Towards Ubiquitous Information Space Management

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Abstract
Large, high-resolution display spaces are usually created by carefully aligning multiple monitors or projectors to obtain a perfectly flat, rectangular display. In this paper, we suggest the usage of imperfect surfaces as extension of personal workspaces to create ubiquitous, personalized information spaces. We identify five environmental factors ubiquitous information spaces need to consider: 1) user location and display visibility, 2) display gaps and holes, 3) corners and non-planarity of the display surface, 4) physical objects within and around the display surface, and 5) non-rectangular display shapes. Instead of compensating for fragmentations and non-planarity of the information space, we propose a ubiquitous information space manager, adapting interaction and window rendering techniques to the above mentioned factors. We hypothesize that knowledge workers will benefit from such ubiquitous information spaces due to increased exploitation of spatial cognition.

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ubiquitous displays, information management

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Introduction

Large display surfaces provide the opportunity to show a lot of concurrently visible information. They also provide sufficient space for organizing and categorizing information artifacts, leading to productivity benefits [7] and increased user satisfaction [4]. Thus, a lot of effort has been put into the construction of very large displays with a huge amount of pixels, by combining multiple monitors or projectors into a combined space. Usually, special care is taken to create a uniformly flat or curved continuous display.

However, constructing such a perfectly flat and continuous displays is not always feasible around people's existing workspaces. To better understand irregular display spaces, we therefore conducted an exploratory study to detect emerging window management strategies of users coping with a non-planar, non-rectangular projected display [19]. We were surprised to find out that users actually did not struggle to *overcome* the introduced irregularities, but they rather struggled with the limited possibilities of the window manager to exploit the non-planar, discontinuous nature of the display for maintaining a more meaningful spatial window layout than possible on a perfectly flat display.

These observations motivated us to further investigate how information spaces can be smoothly embedded into the existing environment, with all its corners, doors, and picture frames on the walls. We identify environmental factors shaping and characterizing ubiquitous information spaces, discuss their potential impact on users' spatial cognition, and provide suggestions how window managers, or equivalent content management systems, could utilize these factors for more efficient information management.

Background

Spatial cognition plays an important role in users' information and task management operations. Large displays can be seen as *external memory* to spatially organize and memorize information artifacts [1]. It has been observed that users partition very large display space into designated functional areas [11, 4, 1]. If display space is not continuous, for instance due to monitor bezels or non-planarity of the projection surface, users incorporate these physical discontinuities to organize their information artifacts into focus and peripheral activities [9, 11, 19].

One advantage of information management with tangible items, as compared to graphical items on a computer screen, is that users can employ "reference frame based positioning": It has been observed that users utilize contextual cues of the environment, such as the physical computer monitor, to remember the location of tangible items [15]. Exploiting this spatial cognition by placing application windows in a virtual environment rich of architectural landmarks was the major objective of *Task Gallery* [18]. Our vision of ubiquitous information spaces can be seen as a physical version of the *Task Gallery*, using interaction and presentation techniques for managing a large amount of virtual information in the context of real-world landmarks.

One of the first window managers taking into account the physical environment for spatial organization was an augmented reality system, viewed through a head-mounted display [8]. More recent "dynamically defined information spaces" use handheld projectors to explore virtual information attached to real spatial locations [5]. In *Kimura* [12], large display walls serve as peripheral displays containing "montages" of suspended tasks. However, the system also relies on a perfectly planar peripheral display, artificially integrated into the user's workspace.

A number of window management techniques have been proposed to ease spatial organization on large displays. Examples include *Scalable Fabric* [17] for managing central focus windows and peripheral groups of iconified context windows, *Window Clippings* showing only highly relevant information in peripheral windows [13], and techniques for managing piles and other spatial organizations of window groups [2]. While these examples address the physical size of the display, they do not take other environmental factors – that could be potentially useful for spatial cognition – into account.

Environmental Factors

We see ubiquitous information spaces as an extension of the user's desk, equipped with standard desktop computing hardware, much like proposed by MacIntyre *et al.* [12]. This ubiquitous information space could be created by a single or multiple projectors illuminating the walls around the user's desk, as illustrated in Figure 1. We previously built a multi-display framework [16] capturing multiple projections and monitors that were registered into a common three-dimensional coordinate system. The resulting information space is operated by conventional mouse/keyboard devices, allowing for accurate and effortless point-and-click interaction even at a far distance. Information is contained in windows of unmodified legacy applications, since knowledge workers often have to deal with information spread across multiple windows and applications, respectively. Motivated by the idea to use real landmarks to spatially partition the virtual information space, we gathered a list of environmental factors we believe should be addressed by ubiquitous information spaces:

User location and visibility: Large displays, especially those constructed in the periphery of a user's workspace, lead to unconventional viewing angles and distances. A narrow viewing angle can have a negative impact on the perception of basic visual artifacts [3], and users have shown a tendency to keep primary information artifacts physically close when working in a large display environment [4]. Ubiquitous information spaces should therefore register the user's most common location and evaluate the visibility of all display regions with respect to this location. When information artifacts are moved within the environment, window rendering should take into account the estimated visibility. Similar to existing focus+context window management systems (*e.g.*, [17]), information is rendered normally in the focus regions. When moved to a more distant location, it could be automatically enlarged to maintain readability and *clipped* according to content relevance [13] to reduce overall space requirements. Peripheral regions with very poor visibility may be populated with purely ambient information or unrelated information artifacts, like the daily specials of a nearby restaurant. Users in our study also employed a low visibility area to pile up temporarily irrelevant windows, instead of minimizing or closing them [19]. In addition, the system should provide privacy settings, so certain applications, like e-mail clients or instant messengers, will not be moved to exposed regions.

Gaps and holes: Gaps and holes in a display could be caused by physical objects mounted on the wall, such as picture frames or light switches, or space that cannot be reached by the projectors. While bridging display-less space has been addressed from both, an interaction and visualization point of view (*e.g.*, [14]), holes on vertical displays introduced by physical objects represent a new challenge. Ubiquitous information space managers need to avoid information being projected on top of physical objects. A fragmented display space could be seen as opportunity to keep the virtual display space tidied up, by snapping windows to "sticky" display boundaries and physical items. Temporary gaps caused by users casting shadows onto a front-projected display can be resolved by occlusion-aware techniques known from tabletop research (*e.g.*, [6]).

Figure 1: Conceptual sketch of a ubiquitous information space with (a) focus display regions with good visibility, (b) display holes due to picture frames (partially with aligned windows), (c) a room corner, (d) information anchored to a physical telephone, (e) bookmarks and notification widgets in narrow display regions.

Corners and non-planarity: Projected displays spanning physical room corners introduce an explicit separation between areas of varying visibility. In our exploratory study, users did not like the idea of spanning windows across a physical room corner [19]. This behavior is similar to the previously observed phenomenon that users usually do not span windows across monitor bezels [9]. Instead, this inherent separation of the display space was adopted by most users to establish semantically meaningful regions for organizing information. Despite the low resolution display used in our experiment, users described window dragging between physically separated display regions as exhausting. They suggested "throwing" gestures for relocating a single, or groups of windows, between physically separated display regions [19].

Physical objects: Real physical objects located within or next to a projection surface could serve as "anchors" for virtual information. Anchored items could contain semantically related information artifacts, such as a web page listing contact details of a company's employees anchored to the physical phone. Interesting papers bookmarked for later reading could be attached to a physical bookshelf. Physical objects can also serve as purely abstract references to unrelated information, such as a bookmark to windows of a currently suspended task. The system could be instructed or trained to associate certain applications or windows displaying specific content (which could be derived from the window title name) with dedicated physical objects.

Non-rectangular shape: Imperfect ubiquitous displays do not have rectangular outlines. Due to occlusions, display holes, and oblique projection angles, they tend to have narrow regions that seem rather unusable for displaying information contained in conventional rectangular windows. However, we argue that these regions can be a permanently visible home for widgets, notification areas, bookmarks to important pieces of information, and icons serving as reminders for yet to be finished tasks. Targeting to these regions with an indirect pointing device may be quite tedious. Keyboard short-cuts or an icon in the focus area could temporally relocate these items to a more convenient location.

The suggested environment-aware interaction and presentation techniques can be implemented by any information analysis tool relying on multiple, flexibly arrangeable views. However, a lower level integration of environment-aware space management techniques in the window management or GUI toolkit level would support a wider adoption.

Discussion and Conclusions

Ubiquitous information space management suggested in this article uses interaction and presentation techniques exploiting environmental factors that are traditionally considered disturbing for the creation of very large information spaces. We identified five environmental factors that could be beneficial for spatial cognition during knowledge work, for instance by anchoring windows to physical items, snapping windows to physical objects for a tidy information arrangement, or using abandoned, small display regions for constantly visible bookmarks and notification areas.

The concept of ubiquitous information space management is not limited to personal displays. Public notification boards or semi-public ambient displays could similarly exploit environmental factors for ubiquitous information management. Display factors known to influence collaboration (*e.g.*, [10]) should additionally be considered in this case.

Of course, ubiquitous information spaces are not always desirable. If the goal is to create a single, seamless image such as a high-resolution map, display gaps, holes, and non-planarities are indeed disturbing. During information analysis processes, however, the investigator often manages small chunks of information contained in multiple windows (*e.g.*, [2]). In this case, the above listed environmental factors could have a positive impact on the analyst's performance, when supported by ubiquitous information space management.

In the future, the potential of these environmental factors to support spatial cognition for information management should be explored in detail. Subsequently, we should aim to exploit these factors by designing environment-aware interaction and presentation techniques, rather than working around them.

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