SURFNET /

Designing Digital Surface Applications

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HUMANIZING THE DIGITAL INTERFACE

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Focus Areas:

- 1.1 Understanding the Fit Between Surfaces, Humans, & Human Activity
- 1.2 Interacting with a Single Surface
- 1.3 Interacting with Multiple Surfaces
- 1.4 Adapting Interface Concepts to Real-world Settings

Introduction

Theme 1 research focused on expanding our understanding of the fundamentals of surface interaction. Interacting with digital surfaces is fundamentally different than interacting with mouse-and-keyboard-based computers like desktops or laptops. This has required new knowledge about how best to design interfaces, interaction techniques, and applications that provide the most effective use of the new interaction capabilities provided by digital surfaces. Moreover, across the course of the SurfNet research program, there has been exciting and rapid changes in the variety of "surface" computing devices, and related interaction modalities available for these surfaces. Small, personal multi-touch surfaces (e.g. smartphones and tablets) have seen wide-scale adoption in Canada and other Western cultures. New consumer hardware (e.g. Microsoft Kinect, Leap Motion) enabled low-cost whole- and part-body interactions with large surfaces, significantly expanding possible interactions on digital walls and tabletops, beyond touch-based interaction. SurfNet research, throughout all three Themes, played a significant role in extending the capabilities and application use of the emerging input and surface device hardware to enable more extensive interfaces and interactions across a wide variety of application contexts.

As the overarching goal of Theme 1 research was to design, develop and evaluate interaction for surface technologies that supports and participates in, rather than ignores, the everyday-world practices of people, these expanding hardware capabilities usefully expanded the "surfaces" toolbox which to draw from during our design and development activities. As we describe in the following focus area discussions, this expanded toolbox led to innovations, such as multi-surface interfaces that enable the use of smartphones or tablets in conjunction with large digital walls or tabletops during a collaborative analysis task, and large public wall displays that "react" to people as the approach they display (even before they touch the surface).

Important new HCI questions emerged along with this new hardware, such as when is a small surface beneficial?, when is a large surface beneficial?, and how can different surface form factors and interaction modalities best be used together to provide an effective user experience? Theme 1 has adapted to investigate these emerging questions by studying and creating interfaces, interaction techniques, and whole applications for a wide range of surface form factors and interaction capabilities in a variety of different application domain contexts. The network approach to SurfNet research enabled this agile research approach as it required access to a substantial amount of different surface hardware devices and access to a variety of application contexts. This breadth of research, and extensive knowledge gained on the value and limitations of digital surfaces (of all forms) in different contexts, is reflected in the following focus area discussions.

The primary purpose of Focus Area 1.1 was to understand the fit between surfaces, humans, and human activity. Focus Areas 1.2 and 1.3 targeted understanding the advantages and limitations of single and multi-surface set-ups respectively, and how best to leverage their unique advantages to support human activity. Focus Area 1.4 focused on adapting interface concepts to real-world settings, specifically how best to adapt theoretical or idealized interface concepts to particular application areas.

1.1 Understanding the Fit between Surfaces, Humans, and Human Activity

This focus area targeted fundamental research into human activities with and around surfaces. Here we improved our understanding of the relationships between people and all types of surfaces, from the traditional to the digital, from large to small, from single to multiple, in co-located and distributed venues appropriate to our application areas. We closely studied human abilities that are affected by or involved directly with the use of surface technologies.

A significant amount of activity in this focus area explored the use of surfaces—

and increasingly multi-surface set-ups—to support collaborative and social endeavours, especially in co-located settings. For example, contributions were made in understanding the collaborative and cognitive benefits of large tabletop surfaces during group creativity tasks (Hajizadehgashti 2012; Scott et al. 2015); in understanding the cognitive and communicative benefits that large surfaces and multi-surface environments support collaborative sensemaking (i.e. data triaging and analysis) (Wallace et al. 2013; Kuzminykh et al. 2015); and in applying social theories of proximity, body positioning, and territoriality to improve large and multi-surface interactions (Chen et al. 2012; Marquardt et al. 2012a; Marquardt et al. 2012b; Scott 2014).

Facilitated by the recent innovations in input and surface hardware, we used our improved understanding of how people interact with and around surfaces to springboard inventions of new interaction techniques and information presentation methods for surfaces. Important contributions were made in exploiting human proxemics as interaction triggers, for instance, to better engage passersby with large surfaces in public settings (Greenberg et al. 2011; Marquardt et al. 2012a; Marquardt and Greenberg 2012; Marquardt et al. 2012b; Wang et al. 2012; Marquardt 2013; Mostafa et al. 2013). This research has had significant impact both internally within SurfNet and externally among the international surface computing research community: proxemic interactions was the topic of a dedicated invited Dagstuhl seminar workshop in 2013 (Greenberg et al. 2014b) and has contributed to numerous publications by SurfNet (Boring et al. 2014; Brudy et al. 2014; Greenberg et al. 2014a; Mueller et al. 2014; Cheung and Scott 2015a; Cheung and Scott 2015b; Ledo et al. 2015) and external researchers in subsequent years, e.g., (Henrik Soerensen and Kjeldskov 2013; Raedle et al. 2014; Dingler et al. 2015; Jakobsen and Hornbaek 2015; Zhou et al. 2015). Another key contribution in this area was the extensive exploration of novel information visualization techniques for large and multi-surface set-ups to facilitate both individual and collaborative analysis and decision-making around large and/or complex data sets (Anslow et al. 2013; Bhaskar et al. 2014; Huron et al. 2014; Oskamp et al. 2015).

1.2 Interacting with a Single Surface

Our research in this theme focused on interaction issues with single surfaces: developing new input and interaction techniques; creating effective visualizations and feedback for surface interactions; generating new interfaces that promote individual and group information organization and sharing; and, exploring the interaction issues that stem from displaying information on, and interacting with, different surface form factors including horizontal, vertical, small, and very large.

Early research outcomes in the area of interface and interaction design from SurfNet and other surface computing researchers has allowed development of more advanced surface software applications designed to address real-world tasks. This shift exposed the need for more sophisticated and nuanced surface interfaces and interactions that better supported complex task and social interactions. SurfNet adapted to meet this need. Over the past few years significant research activity focused on designing more effective feedback and awareness mechanisms to improve the usability of surface applications across a variety of different surface form factors. For example, several of our projects focused on developing interfaces that more proactivity respond to people's interactions on and around the surface to help teach novice users what the system has to offer and how to effectively use the system, particularly in the case of large surfaces installed in public settings (Seto et al. 2012; Hinrichs et al. 2013; Cheung and Scott 2015a; Cheung and Scott 2015b). Contributions were also made in designing interface elements that help people understand and maintain awareness of automated system changes during ongoing collaborative tabletop activities (Wallace et al. 2012; Chang et al. 2014), and in using tactile feedback to help mediate group coordination when using virtual embodiments (e.g. virtual arms that allow for extended reach at a large surface) during tabletop collaboration (Doucette et al. 2013).

Research in this focus area also investigated the use of large surfaces as a collaboration tool, beyond their task-specific application features. Consistent observations by SurfNet researchers have revealed that when groups gather around a large wall or tabletop surface, they often want to "draw" over the task interface to help strategize, coordinate, or communicate about the task at hand. SurfNet researchers developed various mechanisms to support such abstracted "communication" interactions, including providing annotation capabilities directly into a task application (Bortolaso et al. 2014), providing an additional "add-on" program that interfaces with other software applications to provide common collaboration tools, including an annotation layer over the application software (Simonyi 2015), and visualizing above-the-table gestures in a tabletop interface to better contextualize any communication gestures made during group work (Genest and Gutwin 2012; Genest et al. 2013).

Finally, recent SurfNet work also included projects to improve individual interaction with small surfaces such as smartphones. For instance, contributions were made in improving command selection on smartphones using knowledge of ergonomics and common device grip behaviour (Gutwin et al. 2015), and in developing improved CAPTCHA interaction (a common computer security method) optimized for multi-touch smartphone use (Reynaga et al. 2015).

1.3 Interacting with Multiple Surfaces

While single surfaces provide many advantages for supporting groups, each surface form factor (e.g., large, small, horizontal, vertical) has benefits and limitations. By combining multiple surfaces together we can take advantage of the specific properties of each surface type, thus enabling interfaces that are more efficient and powerful than the sum of their parts. The increased variety of surface form factors and interaction capabilities, along with the greater commercial availability of surface devices, led to a substantial growth in research on multi-surface environments (MSEs) within SurfNet. This MSE research was also enabled by early research outcomes on single surfaces that addressed many of the basic device-specific challenges: with a stronger understanding of how to design for individual surfaces, we were better able to focus on more complex multi-surface interfaces and interactions.

Our extensive investigations on MSEs over the past few years also revealed just how challenging designing effective multi-surface interfaces and interactions can be: different surface devices have different interaction affordances and capabilities that must be combined in meaningful and usable ways. As MSEs are still relatively rare in practice, there remains a lack of design intuition about what does and does not work in given application contexts. Despite these complexities, we made significant contributions in this area, and were leaders in the international surface computing and HCI fields in the development of novel MSE interfaces and interaction techniques, evidenced by recent workshops and tutorials led by SurfNet researchers on these topics (Marquardt 2013; Anslow et al. 2014; Greenberg et al. 2014b; Isenberg et al. 2015; Scott et al. 2015). Our contributions in this area include examining the benefits and limitations of different device configurations, device form factors, and cross-device interactions during group work in different task contexts (Wallace 2011; Marquardt et al. 2012a; Marquardt et al. 2012b; Wallace et al. 2013; Scott 2014); developing new user and device tracking techniques (Marquardt et al. 2011; Genest et al. 2013; Azazi et al. 2014), and interfaces to leverage those tracking techniques, for instance, to facilitate interconnectivity of devices in a large space (Marquardt et al. 2012a; Chokshi et al. 2014; Scott et al. 2014).

While most multi-surface projects targeted co-located environments, contributions were also made in the area of distributed surfaces. These projects primarily focused on facilitating group communication at remotely connected large surfaces, for example, by displaying arm shadows that indicated a remote collaborator's above-the-table gestures during remote tabletop interactions (Genest and Gutwin 2012; Genest et al. 2013), or utilizing whole-body interaction and large surfaces to build shared virtual scenes that enable active freeplay between friends over a distance (Ledo et al. 2013).

1.4 Adapting Interface Concepts to Real-world Settings

This focus area—which combined research efforts from focus areas 1.2 and 1.3 into the exploration of possible interactions and interfaces in real-world situations—saw increasing activity over the lifespan of SurfNet. The overarching goal for this focus area was to facilitate the use of SurfNet interface designs in feature-rich surface application interfaces capable of supporting complex human activity in real-world settings. In the past few years, the range of targeted application areas grew increasingly broader. This increased breadth was largely driven by the diversity of interested application partners, demonstrating the wide appeal of surface computing to real-world partners.

A highly active area of research was applying and adapting surface interfaces and interactions to surface software applications optimized for different usage contexts. Real-world application areas included music and media, gaming, health, command and control, creativity and design, browsing library holdings, air traffic control, computer security, security analysis, data analysis, and geospatial terrain analysis. We gained significant practical knowledge through these projects about utilizing surfaces in real-world settings. For example, there is an important design tradeoff to make between providing "simplistic" interfaces (e.g. visually streamlined, with minimal touch interaction) and providing sufficient accuracy and precision for the task at hand. For instance, in a project focused on supporting simulation training exercises for the Canadian Army, significant design iteration occurred around the design of a touch-based route-planning feature to provide the right mix of simplicity, precision, and utility for end-users (military personnel) who had limited experience with touch devices (Bortolaso et al. 2014).

Another contribution of this focus area was to invent new ways of using surfaces to address real-world problems. For example, many military missions rely on accurate terrain analysis; however, many soldiers do not know how to read traditional two-dimensional (2D) maps containing contour lines (i.e. shaded colours representing slope, relief, elevation, etc.). One project explored a multi-surface system that provided a real-time viewshed (showing the areas of visibility from a certain geographical ground position), a three-dimensional (3D) panoramic view, and a "helicopter" view controlled by an optically tracked tablet (Oskamp et al. 2015).

Significant contributions were also made in designing more effective interfaces and interaction techniques for large displays installed in public settings—a setting where potential users encounter significant social and interaction barriers to using large, especially unfamiliar, surfaces, and thus, tend to avoid using them altogether (Cheung et al. 2014). Across a number of projects, we explored different mechanisms to reduce these barriers and successfully engage passersby in public settings such as lobbies, museums, and libraries (Hinrichs et al. 2011; Thudt et al. 2012; Cheung and Scott 2015b; Thudt et al. 2015).

Conclusions

Over the lifespace of SurfNet, the scope and complexity of projects have significantly increased due in part to the strong basic research outcomes of our early SurfNet efforts and in part to the changing technological landscape in the consumer domain and broader research fields. This foundation enabled us to undertake much more complex surface computing research, especially in the area of multi-surface interfaces and interactions than previously possible. We made substantial progress on our application goals of exploring the potential of surfaces in a wide variety of application contexts; first in our target application areas, and then much more broadly to other domains such as healthcare, farming, music, computer security, etc., as the success of our early research became known outside of SurfNet and opportunities to work with increasingly diverse application partners arose.

SURFNET / Designing Digital Surface Applications is a compendium of research findings from a Canadian research network that integrated innovative research in two critical areas –software engineering (SE) and human-computer interaction (HCI)– to identify critical requirements, design new engineering processes, and build new tools for surface-based application development. Funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) from 2009 to 2015, SurfNet's research clustered around three themes: Humanizing the Digital Interface, Improving Software Time to Market and Building Infrastructure for Digital Surfaces. Research was driven by the needs of four application areas: Planning, Monitoring and Control Environments; Learning, Gaming, New Media and Digital Homes; Software Team Rooms; and Health Technologies.