Exploiting Spatial Memory to Design Efficient Command Interfaces

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Abstract

A common goal for user interface designers is to design efficient UIs that facilitate high levels of performance. In point-and-click interfaces, spatial memory has been shown to play an important role in reaching this level of performance, since it allows users to make quick decisions about item locations rather than resorting to slow visual search. However, spatial memory is rarely exploited by modern applications. Hierarchical menus force users through laborious action sequences to access commands, while window content is frequently elided and reshuffled in response to changing window geometries.

In order to inform the design of UIs that better support spatial memory, we are studying the human and interface factors that affect the growth and resilience of spatial knowledge, and producing a series of exemplar interfaces that exploit users' spatial memory to rapidly achieve high levels of performance. A new command selection technique called *CommandMaps* demonstrates that when users have spatial memory of an interface, target acquisition can be vastly improved by removing control hierarchies. *StencilMaps* builds on the CommandMap technique, highlighting salient commands to accelerate novice visual search. Our ongoing research investigates the robustness of spatial memory and the role of 'effortful' learning in the development of spatial automaticity.

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ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces – Interaction styles.

Introduction

The hierarchical controls of modern desktop interfaces, such as menus and Ribbon toolbars, are known to slow down expert users [2], with an expert's rapid spatial decision-making capabilities 'bottlenecked' by relatively laborious mechanical action. Furthermore, interfaces often elide, reposition and reshuffle UI elements (e.g., in response to changing window geometry), which prevents users from utilizing their spatial knowledge for quick item retrieval.

The goal of this PhD is to better understand how users develop and utilize spatial memory, and in doing so, design new interfaces that allow and encourage users to rapidly attain high levels of performance.

Background and Related Work

Spatial memory is a powerful human capability. When users have spatial knowledge of a group of items, they can decide on item locations in log time, instead of relying on linear visual search [4]. Furthermore, spatial memory lasts a long time [6] and has a large capacity [10]. Spatial knowledge is typically developed as a side-effect of interacting with items [7], but there is evidence to suggest that spatial learning is more effective when effort is involved [5].

In HCI, various interfaces have already been developed that support spatial memory. Robertson et al's Data Mountain [12], which allowed users to spatially arrange bookmarks, was shown to be faster than a standard bookmarking system. Gutwin and Cockburn presented ListMaps [9], which presented a list of 225 alphabetical items as a 15*15 grid. ListMaps was shown to enable rapid revisitation for users familiar with item locations, but the layout caused novice users to perform significantly worse. Spatially stable arrangements have also been shown to be effective for document navigation [3] and window switching [16].

While flat, spatial organizations enable efficient revisitation, novices may still require assistance to locate items. Researchers have attempted to improve novice performance in UIs by providing reduced-functionality interfaces, which hide or disable advanced or unnecessary functionality (e.g., [1, 11]). Adaptive solutions have also been shown to improve novice visual search time, such as *ephemeral adaptation* [8].

Research Situation

I am a PhD student in Computer Science at the University of Canterbury, Christchurch, New Zealand, in the 2nd year of a 3-4 year program. I anticipate finishing my degree in early 2014. While I primarily identify as a computer scientist, I am strongly interested in the human factors that affect interaction. My work focuses on the design and evaluation of new interfaces that exploit spatial memory to provide rapid expert interaction, while supporting the development of user expertise. This work follows on from my Honours (undergraduate) dissertation [15]. So far my PhD has produced a full paper publication in CHI 2012: "Improving Command Selection with CommandMaps" [13], which won a Best Paper award, and a further full paper in CHI 2013: "Testing the Robustness and Performance of Spatially Consistent Interfaces" [14].

From the Doctoral Consortium, I hope to gain feedback on the general direction of my dissertation. So far, my research has led to several discrete projects – I would therefore like feedback on weaving these projects into a cohesive whole, as well as insight into which projects are most interesting and deserve future development.

Research Goals

My PhD has two main goals: *improving our understanding of spatial memory*, and *designing*

Figure 1. Partial view of a CommandMap for Microsoft Word. All Ribbon tabs are displayed simultaneously, utilizing the whole screen. The interface is activated with the Ctrl key.

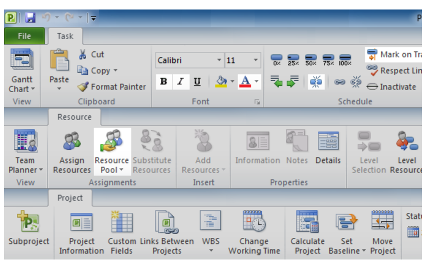

Figure 2. Partial view of a StencilMap in Microsoft Project. Relevant commands are highlighted using a translucent stencil overlay.

interfaces to support spatial memory. We are working toward the two goals in parallel.

To achieve the first goal, we have studied (or are intending to study) the robustness of spatial memory, and the ways in which users progress to automaticity with an interface. We achieve the second goal by designing interfaces based on these results.

The following sections describe the work in these areas that has already been completed.

CommandMaps (CHI 2012)

At CHI 2012, we introduced a command selection interface called CommandMaps [13]. CommandMaps display a flattened hierarchy of commands (Figure 1), allowing for rapid point-and-click invocation, and they are spatially consistent, leveraging the power of human spatial memory to provide quick location of controls.

We performed three experiments evaluating the performance of CommandMaps in different situations. The first showed that knowledgeable users were 34% faster at selecting commands from a CommandMap than from a top-level menu, and 25% faster than with a Ribbon interface. The second showed that novice users did not perform significantly differently with the three interfaces. The third evaluated different adaptations for small window sizes; pop-up, full-size CommandMaps were shown to be significantly faster than a scaled-down version with a pointing lens.

StencilMaps

CommandMaps demonstrated a point-and-click interface designed for rapid command selection by expert users. A follow-up paper, currently unpublished, explores the idea of improving CommandMap performance for novices. Our technique, called StencilMaps, uses a translucent 'stencil' overlay on top of a CommandMap to highlight subsets of commands that are most likely to be relevant to the user's current task or workflow (Figure 2). The goals of the technique are to accelerate visual search for novice users, while allowing for long-term item location learning. Existing tools, such as AdaptableGIMP [11] and Carroll's "Training Wheels" [1] fail to satisfy both of these goals: AdaptableGIMP arranges items in a palette which differs from the full interface, hindering location learning, while Training Wheels disables functionality without altering visual appearance, failing to improve visual search time.

We evaluated StencilMaps in two experiments. The first studied the differences in visual search time of StencilMaps compared to base CommandMaps, as well as an alternative design based on Findlater et al.'s *ephemeral adaptation* [8]. We found that StencilMaps significantly decreased visual search time overall compared to both the alternatives, and that the benefits of StencilMaps lasted beyond the initial few selections of each item. Our second experiment compared StencilMaps to a palette-based subset interface, evaluating the trade-offs in ready-to-hand performance and long-term location learning. We found that while palettes were faster for the first in-subset selection of each item, StencilMaps delivered lasting performance benefits after the subset was removed.

Spatial Transformations (CHI 2013)

In order to design interfaces to best make use of spatial memory, more data is required to understand in what situations spatial memory can be applied. We

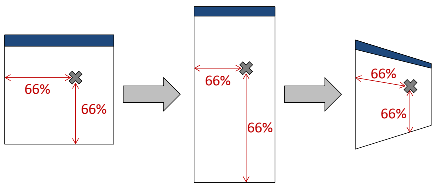

Figure 3. Spatially consistent interfaces keep items in predictable locations, even when the window bounds change.

performed an experiment characterizing the effects of *spatially consistent* interfaces, where item locations are kept in proportion to a changeable frame of reference (Figure 3). Our results showed that translation, scaling, stretching, and perspective changes had minimal effects on selection time for familiar items when the interface was kept spatially consistent. A follow-up experiment applied these results to a realistic interface based on the Windows 7 control panel, showing that a layout that scaled the item grid when the window size changed outperformed the standard layout (which "reflows" items to fill the available space). These experiments form the basis for a full paper which was accepted to CHI 2013 [14].

Future Work

Over the next year, I plan to pursue a number of projects on the topic of spatial memory, with two already planned out. The first is a comprehensive survey of spatial memory literature in HCI. The second is an analysis of automaticity, especially regarding spatial decision-making – the goal of which is to determine whether effortful learning is more effective than simple repetition for learning item locations.

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