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Contents

Design Framework for Interactive Highlighting Techniques

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ABSTRACT

Highlighting techniques are a diverse class of visual communication techniques that make users aware of salient information in a timely manner. Any visual effect can potentially be used and manipulated to create highlighting effects given the right context, making the design space for highlighting techniques broad and rich. Although highlighting techniques are a common and important part of user interfaces, there is a lack of understanding about how to select, apply, and control their effects for achieving the best results.

To address this knowledge gap, we present a new structured design framework – Parametric Control and Construction of Highlights (PCCH) – for describing highlighting techniques in a concise and objective way, using parameters to accurately specify highlighting technique configurations. We then review the current understanding of highlighting techniques, their effects, and prior methods of measuring those effects. We also review underlying human factors that affect how users interact with highlighting techniques.

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1

Introduction

Highlighting techniques are a common and important part of user interfaces as they enable users to become aware of salient information in a timely manner. Some commonly encountered examples of highlighting techniques include the shaded rectangles used to indicate the selected item(s) in a list view, the "red number badges" used in mobile apps to indicate unread messages, notification bubbles that alert users to incoming email, "bouncing" icons in the Mac OS X Dock or flashing window title-bars that indicate an application in need of attention, animated window expansion/contraction, the Mac OS X oscillating blue arrow that helps users find menu items, and even the flashing caret in word processing software.

The design space for highlighting techniques is broad and rich, as *any* visual effect can be used to create highlighting effects given the right context. However, user interface designers only have a limited understanding about how to select, apply, and control highlighting techniques to achieve the best results. For example, UI designers often struggle to determine how highlighting techniques can be manipulated to maximise the desired *noticeability* of a stimulus (e.g. to ensure that important / urgent information is able to capture the user's attention),

while minimising the undesired *distraction* it causes (e.g. to minimise the risk that the user's attention is needlessly diverted away from their primary task).

Rosenholtz *et al.* (2011) found that there is considerable demand among UI designers for more empirical data on the effects of highlighting techniques (along with automated/semi-automated predictive tooling based on this data) to serve as an external/objective source of guidance during the design process. They also found that it is often hard for designers to extrapolate from general "rules of thumb" to the complex scenarios they are faced with (Rosenholtz *et al.*, 2011). This raises the question: What do we need to know to resolve this knowledge gap, and how we can solve these deficiencies?

1.1 Key Opportunities

Leung's PhD thesis (2017) (from which this monograph is derived) argued that there are three key opportunities for bridging this knowledge gap about the design, usage, and resulting effects of highlighting techniques:

1. **There needs to be a structured framework for describing the control and construction of highlighting techniques.** Existing ways of describing highlighting techniques are ad-hoc, imprecise, and inadequate. Currently, highlighting techniques are described and referenced using varying terminology to describe the same effects (e.g. a "side-to-side movement" (Harrison *et al.*, 2011) in one paper may be the same thing as a "linear oscillation" (Bartram, 2001) in another). Furthermore, the intensity/strength or nature of those effects is unclear, as this is often described using ambiguous and imprecise terms (e.g. a "Fast" movement in one paper may refer to an animation cycle which repeats at 2 Hz, whereas another may deem that "Fast" refers to a frequency of 3 Hz or greater (Bartram *et al.*, 2003; Davies and Beeharee, 2012)). Finally, there is a lack of a cohesive understanding of how all these effects fit together (i.e. most attempts, including Bertin (1983), Liang and Huang (2010), and McCrickard *et al.* (2003b),

have followed the "Graphic Design textbook" approach (Koffka, 1935; Bertin, 1983; Carpendale, 2003; Liang and Huang, 2010; Ware, 2000) of considering visual effects such as Colour, Shape, Size, Motion, and Texture as being independent, non-interacting, non-combinable effects that are used in isolation, instead of being used as parts of a visually complex element in a UI).

2. **There needs to be more reusable empirical data about the effects of highlighting techniques, so that designers can use/refer to this for objective design guidance**.
While many studies in the HCI and Perception literature have examined the noticeability of different visual effects, it is often not clear how these results can be applied to a given highlighting technique instantiation. This problem is accentuated by the fact that there are often fundamental differences between the experimental method/protocols used (e.g. visual search (Kieras and Hornof, 2014) versus contrast matching (Watson *et al.*, 1986)), the units of the measurements (e.g. Lumens/Watts (Watson *et al.*, 1986) versus RGB pixel brightness values (Hasler and Suesstrunk, 2003; Yendrikhovskij *et al.*, 1998)), and the degree of internal versus external validity (i.e. how "abstract" or "concrete/realistic" the tasks and stimuli are). Therefore, practitioners are forced to resort to using generalised heuristics and "rules of thumb" (Rosenholtz *et al.*, 2011).

3. **There need to be standardised methods / protocols for empirically measuring the effects of highlighting techniques**
In support of the second key opportunity, there is a need for the HCI community to identify and achieve consensus on what empirical method or set of methods should be used for measuring the effects of highlighting techniques. Several classes of protocols have been proposed and used in the literature, as discussed in later sections of this monograph. However, there is currently a lack of clarity on which of these methods are most suited for use by the HCI community – for example, what metrics should be used (e.g. noticeability only, or noticeability and distraction), and how

these metrics should be obtained. Also, the diverse range of use cases for highlighting techniques pose challenges when developing or selecting protocols with sufficient external validity to provide useful insights.

1.2 Our Approach

This monograph lays the foundations for addressing these concerns, with a particular focus on the first one. It attempts to unify several parallel strands of research in the literature by identifying the common body of knowledge underpinning these, and developing a design framework for describing/modelling the construction and control of highlighting techniques. On top of this foundation, we then address some of the knowledge gaps most relevant to the Human Computer Interaction (HCI) community.

This work is important because the literature on Highlighting Techniques currently spans multiple domains including *Graphic Design* (Koffka, 1935), *Information Visualisation* (Ware, 2000; Bertin, 1983; MacEachren, 1995; Liang and Huang, 2010; Bartram, 2001), *Novel UI Techniques* (Willett *et al.*, 2007; Fitchett *et al.*, 2013; Agapie *et al.*, 2013; Findlater *et al.*, 2009), *AR/VR Interfaces* (Trapp *et al.*, 2011), *Information/Cyber Security* (Anderson *et al.*, 2015), *Notifications* (McCrickard *et al.*, 2003b; McCrickard and Chewar, 2003; McCrickard *et al.*, 2003a), and *Psychology/Perception* (Boff *et al.*, 1986; Rensink, 2005; Moher *et al.*, 2015; Gallivan and Chapman, 2014; Rosenholtz *et al.*, 2007; Rosenholtz *et al.*, 2011; Rosenholtz *et al.*, 2012). As a result, there is a considerable amount of duplicated effort and "information siloing" (Vayghan *et al.*, 2007) due to each domain using a slightly different set of terminology and keywords, with little evidence of cross-pollination of relevant knowledge.

1.2.1 Interactive Highlighting Techniques

This monograph introduces the concept of "*Interactive Highlighting Techniques*" (IHT) as a superset and extension of "*Highlighting Techniques*" (HL). The main difference between the two is that IHT's rep-

resent the full range of temporal and interactive behaviour exhibited by highlighting techniques used in UI's. For example, see Section 2.1.3 for details about how multiple individual highlighting techniques may be combined together to form a single IHT (i.e. one HL for each of the IHT's states). This leads to the following definitions:

Definition 1.1. A **Highlighting Technique** (HL) is a visual communication technique used to make users aware of important or task-relevant information in a timely manner.

Definition 1.2. An **Interactive Highlighting Technique** (IHT) is a set of Highlighting Techniques (HL's) used in conjunction with each other to make users aware of important or task-relevant information in a timely manner as part of a computer-based user-interface.

IHT's are referred to as being "interactive" to emphasize the dynamic nature of these techniques. Specifically, they play an integral role in user-interface systems, where they are used as a way of making the user aware of important or task-relevant information by attempting to direct the user's attention. To do this, IHT's may need to vary their behaviour in response to user input (or the lack thereof), or changes in the system state they may be representing. For example, an IHT with such dynamic behaviour is the flashing taskbar notification in Microsoft Windows (Microsoft, 2018b): when triggered (i.e. because an application wants to draw the user's attention to itself), it blinks/flashes the window title and taskbar button associated with that application to get the user's attention; if the user does not attend to the window after a fixed period of time, the IHT will switch to showing a static non-blinking orange highlight on the affected taskbar button instead. This example demonstrates how a single IHT can be in one of 3 states – *Normal*, *Initial Onset*, and *Highlighted* (see Section 2.3.2 for a deeper discussion of these concepts) – based on the user's interactions with the system. It also demonstrates how each IHT can be composed of set of multiple HL's, with the *Initial Onset* and *Highlighted* states each using a different HL technique (i.e. "flashing" and "static coloured background" respectively).

1.3 Intended Audience

This monograph was written with the following specific audiences in mind:

1. **Industry Practitioners** – e.g. UI Designers, Software Engineers, and/or Domain-Expert Requirements Specialists using highlighting techniques in their UI designs

2. **HCI Researchers** – e.g. Academics and students investigating the design and use of highlighting techniques, either as the primary object of study, or for applications in a particular domains (e.g. as part of a visualisation or interactive environment).

3. **Behaviour Modelling and Design Tooling Specialists** – e.g. Human Behaviour Modelling Researchers, and/or Computer Aided Design Tooling Developers

For the purposes of our discussion, we are referring to "Industry Practitioners" as individuals or groups whose primary interest in highlighting techniques is for using/applying such techniques within an interface they are designing/building (e.g. User Interface Designers, or software engineers building/implementing UI's). In contrast, "HCI Researchers" are assumed to be more typically academics or research scientists whose focus lies more in understanding and expanding the frontiers of knowledge by exploring "bleeding-edge" techniques, and are assumed to be more well versed in the academic literature and/or related areas (e.g. psychology).

1.3.1 Take-aways for Industry Practitioners

First and foremost, this monograph was originally conceived to answer the question:

> What should Industry Practitioners need to know about how to create and manipulate highlighting techniques?

In particular, this monograph was motivated by a sense of frustration and curiosity about understanding *why* some highlighting techniques

appeared to elicit visceral responses from users, while others would be completely ignored.

Therefore, it is intended for this monograph to act as a guidebook to illuminate useful insights and concepts from the literature for further exploration. We envisaged that our work could serve one of the following purposes:

- To provide specific ideas to inspire new design approaches (e.g. findings from comparative studies),
- To help practitioners identify additional factors (and bodies of relevant knowledge) to consider when evaluating designs (e.g. Change/Inattention Blindness and/or the effects of Clutter and Crowding),
- To expose practitioners to processes/techniques that, with some further investigation, become important tools as part of their design process – for example, understanding Colour Science and Colour Representation in Digital Media; or incorporating tools and techniques for considering how highlighting integrates and interacts with the user's task flows and conceptual/mental models (e.g. Sampling Payoff Matrices, and InfoScent ratings)

1.3.2 Take-aways for HCI Researchers

There were two primary objectives we aimed to achieve with this work for this audience:

1. **Provide a unifying framework/architecture for organising all the work that has been done and is being done on highlighting-related topics**. The key problem we are addressing here is the problem of information silos and the resulting duplication of effort that occurs.
2. **Illustrate to the research community where the gaps in relevant knowledge exists (from the perspective of other interested stakeholders)** - Specifically, this is from the lens of: "What do practitioners need to know that we cannot currently provide simple clean-cut answers for?"

1.3.3 Take-aways for Behaviour Modelling / Computer-Aided Design Tooling

For this audience, our primary objective with this work is to raise awareness of the unmet need for automated/semi-automated tooling in this area, and to identify promising directions for research into what tooling could be developed and how this could be done. In particular, we argue that there are opportunities for developing tools for helping UI designers to predict the effects that different highlighting techniques may have, similar to how there are now code quality "linting" tools and/or automated accessibility assessment tools (e.g. for colour blindness).

1.4 Key Contributions

This monograph presents a structured review of the prior literature and background knowledge necessary for understanding highlighting techniques. It is divided into three main sections, corresponding to the following key contributions:

1. A new structured design framework for parametrically describing the construction and control of highlighting techniques (Section 2).
2. A review of the existing literature on highlighting techniques (Section 3).
3. A review of the underlying human factors (Section 4) governing how we respond and react to highlighting techniques.
4. A summary of the insights gained from this material (Section 5), and suggestions for future research directions.

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