Appropriateness of Foot Interaction for Non-Accurate Spatial Tasks

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ABSTRACT
This paper describes alternative methods for manipulating graphical user interfaces with a foot. Feet are used in many real world tasks together with the rest of the body, but in computer environments they are almost completely put aside as an interaction possibility. One of the major problems in choosing input methods for different tasks in user interfaces is determining what kind of method is appropriate for a certain task. Feet could easily be used as a supportive input method in interaction with computers together with the traditional mouse. In this paper, we discuss the possibility of using foot input in different non-accurate spatial tasks, and the efficiency and usability experience the users have of foot interaction compared with a traditional hand-based interface with the same input device. The aim is to find out how well foot interaction suits for non-accurate spatial tasks.

Categories & Subject Descriptors: H5.2. [**Information Interfaces and Presentation**]: User Interfaces – *Interaction styles, input devices and strategies, evaluation/methodology*; I3.6. [**Computer Graphics**]: Methodology and Techniques – *Interaction techniques*

General Terms: Experimentation; Human Factors; Measurement.

Keywords: Input; Interaction; Multimodality; Usability.

INTRODUCTION

Computers are mostly operated today by using spatial interaction methods with a mouse, i.e., objects are moved, resized and selected with a mouse. Several of these tasks interrupt users' workflow with information. For example, when a user is reading a webpage or writing a document, the window has to be scrolled every so often and this is usually done with a mouse. Currently this part of the task can be done separately with a mouse wheel, which is an example of how tasks can be divided into different subtasks that can be done simultaneously. Some of these supportive non-accurate subtasks could also be executed by foot without any interruptions to current workflow. For example, while writing the use of the mouse wheel requires interrupting the writing task. If these kinds of subtasks would be operated with a foot, users could keep their concentration on the work they are doing and workflow would not be interrupted. Currently, feet are mostly used in expensive virtual environments as an additional input method [4], but for example a trackball could be a cheap additional input device to be used by feet and it would provide the users with a less interruptive way to handle supportive subtasks like scrolling or moving objects in their document.

The factors limiting interaction possibilities with feet are human capabilities to operate conveniently, efficiently and accurately enough, i.e., human cognitive and psychomotor capabilities and users' subjective experiences of the interaction method. Generally, this means simpler tasks, and easier input methods mean more efficient and more accurate input results. Fitts' law and its derivatives [5] have in many cases been proven to fit in measuring human psychomotor capabilities, but no form of the law takes into account a user's subjective experience of an input method. This leads to a situation where the law describes the efficiency of an input method, but an efficient input method is not necessarily preferred by the users only because of its efficiency. The subjective satisfaction of an input method strongly affects which input methods the users prefer.

In several studies based on Fitts' law [e.g., 5, 3] it has been shown that the non-dominant hand and feet are in psychomotor aspect less effective than the primary hand. The order of the efficiency of input limbs is the dominant hand, the non-dominant hand, the dominant foot and the non-dominant foot. Feet have been used as an alternative method for the hand [6, 7], but it has been proven that foot interaction is suffering more in execution times with accurate tasks than the hands, so hands are better suited for accurate subtasks and the hands are also about twice as accurate as the feet [3].

In human cognitive processing the question is how to divide the subtasks so that users do not have to do several primary tasks at once. With the primary task we mean tasks that require the user's attention and that way cause more cognitive load to the user. In psychological research it has been shown that humans are capable of efficient parallel action if the secondary actions are processed automatically [2]. This means that the user's attention should not be divided into several parts. This leads to a need for finding methods to decide which actions in the user interface are primary actions requiring the user's attention and which are secondary actions that can be processed automatically. So using multimodal input is more efficient, if the tasks are related to each other and if parallel input supports co-operative work for different modalities in the task [1, 3]. This leads to situation, where meaningful subtasks left for foot would be non-accurate supporting tasks for the current workflow, such as scrolling, moving or resizing objects.

RESEARCH APPROACH

Appropriateness of feet in the user interface was measured by testing the use of a trackball in tasks with different complexity levels making use of the dominant foot and hand. Results were compared and conclusions made from test results.

Different user interactions can be evaluated by the complexity of the tasks. Here we briefly introduce a new way to evaluate and generalize spatial interaction complexity by describing it with three variables affecting the interaction. Complexity can be determined by these variables which are the *controlled input dimensions (ID) of the task*, *independent feedback dimensions (FD) of the task*, and *cognitive load (CL) of the task*. Noteworthy in these variables is that these dimensions do not mean traditional dimensions in space, but are more like mathematical dimensions. Dimensions are describing independently acting parts of input that have to be controlled independently and feedbacks that are giving separate independent feedbacks that have to be observed separately.

For example, moving a slider with a mouse has one-dimensional control level and one-dimensional feedback level, because only one point of focus has to be observed and one direction of movement is controlled. However, scrolling a window in two directions has two-dimensional control level and two-dimensional feedback level, if the content of the window is not shown while sliding, because feedback is given with two measurements through two sliders that are independent of each other and both of them have to be controlled separately. Cognitive load can be determined with the level of required cognitive processing needed to complete the task, e.g., reading or recognizing the correct icon. Using these variables, spatial tasks can be given a complexity level which describes interaction complexity.

By generalizing user interaction by using generalized variables based on the subparts of interaction elements the results of the test can be generalized to similar kinds of tasks as the tasks executed in the test. In this study different tasks with different complexity levels were tested with a trackball used by the dominant hand and by the dominant foot, and the complexity level of tasks was determined from the results to find out tasks that can be executed as secondary tasks with a foot. Our hypothesis is that if a task is more complex it requires more of the user's attention, thus there is a certain complexity level for a task which forces a task to be a primary task. Primary tasks are much slower and cognitively harder to execute than less complex secondary tasks. This way there can be a limit for task complexity which makes a task hard or impossible to process automatically and thereby hard or impossible to execute with a secondary input method. By measuring execution times, accuracy and user satisfaction for the tasks with different complexity levels, the applicability of the tasks as primary or secondary tasks can be evaluated, as well as the applicability of other tasks with a similar complexity level.

EXPERIMENT

To evaluate the effect of the complexity of the task in performance and user satisfaction, i.e., execution time, accuracy and user experience, different input methods were measured in tasks with four different complexity levels. Execution times were measured with the accuracy of milliseconds, the accuracy of distance in pixels from the perfect accuracy, and the user satisfaction with five questions about the task which had a scale from one to five. The questions measured how the user felt about the accuracy and speed of the task, how easy and pleasing the task was, and would the user carry out this kind of task if it were available as an interaction method.

The tests were executed with nine subjects that were experienced computer users with the average of 10 years of experience with graphical user interfaces. Their average grades of experience from graphical user interfaces were 4.67 and from mouse usage 4.89 with the scale from 1 to 5. The experience grade with the trackball was 2.11 in average with the same scale, so the users were quite novices with the trackball, but not completely unfamiliar with it. All users were right-handed and right-footed.

Test setup

A large trackball was chosen as an input device because it suits for both hands and feet. It is also not too unfamiliar to users so that the test can be assumed to describe natural input situation. For minimizing learning effect tests were randomized so that different tasks were in different order in every test and within subjects and targets for selection were also randomly varied. Also the order of the limbs used in test series was randomized.

All tasks were designed so that the required range of movement was 300 pixels from the starting point and the direction of movement was random. The users were first shown the task they should do and a picture of the target which they had to spot in the task screen and do the task. In every trial, the users started with a mouse click in the briefing screen and ended the task with a mouse click. Every task was repeated three times to balance results from random changes in performance. After last repetition of every task, the users were given questions measuring user experience from the task. The users were asked to execute tests with such an accuracy and speed they would normally do while working. This way the speed-accuracy tradeoff reflects a natural working condition.

Tasks used in the test series were:

1. Selection of the correct folder from eight folders. The difference between the folders was the name of the folder, so cognitive load was to recognize text. The complexity level was ID: 1, FD: 1, CL: reading (level 2).
2. Moving an open folder window to a correct position in the screen. The position to move the folder to was depending on the starting position. The complexity level was ID: 2, FD: 1, CL: recognize the direction to move to (level 0).
3. Scrolling a window so that a correct picture was in the correct position which was marked with markers in the border of the window. The content of the window was not shown while scrolling. The complexity level was ID: 2, FD: 2, CL: picture recognition (level 1).
4. Scrolling a window so that a correct picture was in the correct position which was marked with markers in the border of the window. The content of the window was shown while scrolling. The complexity level was ID: 2, FD: 2-1 (two independent feedbacks with the supporting feedback), CL: picture recognition (level 1).

RESULTS

Average execution times and accuracy values were calculated from all tasks separately. User satisfaction values were summed up and transformed to a percentage value which reflects an average user satisfaction in the task. The results were compared between hands and feet so that differences between limbs could be determined. Calculated values were then evaluated to find out how complex tasks could be done by foot without noteworthy impact to the performance and user satisfaction.

The average results of the tests are shown in Table 1. As can be calculated from these values, feet are in average 1.2 times less accurate, 1.6 times slower and 1.6 times less comfortable for the users than hands. Earlier Hoffman [3] has got the result that feet are 1.7 to 2 times slower than hands, but these results were in accurate tasks. It seems that a user can perform a little faster when the accuracy may be compromised.

	Accuracy (Pixel)		Time (ms)		Satisfaction (%)	
Task	Foot	Hand	Foot	Hand	Foot	Hand
1	8.91	8.45	4184	2746	50	80
2	8.97	5.27	6264	3917	48	76
3	9.92	7.17	10136	6854	44	70
4	8.95	11.83	9037	5506	51	78

Table 1: Averages of results

As can be seen in Figure 1, the users could perform quite evenly accurately independent of task complexity, but execution times increased when the task complexity increased. The accuracy, however, was close to ten pixels, so there was a limit to how accurate tasks users can perform with a foot. Interaction tasks designed to be used with a foot should not require an accuracy of more than ten pixels according to the results got in this study. Supposedly user satisfaction and execute times would be better if tasks required less accuracy than in the tasks used in this test series.

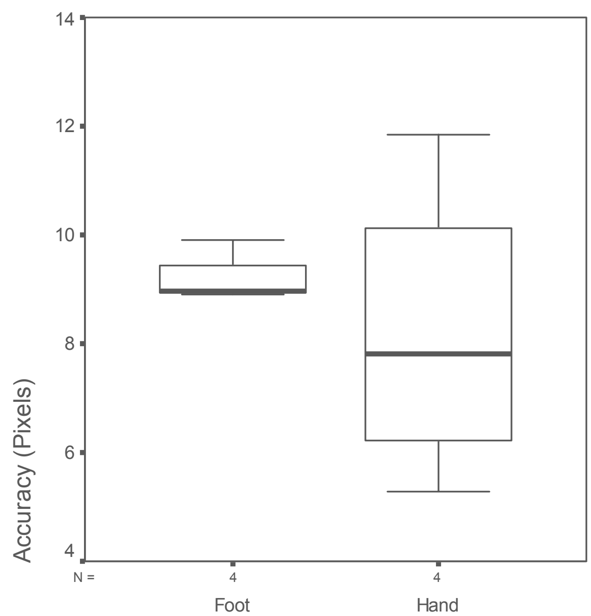

Figure 1: Average execution accuracy of all tasks

In relation to the execution times, the results in Table 1 and Figure 2 show that at the lowest two complexity levels the users could perform approximately as fast with feet as on higher complexity levels with hands. In the higher two complexity levels execution times increased in average 1.8 times higher than in the lower two levels, and thus the feet are only applicable for tasks not requiring fast execution times.

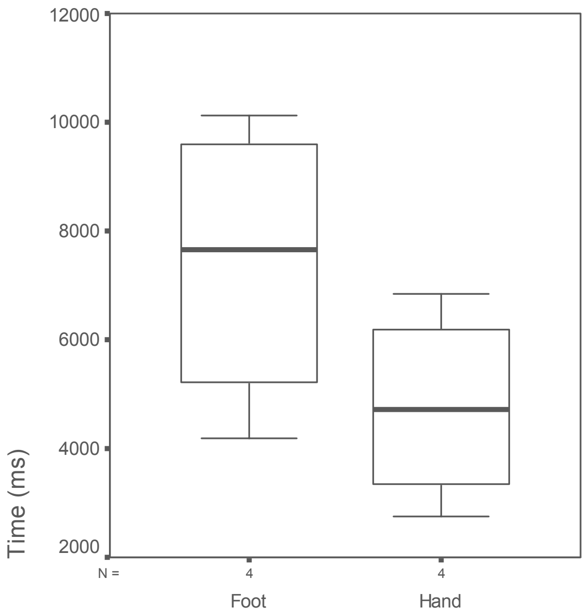

Figure 2: Average execution times of all tasks

User satisfaction was poor in all conditions used here, but still not completely unsatisfactory, as can be seen in Figure 3. The users might get used to using their feet in the user interfaces if tasks were simple and non-accurate enough.

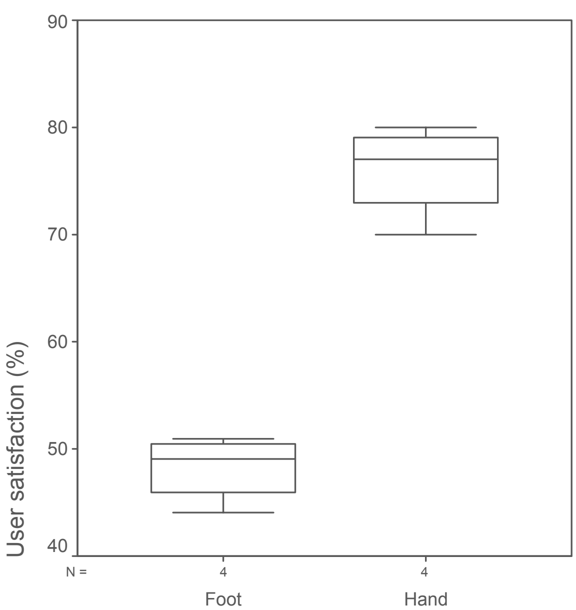

Figure 3: The average user satisfaction of all tasks

CONCLUSION

The users were capable of executing the required tasks with feet maintaining adequate accuracy and execution time. This shows that feet are suitable for the secondary tasks that do not require high accuracy or execution times. User satisfaction for using feet was rather weak but not completely unsatisfactory. These tests were done with users who were not used to using their feet with computers, so user satisfaction might get better during a longer experience of using feet in human-computer interaction. Requirements for accuracy in foot interaction should not be more than ten pixels and tasks should not require speed. Further research would be needed on impact of lowering accuracy requirements and training users for speed. Several specific interaction techniques for different tasks should also be developed and investigated based on these results.

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