain.

Similarly, there is copious room for a critical challenge to the current state of interface design for manufacturing decision support. This chapter is my attempt to diversify the pool of available design alternatives within this particular suite of interfaces, as well as to diversify the ways that we approach the act of designing such interfaces. I consider RPB Theory through the lens of Feminist HCI and Critical Design, positioned in the context of interface design for manufacturing decision support. What follows is a review of RPB principles and tools, with a proposal of how those could be reconsidered, applied, reframed, and expanded. What I hope will emerge out of this chapter are examples of radical departure from existing designs within the domain under investigation. I want to provide a case study for idea diversification, done to "enrich and expand our experience of everyday life" (Bardzell et al., 289), making visible that which has become – through habit, tradition or institution – obscured.

Chapter 5 is subdivided into four sections. I begin by framing the domain of manufacturing decision support within the five existing rich-prospect browsing principles developed by Ruecker and the two contributed by Giacometti. I continue by doing the same to the collection tools proposed by Ruecker. In the third section I propose four new RPB principles by considering the theory through the lens of Feminist HCI. The Chapter concludes with a brief challenge to the notion of refuge as discussed by Ruecker.

Locating RPB **Principles** in Manufacturing DSS

In order to be considered a rich prospect browser, an interface must meet the original five criteria as proposed by Ruecker (*Affordances of Prospect,* ff). First, the primary screen of an RPB will show a meaningful representation of every item in a collection. Such representation may, in some instances, be closely evocative of the collection item's original form, or the form may be arbitrarily assigned. For example, in the *Slot Machine* interface (see Fig. 5.03) the first column features the entirety of Gertrude Stein's *The Making of Americans* in micro text, with subsequent columns generated based on a user's search of a repeated phrase (Radzikowska, Ruecker, Fiorentino, and Michura). All columns are aligned along a reading slot that magnifies the repeated phrase and its immediate context. The *Slot Machine* is a good example of an interface where there is a close connection between the item in the collection (the novel) and its graphical representation (a column made of a micro text version of the novel). Using Peirce's terms (Chandler, n.pag.), the micro text is an icon: the signifier (column of micro text) is perceived as resembling or imitating the signified (the novel). In the case of the *Slot Machine* this close connection in representation is of benefit since it facilitates an exploration of the text across and within multiple contexts. At the same time, a micro text representation of a novel (even one that is not 1,000 pages in its original form) requires the use of specialized technology, such as a wall-size display, making such representation possible but impractical.

Fig. 5.03: The *Slot Machine* (Radzikowska, Ruecker, Fiorentino, and Michura).

In contrast, the *Paper Drill* interface displays an article's citations (items in that collection) using a gridded series of coloured squares, with each square representing one citation source and the colour the distance of that source from the citing article (Ruecker and INKE Research Group). Using Peirce's terms (Chandler, n.pag.), these squares are symbols, arbitrarily (though carefully) assigned to represent not only the citation, but also the original text. This connection – between a square, its colour, and the text – must be made explicit in the interface, and learned by its users. In the case of the *Paper Drill*, symbolic representation allows for a prospect view on all the items in a very large collection (Fig. 5.04 shows 1,666 citations by 36 authors).

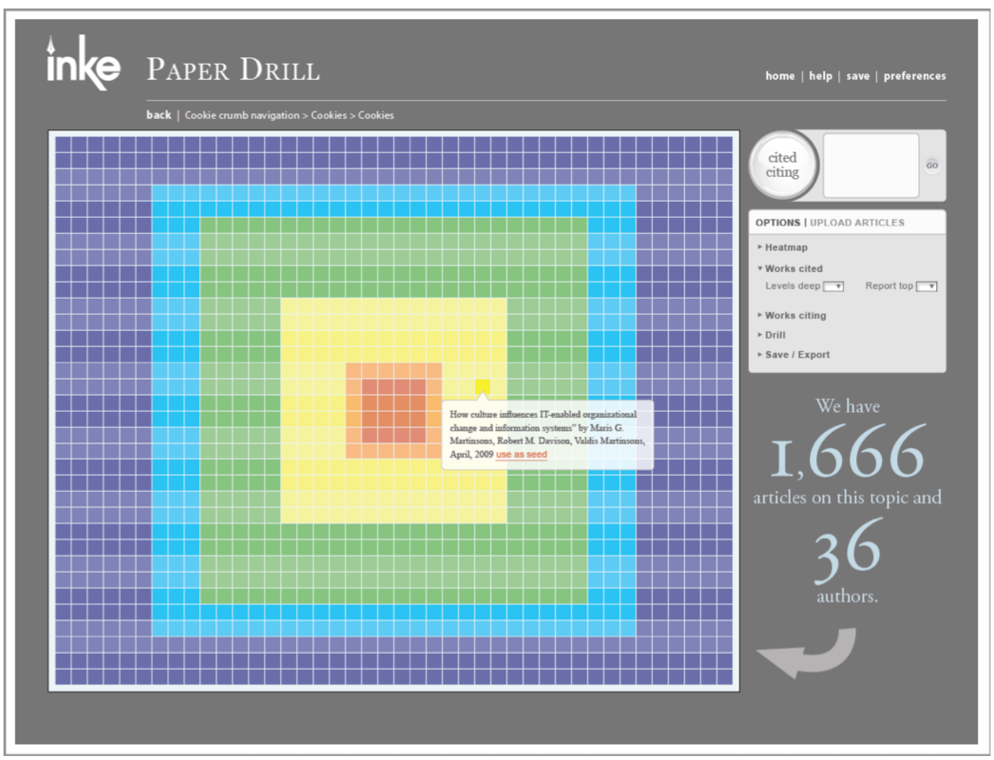

Fig. 5.04: Sample sketch from the *Paper Drill* (Radzikowska).

For some collections, an iconic item representation may be not only possible, but preferable given the nature (and size) of the collection and the types of tasks that are likely to be performed with it; while for other collections a more abstract (or symbolic) item representation may be required. In the context of designing an RPB for decision support in manufacturing, we must first consider what constitutes a collection of items. The primary screen could show a meaningful representation of all parts of a linear equation, essentially providing users with a prospect view on the entire decision-making process. Or, in an alternate view, users could explore multiple solution scenarios, once those have been generated. In such a case, the display could show all alternatives generated within some pre-defined time period, or enable the clustering of decisions based on a particular constraint, or which alternatives were implemented vs. which were considered, then rejected. We can also consider extending the notion of a prospect display to controls or processes.

Ruecker et al. provides the following list of collection characteristics to be considered when determining whether a particular collection would make a good candidate for an RPB (*Visual Interface Design*, 101):

- Possible uses of the collection;
- Number of items;
- Characteristics of the items;
- Degree of homogeneity among items;
- Possibility of providing some logical, consistent, and meaningful representation of each item; and
- Extent of the markup of the collection.

Several properties make interfaces for decision support good candidates for RPB. Decision support is essentially made up of a series of sub-systems, each with an interconnected set of processes. Imagine that the starting point for a user is the question "should I allocate 20 four-ton trucks or 50 two-ton trucks to transport this month's raw product?" She will manipulate the constraints (a subcategory of variables), then generate and review the optimal solution. Viewing every part of the formula all at once may be beneficial since it makes visible the specific factors being considered by the system in generating the solution. If the generated solution is displayed on the same screen as the controls, the user can go back and forth between controls and solutions, adjusting then reviewing the results. There is a potential for immediacy to this kind of display that is not available on multi-screen alternatives.

Many of these collection characteristics also determine what kind of meaningful representation (ionic, indexical, or symbolic) may be possible for a given collection. For example, a collection of 1,000 pills that in their original form have a simple graphical composition (limited set of geometric shapes, little detail, limited colour palette) may be comfortably displayed in their original (iconic) form, using the one-screen RPB model. Even at a relatively small size, individual pills can be reasonably distinguished from one another and from their contextual space. Faces, on the other hand, require greater size to be effectively differentiated from each other. Thus, the digital versions of the photographs could be used for smaller collections. For collections with items numbering in the thousands, a graphically simpler symbolic form would need to be created.

Out of Sight, Out of Mind (Pitch Interactive), an interactive project on the use of drone technology in Pakistan, based on a dataset maintained by the Bureau of Investigative Journalism hopes to inform us about the number of drone strikes, and the number and type of casualties that they have caused (see Fig. 5.05). The visualization's creators at Pitch Interactive aim to emphasize the low success rate for the strikes and their impact on civilian populations: since 2004, there have been 3,213 casualties attributed to drone strikes, with only 2% of those identified as high-profile targets. While graphically abstracting both the drones, in the form of curved, moving lines, and the casualties, in the form of rectangular boxes, the visualization provides a prospect, multi-year view on the strikes. At the same time, the design includes a meso view on the human component in the form of group statistics that appear when you roll-over the collection of rectangles – all casualties from a single strike. The strikes are also contextualized through the display of key political events, such as the beginning of the Obama presidency.

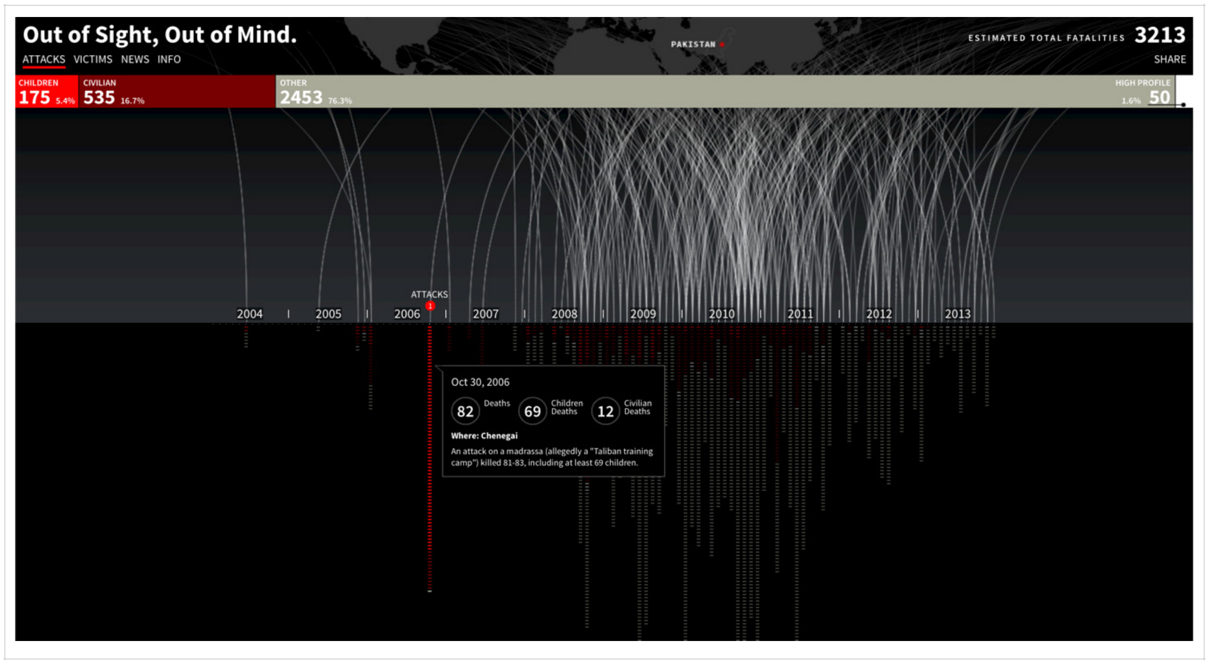

Fig. 5.05: *Out of Sight, Out of Mind* (Pitch Interactive).

This design strikes a beautiful balance between the meso and the prospect, or macro view, personalizing each event, while overwhelming us with the number of strikes and nature of the casualties. They place emphasis on the comparison of impact on the four human categories: children, civilian, other, and high profile. The shape and movement of the curved lines used to represent the drones creates a pattern that suggests the relentlessness of a rain storm.

The *U.S. Gun Deaths* (Kirk, Kois, and @GunDeaths) project goes a step further, by giving us the micro view on not only the name and age of every person killed, but projecting the length of years they may have lived (see Fig. 5.06). Some of their data comes from the FBI's *Uniform Crime Reports*, combined with a projection of alternate stories for those who have been killed using data from the World Health Organization, while some comes from a collection gathered by an anonymous Twitter user, @GunDeaths, gathering and tweeting gun-related deaths in the U.S.

In both the drone and the gun death project, graphical representation takes the form of simple, curved lines that have vastly different meanings. The lines in *Out of Sight, Out of Mind* are a visual metaphor for the path to earth taken by the dropped aerial bombs. In *U.S. Gun Deaths* each line represents a length of time – one person's lifespan. The orange segment is the actual life, and the grey segment is the remaining years if they had not been killed. In both cases the collection of lines overwhelms us with its dense pattern.

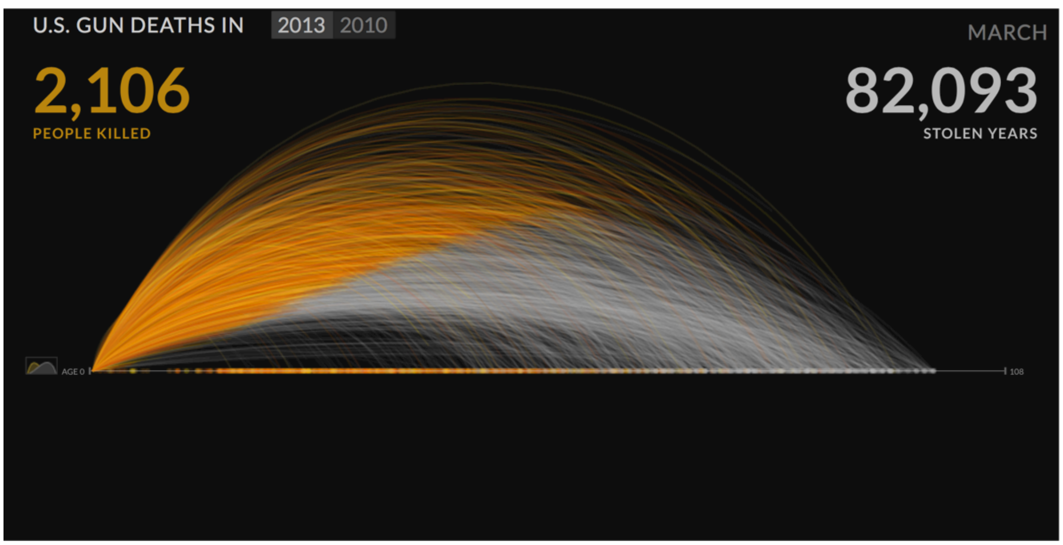

Fig. 5.06: *U.S. Gun Deaths* (Kirk, Kois, and @GunDeaths).

The second RPB criteria (Ruecker et al., *Visual Interface Design*, 3) states that the user will be provided with a set of controls for the manipulation of the display and the re-organization of the items found in the collection, for example by grouping or subsetting the meaningful representations.

Controls for such manipulation emerge out of the type of items found within the collection (the third RPB criteria). Additionally, for most (if not all) RPBs, controls are proximally located to the area of the display that is housing collection items. Thus, when users manipulate the display, they can immediately see the effects of their choices. Complex collection sets will tend to have more and more complex tools than simpler sets. In the *Paper Drill*, for example, all controls for manipulating the display sit to the right of the collection display. These controls include a search function specific to searching either cited or citing articles, and options for how the results will be displayed.

Requiring a set of emergent controls for the manipulation of the display stands in direct contrast to displays where users must navigate multiple, hidden menu systems or screens to see results. One example of a multi screen display is *ManyEyes* (IBM Cognos and IBM Research Group), where users are provided a three-step process to complete their visualization task, with every step located on a separate screen (see Fig. 5.07).

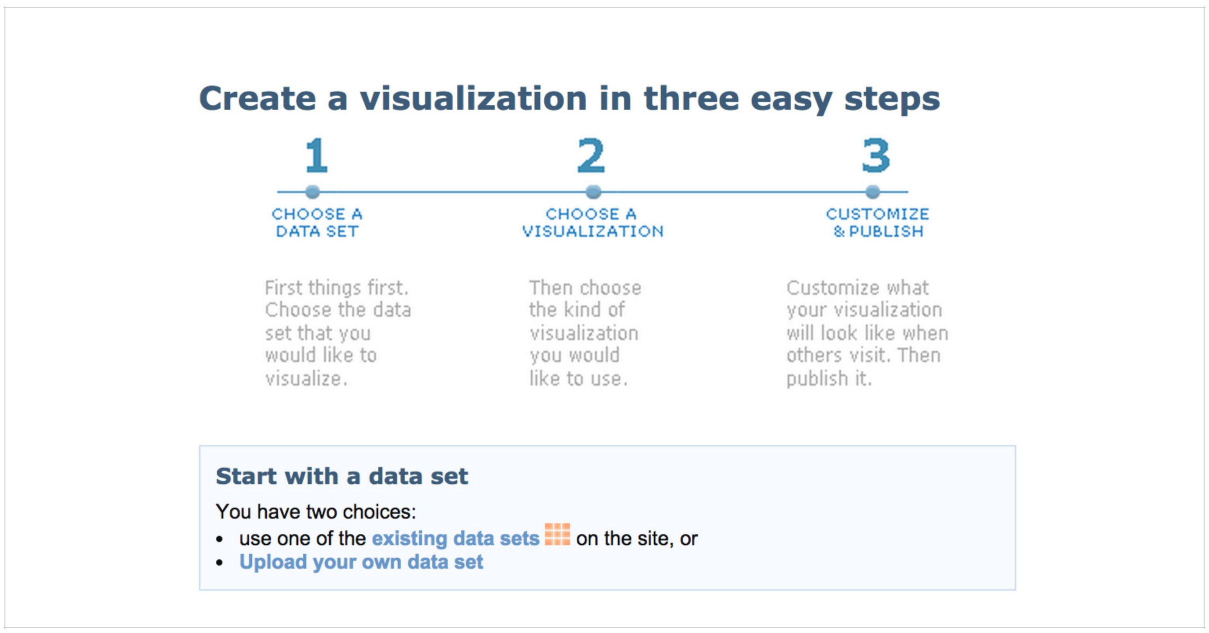

Fig. 5.07: The *ManyEyes* interface (IBM Cognos and IBM Research Group).

Tools for a decision support RPB would be based on the nature of the RPB collection. An RPB collection could consist of, for example, all available constraints and another of result scenarios. In that case, the browser would require one set of tools for the manipulation of constraints and another set of tools for the manipulation of result scenarios.

The fourth RPB criteria asks that, where possible, more than one meaningful representation of collection items be provided. For example, in a collection that supports browsing prescription pills, the display would support the viewing of either side of a pill, or both sides simultaneously, and changing the display between these three representations would be under the user's control. *The Johnny Cash Project* (see Fig. 5.08) is a good example of a browser that supports nine different views (Milk). Working within the original music video for the song "Ain't No Grave", users are invited to draw their own versions of frames from the video. The newly drawn frame is then combined with frames by other users from around the world, and integrated into a collective reconstruction of the video. This interface provides a prospect view on all the user-created frames, with the added functionality of switching the view between frames that received the highest user rating, those that were selected by the site's curator, or those that were defined by a particular artistic style (pointillism vs. abstract, for example).

Fig. 5.08: *The Johnny Cash Project* (Milk).

The Johnny Cash Project is also an excellent example of the fifth RPB criteria: each representation of an item in the collection becomes the means of accessing further information on that item (Ruecker et al., *Visual Interface Design*, 3). When a user selects one of the frames, an information panel appears to the right of the frame listing such details as the frame number, artist's name and location, drawing time, and number of brush strokes (see Fig. 5.09). Users can easily navigate between frames using the prospect view below the video playback or, when in the detailed frame view, by using the previous and next frame buttons.

Fig. 5.09: Detailed view of one frame found in the *Johnny Cash Project* (Milk).

In an RPB for decision support, multiple meaningful representations of collection items are possible. For example, the user may be given the option to view solutions iconically, indexicaly, or symbolically, and at various levels of detail.

Subsequent work by Giacometti proposed that users should be provided with the ability to mark collection items in some way, and that the items should start out with an appropriate, initial organization (106). These are both valuable contributions to RPB theory when you consider a display such as the one found in Fig. 5.10 where the user is faced with an initial display of 1,000 pills (Ruecker, Given, Sadler, and Ruskin).

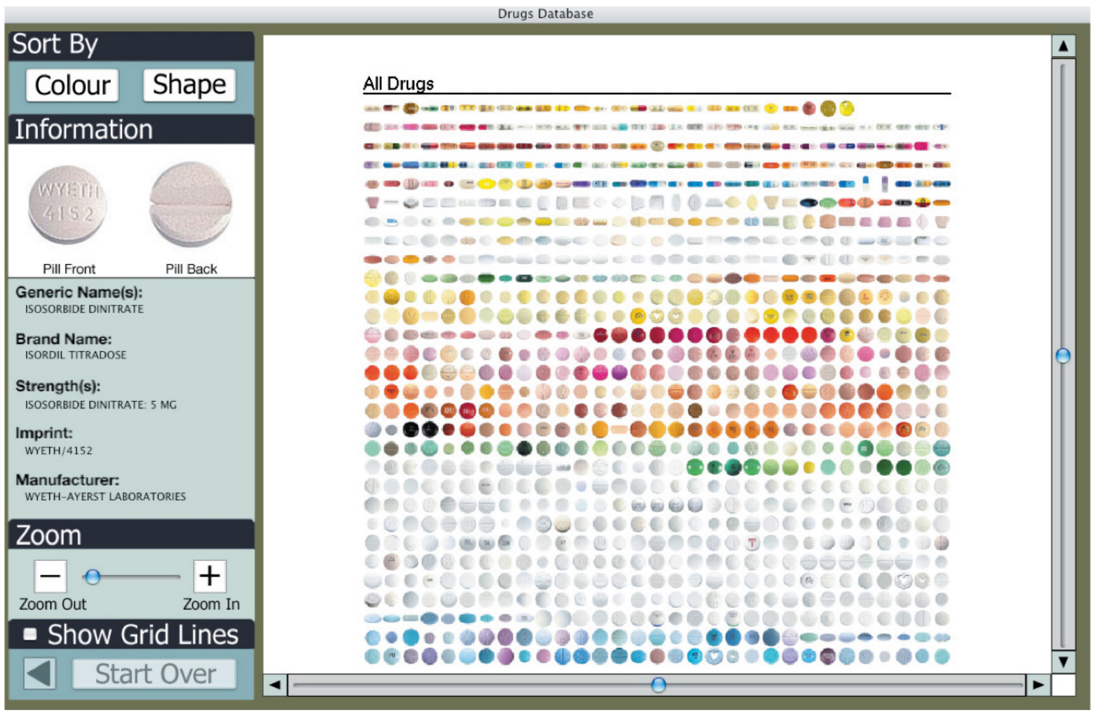

Fig. 5.10: An RPB of pills (Ruecker, Given, Sadler, and Ruskin).

In an RPB for decision support, a solution could be connected to the computational results of the decision model that was used as the equation, or solutions could be connected to others, based on some commonality, that have been implemented in the past, as well as their outcomes or consequences. Users could also be provided with the ability to mark solutions in some way, allowing for the capture and retention of not just the quantitative solutions, but also the qualitative experience of the decision makers. For example, a user could experiment with multiple solution alternatives, and then choose to implement one of them. She could note the rationale behind her choice, as well as track it for potential, future consequences.

Locating RPB Tools in Manufacturing DSS

Ruecker et al. acknowledge certain challenges with any Rich-Prospect interface. The primary problem is that showing so much information on a single screen can be an overwhelming experience to users (*Visual Interface Design,* 135). They suggest several strategies for use in the design of an RPB in order to help manage the user experience, the primary of which is to represent collection items in a way that is meaningful and to provide users with tools for manipulating and organizing items. In addition to these primary strategies, Ruecker et al. describe nine interface tools that may be useful in an RPB: zooming, panning, sorting, selecting, grouping, renaming, annotating, opening, and structuring.

Magnification (zooming) tools allow users to move from a macro view, through various levels of granularity, to a micro view of a collection. In a decision support RPB zooming may, for example, allow users to explore a prospect view of solutions across a pre-defined time frame or emergent from a specific decision maker, then magnify one solution for closer inspection. A selective zoom would allow users to explore a sub-selection of solutions, thus supporting comparison. Zooming could also support a detailed exploration of sorted or categorized items. Fig. 5.11, for example, shows a prospect view on production (implemented solutions) of six ice cream flavours from January to the end of April. Users can spot trends across time or visually compare the production of one flavour to another, then dive into a more detailed view (Radzikowska et al., "Human Decisions for a Machine World", n.pag.).

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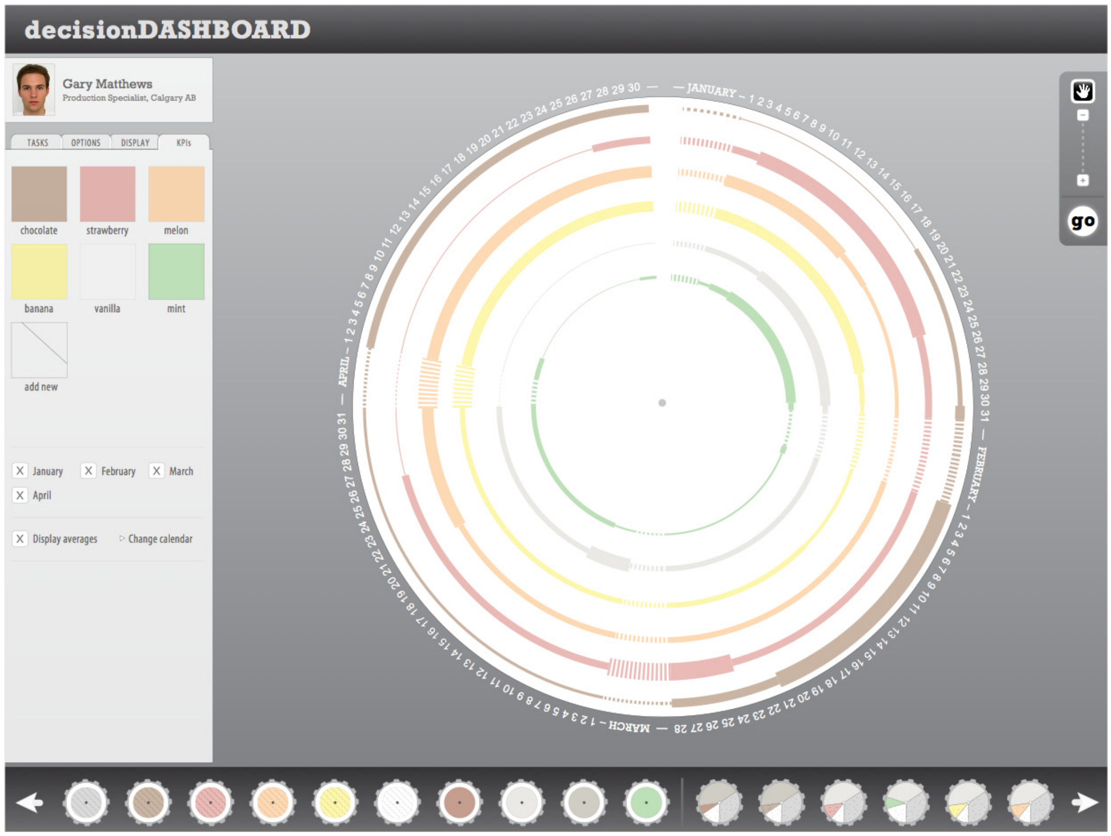

Fig. 5.11: Gears representing parts of the linear equation are constrained by a circular calendar. (Radzikowska et al., "Human Decisions for a Machine World", n.pag.).

Panning tools are closely related to zooming tools. They provides users with the opportunity to move over or through the display, most often once they have zoomed in towards a micro view. For example, users could zoom in on a grouping of solutions that optimize vanilla ice cream production, and then pan over to compare the vanilla grouping with a group of solutions that, instead, optimizes chocolate ice cream production.

While zooming and panning changes the user's relationship to the data found within a display while not actually modifying the data's display, *sorting* tools affect the data's organization. Numerous sorting strategies exist that allow for the arrangement of items in a display. Of particular importance are those that support the creation of meaningful relationships between the data. Most commonly, items are sorted according to one of the

LATCH strategies proposed by Wurman: Location, Alphabet, Time (chronology), Category, or Hierarchy (40). For example, articles could be sorted according to their citation frequency, or solution alternatives could be sorted according to their date of implementation or number of consequences.

Users need the ability to work with individual items or a subset of items within a collection. Many standard selection mechanisms exist, from menus to shift-clicking on an item (for an extensive list see Ruecker et al. *Visual Interface Design for Digital Cultural Heritage,* or visit usability.gov for a short list.) In a manufacturing DS, standard selection mechanisms could be used (as in any other RPB), and their specific implementation would be device dependent. However, as can be noted using the example in Fig. 5.12, certain experimental interfaces may pose unique selection challenges, in particular when it comes to differentiating an action for multiple gear selection from an action that is meant to bring up a detail view. Applications such as Adobe Illustrator have attempted to solve that problem through the use of a tool bar containing a wide range of selection tools and tool-specific palettes. In contrast, other applications use the right mouse click action to bring up item-specific options that may include a detail view, reserving the single or left mouse click to selection and a repeated mouse click to de-selection. There is an opportunity for further innovation in this area.

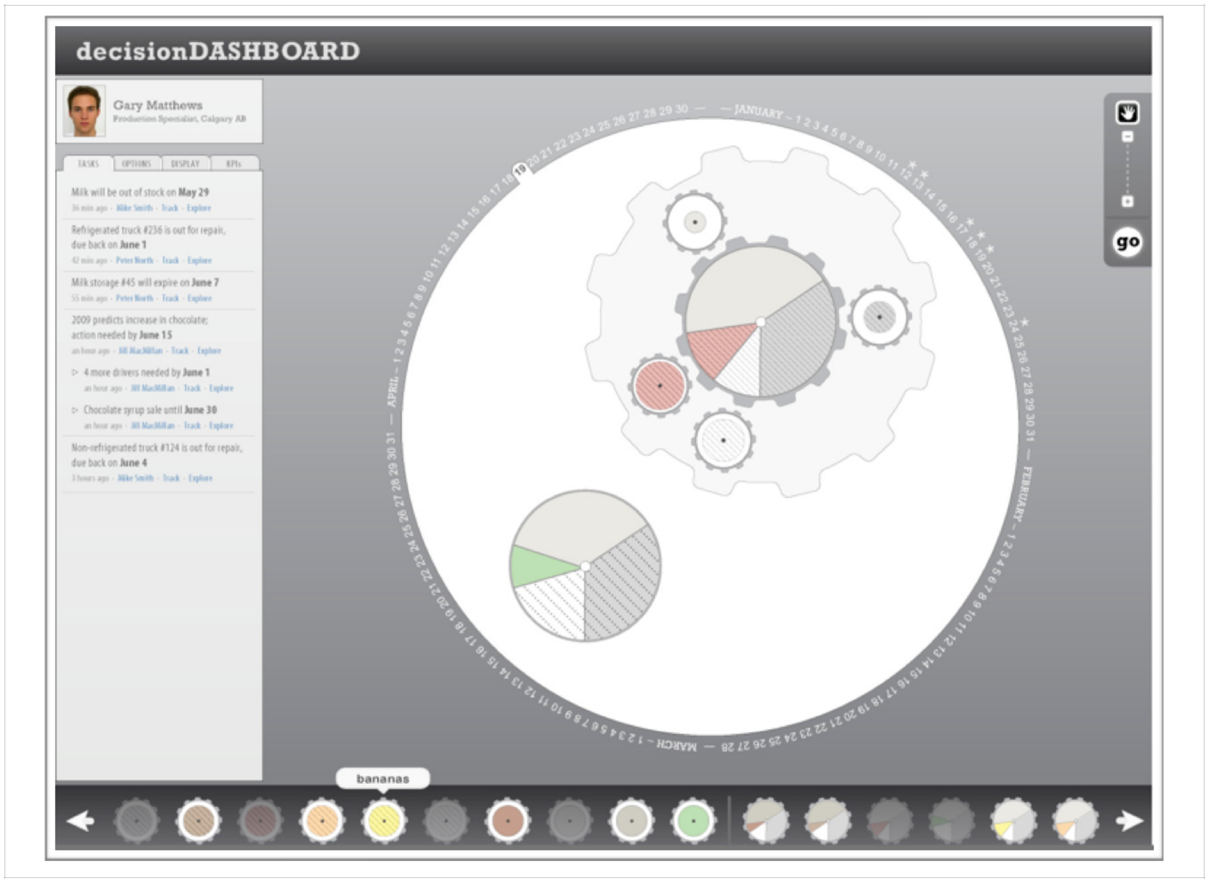

Fig. 5.12: Gears representing parts of the linear equation constrained by a calendar. (Radzikowska et al., “Human Decisions for a Machine World”, n.pag.).

Grouping is similar to sorting, though unique in that groups contain sub-sets of items while a sorted list only contains the items themselves. Users can be provided with pre-established groupings, as well as with the ability to customize their own sub-groups. Groupings, for example, could be established according to the user who experimented with particular solution alternatives, i.e. Margo’s solutions vs. Jen’s solutions. Groups can be compared against one another according to some criteria. There is an opportunity for further innovation in the visualization of cross-belonging: where an item belongs simultaneously to more than one group. For example, if a manager was to review a set of decision alternatives for one problem, generated within a given time period by multiple decision makers, it might be of benefit to note that the same solution emerged from multiple decision makers. It would be of benefit to highlight that repetition, where it occurs, for which decision makers, and why it was implemented or discarded.

Users can also be provided with the option of selecting the representation most meaningful to their particular task from a list of options. For each item in a collection, for example, there could be some text, an image, a diagram, or a mathematical formula associated with it. Users could select which of these they see. In the case of solution alternatives, users could also choose to view them as different types of information graphics (pie charts instead of bar graphs, for example).

In some cases, users might want to *annotate* the collection, the groupings, or individual items within the collection in some way. In a most basic form, annotations could be text or labels; while in more complex forms, annotations could be text, images, sound, or other media. Those experimenting with solution alternatives could annotate the items they generate with related key performance indicators (KPIs), observations from the field, thoughts behind implementation, etc., thus capturing both the quantitative data as well as their qualitative experience. Annotations could be shared, exported, or hidden.

In certain instances, users may wish to open the simple item representation available in the RPB, revealing additional data or a more complex item representation. For example, the simple item representation may be in the form of a cropped-in image thumbnail, while the more complex representation could be the entire image at a large scale, combined with relevant metadata. The simple representation could be in the form of a bar graph, while the more complex representation could be a larger version of the bar graph with detailed numerical values, the formula, and annotation.

Extending Existing RPB Principles

A linear programming problem of the type that underpinned the design task defined by Syncrude (and described in the Introduction Section of this Dissertation), is mathematically formulated as shown in Fig. 5.13 (called the Standard Form) (Free Software Foundation). Thus, the model we used to calculate potential optimization solution alternatives consisted of one objective function which is a linear equation that must be maximized or minimized, combined with a number of linear inequalities or constraints. This was my starting point for the design of DS interface alternatives.

$$
\begin{array}{ll}
\text{maximize} & C^T x \\
\text{subject to} & A\,x <= B \\
 & x >= 0
\end{array}
$$

Fig. 5.13: Sample linear programming problem, written in the Standard form (Free Software Foundation).

Once the formula has been calculated, the result is a numerical solution to the problem. It would be possible to translate this visual system into an RPB, presented in a tabular form, for example, as is made possible with the Microsoft Excel Solver shown in Fig. 5.02. Every numerical solution would become one item in a cell of the table.

Other, more graphical alternatives to the display of numerical results are possible (see Table 1.01). In Design Z these graphical alternatives take the form of gear-like shapes. In Design A +1 they take the form of sliders and bar graphs. In Design B, they appear as lines and circles. At this point it may be useful to recall that all designs generated for the *Oil Sands Project* are based on an ice cream manufacturing scenario, as dictated by our industry partner.

Below is a descriptive reflection of the three design alternatives – Z, A+1, and B – at the leaf, or micro level, followed by a critical reflection on the design choices made regarding the designs' visual form, and the consequences of these decisions.

Descriptive Reflection: Design Z (Gears)

The visual system for Design Z assigned meaning to differences in a gear's internal structure, use or lack of a border, border shape, and gear colour; I manipulated the size and the number of gears, the complexity of their shape, their colour, and level of transparency. I also developed a set of rules that would govern the creation of a gear's visual appearance:

- a gear's border would have meaning;
- the colour of a gear would relate, cognitively, to the type of item it is representing;
- colour use would remain consistent;
- a colour that attracts a high-degree of visual attention will signal importance or alert (more than one colour may be needed here, depending on the level of alert); and
- a relationships between gears will be visually represented, as will a lack of a relationship.

I designed two gear structures: gears for parts (ingredients) and gears for wholes, containing parts (ice cream flavours) (see Fig. 5.14). The flavour gear design can accommodate situations when a flavour is made up of multiple ingredients and situations when a flavour is made up of only one ingredient. I used a toothed-border, common to a gear, to signify that a gear has a dependent relationship to other gears. A lack of a toothed border means that the gear is independent of other gears.

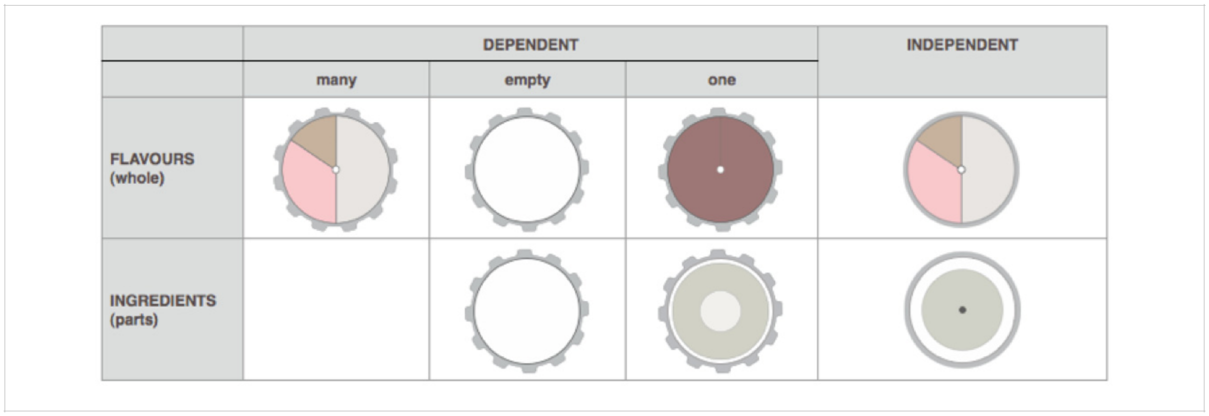

Fig. 5.14: Two gear designs: one for flavours and one for ingredients.

Each ingredient has its own colour and/or texture (see Fig. 5.15). Coloured gears signify liquid ingredients, while coloured and textured gears signify dry ingredients. This distinction provides an additional layer of information and a greater range of options for colour coding.

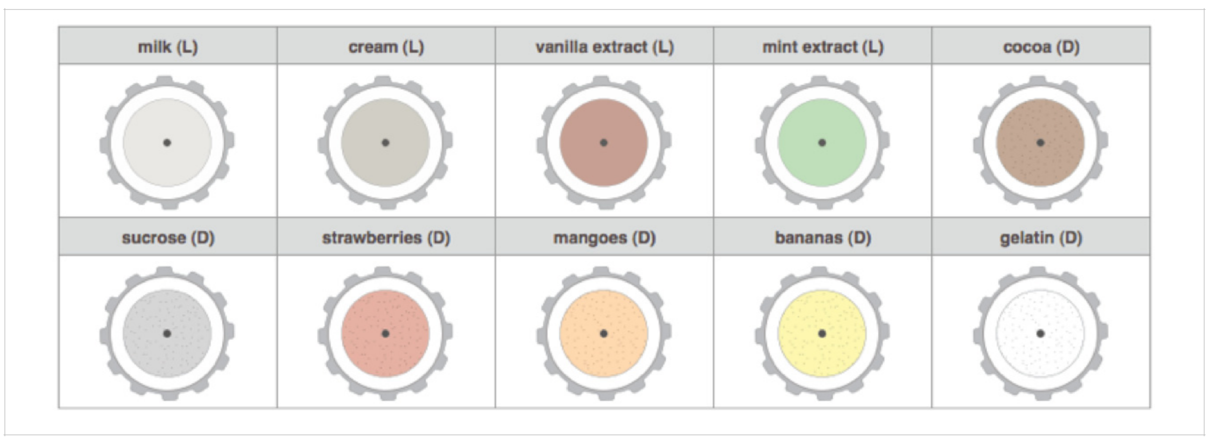

Fig. 5.15: Colour as applied to the ingredient gears.

Flavours are made up of a combination of those colours and/or textures that have been assigned to their ingredients. The recipe for every favour is viewable at a glance: every gear is a pie chart displaying the ratios of each ingredient to the whole recipe (see Fig. 5.16). For example, the recipe for vanilla flavoured ice cream is made up of almost equal parts cream and sugar, with some gelatine and a bit of vanilla extract.

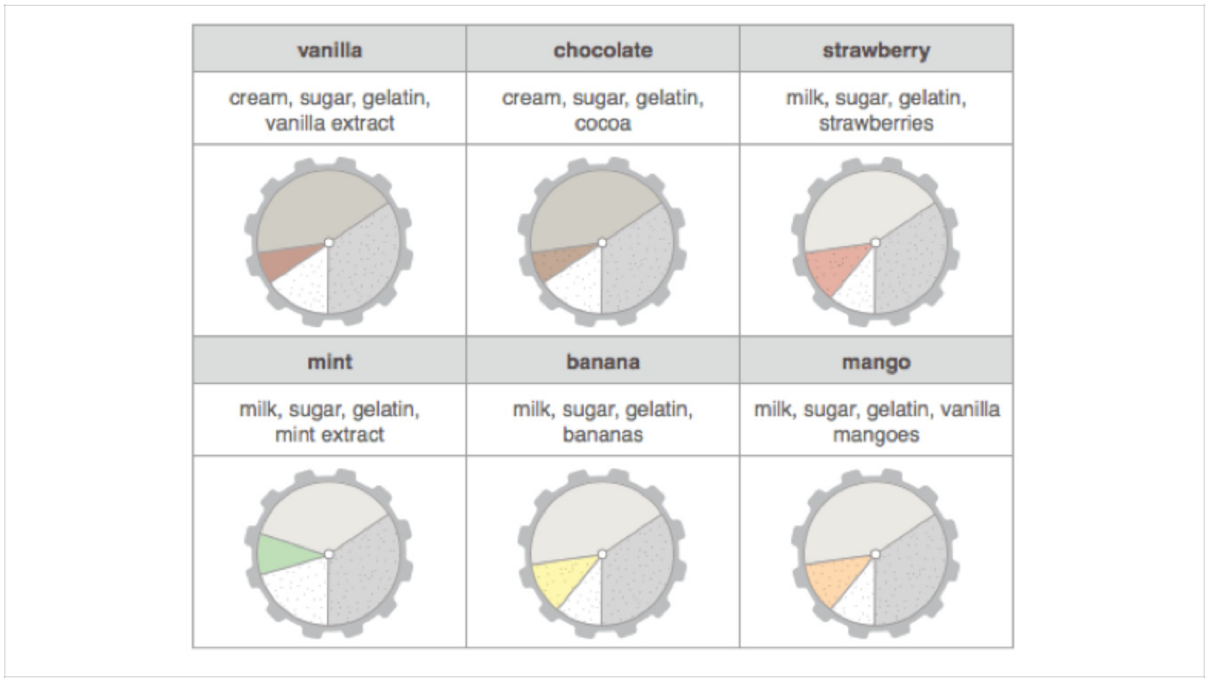

Fig. 5.16: Flavour gears.

Descriptive Reflection: Design A+1 (Bars & Sliders)

I completed a thorough exploration of alternatives to the visual representation of the solution portion of Design A+1 (located at the bottom portion of the display), and developed 24 unique designs, sub-divided into 7 categories:[18]

1. Visualizing current vs. solution vs. total capacity values;
2. Visualizing the increase or decrease of production values;
3. Exploring options for numerical value treatments;
4. Exploring horizontal instead of vertical bar graphs;
5. Exploring regular instead of stacked bar graphs;
6. Exploring pie charts instead of bar graphs; and
7. Exploring an experimental solution.

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18 See Appendix **A** for all 24 alternatives.

The 24 alternatives included bar graphs, stacked bar graphs, and pie charts, with varying amounts of labeling and numerical support. Each design alternative had its own functional advantages and disadvantages (see Fig. 5.17 for one alternative and its functional overview).

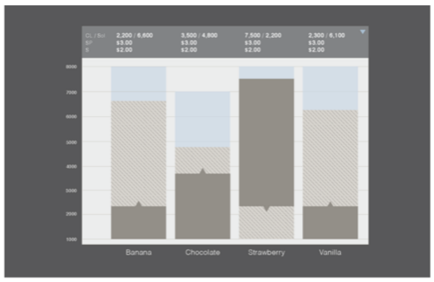
		Advantages:	Disadvantages:
2e	 Small, triangular arrows (without stems), placed on top of the "current level" portion of each bar.	• The arrows' proximity to the current level portions of the stacks may provide a clearer reading than in 2d.	• In a situation where the increase or decrease of a value is very small, the space won't be able to accommodate the height of the arrow. • This alternative has the potential to be confusing – should the current level be read to the height of the bar, or the height of the arrow? • Due to the small size of the arrows, the above-mentioned disadvantages have a lesser degree of impact than alternatives 2a–2c.

Fig. 5.17: One of the 24 unique designs explored for Design A+1.

The experimental solution alternative (see Fig. 5.18) emerged as particularly unique and compact. Although, still a stacked bar graph, it combines all four flavours into one graphic, making comparison of the flavours against one another easier, for both the current and solution levels. The addition of vertical lines also supports comparison of current values with solution values. In this design, numerical values are proximal to the graphical representations, while still using less space than the other solution alternatives I proposed.

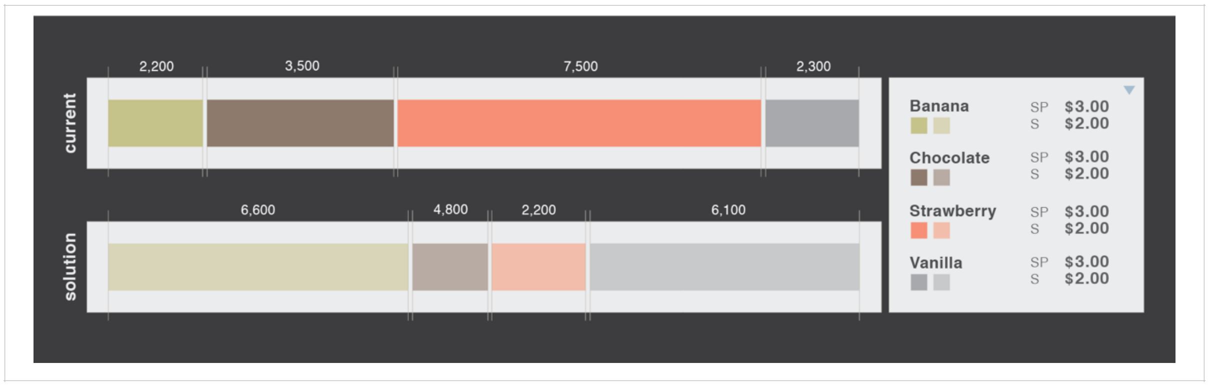


Fig. 5.18: The final, experimental solution alternative, from Design A+1.

Descriptive Reflection: Design B (Lines & Dots)

Design B emerged as the graphically-simplified version of Design A+1. Solution alternatives are presented as half circles, with the outline representing the current state of production and the solid fill representing the suggested level (recommended solution). For example, in Fig. 5.19, the system recommends a substantial decrease in the production of strawberry ice cream and an increase in the production of vanilla.

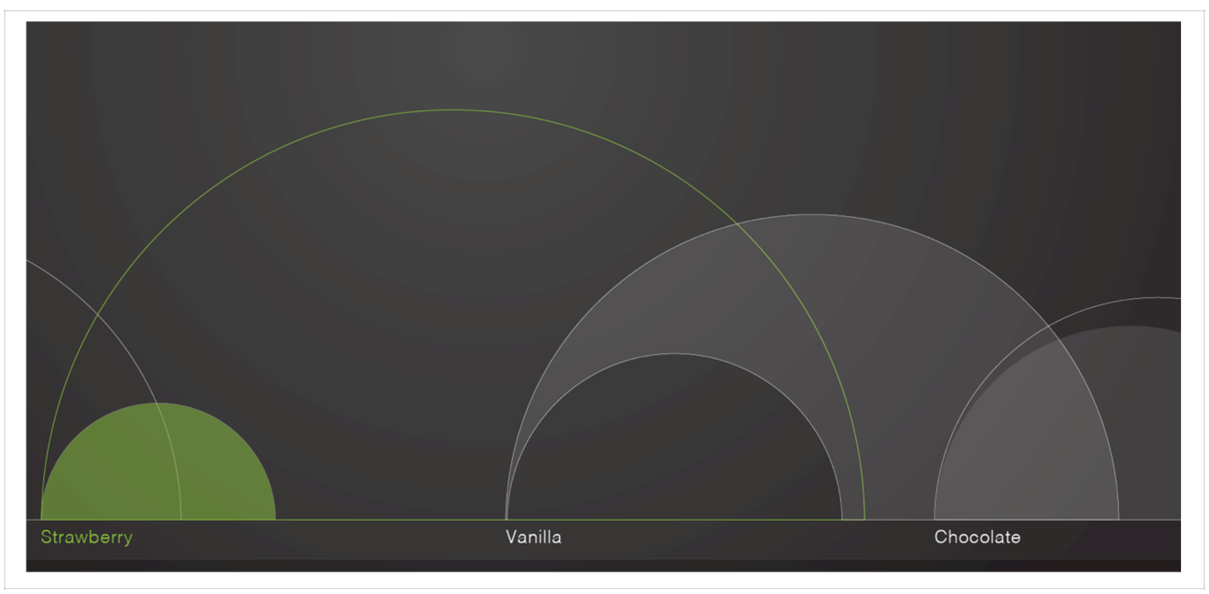


Fig. 5.19: Partial solution visualization, from Design B.

Descriptive Reflection: Controls vs. Solution Alternatives

Each design – A+1, Z, and B – consists of two parts: the controls and the solutions. In the gear design, the controls and the solutions are intentionally combined into the same set of graphical objects. Users would drag the appropriate gears into the central screen space, then manipulate them: increasing a gear's size, for example, to signify an increase in production. Constraints that are dependent on one another remain spatially connected and change together as needed. For example, if an increase in the production of strawberry ice cream affects the number of trucks required for distribution, the gear representing trucks connects to the gear representing strawberry ice cram, and their size changes accordingly. In contrast, both Designs A+1 and B contain a spatial separation of controls and solutions. Controls are located at the top of the screen, and solutions appear at the bottom, once the appropriate set of user actions (setting up the constraints and selecting "Solve") have been completed. At the same time, controls and solution alternatives remain visually connected through the use of a unified colour palette, typographic structure, and graphical system.

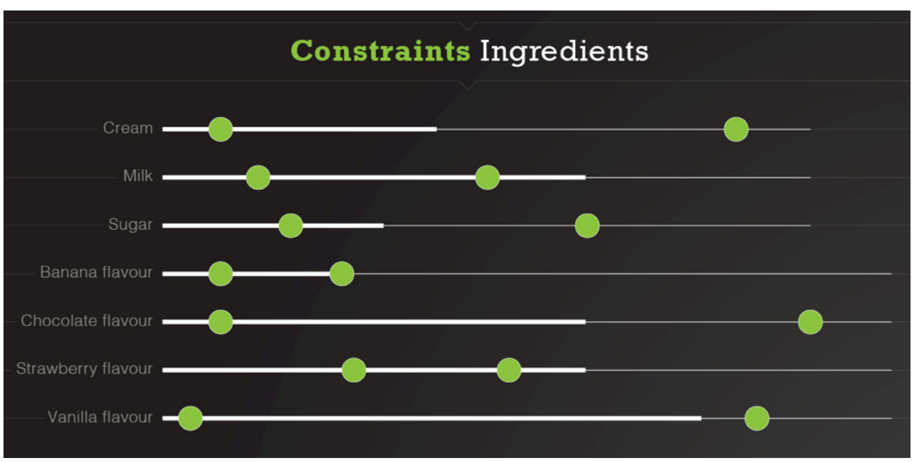


Fig. 5.20: Controls for setting the ingredients bounds, from Design B.

Analytical Reflection of Designs A+1, B, and Z

Above is, more or less, a visual and functional description of the three designs, derived primarily out of discussions with the academic team and our industry partner. Next, I will attempt a reading of these designs as text, to determine not only what has been graphically constructed, but also how the choices around the details of that construction may be interpreted.

In terms of geometry, Designs A+1, B and Z range from the simple to the complex. Design Z constitutes a layering of circular shapes that suggest gear-like structures, reminiscent of the inner working of clocks, car parts, and machines. In this way, Design Z can be read as iconic, indexical, and symbolic. As an index, these gears represent factory production or industry. Symbolically, they are meant to represent connectivity and interdependence, since a gear's teeth make it possible for it to connect with other gears in order to form a more complex system. Thus, the fact that the manipulation of one gear affects or changes another constitutes a rather short metaphorical leap – a reasonable mapping to the natural world. Furthermore, in the specific instance of the case study presented by our industry partner – decision making in manufacturing – gears are part of a familiar, if rather dated, visual language. This design leverages what has been recently termed skeuomorphism: where an artefact retains ornamental design cues from structures that were necessary in the original (Basalla, 107). An email application using the iconic graphic of a paper envelope to suggest the sending of written communication is one example of skeuomorphism in HCI.

Adding the soft colour palette to the gears – pinks, yellows, blues, and tans – is meant to suggest a particular type of machine-based production: ice cream flavours. This particular colour choice moves the design away from the harsh contrasts typically associated with metal gears and industrial machinery: greys, blacks, and dark browns. The pastel colour palette has a potential downside, anchoring the design in ice cream production, making it less transferable into other types of manufacturing.

Direct gear manipulation provides users with the perception of unmediated control over outcomes – for example, as a user changes a gear's size to suggest an increase in the production of a flavour, that increase initiates the calculation, generating an appropriate set of codependent outcomes.

Design A+1 borrows from a visual language of bar charts, familiar to those who use Excel spreadsheets or read financial reports. The colour structure in this design consists of greys, white, and black, with a simulated-metallic background pattern. Thickness of bars represents lesser or greater amounts. Lack of direct manipulation, the visual separation of controls from outcomes (solutions), and the addition of the "Solve" button, places the system (the algorithm) in the authority role – the user asks, waits, and receives the "optimal" answer.

Design B is, in many ways, very similar to Design A+1, with two major differences. While Design A+1 is rigid with its use of vertical and horizontal lines and rectangular shapes, Design B appears much more delicate and organic. Numerical detailing has been intentionally omitted. This, combined with swooping arcs, a green tone, and an overall lack of mass, gives Design B an almost ephemeral quality. The potential result may be an increased willingness to consider the interaction as decision experimentation rather than decision implementation. Though the colour structure – green on black – may suggest a 1980s computer terminal, the overall look and feel appears the more technological science fiction (see Fig. 5.19).

While each of the three designs uses a different look and feel (some more literal, some more metaphorical) in an attempt to connect with its users and the subject matter, each one is also in some way allied with the visual language of industry or technology and its emergent social and cultural traditions. Design Z appears the most connected to its industrial legacy while, at the same time, suggesting the most recent use of interaction technology (through its application of direct manipulation). In design, there is now wide-spread recognition of the need for user involvement throughout the design process, and various methods to do so have either been developed or imported from the social sciences. In the case of the *Oil Sands*

Project, our team had contact with three people in upper-management positions, all male with backgrounds in industrial engineering. We were unable, due to understandable constraints, to engage a wider and more diverse user group. Thus, it is reasonable to question the appropriateness of a visual language connected to an industrial past or a futuristic, technological future. Aside from concerns over look and feel, there is an aura of hierarchy and authority that is suggested by the functionality expressed through Designs A+1 and B: selection of constraints, request of formula, and review of generated solution. It removes the user from a place of ownership and accountability that may or may not be appropriate within manufacturing decision support.

Feminist RPB in Manufacturing DSS

Woodrow W. Winchester III, in his paper on culturally responsive design tools (14), reflects on Elizabeth Churchill's exploration of gender in design as she asserts that designers "are not passive bystanders (of the process) . . . we design products with implicit or explicit assumptions about how products will be used and by whom" (n.pag.). Both Churchill and Winchester challenge the notion of the universal user as, somehow, representative of the diverse populations that typically engage with technology. Most product and technology designers are male, white, and most likely of a higher socioeconomic status (plus, further provoked by Winchester, tend to identify as heterosexual) (Winchester, 15). As a result, that "universal user" becomes an unexamined and unquestioned self reflection of the dominant group. The manufacturing domain appears particularly problematic in this respect. In the U.S., for example, while manufacturing companies face a "widely acknowledged talent shortfall", women remain underrepresented at all levels of the workforce (Manufacturing Institute, 3). The literature in decision support design, with its recommendations regarding standards and best practices, is also predominantly written by men. Rich Prospect Browsing, if it holds to its feminist origins, may help us question the conditions under which decision support (and decision implementation) takes place. It may help us consider what decision factors are made part of the decision-making process, and which are made obscure or invisible. We may begin to challenge how different types of decision factors are currently represented and, through such representation, given a hierarchy of priority or importance, and whether we are considering the situated (contextual) nature of decision making. Finally, we may become more acutely aware of the ways in which we currently obscure the role, characteristics and responsibility of the decision maker and how such lack of self disclosure impacts those imbedded within the decision making process.

Critical Reflection Using Feminist HCI

Next, I will attempt a critical reading of Designs A+1, B, and Z through the lens provided by the six qualities proposed by Bardzell: pluralism, participation, advocacy, ecology, embodiment, and self-disclosure, once again focusing on the graphical representation of solutions (items in the collection) (Bardzell, "Feminist HCI", 1305).

Pluralist design challenges the notion of the "Universal User" by recognizing that its default is white, middle class, heterosexual and, most likely, male. In contrast, pluralism aims to be sensitive to marginal or marginalized users, thus becoming more inclusive, more diverse, and more representative of particular, specific user communities (Burnett et al., 450).

Current iterations of Designs A+1, B, and Z resist pluralism in several ways. They do not consider the diversity with which different types of users may want to engage with the interface. According to the formula used to underpin the decision calculations, users must select and manipulate some set of constraints in order to generate a solution. Thus, all users must follow the same process in order to engage with and/or construct their solution collection. On the other hand, since users are generating their own collection and, according to RPB Theory, can subsequently browse and manipulate that collection, there is promise that different types of users could generate different types of collections (based on their own interests and agendas). When considering what kinds of items act as constraints, it would be important to require those that represent marginalized interests, not only those that are most often considered in terms of manufacturing decision making (cost of materials, production levels, distribution, etc.) Then the question becomes whether all types of constraints should be given the same type of graphical form. In Design Z, all constraints are circles or gears, though differently coloured. In Design A+1, all constraints are squares or rectangles. In Design B, they are the same line and green dot pattern. If we expanded what we considered as a constraint into, for example, hours worked by the employees of the plant, should we then consider a different graphical representation for, in this case, human versus mechanical constraints?

The qualities of participation and embodiment contribute to this argument, warning us against speaking for others (Muller 447–449) and emphasizing that our understanding of ourselves and our world "derives crucially from our location in a physical and social world as embodied actors" (Harrison, Tatar, and Sengers, 6). It encourages us to actively seek out and listen to the voices we are describing or discussing. Thus, if we support the user in manipulating constraints that have human consequences, should we not give those human constraints a voice, some form of agency in the manipulation? Of course, it would be irresponsible of me not to, at this point, underscore the reality that certain groups will hold more privilege than others within the decision-making process. Privilege, in this context, refers to the position that some groups hold unearned advantages (and power) relative to that of others, thereby perpetuating social inequality – some are more likely to be the decision makers while others the human agents, affected by the decisions (Twine 8–10).

As described above, both Design A+1 and B have the potential of disempowering users by suggesting that the formula is the agent of knowledge – the one who will determine the best solution to the human-proposed problem. Reinforcing the browsing model – where users generate numerous potential solutions, then are encouraged to browse them in order to determine "best fit" – has the potential of remediating the disempowerment. Additionally, browsing supports advocacy (the third of Bardzell's Feminist HCI qualities (1306)), in enabling users to take a position or course of action. In the end, it is the users who determine the best decision to implement, not the formula. In order to make the connection between person and action more transparent, each decision that has been selected for implementation should be connectable back to the person who generated it, thus providing the potential for future retrospection.

Assigning different graphical forms to solutions that privilege different types of outcomes (production optimization versus labour hours, for example) can also support a questioning of the point of view (lens) and the position(s) that individual decision makers aim to assert in their communities. A design that considers the quality of self-disclosure renders visible the ways that it affects its users. It calls to attention what the design is trying to make of its user, introduces a critical distance between itself and the user, and creates opportunities for users to define themselves.

The quality of design ecology considers the ways that an artifact exists in relationships with other artifacts, how they affect one another, and how these relationships determine meaning. Most recently, designers are particularly focused on environmental, gender, race, social class, and international consequences (Bardzell, "Feminist HCI", 1307). Thus, should all solution alternatives be given the same graphical form, even if they carry with them negative consequences? Currently all three designs equalize decision alternatives, independent of their outcomes.

Critical Reflection Using the Framework Proposed in Chapter 4

Finally, I will subject my work on Designs A+1, B, and Z to a reading using the lens provided by the six-point framework proposed in the previous chapter. In attempting such a reading, I hope to demonstrate my own adherence to the framework's sixth principle: *to expect and welcome being subjected to rigorous critique*. Through this reading, I will not address the fourth (consider the micro, meso, and macro) and the fifth principle (privilege transparency and accountability) since these are the focus of the rest of this chapter. Instead, I will discuss the remaining three principles as they relate to my work on the *Oil Sands Project:* (1) Challenge existing methods, beliefs, systems, and processes; (2) Focus on an actionable ideal future; and (3) Look for what has been made invisible or under represented.

It is when we consider these three principles in concert – challenging existing practices while striving for an actionable ideal future and considering that which has been made invisible or under represented – that we encounter the wicked problem of interface design for decision support in manufacturing. Seeking an actionable, ideal future begs the question: ideal for whom? While A+1, B, and Z differ in their likelihood of implementation (and the amount of resources they would require to be implemented well) each of them is, in fact, implementable. If we consider the perspective of the industry partner – Syncrude Inc. – two of these designs would be considered ideal: A+1 and B are successful in visually representing the linear programming formula and in guiding users towards generating an optimized solution. The fact that these designs ignore human and environmental constraints may also be considered a positive. If we shift perspectives and attempt to challenge existing beliefs and practices, such a narrow definition of manufacturing decision-making comes under question – we can not accomplish one without, either, discarding the other, or shifting who we consider as the ruling authority over our design. Thus, who is our master? Is it the client, with his requirements, constraints, context of use (as well as the monetary and logistical support for the project)? Is it those who will affect and be affected by the decision making? Or is it the designer, with her moral code and design research agenda?

The relationship between a paying, industry partner or client and the designer is, acknowledgedly, complicated. On the *Oil Sands Project,* our industry partner made the decision for our team to use an ice-cream instead of oil production scenario. They argued that ice-cream manufacturing was the same as oil in terms of the formula that would drive the decision-support system, with similar number and type of constraints. However, the ice-cream scenario hides the context of the real problem: in Alberta and beyond, the oil sands are controversial in terms of their environmental and community impacts (Gosselin et al., ff.). The same can not be said for ice cream manufacture. Similarly, when issues of gender, diversity, or inequality are either not perceived, or are perceived with hostility towards them, transparent negotiation about including their consideration as an important aspect of the project becomes challenging if not outright counter productive. Hence, such questions as who works at an oil extraction and processing facility, what kinds of positions they hold, who is impacted by who's decisions and in what ways, are there differences in decision-making styles or approaches, where the inequality lies and how it manifests, and others can never be explored. Acting as though potential differences in status and authority do not exist isolates the design process from critical engagement, reinforcing the status quo and entrenching the resulting artefact in a fundamentally patriarchal understandings of its users. Finally, positioning the scenario in ice cream instead of oil adds a level of insignificance to the DSS that, once again, does not match real-world application.

If we are to make a difference in the form of implementable design, must we accept the realities of most (if not all) design practice: those who pay the bills, make the rules? Is that, fundamentally, why most examples of critical design have been relegated to the gallery? In certain situations it may be enough that we are open and transparent about the limitations placed on us and our design efforts, acknowledging the narrow view addressed by an artefact. Designers do this already, and the design discipline, in fact, celebrates the successful focusing of a problem and addressing of specific, well-defined client and user needs. If we add to that a transparency around what has been excluded and why, and a visibility around the designer's positionality, there will be no shame in meeting the project brief. However, we are still accountable for not questioning if there were other than ice cream options for our scenario. Could we have successfully pushed back against that decision, or proposed a scenario, not grounded in oil, that has a similar potential for human and environmental consequences? In the *Oil Sands Project* the significant, unspoken power hierarchy that placed design research as in service to other disciplines made such a challenge highly problematic.

If we fail to challenge the agendas established by industry, what happens to Z or Z+1? Under client-driven constraints, how can design move beyond incremental improvements and into design innovation? On past projects in DH, my research partners and I have argued the following: for interdisciplinary research to be a worthwhile endeavour for all the disciplines involved in the project, we must agree to respect and work towards accomplishing every discipline's research agenda and meet its publishing requirements (Ruecker and Radzikowska, "The Design of a Project Charter". 288). One discipline cannot become only a service to another. Such a hierarchy is easily the default in design, since its research practice is newer than most others, while its industry practice one of the most visible. However, in academic projects, design researchers must strive for equal representation by seeking funding and establishing and promoting their own research agenda.

Proposing New RPB Principles and Tools

I propose the following four new principles in an effort to, first, extend Rich Prospect Browsing Theory and, second, challenge existing notions of what constitutes a good quality interface for decision support. These new principles draw heavily from work by Bardzell and colleagues in the area of Feminist HCI (see Chapter 3 of this dissertation), where feminism is proposed as a critical lens through which we can question core concepts, assumptions, and epistemologies of HCI.

1. Principle of Participation: Leverage User-Generated Data

Most of the examples of Rich-Prospect browsers described by Ruecker et al. utilize pre-existing collections (*Visual Interface Design for Digital Cultural Heritage,* ff). For example, the Pill Browser uses an existing image and metadata collection of pills (Ruecker, Given, Sadler, and Ruskin). In certain RPBs users have the ability to load their own collection, though even in those cases the collections are not user-generated, but user uploaded (speeches in Shakespeare's Coriolanus, for example). In an HCI for DS, users could start off working with items from a pre-established collection, constraints, for example, or solutions emergent from past experiments. However, once the user begins to generate new optimal solution alternatives, a new collection would be created. A collection could be made up of items generated within one experiment session, or could be made up of items generated in multiple sessions, or even combined from sessions by multiple users. Finally, users could be provided with a combined view of solution alternatives, plus implemented solutions and their consequences, thus combining multiple data sources: solution experiments and implemented solutions (multiples generated by the user(s)) and consequences to the implemented solutions (collected by the system).

Such functionality has the potential of engaging with, and moving beyond, the second quality proposed by Bardzell (Feminist HCI, 1306), *Participation*, which encourages us to actively seek out and listen to the voices we are describing or discussing, especially if those are the individuals who are conventionally silenced (Muller, 447–449). In the case of a DS HCI, participants become co-creators of collections. If combined with an advanced annotation functionality, such collection items would gain a connection to their originators – real people with experience in considering and implementing decisions within a particular manufacturing context.

Alternatively, the system could consider all combinations of available constraints, then pre-calculate all the possible solution alternatives that could be generated through their manipulation and store them in a database. Then the starting point for the DSS would not be the controls, rather the entire collection with appropriate tools for its manipulation. This crates a fundamental shift in the power dynamics between system/technology and person.

2. Principle of Association: Make Relationships Visible

This principle is similar to the existing RPB *Grouping* tool, but calls for a permanent graphical representation of relationships between items. Relationships could take on several forms. In an RPB for decision support, a relationship could mean the interdependency between constraints where, for example, adjustments in certain parts of the equation could affect other parts of the equation; or certain constraints palettes might need to be viewed and adjusted together to generate a solution. A visual indication of a relationship between constraints is needed to communicate them as a grouping, in some way separate or different from the others. In RPBs where the function is not primarily decision support, relationships would mean some kind of visual grouping of like items. This principle could appear similar to the second, original RPB principle of providing users with tools to manipulate the display. However, this principle differs from a tool in that, in the examples described above, certain items in the collection can not be manipulated by a tool independent from one another. When this is the case, the relationships between these collection items need to be made explicit at the start of the browsing. For instance, if A causes B or A opposes B or B can not exist without A.

Related Tool: Connection-Making

In order to recognize the users of an RPB for decision support as creators, we must also empower them to construct relationships between items in the collection. Decision makers could use this tool to connect solutions to one another or to other information, for instance, by day of the year or by operator or by a shared objective function (maximizing profit vs minimizing cost, for example).

3. Principle of Contexuality

The criteria of contexuality combines two qualities proposed by Bardzell: *Embodiment* and *Ecology* (*Feminist HCI,* 1307). Contexuality asks that collection items still exist independently but, when appropriate, become automatically connected to a contextual surface space. Thus, decisions would never stand on their own – as independent collection items – but become situated within a surface that is made up of information about their decision maker, related key performance indicators, consequences of implementation, related factors, etc. This notion is particularly powerful in manufacturing scenarios where decisions are connected to a limited set of constraints (cost of materials, labour, and waste disposal, transportation, and production time), but are viewed independently to individual, social, or ecological impacts. Current displays for solution alternative fragment the reading experience. Contexuality suggests that certain collections require a situated reading to be fully understood. I argue for both a "bag of solutions", to borrow from Bhattacharyya et al. (5), and for situated reading that comes from the permanence gained through contextuality.

Related Tool: Structuring

It addition to tools for sorting or grouping, the RPB could allow users to arrange items (or subsets of items) within some other more complex, meaningful structure in order to make the display easier to browse and the items more meaningful to explore. For example, items could be arranged in columns or according to a grid system. Solutions could be browsed according to a visual timeline. More complex structures are also possible. One example of a complex structure applied as an organizational system for data is provided by the *Structuring Surfaces* project (Radzikowska et al. 19–21). It enables users to generate visual diagrams from their data, and then introduce an additional cognitive layer underneath the data display in order to help the user mentally structure the information. The surface also helps to extend the diagrams' meaning (see Fig. 5.21).

Fig. 5.21: *Structuring Surfaces* project (Radzikowska et al. 19–21).

4. Principle of Pluralism: Nurture the Marginal

The feminist quality of *Pluralism* focuses on that which is on the margins (Bardzell, “Feminist HCI”, 1305). Pluralist design would resist any single or universal point of view (Muller, 448). In HCI for DS, pluralism could be interpreted in several ways. First, pluralism could mean opening space for that which occurs on the margins, for example, solutions that have gone unimplemented, or those that are based on underrepresented constraints. Second, an HCI for decision support could provide users with the ability to select a different starting point than the one suggested by the design. Since the visual representations of constraints that comprise the initial equation presented to the user may not be the parts they need to generate appropriate solution alternatives, the design would need to be flexible enough to allow users to customize the equation from a palette of constraint options. Repeated users could start the display on the customized equation they use most often. As an alternative, users could be provided with all of the available constraint palettes, then given the ability to customize the equation most fitting to their scenario.

Related Tool: Inverting

This tool would enable users to make the invisible, visible. It would flip the display and give graphical form to that which is opposite of what is currently being viewed, or that which sits on the outskirts. This tool is different from the sorting or grouping tools in that it looks at what is a part of the collection and assesses that which is not, then makes it browsable. For example, when viewing a solutions collection, users could choose to look at solutions that were never suggested by the algorithm. When looking at a collection of implemented solutions, a manager could look at all solutions that were never implemented by her, then sort them according to who generated those solutions, and look for patterns based on gender, length of time at the plant, type of solution, or others.

A Critical Challenge to the Power Embedded in Prospect & Refuge

I will close this chapter by reflecting on Ruecker's extension of refuge, developed as part of Rich Prospect Browsing Theory. Appleton argued that two features of landscape are directly related to the survival of people and animals in their habitats: prospect and refuge: "Where he has an unimpeded opportunity to see we can call it a prospect. Where he has an opportunity to hide, a refuge" (73). Appleton based his theory on natural selection, where survival was the result of, in part, the ability of the individuals of a species to identify and capitalize on opportunities for prospect and for refuge. Such individuals had, theoretically, more opportunities for hunting, shelter, and concealment, as well as for the establishment and maintenance of territory, with the emotional results of ease and satisfaction (41). Ruecker supports Appleton's argument when he states:

> the suggestion that prospect and refuge are universally relevant due to human biology is not without merit. Leaving aside natural selection for a moment, it is true that human beings are biological organisms, bipedal, with two highly-specialized eyes on the same side of the head and a tremendous amount of brain capacity dedicated to the processes of visual perception. This physical conformation suggests

> that certain kinds of environments are going to be privileged by this creature, where plenty of visual information is available in the front and the unobserved back of the head is protected. Appleton's prospect and refuge meet this description nicely (*Affordances of Prospect,* 39).

While Ruecker's work focuses, primarily, on the prospect portion of Appleton's theory, there is much opportunity left to consider refuge. If we support the natural selection argument we will, undoubtedly, consider the use of prospect and refuge to be a positive, survival-enabling skill. Fair enough. Those who can seek shelter are more likely to survive. Those who can hide in ambush, are more likely to surprise their opponent. Those who can utilize a prospect view, observing their prey at a large distance, are more likely to go unnoticed or circle around for an attack. Distancing acts that result in anonymity, concealment, and secrecy become rewarded with survival, creating a power hierarchy between those who have and do not have the ability to take advantage of said skills. In fact, the concepts of prospect and refuge are both positions of power: prospect gives power through increased perception, while refuge gives power through concealment. Thus, it begs the following questions: who gets to see and who doesn't; who gets to conceal, and who doesn't? The DS interfaces designed as part of the *Oil Sands Project* were meant to be used by managers to aid in decision making around production and distribution. Most corporations are heavily hierarchical. While the span of control (the employee to manager ratio) varies across industry types and individual corporations, a ratio of supervising 6 to 10 employees per manager is common, with some literature suggesting 15 to 20. In situations where employees are performing repetitive work and the management team is fairly experienced, a larger span of control is possible (Davison, 23). It is important to recognize that there are many layers of management in organizations, each one with a different type of decision making, with consequences to a varying number of individuals. BP Oil, for example, has an executive team of eleven that makes decisions affecting over 84,000 international employees. In a manufacturing scenario, the higher up the managerial hierarchy, the more of both prospect and refuge is gained by a manager.

It is not within the scope of this dissertation to construct an argument against corporate secrecy or for government transparency. Much valuable work exists on both fronts. However, given that my interest lies, in large part, on engaging with and extending Rich Prospect Browsing Theory, even proposing, in this chapter, new RPB principles and tools, I would feel it unethical to not question the privilege that appears embedded in the concept of prospect and refuge, particularly since Critical Theory and Feminist Theory are a substantial positional underpinnings of this dissertation. For example, arguments for fiscal government transparency through "ready access to reliable, comprehensive, timely, understandable, and internationally comparable information on government activities … so that the electorate and financial markets can accurately assess the government's financial position and the true costs and benefits of government activities, including their present and future economic and social implications" (Kopits and Craig, 1) have been made by the International Monetary Fund, World Bank, and several independent research institutions.[19] Counter arguments have also been made that "transparency results in government indecision, poor performance, and stalemate" (Bass, Brian and Eisen, 1). However, from a Critical Theory perspective, the economic and political dominance gained by the bourgeoisie through the use of capitalism and industrial mass production continues to be problematic (Dobrin). Lack of transparency, control over the availability of information, and silencing of diverse voices prevents use from being able to fully engage in questioning and examining our worlds.

Refuge, in particular, if it supports already-established positions of power, lies in direct opposition to several principles of the Critical Action Design Framework proposed above: challenging existing practices; looking for what has been made invisible or under represented; considering the micro, meso and macro; privileging transparency and accountability; and welcoming rigorous critique could be interpreted as a direct challenge to the idea of a power hierarchy created through the use of refuge. However, refuge can act in

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[19] For a comprehensive list, see Kopit and Craig.

service to those who need it most: workers and communities that are impacted by managerial decisions.

Thoughtfulness

Lowgren and Stolterman argue that it is the responsibility of every interaction designer to equip themselves with the "appropriate tools for reasoning" in order to "sort out what is important, make necessary judgment calls, distinguish true needs for more information from better-safe-than-sorry approaches, and identify fruitful directions in the exploration of possible futures that is called design" (Löwgren and Stolterman 171). Part of that thoughtful practice and its immense value, I would argue, is the process of critical reflection as I attempted to demonstrate through this chapter: engaging beyond a community of readily-available, easily-identifiable users, questioning what may have become invisible, and attempting to challenge the limitations constructed by our limited world views.

Chapter 6: Summary & Conclusions

> "The political, economic, social and cultural implications of technologies are never local but always global and systemic – they ripple out and affect people you may never know or see in your lifetime. It's great to believe in the promise of technological progress when you belong to a class and a society that will directly get to reap its benefits in the end."
>
> Ahmed (qtd. in Prado and Oliveira)

The primary goal of this dissertation was to make the appropriate case for further research into the development and use of a critical and reflective approach to the design of GUIs, specifically to the design of interfaces aimed at facilitating human decision-making within a manufacturing context. There were also three secondary goals, namely to demonstrate the outcomes of interrogating designed artefacts, first, through a critical lens and, second, through a feminist lens; to suggest a framework for the application of critical design to HCI; and to propose an extension to RPB theory in the form of new tools and principles, emergent out of both a critical and a feminist reflection on DSS.

Strengthening the Theoretical Grounds for a Critical Reflection

The process began in the design of three visual experiments that were based on the combination of a cross-disciplinary and user-driven design process, with the theory of Rich-Prospect Browsing. The process was cross-disciplinary in that it responded to the direction and feedback from our academic and industry-based team that included folks with science, arts, and humanities backgrounds. Our industry partner provided feedback from the perspective of operations management. The original RPB Theory, developed by Ruecker, enabled users to browse the entire contents of a collection using a single screen. Hence, all three designs were in some way based on the principles proposed by RPB, providing a prospect view on the entire decision-making process with emergent tools for the customization and manipulation of that process.

The creation and subsequent intellectual exploration of these experiments followed the notion, proposed by Galey and Ruecker, that a designed artefact can hold some kind of argument about the design of similar artefacts (ff); Bardzell's assertion that design contributes to human knowledge ("Design as Inquiry"); and Fuller's argument for an increased welcoming of intellectual contributions from non-neighbouring disciplines (10).

Three distinct proposals for the design of interfaces for decision support emerged, constructing three points that define one possible landscape of DSS alternatives: A+1 that was a small shift from existing DSS design literature; Z that was an experimental departure; and B that attempted to bridge between the two extremes.

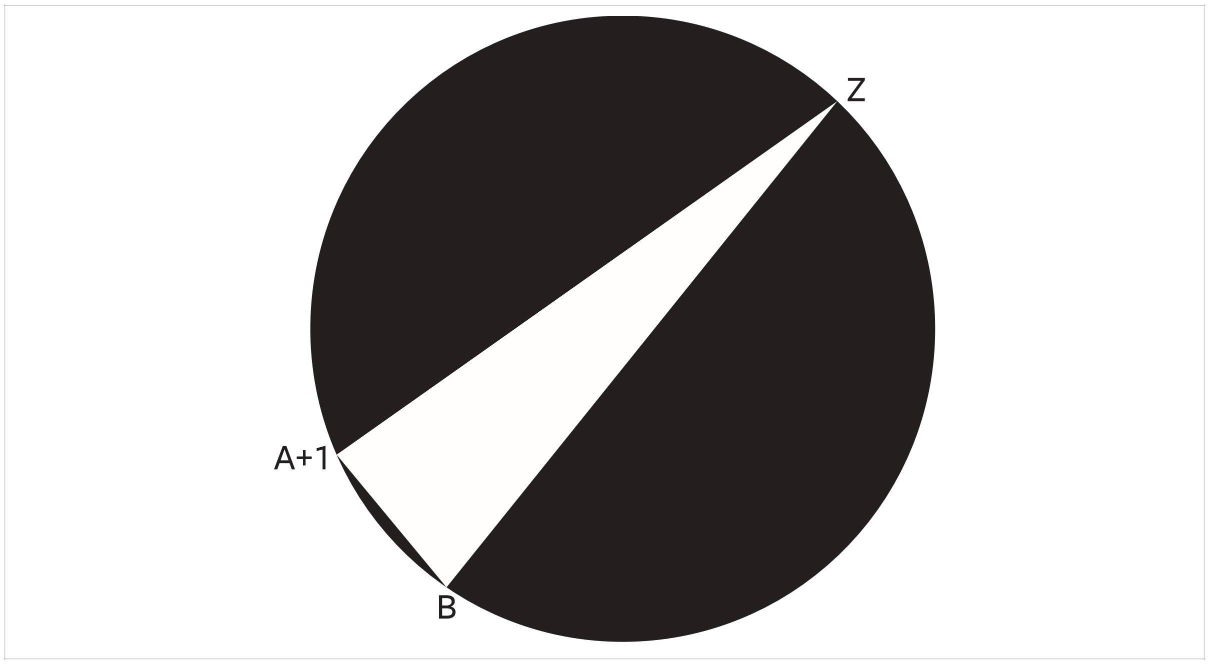

Fig. 6.01: Design space defined by alternatives A+1, Z, and B.

What followed was a process of reflection on the area defined by these three visual experiments, and what fell inside and outside of that space (see the white triangle shape vs. the black "negative" space in Fig. 6.01), driven by the following questions: what is located within the black circular area; and what kinds of new insights into interface design for DS would emerge out of pushing into that space?

To consider the first question, I looked at the territory defined by literature related to design of interfaces for manufacturing: HMIs, DSSs, and information dashboards. Since one of the grounding points for the project was RPB, I also considered the territory that it defined, mainly visualization and interface design for large collections, but also Feminist HCI. Each of the areas I examined contained some form of unexplored space, cast in shadow. For example, various literature on HMI design included instructions on how to better such design; however, none discussed HMI design at the micro, meta, and macro levels, and considered all levels as intricately connected to and affecting the others. Existing literature also contained very limited discussion of the DS interface as a situated, contextual object, with the potential of affecting and being affected by the people who were using the interface, and those who became part of the equation. Thus, I looked more broadly at what insights could be gained from design, Feminist HCI, and critical design, leveraging the interdisciplinary nature of my own background and the nature of this dissertation. Design provides us with perspectives on "wicked" problems. Among other characteristics, such problems can not be definitively described, they cannot be meaningfully, or absolutely correct or false, and we can not emerge from the process of interacting with them with definitive and objective answers (Rittel and Webber, 159–167). Design helps us to consider the totality of an artefact, its form and its function at equal and interdependent levels. Feminist HCI argues for transparency and looking for and beyond the privilege established by the status quo. Critical design encourages us to see design as inherently political, challenge existing design practices, and interrogate our assumptions about the role played by designed objects in our everyday life. Critical design, and its neighbouring disciplines of Agonism, Design Fiction, Speculative Design, and Slow Design, force us to question the impact of contextuality on our interpretation of designed objects, and how we can move critical objects out of the intellectual space and into everyday life.

Interrogating Designed Artefacts

Reflecting, through the lens of Feminist HCI, on the notion of meaningful item representation as discussed by Ruecker and Ruecker et al. ("Affordances of Prospect" and "Visual Interface Design for Digital Cultural Heritage"), created a focus on what constitutes meaningful representation, and the value of sameness and difference in graphical representation. Standard desktop icons, for example, though graphical are not meaningful when used to represent collections through an RPB. Icons, when used to represent hundreds or thousands of documents, become "a complex pattern composed of identical elements" (Ruecker, "Affordances of Prospect", 77). They convey the size of the collection but not information about any uniqueness of the items contained within it. In a file folder, textual labels need to be added to differentiate one file from another; thus, reducing the usefulness of the graphical representation.

What constitutes meaningful representation depends, primarily, on what kinds of knowledge we expect to extract from its browsing. For example, one shopping cart icon is meaningful by itself, signifying online purchasing. In a collection of shopping cart icons, displayed in an RPB, we may be able to explore the different ways icons have been drawn to represent online shopping, their colour structures, that some are carts and some bags (see Fig. 6.02). If we have additional information attached to each graphical representation – country of origin, type of online shop where it is used, attributes of its designer – our exploration can become much more meaningful. We may be able to consider cultural or social trends, change in design over time, and much more. In another example, imagine that we are looking at images of sheep, from a farm that produces merino wool to be made into sweaters. If our hope is to see photos of Betsy (one, specific sheep) and her human and animal family but are, instead, shown generic sheep-like icons, we will be disappointed. If, instead, we are exploring sheep types found in New Zealand's wool industry, more generic, icon categories may be appropriate.

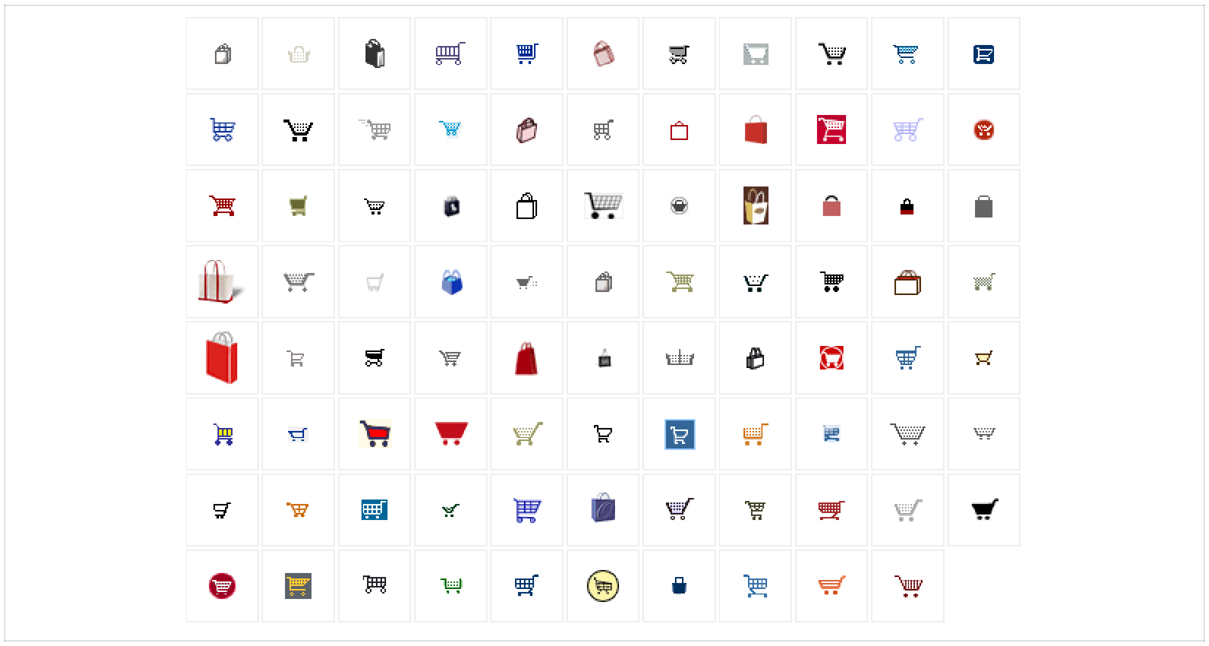

Fig. 6.02: Collection of shopping cart and bag icons (Google image search result).

The design of meaningful graphical objects to represent collection items must balance the following: amount of useful information that can be communicated through the object's graphical form, meaningful graphical difference between individual or groups of items, and restraint in form complexity to allow for the simultaneous display of all collection items at a small size.

Additionally, the design of collection item representation for manufacturing decision support I believe holds certain, perhaps unique, challenges. Design Z visually differentiates ingredients from formulas. Design A+1 differentiates ingredients from pricing and from truck allocation, while maintaining a similar, rigid design structure for all. Design B visually treats all constraints the same way, but we must ask: Is graphically representing all constraints in the same manner the most appropriate design strategy? Are graphical differences based on object type more appropriate? How should the sub-categories be constructed?

What is a constraint?

In 2010, The Royal Society of Canada produced a report on the environmental and health impacts of Canada's oil sands industry (Gosselin et al. ff). The report's major findings included nine concern areas that focused on the industry's impact on people, communities, and the environment, while acknowledging the value of the oil sands to Canada's economic well being. Environmental concerns include reclamation, long-term financial security, water quality and supply, air quality, and environmental regulatory capacity. Concerns over people and communities include health impacts of environmental contamination and impacts on community infrastructure. The concerns tend to overlap. For example, air quality, while an environmental concern, has an impact on individual health which, subsequently, affects the health of communities. While there appears to be no current evidence that water quality has been negatively affected in the Athabasca River system, there are "valid concerns about the current Regional Aquatics Monitoring Program (RAMP) that must be addressed" (2) and the report acknowledges that the "regional cumulative impact on groundwater quantity and quality has not been assessed" (2). Some parts of the report that dismiss concerns still provide useful insights into the need for addressing them: while there appears to be no evidence of "environmental contaminant exposures from oil sands reaching Fort Chipweyan at levels expected to cause elevated human cancer rates" (1), First Nation communities are concerned and those concerns need to be addressed. Finally, both Alberta and Canadian Governments have not kept pace with the rapid expansion of the oil sands industry. The current Environmental Impact Assessment (EIA) "has serious deficiencies in relation to international best practice" (2). Since decision makers relay on the EIA to "determine whether proposed projects are in the public interest" (2), their processes, standards, and data needs rapid improvement.

Considering that manufacturing decisions appear to have consequences – positive and negative – on individuals, communities, and environments, we should at least consider that our notion of what constitutes a constraint explicitly acknowledges human and environmental factors. If we do, we emerge with the following four initial categories of constraints: People, Environments, Processes, & Parts and Materials.[20] The people category includes individuals, groups, and communities. Environments are both those that are natural and those constructed: machines, working spaces, surrounding spaces, and electronic spaces. Processes include steps, time, decisions, upsets, consequences, factors, communications, relationships and dependencies. Parts and materials also include waste. Thus, constraints that have to do with the material aspects of production – raw materials, waste, resulting products, and methods of distribution – can be considered as different from those having to do with people – working hours and conditions, sick leave, and safety concerns – and different still from environmental considerations.

If all these constraint types are given the same graphical representation, would the design suggest that people are considered of the same importance as the amount of waste or its disposal? There may be a benefit to both interpretations: sameness as equality, thus positive, or sameness as a devaluing of the human condition, thus negative. From the perspective of meaningful representation, difference holds more information than sameness, when that difference is, in fact, meaningful. If each of the four categories was given a perceptually different graphical representation, users would be able to see that there are four, in some way, unique categories. We must also consider that difference may, and usually does, indicate a hierarchy of importance. If our choice of graphical representation places emphasis on one category of constraints over another, that emphasis will also hold meaning. Empowering the user to assign what type of graphical representation is given to which category empowers the decision maker, but it potentially disempowers those captured in the categories, especially if they form a typically marginalized community.

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20 This list is similar to the POEMS (People, Objects, Environments, Messages, and Services) framework described in Kumar and Whitney, *Faster, Cheaper, Deeper User Research*, 53.

Whether we use iconic, symbolic, or indexical representation could impact the user's perception of a category (and the member items it holds), the category's level of importance when considered in the decision-making process and, potentially, the user's and category member's perception of the self. For example, if I am one of a thousand rig workers and my manager is deciding my work schedule by using an icon of a shovel as my graphical representation, how do I view my identity? How does he? Is my constructed identity important to me, to the company, or to the decision maker?

Applying Critical Design to HCI: a New Framework

Though critical design provides a valuable foundation for questioning the social, political, and cultural roles enacted by designed artefacts, its intellectual context is problematic when attempting to serve design problems positioned within a real-world context such as the one offered by the *Oil Sands Project*. In an attempt to reflect both the principles developed as part of Feminist HCI and the spirit of critical design, I propose a six-part conceptual framework for the interrogation, construction, and reflection on artefacts created as part of a critical design practice:

1. Challenges Existing Practices – intentionally diversifies the pool of existing design ideas, with a focus on extreme departures;
2. Aims Towards an Actionable Ideal Future – creates actionable design that is meant to enact positive change on its world;
3. Looks for What Has Been Made Invisible or Under Represented – searches for what exists outside the bounds of typical discourse;
4. Considers the Micro, Meso and Macro – designs to support macro, meso, and micro views on the collection, offering tools for changing between these views, revealing new or more detailed information;

5. Privileges Transparency and Accountability – self discloses about the design's position on and perception of its users, and the positionally of its designers; and
6. Expects and Welcomes Being Subjected to Rigorous Critique – considers every instance of critical design as an iteration, thus subject to interpretation and questioning. Invites and engages in such critique.

The above-described framework is an attempt to build on past work by DiSalvo, Dunne and Raby, Bardzell et al., Stauss et al., Bowen, Bertelsen and Pold (see Chapter 3 of this dissertation), and others who are attempting to translate Critical Theory, Critical Design, and Feminist HCI into approaches that are useful, actionable, and hold the potential for critical reflection as part of a critical design practice.

Extending RPB

Principles and tools proposed as part of RPB Theory can also be appropriately applied to the design of interfaces for decision support, making possible new opportunities for action: manipulating the display of meaningful representations of content items through zooming, panning, sorting, selecting, grouping, subsetting, renaming, annotating, opening, and structuring. Those using an RPB to experiment with decision alternatives would gain several perceptual features: direct insight into contents, structure, context, features, limitations, connections, trends, anomalies, navigation, reminders, reassurance, with the potential of a reduction, as argued by Ruecker, in the users' sense of helplessness (*Affordances of Prospect,* 91).

In addition to leveraging existing principles and tools, I developed the following four new RPB principles in an effort to, first, extend Rich Prospect Browsing Theory and, second, challenge existing notions of what can constitute a decision-support interface:

1. Principle of **Participation** – leverage user-generated data
2. Principle of **Association** – make appropriate relationships between items in a collection visible
    i. **Connections** Tool – supports users as creators, empowering them to construct relationships between items in the collection
3. Principle of **Contexuality** – items still exist independently but, when appropriate, become automatically connected to a contextual surface space.
    i. **Structure** Tool – users can arrange items (or subsets of items) within some other more complex, meaningful structure in order to make the display easier to browse and the items more meaningful to explore.
4. Principle of **Pluralism** – open space for that which occurs on the margins, for example, solutions that have gone unimplemented, or those that are based on underrepresented constraints.
    i. **Pluralist** Tool – enables users to make the invisible, visible.

Conclusion

Permit me to return to Fig. 5.02 for a moment: the example from Microsoft Excel Solver. Solver's functionality is limited to numerical input and the generation of a numerical output based on a set of user-selected presets. Not only does it not support data exploration, knowledge discovery, and hypothesis formulation, it drastically reduces a decision maker's view on a problem to a mere pin prick. It fails to suggest that a problem could be viewed as anything other than inputs, presets, and one culminating output. It is very clearly a tool for one, narrowly defined task. Solver exemplifies McCarty's critique of the limited nature of new technology:

> In the early stages of a new technology, people tend to think that its purpose is merely to replace and improve on something they already know. The promise of the new is thought to be quantitative: the new thing will do the old job faster, more efficiently, and more cheaply. Tools, however, are perceptual agents. A new tool is not just a bigger lever and a more secure fulcrum, rather a new way of conceptualising the world. (McCarty, n.pag.)

Thus, a formula that could be solved with pencil and paper, can simply be solved faster and with a greater level of detail by the computer. In contrast, an interface for decision experimentation and exploration that considers the framework proposed in Chapter 4 and the new and existing principles of Rich-Prospect Browsing becomes a way to consider human decision making, when mediated through technology, as the complex and multi-dimensional act that it is: where relationships between parts hold meaning, where context holds the promise of a more ethical engagement outside of the industry (with people and environments), where that which exists on the margin is given space for consideration, and where decision makers are seen as both keepers of knowledge and points of privilege.

Chapter 7: Further Research

> " The value of design experiments should not of course be measured only by what succeeds, since failures are often steps towards new discoveries."
>
> Steven Heller, *Cult of the Ugly*

The areas of possible further research identified in this dissertation have been subdivided according to type of research activity: critical design thinking, critical design making, and critical design evaluation. The introduction to each section below also suggests where these projects may relate to some of the objectives of the dissertation.

In summary, the objectives of this dissertation were:

- Make the appropriate case for further research into the development and use of a critical and reflective approach to the design of GUIs;
- Demonstrate the outcomes of critically interrogating designed artefacts;
- Propose a framework for the application of critical design to HCI; and
- Extend RPB theory in the form of new tools and principles.

Topics for Further Research

The following areas of interest have been identified as possible topics for further research within the areas of critical design thinking, making, and evaluation:

Research Area	Research Questions / Topics	Outcome
Critical Design **Thinking**	1. The Elephants in the Room: Is an Interface a Teachable Moment?	Make the appropriate case for further research into the development and use of a critical and reflective approach to the design of GUIs.
	2. What lies beyond Liberal Feminist HCI?	
	3. What does transparency and accountability look like when applied to design thinking, making, and evaluation?	
	4. How do we extend the three levels: micro, meso, and macro into a spectrum instead of a three-point system?	Demonstrate the outcomes of critically interrogating designed artefacts.
Critical Design **Making**	1. Is the proposed framework transferrable to design work that falls outside of DS?	Propose a framework for the application of critical design to HCI.
Critical Design **Evaluation**	1. When provided with the opportunity, what kinds of constraints do users choose to engage in the decision-making process?	Propose a framework for the application of critical design to HCI.
	2. How do the decisions differ between users who are and those who are not provided with access to people-based and environmental constraints?	
	3. How do people prefer to be graphically represented when part of a DSS?	Extend RPB theory in the form of new tools and principles.
	4. How do the proposed RPB principles impact rich-prospect browsing?	

Table 7.01: Summary of potential future research topics.

Critical Design Thinking

1. *The Elephants in the Room: Is an Interface a Teachable Moment?*

All aspects of the work discussed as part of this dissertation is attempting to be, fundamentally, both critical and feminist. The framework proposed in Chapter 4 and the extensions to RPB proposed in Chapter 5 are based on work in Feminist HCI and Critical Design, as is my related call for designer transparency and accountability. It is my hope that future engagement with this work would result in the design of interfaces that would be critical and feminist. However, the following questions remain: can an interface be feminist even if those using it are not; can the use of an interface result in critical reflection or insight even if those who are using it are not interested in such engagement?

2. *What lies beyond Liberal Feminist HCI?*

The principles of Feminist HCI proposed by Bardzell are grounded in Liberal Feminism. However, there are other feminisms. Intersectionality, as an example, has become an important focus of some feminist thought. Rode lists several feminist theories, besides liberal, as potential contributors to HCI: Technology as Masculine Culture; Gender Positionality; Lived Body Experience; Radical Feminism; Marxist and Socialist Feminism; Psychoanalytic Feminism; Multicultural, Global, and Postcolonial Feminism; Ecofeminism; and Postmodern and Third Wave Feminism. More work is needed in this area.

3. *What does transparency and accountability look like when applied to design thinking, making, and evaluation?*

The critique of the three interface designs produced as part of the Oil Sands Project is meant to hold this designer accountable to what she considers to be substantial shortcomings of her design process outcomes. As I have attempted to argue through this dissertation, designers do engage in work that either has or has the potential for significant impact on the worlds they inhabit. More work is needed to determine strategies for encouraging designers to practice transparency and accountability.

4. *How do we extend the three levels: micro, meso, and macro into a spectrum instead of a three-point system?*

While Ruecker describes two levels of granularity for the display of information: prospect and detail, and I have argued for three: micro, meso, and macro, more work is needed both in demonstrating the application of the three levels in interface design and in exploring either the possibility of additional views or in expanding this notion into a spectrum.

Critical Design Making

1. *Is the proposed framework transferrable to design work that falls outside of DS?*

The focus of this dissertation was on decision making in manufacturing, with a case study in ice cream production and an industry partner from the oil sands. Extensions of the framework and the proposed RPB principles and tools into other domains, however, may be possible. Exploration of factors related to online purchasing or donating, for example, may result in more transparency on the part of the retailer or agency and better informed decision making on the part of the user. Work in this area has already taken place. *IceBreaker,* a company from New Zealand that produces marino wool products, includes a code located on each of its garments. I was able to enter the code from my IceBreaker sweater on the company web site, and explore the production process, tour the farm where the sheep that produced the wool live, even read about the farm's owners (see Fig. 7.01).[21] Though I was not able to track down the name of the specific sheep (I imagine her name is Betsy) that made my sweater, this is still a case of clever (and, hopefully, honest) marketing. However, imagine that amazon.com creates the potential for such detailed information display for the products sold on its site. Not all manufacturers would take advantage of it, but those that did could experience an advantage. For the user, the benefits are potentially quite significant, if I

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21 See http://ca.icebreaker.com/en/why-icebreaker-merino/trace-your-garment-with-icebreaker-baacode.html

can expand my capacity for decision making beyond product availability, price, and brand name, and into manufacturing conditions, worker pay, environmental impact.

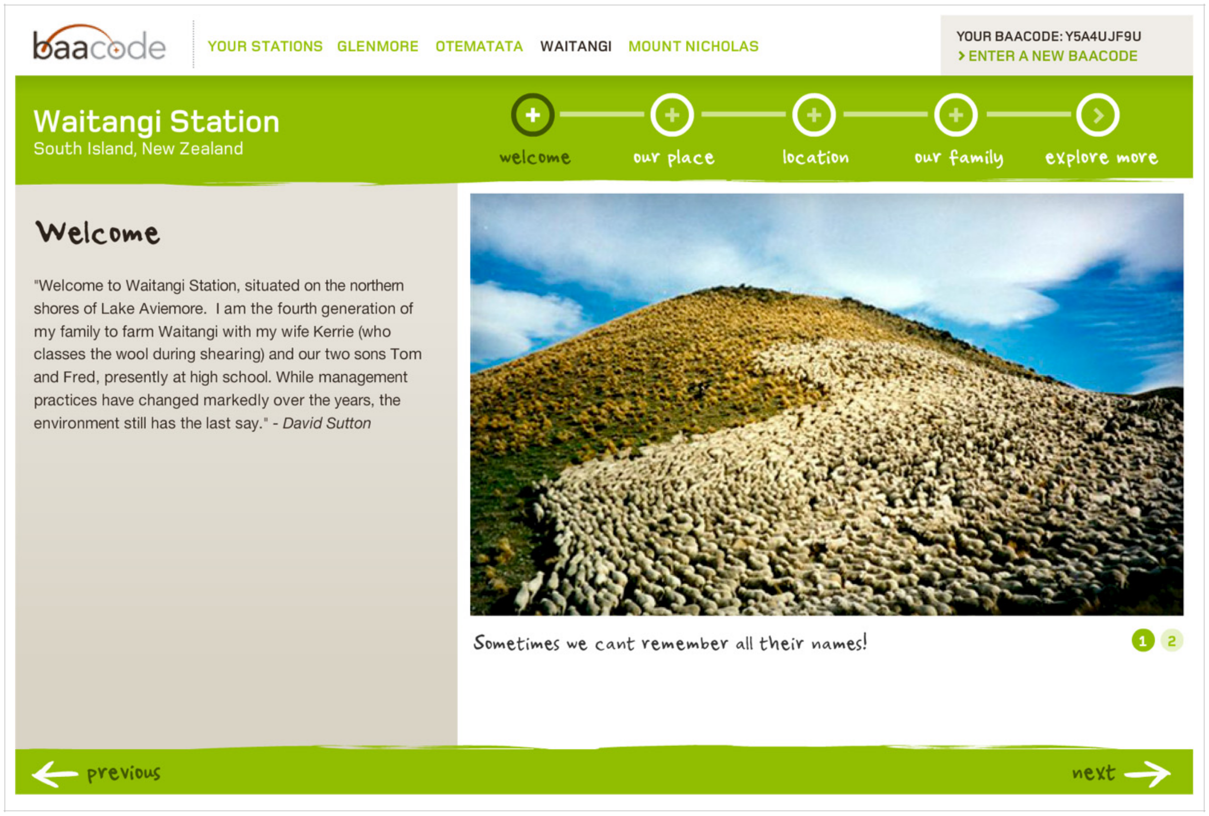

Fig. 7.01: Exploring the life of the sheep that helped to make my sweater (Icebreaker).

Critical Design Evaluation

More work is needed to determine user reactions to the framework proposed in Chapter 4 and the extensions to RPB described in Chapter 5. Research into these questions should be situated within a design-making project, and could take place both within and outside of the DS domain. Possible research questions include the following:

1. *When provided with the opportunity, what kinds of constraints do users choose to engage in the decision-making process?*
2. *How do the decisions differ between users who are and those who are not provided with access to people-based and environmental constraints?*

3. *How do people prefer to be graphically represented when part of a DSS?*

4. *How do the proposed RPB principles impact rich-prospect browsing?*

Design Criticism

I will conclude by proposing that interface design needs its own tapor.ca: a place for designers to make their work public, with an accompanying critical statement. This work would be made available for readings by other designers, researchers, or members of the user community. Its strengths and weaknesses would be made public as it became subjected to a wide variety of positions and interpretations. Throughout, the designer would remain attached to her work, becoming transparently accountable for it.

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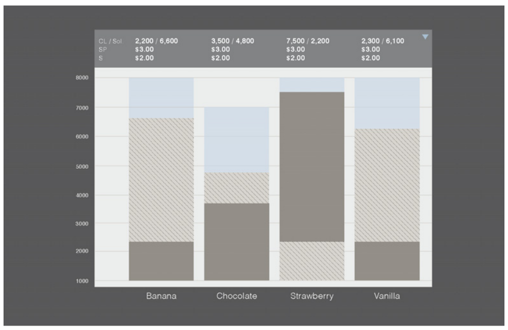
Appendix A

Original design

This stacked bar graph contains a visual display of current, solution, and total capacity quantities. The three values are differentiated through colour and texture. Values are read by either aligning to the x-axis or via a collapsible values legend at the top of the graph. In this alternative, the darker brown colour represents current levels; the lighter brown colour represents solution levels; and, the blue colour designates the total capacity.



Advantages:

- There's a clear visual distinction between the three values stacked on each bar.
- Numerical values are conveniently clustered together (this may also be a negative).

Disadvantages:

- A separation exists between actual values and the graphical display.
- There's no clear indicator as to which portion of the stacked bar represents current levels (CL) and which represents solution levels (Sol.).

Exploring alternatives for solution visualizations

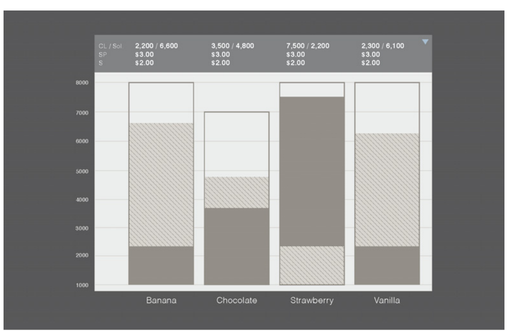
In the following design alternatives, I explore the visual representation of the solution portion of the slider interface. There are 24 designs, sub-divided into 7 categories. These categories are defined according to the focus of my exploration: (1) visualizing current vs. solution vs. total capacity values; (2) visualizing the increase or decrease of production values; (3) exploring options for numerical value treatments; (4) exploring horizontal instead of vertical bar graphs; (5) exploring regular instead of stacked bar graphs; (6) exploring pie charts instead of bar graphs; and (7) exploring an experimental solution.

* marks the strongest design alternatives.

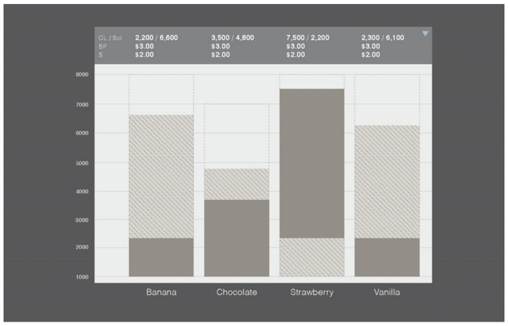
1. Exploring fill alternatives – visualizing current vs. solution vs. total capacity values

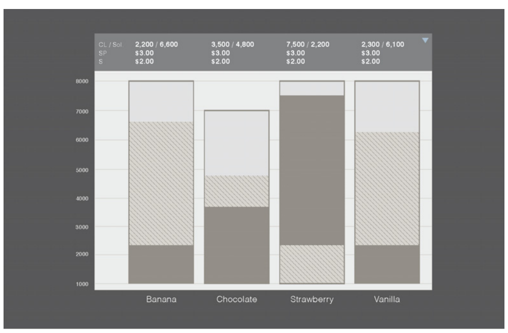
The following designs feature an exploration of colour alternatives for the 3 portions of the stacked bar graphs: current levels, solutions levels, and total capacity for each flavour. These alternatives are meant to answer which colour treatment best signifies empty, full, and potentially full.

<table>
<tr>
<td>1 a</td>
<td>

This alternative uses a high degree of fill contrast to distinguish the 3 values from each other. The darkest colour choice is used to signify the full value (current level). The mid tone is used for potentially full (solution level), and the lightest tone is meant to signify the empty range of values (potential capacity level).</td>
<td>Advantages:
• Since this solution shows a high degree of contrast between the three parts of each stack, there's a clear visual distinction between the three portrayed values.</td>
<td>Disadvantages:
• It's unclear whether a degree of contrast has the capacity to signify the 3 intended values: empty, full, and potentially full, without the use of a legend.</td>
</tr>
<tr>
<td>1 b</td>
<td>

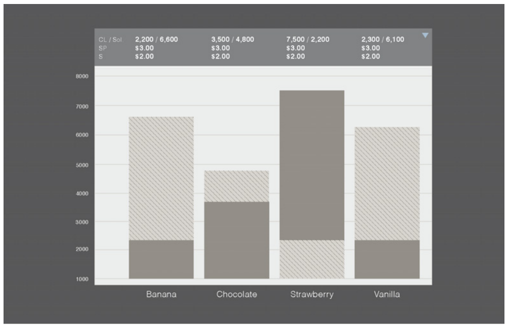
This alternative uses texture to represent the potentially full (solution) value. a high degree of fill contrast to distinguish the 3 values from each other.</td>
<td>Advantages:
• Since this solution adds texture to one of the value representations, there's a clear visual distinction between the three portrayed values.
• The lack of fill in the capacity portion of the bar has the potential to signify “empty” which may, in turn, signify unused portion of capacity.</td>
<td>Disadvantages:
• It's unclear whether a change in texture has the capacity to signify the solution value without the use of a legend.</td>
</tr>
</table>

<table>
<tr>
<td>1
c</td>
<td>

This alternative is similar to solution 1b – it also uses texture to represent the potentially full (solution) value. It also uses a dashed border around the solution and capacity portions of the bar.</td>
<td>Advantages:
• Since this solution adds texture to one of the value representations, there's a clear visual distinction between the three portrayed values.
• The lack of fill in the capacity portion of the bar has the potential to signify "empty" which may, in turn, signify unused portion of capacity.
• A dashed border may function well as an addition cue to signify values associated with the solution and unused capacity.</td>
<td>Disadvantages:
• It's unclear whether a change in fill texture and line quality have the capacity to signify the solution value without the use of a legend.</td>
</tr>
<tr>
<td>1
d</td>
<td>

This alternative uses texture in addition to a lighter and a darker fill to to distinguish the 3 values from each other.</td>
<td>Advantages:
• Since this solution adds texture to one of the value representations, there's a clear visual distinction between the three portrayed values.</td>
<td>Disadvantages:
• It's unclear whether a lighter fill will convey the unused portion of capacity.</td>
</tr>
</table>

1 e



In this alternative, the total capacity portion of the bar has been removed.

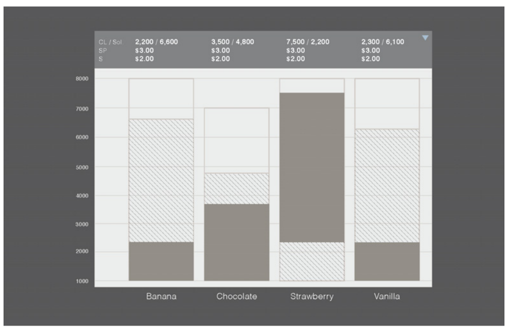
Advantages:

- With fewer values, this alternatives has the potential to be clearer as a representation of current value vs. solution value.

Disadvantages:

- This solution is only valid if each flavour has the same total capacity.

1f *



This alternative removed the fill behind the texture, and combines it with a lack of fill in the total capacity portion of the bar.

Advantages:

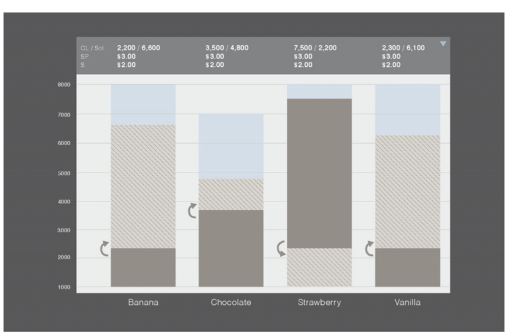
- A lack of fill behind the textured area may act as a helpful cue to communicate a solution value. It makes a clear distinction between solid (current / actual) and permeable (potential / solution).

Disadvantages:

- I feel that this is the strongest of the fill alternatives; however, additional user testing would be needed to determine whether a lack of fill combined with texture, juxtaposed against a solid, untextured fill communicates current vs. solution values.

2. Exploring arrow alternatives – **visualizing the increase or decrease of production values**

2 a



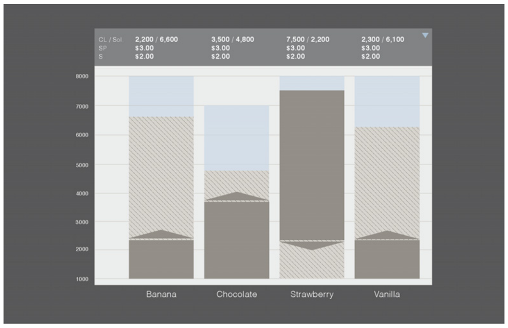
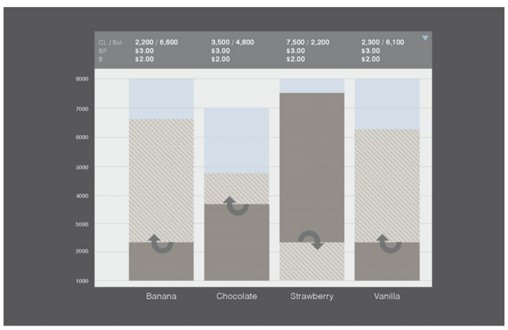
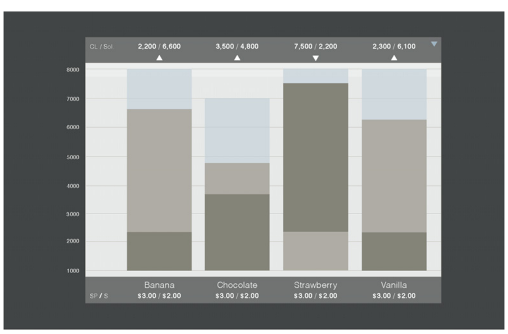
Curved arrows, placed to the left of each stacked bar.

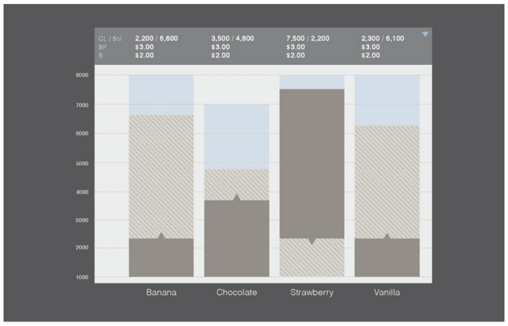
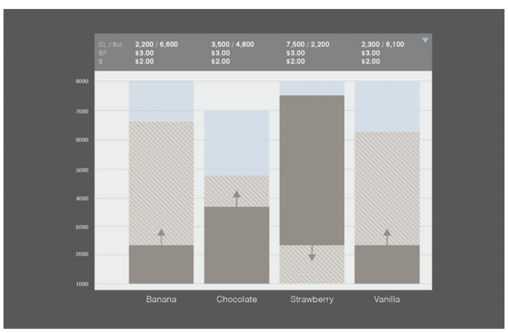
Advantages:

- Since these arrows have been physically separated from the stacked bars, they don't interfere with the reading of their values.

Disadvantages:

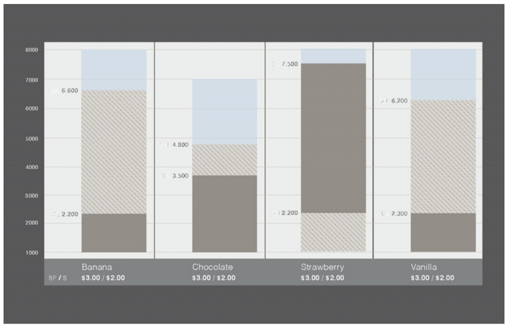
- This solution requires a greater width than the other solutions in order to accommodate the arrows.
- In a situation where the increase or decrease of a value is very small, the arrow will also be too small to be read as an arrow.

2 b	 Triangular arrows, placed on top of the “current level” portion of each bar.	**Advantages:** • Since these arrows have been combined with the stacks, this alternative requires a smaller width than the previous solution (2a).	**Disadvantages:** • In a situation where the increase or decrease of a value is very small, the space won’t be able to accommodate the height of the arrow. • This alternative has the potential to be confusing – should the current level be read to the height of the bar, or the height of the arrow?
2 c	 Curved arrows, point upwards or downwards while attached to the top boundary of the “current level” portion of each bar.	**Advantages:** • Since these arrows have been combined with the stacks, this alternative also requires a smaller width. • Curved arrows have the potential to represent movement and, hence, increase or decrease.	**Disadvantages:** • In a situation where the increase or decrease of a value is very small, the space won’t be able to accommodate the height of the arrow.
2 d *	 Small, white, triangular arrows (without stems), placed near the numerical representations of current level and solution values.	**Advantages:** • Since these arrows have been combined with the numerical values, they use proximity to help represent their meaning. • In this instance, arrows offer an alternate (quick) reading of the numerical values.	**Disadvantages:** • The separation of arrow from bar graph may, in fact, be less clear.

2e	 Small, triangular arrows (without stems), placed on top of the “current level” portion of each bar.	Advantages: • The arrows’ proximity to the current level portions of the stacks may provide a clearer reading than in 2d.	Disadvantages: • In a situation where the increase or decrease of a value is very small, the space won’t be able to accommodate the height of the arrow. • This alternative has the potential to be confusing – should the current level be read to the height of the bar, or the height of the arrow? • Due to the small size of the arrows, the above-mentioned disadvantages have a lesser degree of impact than alternatives 2a–2c.
2f	 Small, triangular arrows (with stems), placed on top of the “current level” portion of each bar.	Advantages: • Stemmed arrows may be easier to interpret than non-stemmed arrows.	Disadvantages: • In a situation where the increase or decrease of a value is very small, the space won’t be able to accommodate the height of the arrow.

3. Exploring labeling alternatives – **options for numerical value treatments**

3a



Numerical values appear to the left of a stacked bar. Values are aligned to a bar's top boundary.

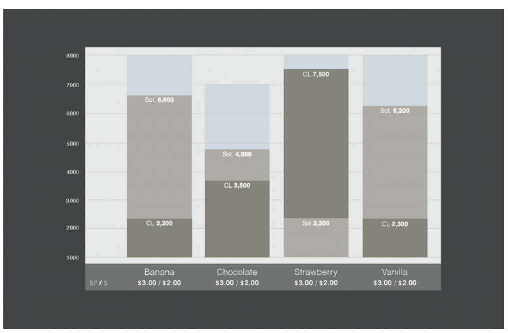
Advantages:

- There's a clear visual distinction between the two values stacked on each bar.
- Numerical values are displayed proximal to the graphical representation.
- Flavor names are clustered together with SP and S.
- There's a clear indicator as to which portion of the stacked bar represents current levels (CL) and which represents solution levels (Sol.).

Disadvantages:

- This design uses more horizontal space than the original design.
- Numerical values add visual noise to the design.
- If a small difference exists between CL and Sol., the corresponding numerical values will collide with one another.
- Since the numerical values are not clustered with one another, a numerical comparison may be more challenging.

3b



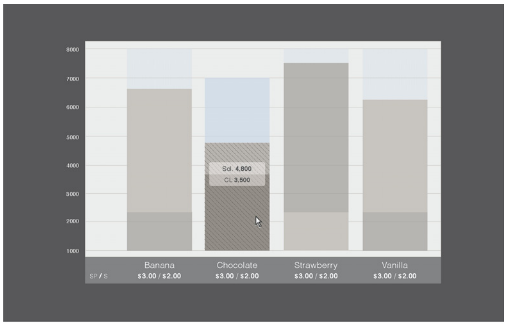
Numerical values appear aligned within the top of each bar.

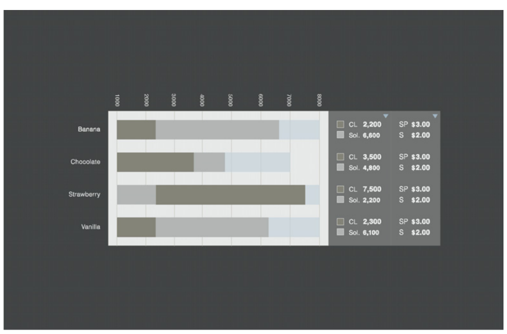
Advantages:

- There's a clear visual distinction between the two values stacked on each bar.
- Numerical values are displayed proximal to the graphical representation.
- Flavor names are clustered together with SP and S.
- There's a clear indicator as to which portion of the stacked bar represents current levels (CL) and which represents solution levels (Sol.).

Disadvantages:

- If one or both values are small, the corresponding numerical values may not fit inside the bars.
- Since the numerical values are not clustered with one another, a numerical comparison may be more challenging.

<table>
<tr>
<td>3
c</td>
<td>

Numerical values appear as roll-overs, within a stacked bar.</td>
<td>Advantages:
• There’s a clear visual distinction between the two values stacked on each bar.
• Numerical values are displayed proximal to the graphical representation.
• Flavor names are clustered together with SP and S.
• There’s a clear indicator as to which portion of the stacked bar represents current levels (CL) and which represents solution levels (Sol.).</td>
<td>Disadvantages:
• Reading CL and Sol. values requires user action (though a persistent value display could be toggled on and off).
• If one or both values are small, the corresponding numerical values may not fit inside the bars.</td>
</tr>
<tr>
<td colspan="4">4. Exploring directionality – horizontal instead of vertical bar graphs</td>
</tr>
<tr>
<td>4
a</td>
<td>

A horizontal alternative with a vertical y-axis.</td>
<td>Advantages:
• Many of the same advantages exist here as in 3a-c.
• 4a-b incorporate a collapsible legend.
• Both designs use up less space than the original design.</td>
<td>Disadvantages:
• May be visually too similar to the ingredients panel.
• There is a large number of clustered numerical values, which begins to resemble a spreadsheet.</td>
</tr>
</table>

4b*

A horizontal alternative with a horizontal y-axis.

Advantages:

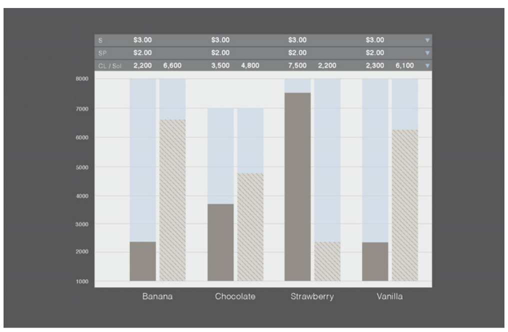
- This design is very similar to 4a, however, the y-axis values are displayed horizontally instead of at a 90 degree angle. This solution may be easier to read.

Disadvantages:

- While easier to read, the horizontal values take up more space. For larger numbers, we would have to widen the graph.

5. Exploring bar graph alternatives – **regular instead of stacked bar graphs**

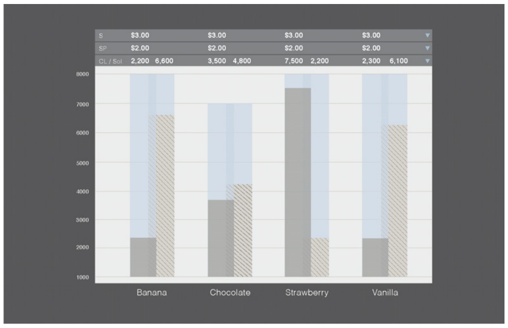
5a

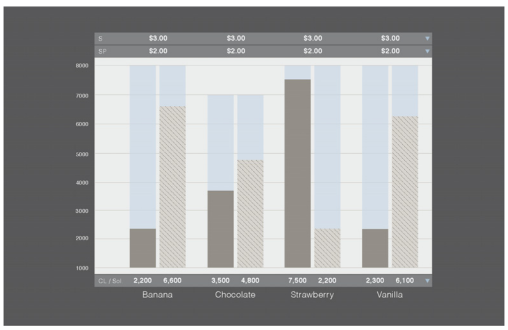


A bar graph alternative to the original design.

Advantages:

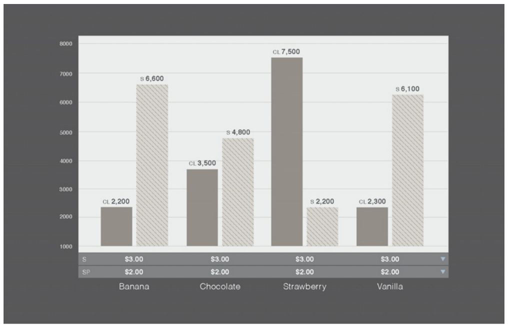
- Bar graphs are used to highlight separate quantities. They are useful for comparing quantities within or among categories.
- Numerical representations of S, SP, and CL / Sol. can be revealed and collapsed independently of one another.
- Designs 5a-d enable easier CL and Sol. value comparison.
- Numerical values are more proximal to their respective graphical representations.

<table>
<tr>
<td>5
b</td>
<td>

A bar graph alternative, with an added semi-transparent overlap.</td>
<td>Advantages:
• The overlay created by the overlap between the CL and Sol. bars may support easier difference comparison.
• There may be alternate functions for the overlay.</td>
<td>Disadvantages:
• The overlay adds additional visual noise to the design and may, in fact, contribute no additional value.</td>
</tr>
<tr>
<td>5
c
*</td>
<td>

A bar graph alternative to the original design, with repositioned numerical values.</td>
<td>Advantages:
• This design is very similar to 5a, however, the CL and Sol. values have been separated from the S and SP values, and clustered with the flavor names.</td>
<td>Disadvantages:
• The separation of the CL / Sol. values from the SP and S values may or may not be a positive.</td>
</tr>
</table>

5d



A bar graph alternative to the original design, with CL and Sol. values proximal to their respective bars.

Advantages:

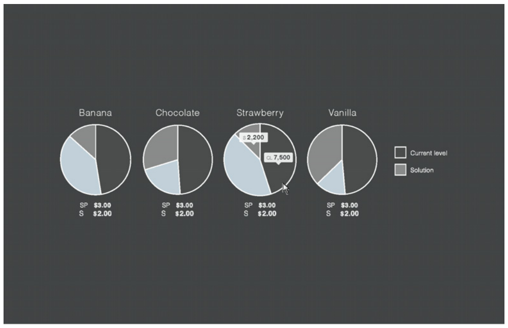
- Numerical values are proximal to graphical representation; there's an easier CL and Sol. value comparison; S and SP values are proximal to flavor names.

Disadvantages:

- Since the numerical values are not clustered with one another, a numerical comparison may be more challenging.
- The width of the individual bars must accommodate the length of the largest numerical value.
- Total potential capacity not displayed (blue area).

6. Exploring graph alternatives – pie charts instead of bar graphs

6a



A pie chart alternative to the original design – with a legend.

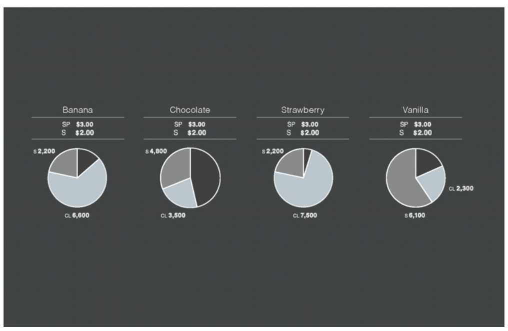
Advantages:

- The main advantage of a pie chart is that it shows percent of total for each category.
- This design includes a legend.

Disadvantages:

- Choice of shade / colour as representation of the none or empty values needs further exploration.
- Reading CL and Sol. values requires user action (though a persistent value display could be toggled on and off). This feature, however, would add substantial visual noise to the design.

6b



A pie chart alternative to the original design – without a legend.

Advantages:

- Numerical values are visible and proximal to their graphical representations.

Disadvantages:

- This design includes more visual information.
- Since the numerical values are not clustered with one another, a numerical comparison may be more challenging.

7. An experimental alternative

This exciting, compact alternative, although, still a stacked bar graph, is important because it combines, for the first time, all 4 flavors into one visualization.

7a*		**Advantages:** • 7a enables easier comparison of the flavors against one another for both the current and solution levels. • Vertical lines may enable easier comparison of current values with solution values. • This design includes a legend. • Numerical values are proximal to the graphical representations. • This design uses less space than designs 1-5.	