What you see is what you feel

Exploiting the dominance of the visual over the haptic domain to simulate force-feedback with cursor displacements

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ABSTRACT
In this paper, we will present an approach to design a more natural user interface without taking resort to special haptic input/output devices. Tactile sensations like stickiness, touch, or mass can be evoked by applying tiny displacements upon cursor movements. Our active cursor method exploits the domination of the visual over the haptic domain. We will show that interactive animations can be used to simulate the functioning of force-feedback devices. A demo is online at http://www.koert.com/work/activecursor (a shockwave plugin is required).

Keywords
Force-feedback, multi-modal, simulation, interactive animation, natural interfaces, haptics, intersensory perception.

INTRODUCTION
In our physical world, the kinetic behaviour of objects looks self-evident. It informs us about the physical properties of an object. If you open a door you will feel a certain resistance that tells you something about the door, how it is placed and what it is made of. When you lift a box you will feel whether the box is full or empty. With computers, it is different. The average desktop computer setup consists of a mouse, keyboard, a flat 2D screen and two small speakers. The vast majority of current graphical user interfaces involve manipulation of onscreen artefacts with a mouse controlled cursor [22]. The mouse is the dominant pointing and selecting device and has become the most frequently handled device in many people's daily lives. More frequent than cash, the steering wheel, doorknobs, pens, hammers, or screw drivers [30]. Its design has not been altered much since its invention by English, Engelbart and Berman in 1967 [12]. There have been some improvements in the ergonomics of the mouse device. Many manufacturers place tiny wheels on the front of their mice and trackballs that users can roll to move vertically on-screen through documents and web pages. Some companies place pointing sticks between the buttons of their mice to allow both vertical and horizontal scrolling. Improvements have been made in its shape and degrees of freedom. Mice have become optical and wireless.

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Haptic feedback

Figure 1. Homo desktop computer. Optimised human for desktop computing.

From a sensorial point of view, desktop computers are extremely limited machines with hardly any physicality to it. They engage only a fraction of the human sensory bandwidth. If evolution would naturally select the human race on desktop computer use, people would evolve towards one-eyed blobs with tiny ears, a small mouth, no nose and a large click finger (figure 1). Objects on your computer desktop lack any bodily properties. Although this weightlessness of cyberspace has some significant advantages, touch can play a powerful role in communication. It can offer an immediacy and intimacy unparalleled by words or images. The firm handshake, an encouraging pat on the back, a comforting hug, all speaks to the profound expressiveness of physical contact. In the real world, touch can further serve as a powerful mechanism for reinforcing trust and establishing group bonding [6,7]. It has often been suggested that improvements in this domain could lead to more natural computer interfaces [4,5]. Research in human-computer interfaces has addressed this issue with the development and evaluation of several force-

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feedback devices [2,3,11,16,23,24]. These devices are used to simulate a wide rang of object dynamics such as elasticity, hardness, and stiffness. Although many force-feedback devices are commercially available, they are not part of the standard desktop setup. Not much software is therefore developed that utilises direct haptic feedback as a primary communication channel.

Renaissance tricks

If we compare the computer screen with the Renaissance canvas, the limitations and goals show some remarkable similarities. Both painters and interface designers are constrained to a flat and square canvas. Their goal is to represent or reflect our rich world of sensations within these limitations. Renaissance painters invented tricks like perspective, sfumato and tromp d'oeil to get the job done. We aim at doing similar work for the contemporary computer interfaces. In this paper, we focus on the use of interactive animations towards a more natural interface. The role of movement in interactive applications is underestimated. Whereas animation of independent objects is properly studied and applied in motion cinema, hardly any research was focussed on animation in direct interaction with a user. In the early days of graphical user interfaces, use of interactive animation was cost inefficient on the scarce processing power. Nowadays, interactive animations can be implemented without significant performance penalty. With this mindset, we designed and implemented a series of experimental interaction styles. Among them, the active cursor, in which haptic effects are induced with tiny cursor displacements.

ACTIVE CURSOR

The point/select task is the primary operation in graphical user interfaces. The cursor channel is used intensely in the interaction with the system. An average user executes about four thousand point/select tasks a day (based on our own informal research). The cursor is the representation of the user within the interface. In a way it is your default avatar in cyberspace. The cursor behaviour has not altered much since its invention [12]. An early improvement is the use of a dynamic cursor icon to inform about the status of the system or the effects of the next mouse action. Changing the cursor icon to an hourglass, hand or I-beam has proven to be effective and intuitive. Another improvement is the use of *sticky icons* and *area cursors*. Sticky icons enabled an automatic 30% reduction of the cursor’s gain ratio as the cursor neared a target, and then returned to normal after passing target. In research by Worden [28], the area cursor and sticky icons had no effect on accuracy, but substantially improved the speed of performance over the traditional pointer.

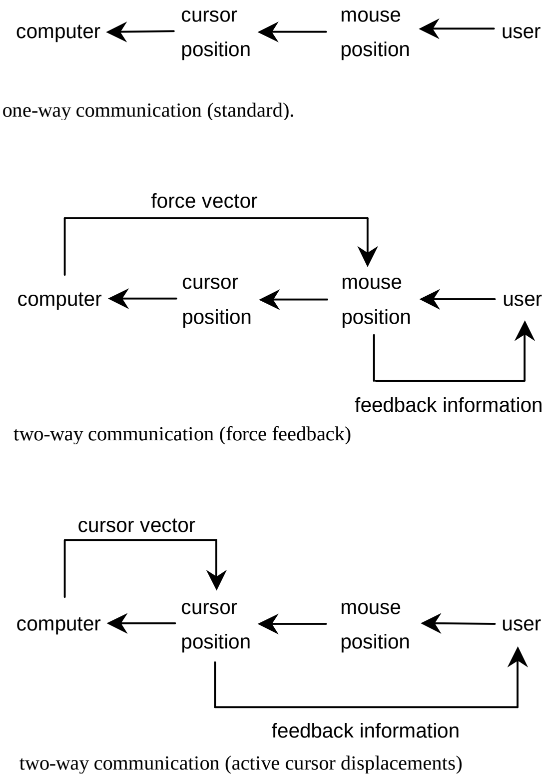

Figure 2 Communication dialog for standard setup, force feedback setup and active cursor setup.

Two-way communication through cursor location

The position of the cursor channel is normally used for input only. We developed a cursor interface in which the system manipulates the cursor position to give feedback to the user. The user still has main control over the cursor movements, but the system is allowed to apply tiny displacements to the cursor position. This system has a lot in common with existing force-feedback systems, except for the fact that in force-feedback systems the location of the cursor is manipulated as a result of the force sent to the haptic display, whereas in our system the cursor location is directly manipulated (figure 2). Since direct two way communication through the pointing device has proved successful with haptic devices, it seems reasonable to expect benefits from direct communication through cursor positions.

Simulated haptic effects

The active cursor displacements result in interactive animations that induce haptic sensations like stickiness, stiffness, or mass. The cursor is displaced as if there are real forces working on the mouse. The user sees this on the computer screen and tends to 'feel' it. This sense of touch is an illusion, based upon the domination of the visual over the haptic domain. We have not yet measured the exact strength and effectiveness of the effect in our simulation. Numerous studies on human perception indicate that stimuli in one modality can evoke experience in another [9,19,25,26,27]. We know that humans exhibit distal attribution, which is the tendency to quickly integrate multi-modal sensory experiences into single sense-making occurrences in the external world [29]. Gibson [13] describes our senses as active interrelated systems providing information for our perception of the real world. A classic and robust example of visual-to-haptic intersensory interaction is the size-weight illusion, documented by Charpentier and Flourney over a 100 years ago [10,15,21]. When lifting two objects of different volume but equal weight, people judge the smaller object to be heavier. Several researchers have demonstrated this dominance of vision over haptics in various experiments [8]. Research by Miner points out that visual stimuli can influence haptic perception in virtual environments [20].

Contextual feedback

Among the virtual haptic objects we created are 'holes' and 'hills'. If the cursor rolls over a hole, it is dragged towards the centre. When rolling over a hill, the cursor is dragged away from the centre (figure 3). The active cursor can guide the user towards preferred positions or communicate properties of the interface to the user. Due to these cursor displacements a hole becomes an easily accessible part of the screen whereas a hill area is hard to access. This sort contextual feedback communicates in a very direct and intuitive way. It is possible to create any 3d slope you want as well as dynamic slopes and textures.

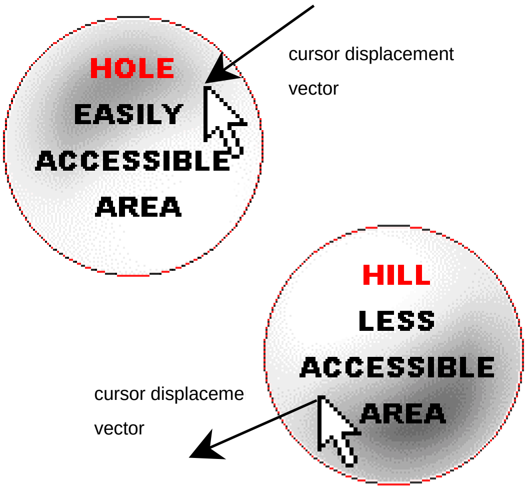

Figure 3 hole and hill.

Another virtual haptic object we created is the decision graph (figure 4). It consists of a number of gutters that push the cursor in a certain direction and some holes that stop the cursor. Every hole represents a starting-, decision-, or endpoint in the graph. Graphs like these can be helpful in guiding a user through a decision dialog. Furthermore, we have also experimented with expressing material properties of 3d objects through cursor displacements (figure 5).
A demo of our work can be found online at
http://www.koert.com/work/activecursor/

DISCUSSION

We simulated haptic sensations within a standard graphical user interface context. Cursor displacements can be used to

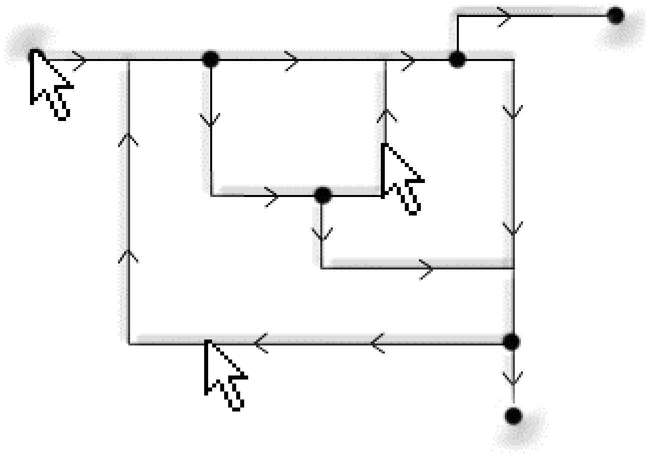

Figure 4. Cursor is guided through the decision graph.

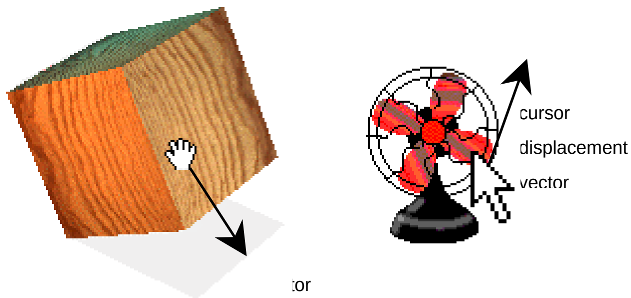

Figure 5. Mapping properties of 3d objects.

simulate most the functions of a real force-feedback device. Although, the effect of simulated touch can be applied only in combination with a visual display, it can be used to display direct contextual feedback. This opens up a broad range of interface design possibilities. Once interface designers can count on its presence, haptic feedback can become a standard communication channel with the user. Our method was developed for use with standard mouse, but should work on any cursor-controlled interface. Depending on the capabilities of the users input device this feedback will be evoked via the device, with cursor displacements, or both.

Simulate your new computer on your old computer

We think manufacturers of haptic devices can benefit from our work. Although the advantages are clear, force-feedback devices have not made it to your average desktop. It might be because of the lack of software applications for these devices. And software is scarce because people do not have force-feedback devices at their homes. Our simulated force-feedback principle could break this cycle. Manufacturers of haptic devices can add a driver to their device that simulates the device in a standard desktop setup. If interaction designers can assume the availability of the haptic device (simulated by cursor displacements or not), the use of haptic information can grow to become a serious factor in human/computer interaction.

Future work

Further research into the potential of simulated force-feedback is needed. Future work deals with the evaluation of the simulated haptic feedback in comparison to regular force-feedback through different perceptual tasks such as discrimination of force experiments. We are currently measuring the effectiveness of both feedback methods in a target acquisition task. Force-feedback devices have proven beneficial in Fitts law [14,17] based target acquisition tasks [1,11,18]. Assessment of active cursor in these type of tasks can learn us more about the effectiveness of the simulation. Contextual feedback through cursor displacements may inspire designers to create a new type of interaction styles. Another path open for research is the potential role of audio in the simulation of haptic feedback.

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