A Life-Sized Desk Display for Peripheral Awareness and Remote Collaboration

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Abstract

We present a horizontal life-sized desk display called the Escritoire. It fills a much larger visual angle than a conventional monitor, and thus exploits the user's peripheral vision. Two-handed input over the extent of the user's reach allows a style of working more like a real desk, and, using two desks, participants in a video conference can share a virtual space for remote collaboration.

Keywords

Personal projected display, planar homography, bimanual input, remote collaboration, task space.

1. Introduction

Conventional computer displays occupy a visual angle of approximately 20 to 40 degrees at the centre of the visual cone and are meant to be read without rotating the neck [10] A much larger display is qualitatively as well as quantitatively different, so simply displaying a larger version of the traditional GUI does not work [9, page 395]. We present a desk display called the Escritoire [1] that is the size of a traditional desk and has an interface modelled on real paper (Figure 1).

The ability to spread documents and images over the desk offers a different style of working to the conventional desktop computer. George A. Miller noted that the location of information in the world is important [7]. Papers on a desk are cognitive artifacts—objects that expand the users abilities by reminding them of pending tasks and providing easily accessible information [8]. They are an example of knowledge in the world which complements knowledge in the head.

The DigitalDesk [12] augmented real paper with projected graphics and systems such as Enhanced-Desk [6] have explored this approach further. We have chosen to simulate rather than augment paper because this allows the desk surface to be under the control of the computer and, in particular, allows remote participants to collaborate symmetrically in the virtual space that they share. The Escritoire combines a large A0 digitizer with an ultrasonic pen to provide two-handed input over the entire area of the desk.

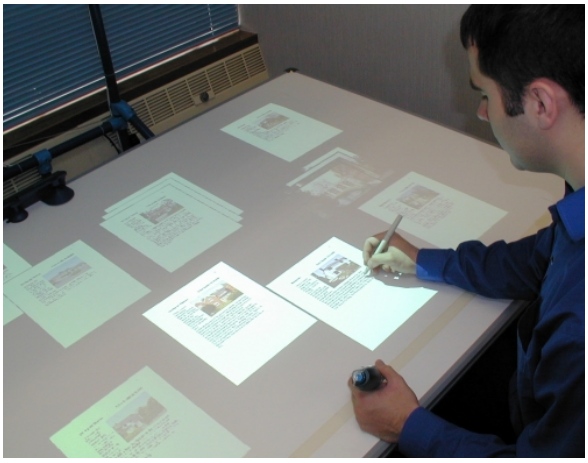

Figure 1. The Escritoire is a desk-sized display on which documents and images can be manipulated.

2. Desk Display

We have used projectors to make an affordable large-format display for a single user. Commodity projectors do not have high enough resolution to fill the desk while also rendering a life-sized PDF file legible. We have therefore combined two projectors to create a *foveal display* that uses one projector to fill the desk with a low-resolution *periphery* and another overlapping one to make a high-resolution *fovea* in front of the user (Figure 2). The difference in resolution is transparent to the applications.

We warp the images before projection to compensate for rough positioning of the projectors and to align the projected displays. We assume that projection of an image to the desk is a case of central projection [5, Chapter 5], thus calibration involves obtaining a planar homography from the desk to each projector—for homogeneous points $\mathbf{d}$ on the desk and $\mathbf{p}$ in the projector we require a 3×3 matrix $\mathbf{H}$ for which $\mathbf{Hd} = \mathbf{p}$ up to scaling. The homography can be found with four or more point correspondences which we obtain by selecting projected points on the digitizer.

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Figure 2. The display of the Escritoire has a *periphery* created by a projector low down behind the desk (left) whose image is reflected in a mirror above, and a fovea created by a projector above the desk (right).

Commodity 3D video cards can easily perform the warping, and our system updates the pair of projected regions at over 30 frames per second as an A4-sized piece of virtual paper is moved. We have found in practice that a planar homography is a good match for the distortion of the projected image. The varying of resolutions between regions of the display is similar to level-of-detail effects that are used in head-mounted displays, where detail in the periphery can be degraded without affecting task performance [11]. The Escritoire's display is like the focus plus context screen of Baudisch *et al.* [2] although their system relies purely on manual calibration and uses the standard keyboard and mouse for input.

The digitizer that forms the desk surface has an accuracy of $\pm 0.25mm$. The ultrasonic pen is less accurate so we calibrate it using a variant of piecewise linear interpolation [4].

3. Interaction

In tests we have found that users are quickly able to use the desk system and can easily use pens in both hands to interleave movement and annotation of virtual paper. Users working individually preferred to have no cursors because they obstruct the information underneath, but users collaborating remotely found pen traces very useful for gesturing to one another (Figure 3). A common problem for front-projection systems is that the user can accidentally move between the projector and the display surface, but our system uses oblique projection from a point near the back of the desk so the user can lean forward without occluding the projected imagery. Groups creating display walls have been working on balancing the intensity and colour of multiple projectors but in our case the obvious difference in brightness between the fovea and periphery is a useful cue to the extent of each region.

When two or more desks are linked they form a new virtual space where the participants interact.

Figure 3. We offered the users the choice of no cursors, cross hairs (left) or traces (right). The remote collaborators preferred traces.

They create a *task space* [3] as opposed to the *person space* of a video conference. In our tests, participants found the audio channel and shared desk we gave them to be much more useful for remote collaboration than the video channel.

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