Wheel matters – Pseudo-haptic approach in designing enhanced touch screen wheel widget

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ABSTRACT

In this paper a design of a general purpose, touch screen based control wheel is introduced and evaluated. The aim was to combine the robustness and feel of control of a physical wheel within the limitations of a touch screen interaction, utilising pseudo-haptics instead of any haptic actuator technology. The design also aims at providing an equal controllability for both the fine and rough adjustments. A pilot evaluation indicated success in fundamental design ideas and helps in the further development of the wheel.

Author Keywords

touch screen, user interface design, pseudo-haptics

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation (e.g., HCI): User interfaces

INTRODUCTION

Touch screen interaction is based on an illusion of direct manipulation of objects. This study focuses on the design and implementation of a virtual wheel controller, utilising the opportunities of touch screen technology. This vertically oriented widget is aimed to be a general purpose controller for adjusting context-specific parameters. The wheel was opted to substitute the current physical wheel of the target product, thus providing with the flexibility and other advantages of a virtual solution.

An ideal controller would combine the strengths of the physical and the virtual. The clearest disadvantage of virtual control elements, compared with hardware-based ones, is the shortage of physical interaction. When using a physical wheel, the essence in the emergence of feel of immediate control is the haptic experience of the wheel and its mechanical properties. Therefore the virtual wheel design aims at triggering such "missing" haptic experience. The intention, however, is not just to simulate a hardware wheel. The potential of virtualisation is in flexibility, as virtual tool-objects are not necessarily dependent on fixed schemes based on hardware controllers. A physical wheel controller is ideal for making fine adjustments robustly. However, it is not well suited for making big leaps along the available scale quickly. Therefore our design concept of a "wheel" is enhanced to enable both fine (and robust) and rough (and quick) adjustments.

Touch screens rarely incorporate haptic actuators. However, the lack of actuators does not prevent haptic design. Rather than conceiving *haptics* as a mere input for touch sensation, we see it as a much broader perceptual apparatus [1], by which the subject actively "picks up" information about the environment. For instance, there is evidence suggesting that haptic system effectively integrates action-related information from other senses [2, 3, 4]. Haptic experiences should thus be evoked, for example, when user's motor activity on the touch screen gets perceptually coupled with the directly related "non-haptic" (sonic/visual) feedback. Such pseudo-haptic illusions [5] refer to physical properties, such as textures or inertia.

WHEEL DESIGN

Design and implementation of the widget progressed in tandem by iterative prototyping done with *Adobe Director* version 11.5 and *EloTouch* 1739L touch screen display. Firstly, in the visual appearance (see Figure 1) we focused on a general affordance of "rotateability" and a smooth and responsive wheel movement. Contrary to the hardware counterparts, the wheel functions even when finger is sliding over its visual boundaries. The wheel embodies evenly spaced horizontal notches which represent points in the wheel where a change in a scale value "snaps into". The feel of going over notches is pivotal for user's ability to make fine adjustments, but the texture of consecutively crossed notches also affects the general mental image of the wheel as an object.

The elements of the pseudo-haptic wheel design relate both to *inertial model* (how wheel behaviour manifests inertial properties) and to *texture* (how wheel notches manifest an action-related texture). Elements relating mainly to the inertial model are:

- *Force dynamics*. A simple model that manages the increment and decrement of the Force value according to the rotation effort directed towards the wheel.
- *FreeWheel*. A mode where, after releasing the finger, the wheel keeps on spinning while enough Force is present (see below) or until the wheel is being touched again.
- *Notch friction*. A factor for decreasing the Force value at each notch crossing while the wheel is in the free spinning. Consecutive notches thus gradually slow down the spinning. When the Force value decreases below the pre-

determined threshold of minimum force, the next consecutive notch stops the wheel movement.

In fine adjustments, it is important that no free spinning accidentally starts at the wheel release. This matter can be managed by fixing the force dynamics, notch friction and the threshold of minimum accordingly.

Elements mainly relating to the wheel texture are:

- *Notch sound*. A short sound sample (200 ms) with acoustic features appropriately illustrating "snapping into a notch". Different kind of samples can function as textures that refer to different materials (e.g., wood, metal, plastic or rubber) but also to property dimensions such as sharp/dull, hard/soft, solid/tenuous or bright/dark.
- *Notch bump*. Visual bump of the wheel intensifies the sound feedback of snapping into a notch (small displacement forwards and backwards). The effect is noticeable only at slower rotating speeds.
- *Force-based filtering* (for notch sound). A spectral slope of the notch sound is varied as a function of the Force value (from negative to positive trend). There is also a subtle change in sound intensity in accordance with the Force. The purpose of this real-time filtering is to illustrate the rotation force of the wheel in the notch sound. The spectral slope has previously been associated, e.g., to the perceived speed of rubbing movements [6].
- *Scale-based filtering* (for notch sound). A center frequency of narrow-band filter boost is varied as a function of scale value. Such a moving resonant frequency (between 162-3240 Hz) is used for illustrating the relative location and direction of movement in the scale continuum. This element extends the object-related texture conception towards the "subject matter" (i.e., scale value) being manipulated. The acoustic nature of this effect can also evoke metaphorical associations about the manipulation, such as "pouring water" into a bottle (amount of fluid) or "tightening" a spring (amount of tension).

For faster transitions in the scale position we utilised two alternative enhancement paradigms in the wheel prototype:

- *FlyWheel* mode is based on intensified operation of the FreeWheel mode. It modifies the free spinning of the wheel by using significantly reduced Notch friction until a wheel stoppage. FlyWheel is automatically enabled when the wheel is revolved with a Force exceeding a specified force threshold value. The enablement is visually indicated to the user by a colour change of the wheel's borders. The user can rapidly move along the scale with a hard single spin and then stop the wheel as appropriate by touching it.
- *GearWheel* mode is based on intensified rotation rate (multiplied by 5:1 ratio) of the wheel when enabled. The usage of this mode presupposes that the FreeWheel mode is disabled, thus the wheel only rotates when being dragged. Identically with the FlyWheel mode, GearWheel mode is automatically enabled or disabled in terms of the used force and a specific threshold value, and the enablement is visually indicated. As the dragging out of the wheel boundaries is allowed, the user can navigate along the scale by varying the speed (thus enabling and disabling the GearWheel) and the direction of a continuous dragging.

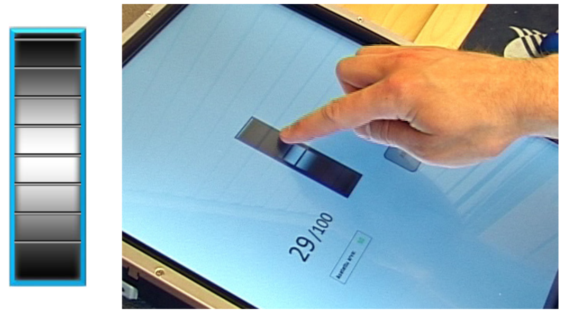

Figure 1. On the left, the visual appearance of the wheel. On the right, a subject is performing an adjustment with the prototype.

PILOT EVALUATION

The current prototype was exposed to a pilot experiment in which 8 subjects tested it in pairs. The experiment had three phases: 1) getting familiarised with the basic wheel (with no other enhancements than Notch sound), 2) getting familiarised with all available enhancement options and 3) choosing the favourite combination of features. In the second phase subjects were able to switch on and off FreeWheel mode (with adjustable friction), Notch bump, both audio filters, and both speed enhancement alternatives (with adjustable Force threshold). During the free testing, pairs discussed about the features. After phases 1 and 3, all subjects performed a timed sequence of 20 adjustments (within 1-100 scale). Each adjustment was confirmed with an OK button. The favoured options were used in the second sequence.

The wheel concept was rapidly adapted and liked, despite some early difficulties experienced due to somewhat "stiff" responsivity of the resistive touch screen. Already the very first comment in the experiment was about the pseudo-haptic effect: a subject stated that "…it feels just like a real". When first trying with the basic wheel, many subjects complained the lack of free wheel and were relieved when it was included as an option in the next phase. Most subjects liked the idea of scale-based variation in sound (included in favoured set by 2 pairs) and gave expressions such as "…sounds engaging" or "…you feel at once the direction you are going to". However, some were concerned about a possible irritation in long term use. The illustration of force in sound was also found useful by one pair due to its subtleness and the feedback it provides for perceiving the force threshold. Audio filters were seen as either-or options, although one pair did not choose either. The Notch bump effect was generally considered quite non-significant.

All four pairs opted for either speed enhancement in their favourite wheel (2×FlyWheel, 2×GearWheel). Discussions and arguments were mainly about the preference between them. The adjustment sequences were performed much faster with the favoured wheel. The performance difference across average times per adjustment is statistically significant in paired t-test, $t(6) = 8.35$, $p < .001$. Mean decrease in times was 23.6%. One subject was excluded from analysis due to a technical error.

CONCLUSION

The pilot study suggested that the design objectives have been reached. It indicated success in the fundamental design ideas and helps in the further development of the wheel towards implementation in the target system.

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