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Interactive Graph Manipulation Tools Enhanced with Low-Frequency Tactile and Force Feedback

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Abstract. Haptic feedback has been reported to significantly improve human-computer interaction in the virtual 3D environments. There are also benefits in using low-frequency haptic feedback in simple interaction tasks in 2D environments. Our study aimed at finding out how tactile and force feedback could be used to improve interaction in a direct manipulation desktop application. According to the user study, the users found the additional tactile and force feedback effects helpful in the events that cannot be instantly visually verified, e.g., when objects were touched with the tool. Both the tactile and force feedback seemed to have potential although some redesigning for the effects must be done.

1 Introduction

In addition to the visual feedback, sound feedback has been used to inform the user of the actions in the graphical user interfaces [2]. However, even when combining both of these, human-computer interaction still lacks many fundamental qualities related to physical interaction with the real world. The haptic modality makes it possible for the user to interact with the concrete objects in the interface. However, a problem with most haptic devices is that they are either special research prototypes or their prices are out of reach for an average computer user. Still, also cheaper alternatives exist and have been used in several studies [1,3,4,10].

A force feedback mouse has been found to improve the performance of combined steering and targeting tasks [3] and it can be used effectively in two-dimensional interaction tasks together with visual feedback in representing graphical data [10]. Also different tactile mice have been utilized to enhance single interaction events, for example target selection [4] and movement [1]. Based on these results it can be suggested that these kind of low-frequency haptic devices have potential when used in the desktop environment although the tactile feedback devices used in the previous studies have only provided static feedback.

In this research, we have added tactile and force feedback effects to the interactive tools of a simple graph manipulation application. The set of direct graph manipulation tools [9] used as the basis of this study is based on the concept of direct manipulation and the tools are visualized as large tool-specific mouse cursors. In this study, we chose to use both tactile and force feedback mice (Fig. 1) to get user opinions on the use of low-frequency haptic effects in a desktop application.

A standard computer mouse does not provide anything but passive feedback of its movement and position as well as sound and feel of clicking its mouse buttons. In our study, we used two kinds of mice to compare the use of tactile and force feedback effects. Both mice take advantage of the TouchSense technology provided by Immersion Corporation [5].

The iFeel tactile mouse [6] (Fig. 1, on the left) generates low-frequency vibrations and shakes with a rotating motor inside the mouse. These effects can be both felt as tactile effects with the hand holding the mouse and heard by the user. The WingMan force feedback mouse [6] (Fig. 1, on the right) has more potential because in addition to tactile feedback it also provides force feedback. The mouse itself is attached to its mouse pad with an axis that limits its movement and makes it possible to produce force feedback sensations generated by the motors inside the pad.

Fig. 1. The iFeel tactile feedback mouse (left) and WingMan force feedback mouse (right) [6]

The rest of this paper is organized as follows. In Section 2, we present our approach for designing and adding feedback effects in the direct manipulation tools. In Section 3, we describe the user study and represent its results. In Section 4, we discuss the results of the user study and present directions for further research. Section 5 concludes the paper.

2 Design of Tactile and Force Feedback Effects

In designing haptic effects, special attention must be paid to the qualities and potential of the feedback device used [7] to ensure that the effects do not disturb but support the intentions of the user [8]. To find out what the users would like to be able to feel in the user interface, we added tactile and force feedback effects in the interaction events that would be haptically available in the real world. Both tactile and force feedback effects were designed individually for each event to be able to take the full advantage of the qualities of both devices.

Table 1 shows the events that were used in the direct manipulation tools. In the table, both tactile and force feedback effects for each event are described as well as the nature of the effect that can be either static or dynamic. The properties of static effects are fixed while those of dynamic ones vary depending on either the number of objects being manipulated or the size of the tool cursor.

Table 1. The use of haptic effects in the interactive graph drawing tools

Event	Tactile Effect	Force Effect	Nature
Tool selection	Periodic	Constant	Static
Tool deactivation	Periodic	Periodic	Static
Object selection	Periodic	Spring	Static
Tool dragging	Texture	Friction	Dynamic
Tool adjustment	Texture	Damper	Dynamic

For the tactile feedback mouse, we used periodic and texture effects. The periodic effects consist of vibrations, the properties of which, such as waveform, magnitude and duration, can be varied. The texture effects are composed of a series of bumps spaced at regular intervals making the target feel like surfaces of different roughness. The tool selection, deactivation and object selection events all had a static periodic effect of their own to distinguish them. Concerning the dynamic effects, the magnitude of texture effect for the dragging event was altered based on the amount of objects selected with the tools, and the texture effect of using the tools was based on both the size of the tool as well as the amount of selected objects.

For the force feedback mouse, tactile periodic effect was used to give the user simple information of the deactivation of the tool. In the tool selection a short pull of constant force towards the drawing canvas was used to simulate the weight of the tool as well as to gently guide the user to the working area. In object selection, a spring effect resisted the tool movement to make the operation feel like collecting something heavy. When dragging the tool, the user could feel the amount of selected objects in the means of increased friction. Adjusting the length of the tool caused a slightly resisting feel like that of acting in liquid environment.

3 User Study

3.1 Test Setup

The tactile and force feedback conditions were tested in a user study with twelve users, nine males and three females, aged between 23 and 33 years. All the users had strong experience in using computers and six of them had previously used at least some of the direct graph manipulation tools without haptic effects. Only one user had not used any kind of haptic devices before, while seven had some experience on either tactile or force feedback mouse.

The tests were carried out in a usability laboratory under supervision and videotaped for more specific analysis. After the test, the users were asked to fill in a questionnaire where they were asked of their background information, 18 questions of both tactile and force feedback effects in a Likert scale (1..5), and their perception on the feedback effects. After filling in the questionnaire, the users were shortly interviewed about their opinions on both of the feedback modes and devices.

The direct manipulation tools were first shortly introduced to the users and they also tried out the tools for a short period of time before the test. Each test consisted of three rounds of three drawing tasks (Fig. 2) that were performed in the same order while the feedback mode changed for every round. The feedback modes used in the study were (1) no haptic feedback, (2) tactile feedback and (3) force feedback. The order of the feedback modes was counter-balanced between the users. In each task, the users were supposed to draw a graph equal to the example drawing given on the paper. The users decided themselves when the graph drawing was ready.

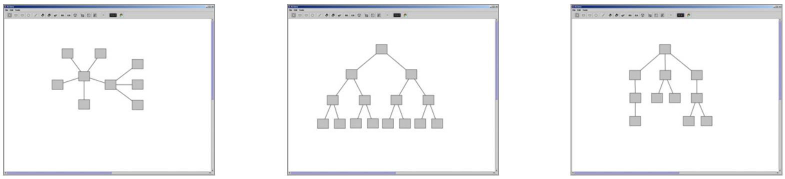

Fig. 2. The drawing tasks the users performed. In the first two tasks (left), the users started with a blank screen. In the third task, the model result of the second task was given as the basis

3.2 Results

The usefulness of tactile feedback divided opinions, as half of the users rated it useful while the other half did not think tactile feedback was useful. In the Likert scale (1..5), usefulness of tactile feedback got an average of 3.17 while force feedback was considered less useful (2.33). The users felt that tactile feedback disturbed them (3.17) and force feedback even more (3.42), and it was evident that they noticed both the tactile (4.5) and force feedback (4.08). Nevertheless, the users were not able to distinguish the effects of different events (2.17 for tactile and 2.08 for force feedback) but thought that all the effects felt the same (4.00 and 3.75). The averages are presented in Fig. 3 with standard deviations.

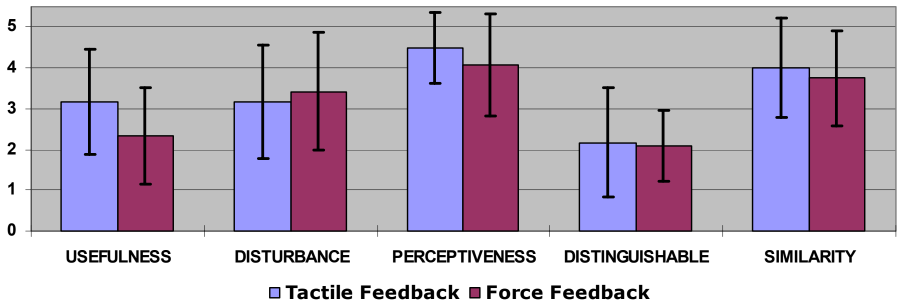

Fig. 3. Average user opinions with standard deviations on some characteristics of tactile and force feedback

Although the user opinions point out that both feedback modes disturbed them at some level, in the interviews most of the users told that they preferred to use the tools with rather than without the additional feedback. Five of the users liked to use the tools more with tactile feedback and two users preferred using tools with force feedback. It was stated that the use of tactile feedback was appropriate while force feedback was used too much, often meaning that it was too strong. The opinions on the strength of tactile feedback varied considerably, possibly because the mouse used in the study provided the feedback mainly to the palm of the hand – this is evidently not the most ideal solution because the finger tips are the most sensitive parts of the hand and not all the users tend to hold the whole mouse in their palm, they rather hold it with their fingers.

Four users thought that tactile feedback improved the naturalness of the tool usage while six of them did not. For the force feedback mode, the corresponding numbers were three for the naturalness and seven against it. The users also stated that the additional feedback received from selecting objects with the tool, dragging the tool on the drawing canvas and adjusting the sizes of the tool cursors was useful. On the contrary, feedback from selecting the tool from the palette and deactivating the tool was considered unnecessary.

Four of the users did not like either of the feedback modes while only one user liked them both. Four of the users both liked and disliked the tactile feedback while two of them liked and seven of them disliked the force feedback. The user that liked both the tactile and force feedback modes did not have any previous experience on haptic devices while another that clearly disliked the tactile feedback mode and liked the force feedback mode uses the PHANTOM device in his work.

4 Discussion

The limitations of the low-frequency haptic devices made it impossible to make use of the intended dynamical nature of some of the effects. As a result, we found out that it was not sensible to try to pursue the feel of real-world interaction because of three main reasons. First, the accuracy and the performance of both the tactile and force feedback mice used in the research are not adequate to be able to generate sufficiently authentic sensations. Second, the users did not expect to get feedback from all the physical events of the tools. Third, both the tactile and force feedback appeared to be too strong for most of the users.

Some of the users found both the feel and the sound of the tactile mouse offending in the situations when it vibrated loudly against the table. This could be easily improved by designing softer effects and maybe also using a soft pad under the mouse. In some situations, the users felt that the force feedback mouse resisted too much their actions and were irritated with that. Here, again, redesigning the force effects could improve the results. Based on the post-test interviews, the tactile feedback mouse turned out to be more popular but also the potential of force feedback was recognized by the users despite the technical limitations of the device used. Overall, according to the study, tactile and force feedback effects should be kept in the background to support visual feedback.

It seems evident that when the visual modality practically provides the same information as the haptic modality, the users tend to concentrate on the visual information and notice the haptic information only when it is not coherent with the visual one. Therefore, we suggest that the additional haptic feedback should be used primarily in the events that cannot easily be visually verified thus supporting the direct manipulation.

5 Conclusions

This paper described using tactile and force feedback effects to enhance human-computer interaction in a desktop application. According to the users' opinions, tactile and force feedback should be used in quite a small role mainly to support the visual feedback. The users, however, found them particularly helpful when the tools hit the objects. Generally, the users hoped that haptic feedback would be used more discreetly and selectively. Force feedback was recognized to have more potential but the functional weaknesses of the force feedback mouse disturbed the users. The user study pointed out issues for improvement in future work.

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