Spotlight Navigation and LumEnActive: Ubiquitous projection user interfaces

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Abstract. We discuss the role of visual information in pervasive systems, and the reasons why displays are often not included in the design of pervasive devices, such as increased energy consumption and cost. In our demonstration we present Spotlight Navigation and LumEnActive, two projection based user interface technologies that are suited to temporarily add display functionality to a display-less networked device. In contrast to network browser solutions on a connected PC or handheld device, the proposed solutions maintain locality, that make the usage more intuitive and understandable also by end users, as the devices are accessed by their physical location rather than by a confusable name or number that may be difficult to interpret or understand. While LumEnActive is an available product and already commercially in use for applications outside pervasive computing, Spotlight Navigation is still in the prototype stage. Both can be used to access also much larger data spaces than can traditionally be handled on displays of small sizes, by utilizing a pan and zoom user interface. By this interface, it is easy to access also high-volume information, guided by a visual and intuitive search process.

1 Introduction

When Weiser wrote about ubiquitous computing as an alternative to personal computing using the desktop metaphor about 20 years ago [9], he speculated that many displays with integrated and networked processors in various sizes (tabs, pads and boards, in a centimeter, decimeter, and meter scale respectively) would be a core element of the distributed infrastructure, and the way users will make use of it. Looking back, we realize that the visual aspects and graphical human computer interaction play a smaller role in pervasive computing than originally assumed. This may be attributed to the fact that displays are not so cheap to include in pervasive devices: For one, graphical displays themselves are still rather expensive parts. Then, having a display in the design can pose additional constraints on the selected processor such as additional interface lines or an included LCD controller (that are likely to make the processor more expensive), or it may even require additional chips to be included on the board. Another reason why displays are in many cases avoided is, that they consume quite a lot of energy (especially if back-lit). Finally, the displays require a minimum size in order to be informative and readable which may conflict with the design goal to have a small and lightweight device. In consequence it seems that a single small screen display device such as a mobile phone or PDA is at the centre of many pervasive applications.

Still, at least now and then, the ability to display extensive information is highly desirable, both for end users as well as developers (or service personnel) of a pervasive system. It is often claimed that end users will configure their pervasive system after purchase or installation, so that it does perform the actions that they want in a certain situation or context. Or, they may want to understand what kind of information is utilized in certain parts of a system due to concerns of privacy or system security, or simply because of unexpected or errant behavior. Also, transparency is an important factor for the acceptance of a pervasive system. Although on a large enough display or paper it may be easy to graphically visualize which parameters can be customized, or how a distributed system is operating (such as which data is flowing where or which data is stored at a certain location), it is challenging if only a small, phone-sized display (or even smaller) is available for exploration. [7] and [1] have shown how projected information can enhance a smart infrastructure, with a focus on mobile smart objects equipped with RFID. [8] show how a projected interaction space can extend the display capabilities of laptops and objects equipped with fiducials.

The solutions that we propose in this demonstration is offering virtually unlimited, *in situ* interaction space for networked devices. On top, it offers an intuitive interface that is capable to access and manipulate a huge data space in an efficient and pleasant manner.

2 Spotlight Navigation

Spotlight Navigation [5, 4] both describes an access principle to information by panning and zooming in a data space, as well as a mobile projection device utilizing this access principle. Users hold the mobile projector in their hand and can project information on almost any sufficiently even and homogeneous surface. Spotlight Navigation is operated as easy as a flashlight. By small rotations of the device, the light spot can be moved to the left or right, upwards or downwards. The interesting aspect is that the tilting and turning of the device is continuously measured during the movement, and the image that is projected is generated in such a way that the movement is compensated for and the projected content stays at the same location on the projection surface (and is of course only visible, while being illuminated by the projector's light beam). Like making parts of the real world visible with a flashlight, parts of a virtual pane are made visible with Spotlight Navigation. Like for a flashlight, the same intuitive gestures of rotating the device and thus pointing the light spot in the intended direction are used to pan around and access a portion of the data space. Next, a scroll wheel on the device can be used to quickly zoom into the data space in order to access more detailed information on the currently visible portion, or to zoom out again to get an overview. By using this panning and zooming, a huge two-dimensional data space can be quickly accessed and intuitively explored (and also manipulated).

3 LumEnActive

LumEnActive [6, 3] is a semi-stationary variation on Spotlight Navigation. As mobile projection devices are still rather dim and thus not suitable for all environments, LumEnActive combines a fixed, standard, wall-outlet powered projector with a custom designed reflection unit that deflects the projected light in almost any direction. (This is why we call it semi-stationary: the projector is stationary, but the projected image is not). If the device is mounted on the ceiling in the middle of a room, through the computer-controlled reflection unit mounted in front of the projector's optics, almost any surface (i.e. except adversely oriented surfaces or those that are hidden behind another object) can be used to project information on to. So, by knowing the location of a display-less pervasive device, such as a sensor, say, it can be easily augmented with a projected display to directly show the information it provides or processes. The aspect of projecting information at changing locations is comparable to everywhere displays [2], but in contrast to it, LumEnActive can utilize the same pan and zoom techniques as Spotlight Navigation uses, as the generation of an image is done in real time with the movements of the mirror. So if a pervasive processing element is in need to display many data, a representation much larger than what can fit on a single screen can be projected and accessed through intuitive panning and zooming. As a disadvantage of the central mounting location of LumEnActive and the characteristics of standard projection optics, projected content at a distance is often too coarse, especially if users are standing close and the suitable projection surface is severely limited. As the content is continuously displayed also during movements, like with Spotlight Navigation, simple graphical means such as following a line from the pervasive device to a more suitable projection area are sufficient to link the location with the displayed information, should there be no suitable projection area near by.

4 Controlling display-less pervasive devices

Both Spotlight Navigation and LumEnActive can be used to control display-less pervasive infrastructure (or inspect and manipulate their processed or stored data). For LumEnActive and a location-fixed pervasive infrastructure, the location of the fixed device needs to be known once (e.g. during installation), from which position the correct angles under which to project can then be calculated. In practice, when installing a new part in the infrastructure, its interface is opened and interactively placed at the right position using the mouse or another pointing device. If the part of the pervasive infrastructure is movable, there needs to be a way to measure the location, if the device itself cannot give this information over the network. The same is true for the Spotlight Navigation device and both fixed as well as movable items: As our Spotlight Navigation prototype does not have a sense of position (only the rotational orientation is measured), the mobile device needs to measure the location of the to be controlled device in order to display accordingly. It is easiest to utilize one of the vision-based technologies developed in the augmented reality and tangible user interface area, such as infra-red beacons, fiducials, or similar technology to relate the location of the pervasive device.

The visual content that is displayed for a pervasive device can be a web site directly provided by the device's embedded web server, or a window exported over the virtual network client (VNC) protocol. LumEnActive and Spotlight Navigation can directly render VNC data, and through a VNC-connection to a server also a web browser that then in turn renders the device's data. To benefit from the pan-and-zoom functionality most, for more high-volume data like log files or communication patterns, it is advisable to utilize tailored interaction techniques. Through the usage of VNC, existing communication mechanisms like vendor-supplied PC-driver software can be utilized without modification, however, if visualization of the exchanged data and configuration options are done ground-up, a more efficient access can be realized.

The treatment of pervasive infrastructures is not properly accounted for by operating a single device. The projection user interfaces can be used to also visualize, configure or reconfigure the interplay between devices. To make a simple example, routing an audio stream from a storage device to a specific set of speakers can be done by simply connecting the two devices with a line, drawn in the virtual, projected space; the audio stream can be stopped again by crossing out a connecting line.

5 Conclusions

We demonstrate a location-aware way of augmenting devices in a pervasive infrastructure with display capabilities, by 'lending' a steerable, projected information space onto the devices or beneath them. Two related technologies, Spotlight Navigation and LumEnActive are shown that are mobile, and semi-stationary respectively, variants of a powerful visualization technique utilizing panning by intuitive pointing gestures and zooming. Although the shown examples are still just proxies for real applications, the technologies are ready for broader exploration in larger scale pervasive installations. Using the technologies can give back the visualization capabilities envisioned in Weiser's seminal paper of the field at least temporarily, to pervasive environments that are often missing displays due to cost or power consumption concerns.

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