Use and Reuse
in Information and Interaction Design

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Abstract

The design of interactive visual displays has long been a topic of interest for desktop computer systems, but the recent popularity of off-the-desktop systems encourages researchers to revisit many of the guidelines for display design that once were taken for granted. This paper describes issues encountered when transferring proved guidelines for traditional desktop systems to nontraditional systems like large screen displays, handheld computers, mobile phones, and ubiquitous computing displays. In each case, features of the user, the setting, the task, and the system dictated how the guidelines would apply. Emerging from our experiences comes a framework for knowledge transfer and reuse based on the notion of claims—falsifiable packets of knowledge that are rooted in the context of use and expressed in terms of a design or situation feature, upsides of the feature, and opposing downsides. The paper discusses ways to categorize, store, and access claims to enhance and improve the design of informational displays, enabling the reuse of guidelines between and among different platforms.

1 Introduction

The early stages of any discipline is often marked by periods of wild innovation, as new tools and technologies inspire a flurry of novel applications with minimal connection to prior work. As human-computer interaction (HCI), and particularly the sub-discipline of information visualization, continue to mature, there has developed a need for scientific advancement rooted in knowledge capture and sharing, capturing lessons for use in new situations. With new computing platforms—e.g., large displays, handhelds, virtual environments, and wearable and ubiquitous computing—becoming more prevalent, without knowledge structures and accompanying processes to access them we risk losing the lessons we learned from traditional desktop displays as we transition to the new platforms.

The more mature discipline of software engineering already has seen initial successes in solutions such as problem frames and Domain Theory (Jackson, 2001; Sutcliffe, 2002). It is Sutcliffe's Domain Theory that first suggests the use of claims as a knowledge unit useful for abstracting a problem space and its design knowledge. Through our own ongoing experiences in building a claims catalog and related design tools, we find that we often view claims as a primary object of focus, helping to center information visualization design on the critical aspects to be debated regarding a design. Context, provided in the scenarios, then helps to situate the claim within new domains, establishing hypotheses to be tested. This approach offers great potential for successes not only within domains for different tasks and situations, but also for cross-domain use as displays migrate from traditional platforms and technologies to new ones.

This paper explores how the use of claims shows promise as a vehicle to transfer knowledge and create hypotheses, weaving a knowledge web to support use and reuse in the creation of visual displays and interfaces. Building on the challenge of Sutcliffe and Carroll (1999), we seek to redefine the structure and use of claims. We first demonstrate how claims can capture knowledge about design in a manner that could be reused. We then look at several case studies where a claims-structured design and experimentation approach would be helpful for information visualization, and we conclude with suggestions for incorporating claims and claims reuse into teaching situations.

2 Using and Reusing Claims

Formally defined, a *claim* is a falsifiable hypothesis that makes explicit the causal relationship between features of an artifact and its positive and negative psychological effects, or design tradeoffs, on the user within a scenario (Carroll, Kellogg, & Rosson, 1991). Claims are proven true or false during design and evaluation of a system under different conditions. In this way, claims provide "designer-digestible" packets of information that can both be used in design and further develop general design knowledge (Sutcliffe & Carroll, 2000). The use of claims for design allows designers to constantly consider the impacts of design choices on the user through the design tradeoffs. The reuse of such solid claims can allow designers to gain new insight into previously unconsidered design features and begin to theoretically and practically bring credibility to a design early in the design process. We further support the use and reuse of claims in design by embedding them in a digital version of the *system image*, a representation of a design that acts as a bridge between the designer's conception of a system and the user's conception of a system (Norman, 1986). This organizes the claims used in an interface design to support communication between designers and users as they reflect on and evaluate the utility of the claims in their designs (Lee, Chewar, & McCrickard, 2004).

A conceptual design of a system can be represented as a collection of claims in which all the claims support the use of each other. A design transforming over time can cause claims to evolve, representing new iterations of a design. The needs of understanding the coherence and dynamic nature of a design are motivations for the use of claim relationships. A *claim relationship* connects two or more claims together by describing the behavior between them. Our research has identified 10 different claims relationships to better explain how claims work together in order to form a solid design (Wahid, Allgood, Chewar, & McCrickard, 2004).

Within coherent claim collections, claims cooperate with one another through unique ways depending on the context; each interaction typically being characterized by a certain relationship type. Rather than just a loosely coupled set of claims, if a set of claims has explicitly defined relationships among the claims, a design can become more coherent. Claims gain a sense of purpose and role within the context of the whole design as relationships are acknowledged. With the intent of improving a design, relationships can also be used to create new claims that may be added into the collection of claims according to the designers needs. Thus, the relationships begin to trace the evolving nature of the claims over time. We demonstrate how claim relationships naturally occur within the evolution of design through several case studies.

To facilitate the reuse of claims, we have designed a claims library to store design knowledge. Each claim has a defined structure stored in English prose with a title describing the claim, a feature describing the use and psychological effects of a claim, and the upsides and downsides of the claim. The library supports searching of claims based on text and attributes. Additionally, claim relationships have been used as a browsing mechanism to sift through networks of claims for potential reuse, providing further structure to the overall claims library (Wahid, Smith, Berry, Chewar, & McCrickard, 2004). Designers use the claims library throughout the interface development process to reuse claims from passed design projects or contribute new claims as they create their own designs.

To illustrate the utility of claims and claims relationships in the design of information visualization tools, we consider three case studies, described in the next section. While the participants in the cases did not always use claims in the manner described, we suggest that the structure they lend to the situation is helpful not only in design and evaluation, but also in capturing key results for future use.

3 Case Studies

To illustrate potential uses for claims-based design and claims relationships, we present three case studies taken from projects in the Center for HCI at Virginia Tech. Note that the projects used the claims-based approach to varying degrees—with the first two cases using and building on claims, and the third performing a more traditional usability engineering design.

3.1 Attraction and Distraction from Blinking

To illustrate the great potential in using claims in knowledge transfer, we start with a simple example: the use of blinking to attract attention. As most can attest who have been annoyed by blinking text and icons on their desktop computers, a claim regarding blinking information should read:

```
Blinking to attract user attention to information of importance
        + draws user focus to a specific physical area
        + prompts rapid reaction to urgent issues
        - BUT can cause significant distraction to the user from more important tasks
```

All might hope that any designer who came across this claim while designing a desktop interface would sparingly (or never) use blinking during normal work situations. However, the opportunity arose in our design of a ubiquitous system to include a blinking light to draw users' attention to changing information. The display being designed, Online Enlightenment, presented a map representation of a research lab to be used by the lab members and visitors to help locate lab members (Heir, Hoon, Terrell, & McCrickard, 2004). Members of the lab are represented by caricatures, with lights beneath each caricature turned on if the person was online and off if offline (see Figure 1). During the design it was suggested that, because the scenario of use was to be so different, perhaps users would be less apt to be distracted yet would still benefit from the upsides. Since it was easy to include in an early prototype, we decided to test it with users.

As testing revealed, lab users still did not feel the tradeoffs were worthwhile. Within hours of the distribution of the prototype, users were complaining that the blinking was annoying, even though it was located about 10 feet away from one of the complainers and was far into the normal periphery. As none of the users noted that they found the additional information it provided particularly useful or obvious, future prototypes and the final system did not use blinking. Based on our testing, we derived a more focused claim through the specification relationship. By definition, this results in a generalization relationship from this claim to the original claim.

```
Blinking to attract user attention to peripheral information on a public display
        + increases likelihood of drawing attention to desired information displayed by
        off-the-desktop systems
        - BUT causes severe disruption to primary task due to greater shift of focus
```

Figure 1: The Online Enlightenment lab presence notification system. Status lights on the display turn on and off (but do not blink!) to reflect the presence of lab members.

The claims library aids designers by allowing them to consider alternative claims using a claim relationship. The mitigation relationship specifically targets a negative effect of a claim and leads to a possibly better suited claim. The following claim targets the downside of the previous claim:

```
Fading to maintain awareness of dynamic information
       + reduces sudden distractions caused by changes in information
       - BUT can reduce reaction to urgent information monitored by the user
```

3.2 Same Platform, Different Task

It is not only when platforms change that reuse of claims must be treated cautiously. In the design of visualizations for secondary displays, researchers in our lab found that ideal encoding schemes for information differed based on primary task (Chewar, McCrickard, Ndiwalana, North, Pryor, & Tessendorf, 2002). Specifically, this work explored the most effective ways to encode information under focal conditions (when the user is focused on understanding the encoding) and under dual-task conditions (when the user's primary attention is elsewhere but the decoding of the information is still desired). Early work by Cleveland and McGill (1984) established well-known guidelines for focal tasks that could be captured in a claim as such:

```
Encoding qualitative information using a mapping of value to object area
       + yields better performance compared to a comparable color encoding
       - BUT yields poorer performance compared to a comparable position encoding
```

Using a Latin Square design, an experiment tested performance in a dual-task setting for values encoded using each of the three methods (see Figure 2). As one would expect, when experiment participants ignored the primary task—essentially defaulting to the Cleveland and McGill single focal task situation—their performance was best with position encoding, second with area, and third with color as Cleveland and McGill's work would predict. However, when the participants were clearly maintaining their primary task performance—operating in a true dual-task situation—color was generally more effective than area at communicating information to the participants. This result yields another claim for the same domain based on the translation relationship:

```
Encoding secondary task information by mapping a value to object position
       + yields better performance compared to a comparable area encoding
       - BUT yields poorer performance compared to a comparable color encoding
```

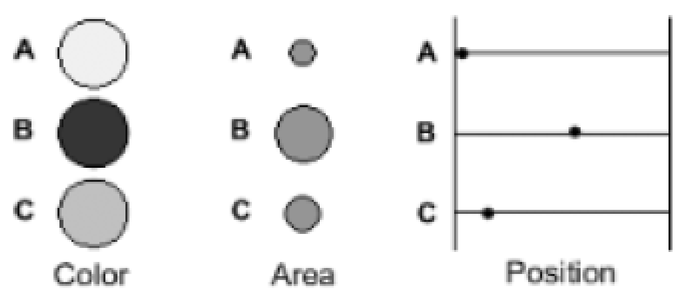

Figure 2: Encodings of three identical values (A, B, C) using the three encoding schemes—color, area, and position.

3.3 Same Task, Different Platform

In the previous example, we provided a case where established guidelines for visualization do not apply for different tasks, even on the same platform. In this example, we will see that the opposite also holds: that guidelines may not hold for a fixed task on different platforms, even if the difference is fairly minor.

An experiment conducted at the Center for HCI at Virginia Tech explored the effectiveness of different labeling strategies for information-rich virtual environments, or IRVEs (Polys, Kim, & Bowman, 2005). In the experiment, objects were labeled either within the virtual world (referred to as Object Space) or on a Viewport Workspace whose position is fixed relative to the user. One condition that was varied in the experiment was the display type, with one group using a single monitor and another using a set of nine tiled monitors (see Figure 3). There were two claims particularly relevant to this experiment, the first extracted from an experiment conducted by Faraday and Sutcliffe (1997):

```
Displaying 2D graphical objects with textual annotations
        + Can lead to association of object and text
        + Can result in better recall than 2D graphic alone
        - BUT requires saccade and fixation between 2D graphic and annotation
        - BUT requires reading time of text
```

This above claim was only validated by Faraday and Sutcliffe in a single monitor environment with the typically limited field of view. Hence, the authors of this study turned to other work that would explore a different interaction paradigm, the virtual environment. Based on the work of Chen, Pyla, and Bowman (2004) as suggested in the Polys paper, the following claim can be extracted:

```
Displaying textual annotations of 3D graphical objects on a Heads-Up-Display
        + Can guarantee visibility and legibility of text
        + Can be advantageous for search tasks (Head-Mounted Display)
        - BUT lacks depth cues consistent with 3D graphical object
```

Upon this backdrop, the authors explored these types of questions in single monitor and nine-monitor display environments. An experiment demonstrated that there was a performance difference based on the type of display, with the single monitor group performing better with the Viewport Workspace, and the nine monitor group performing better with the Object Workspace. The resulting claim based on the fusion relationship would incorporate elements from both of the building block claims, along with supporting rationale from the experiment results, as follows:

```
Displaying textual annotations of graphical objects on a Heads-Up-Display
        + Can lead to association of object and text
        + Can guarantee visibility and legibility
        + Can be advantageous for Search tasks (HMD, Monitor)
        - BUT lacks depth cues consistent with 3D graphical object
        - BUT can be difficult for Spatial Comparison tasks (Monitor, 3x3 Monitor array)
        - BUT may require large saccades to reconcile annotation and referent (3x3 Monitor
        array)
```

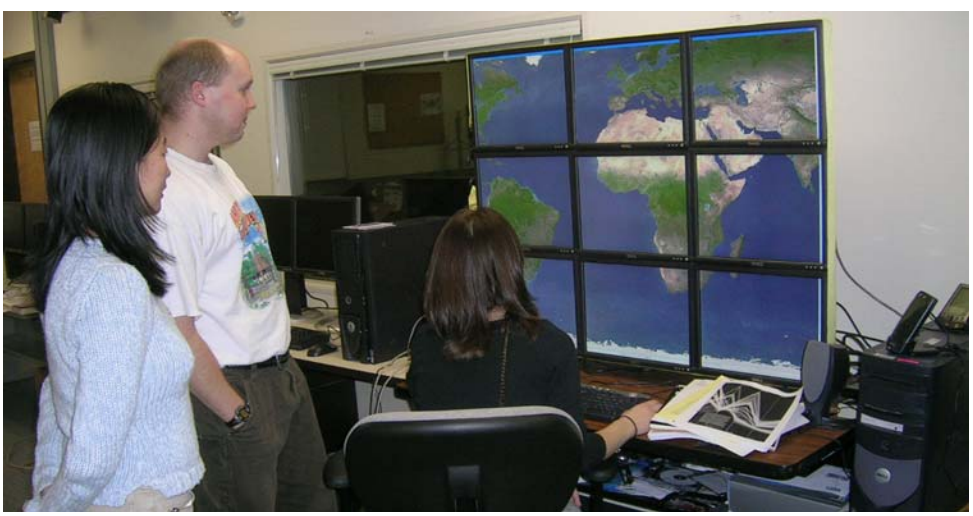

Figure 3: Nine screen display used in the IRVE experiment. Participants either worked in the virtual environment shown on a single monitor or shown on all nine monitors.

In this case, the researchers reached their hypotheses and conclusions without the use of claims. However, we hypothesize that the use of claims—stored in a repository accessible during interface and visualization design—would allow even less experienced designers to build upon prior work. In addition, through the capture and storage of claims during the design process, future developers who wish to adapt the display for other means will have the rationale behind decisions that were made, complete with upsides and downsides considered during design, to help guide new innovation.

4 Conclusions and Future Work

Claims in their earliest forms were used almost exclusively as a lightweight technique to be used early in design to help focus design on both the upsides and downsides of issues and features. More recently, researchers have begun to explore how claims can be used to capture design knowledge for future reuse. In keeping with this "new nature of claims", we seek to extend the definition of claim to include *rationale levels* which make each individual positive and negative effect falsifiable. This additional level of granularity supports more detailed manipulation and development of claims. For example, a fused claim may include rationale derived from multiple disparate sources.

```
Maintaining awareness of group information on public displays using a collage metaphor
        + Accommodates a wide range of different types of information to be conveyed
        through the display
                "Second, collages are customarily used to present unstructured information
                comprising diverse media..." (Greenberg & Rounding, 2001)
        - BUT does not appropriately support topical information through an organizational
        layout
                "...topical information should use categorical, hierarchical, or grid
                layouts..." (Somervell, Wahid, & McCrickard, 2003)
```

With the aid of the case studies, we demonstrated how new design knowledge can be generated with a particular claim relationship in mind. The mitigation relationship demonstrated in Section 3.1 points towards claims that alleviate certain negative effects. The generalization and specification relationships (Section 3.1) show changes in the scope of claims. On the other hand, the translation relationship (Section 3.2) is a similarity based relationship that exists between two claims that have the same scope. Both claims may be either from the same domain or different domains, promoting potential cross-domain reuse. The fusion relationship (Section 3.3) is established between two or more claims that are combined to create a claim depicting a 'larger' concept. These relationships are among several other claim relationships that have been identified (Wahid, Allgood, Chewar, & McCrickard, 2004).

Certainly the list of identified claim relationships is not exhaustive. However, we feel that the current set of relationships is adequate in portraying the many interactions that occur and roles that are played within the context of a conceptual design. Because claims can be created based on a relationship type, they provide valuable knowledge of a claim's history and development for its potential reuse in a different context. Taking it a step further, claim relationships can help to record the evolution of design, helping to supply the rationale behind decisions that are made.

Claims present strengths when used and reused for design by:

- Succinctly encapsulating design knowledge coupled with design tradeoffs
- Focusing development efforts by making critical design features explicit
- Supporting general design knowledge development through claim validation in experiments and design projects
- Allowing development projects to leverage proven design knowledge supported by rationale based on published analytic and empirical evaluations

Our ongoing work is exploring the utility of claims and claim relationships in design, specifically in the teaching of design to undergraduate students. A rigid structure can help students focus on learning the process and why it is important. Our LINK-UP system captures and instantiates claims throughout various stages of design to help designers identify and build on knowledge from previous designs (Chewar, Bachetti, McCrickard, & Booker, 2004). We expect that the addition of a new claims structure and explicit claims relationships to the system, along with modules focused on the development and evaluation of the system image, will further help users build on the work of researchers who went before them.

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