A comparative evaluation of mouse, stylus and finger input in shape tracing

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Abstract
A comparison of the aggregated performance measurements for three input methods in a line-tracing task is presented. Results indicate that users perform best using touch input, both in tasks with and without visual feedback, therefore we recommend touch input as the preferred input method for simple drawing tasks.

Keywords
Mouse, stylus, touch, freehand, tracing, comparison.

ACM Classification Keywords
H.5.2 User Interfaces: Evaluation/methodology.

Introduction
Research on input methods and their influence on human input has been focused mainly on the performance aspects. Many input devices have been tested on their effectiveness in pointing, dragging, crossing and path steering navigation tasks and this knowledge is used for different analyses and comparisons [7, 4, 6]. These standard navigational tasks became the subjects of mathematical modeling. Fitts' Law is a proven method that models linear pointing and clicking tasks but it appears to be not as well suited for modeling two dimensional tasks [5]. This has been supplemented by the Steering Law, which is a

more suitable predictive model for investigating two dimensional navigation tasks by considering them as a constrained motion within predefined tunnels of error [1].

The recent popularity of hand held devices equipped with displays capable of sensing multiple ways of human-input created new opportunities for creative users. Any surface-based human input can be broken down to a time-series of 2D coordinates. Therefore we can use the analogy of line tracing to describe the output of the continuous user's action that takes place e.g. on a touch-sensitive surface.

Line tracing can be an example of a task which might be negatively influenced by the low accuracy of the input method used for drawing lines but also by any kind of constraints imposed on the user. However, we have been unable to find a model specifically designed for unconstrained drawing in freehand input with initially unpredictable user error. Therefore, we decided to investigate the shape-based approach to assess the potential of small screens for unconstrained free-hand tracing tasks.

In order to compare the three most commonly used input devices, namely mouse, pen and touch input, in a drawing task, we performed an experiment with 16 participants.

In the experiment, the participants had to complete a tracing task of tracing a simple, random shape with all three input methods. The purpose of this experiment is to find out if there is a clear difference in performance when performing the tracing task between the three input-devices that are being investigated.

Method

In our study, users were asked to trace over, in one stroke, a greyed-out shape that was displayed on the screen using one of the three input methods in question in a randomized order. Additionally, we controlled the visual feedback of tracing that imitated drawing with black or invisible ink. We have also measured the accuracy and time it took the participants to perform the task.

The shape that was given to the participants was designed with use of a modified version of Method 4 described by Attneave [2]. We created asymmetrical non-sense contour shapes that did not bear any resemblance to well-known shapes. The modification of Attneave's method was limited to making the shapes consisting of at least two of each kind of perceptually meaningful properties like: convex corners, concave corners, straight line segments, and curve line segments. These segments of the shape did not cross at any point and their parameters like length or angle were randomized.

There are multiple factors that can describe the differences between two shapes: general shape, translation, rotation, and scale [3]. In order to calculate the user's accuracy of each trial of the tracing task, we decided to calculate the error score based only on the pixel-wise difference in general shape between the shape given and the shape that each participant produced.

We extracted multiple pixel-based values from each generated shape and used the following equation to calculate error scores for each task:

$$error = \sqrt{\left(\frac{CP}{DP} - 1\right)^2 + \left(\frac{DP}{TP} - 1\right)^2} \qquad (1)$$

Where:

- CP is the number of common pixels between the participant-generated shape and the original shape
- DP is the total number of the participant-generated pixels
- TP is the total number of pixels of the original shape.

The error value is represented by the length of line from points A to B as seen on the plot below:

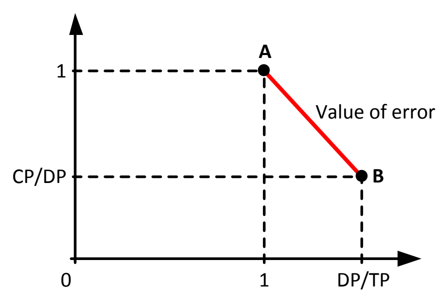

figure 1: Error measurement plot

Point A (1,1) is a perfect score with zero error where CP=DP=TP. Point B represents a user's score.

While performing such a tracing task it is theoretically possible to achieve maximum accuracy. This would mean that a user has traced over a shape perfectly and created the same amount of pixels in the exact same position as the original shape that was presented.

Experiment design

The experiment has a mixed design. The input methods have a within subjects design and were assigned in a randomized order for counterbalancing. The visual feedback has a between subjects design. 8 randomly selected participants performed the task with visual feedback and 8 without it. An HP Touchsmart TM2 Tablet PC with a 12.1 inch screen and a resolution of 1280*800, with stylus and finger input, as well as a Logitech basic optical mouse were used. The HP TM2 was used in tablet mode with the stylus and finger input, parallel to the desk, and in laptop mode with the mouse. Morae version 3 was used in order to acquire time data from the trials. Participants had to fill in a pre-test questionnaire and were offered a minute long introductory session for the stylus and touch input in MS Paint. Then, they were presented with the shape and instructed to "trace over the shape in one stroke, starting from the top right corner". Afterwards they were asked to fill in a post-test questionnaire regarding their preferences and opinions for the input devices that were tested. The following figures display the shape that was presented to the participants along with a high scoring and a low scoring participant attempt.

Results

First the shape error data were analyzed for deviations from normality by means of the Kolgomorov-Smirnov test. A liberal decision criterion of 0.1 was used in order not to use parametric test unduly. However, none of these tests showed any such deviations and the further analyses were performed using ANOVA using a decision criterion of 0.05. The ANOVA for shape error revealed neither significant differences between the input methods ($F(2,28)=0.876$, $p=0.427$), the visualization of feedback conditions ($F(1,14)=0.26$, $p= 0.61$), nor any interaction between these factors ($F(2,28)=0.317$, $p=0.731$). The grand mean error value was 0.741.

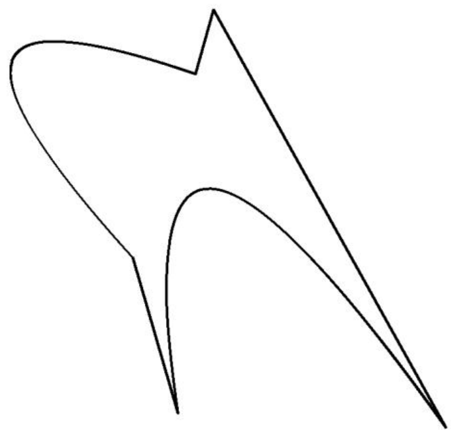

figure 2: Original shape

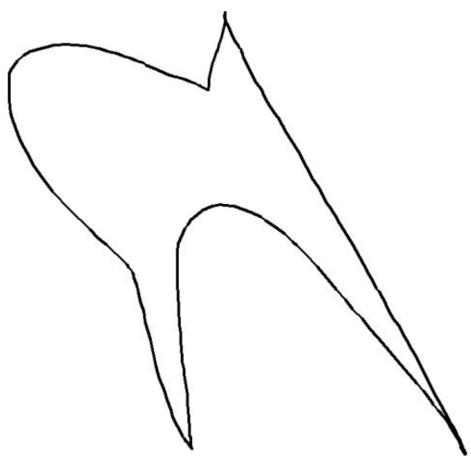

figure 3: High scoring user generated shape

figure 4: Low scoring user generated shape

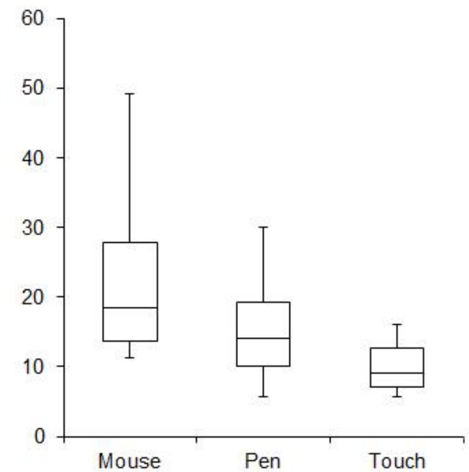

Figure 5: Box Plot of Times Measured

Then we turned to the timing data. The ANOVA was performed on the logarithm of the time in seconds because reaction type data are known to be non-normally distributed otherwise. There was no effect of visualization of feedback ($F(1,14)=0.0613$, $p=0.808$) nor any interaction between this factor and input method ($F(2,28)=0.275$, $p=0.761$). However, there was a clear difference between the input methods ($F(2,28)=49.535$, $p<0.0000001$). The mean times for each input device were mouse=23.00s, pen=15.10s and touch =9.81s.

Conclusion

Results show that all input methods have comparable error scores for the shape that was used. There are, however, large differences between time scores for each input method. Touch outperforms mouse by a factor of 2.3 and pen by a factor of 1.54.

Discussion

The precise line-tracing task might be representative of multiple tasks related from creative graphics design and free-hand drawing to complex linear selections of multiple graphical elements. Therefore the results of our study show that for at least moderately complex drawing tasks touch input is much more efficient than pen or mouse (what was also confirmed in tasks with no visual feedback) and might be the preferred input method in graphics design applications. This was supported by the qualitative post-test data that indicates that our users preferred touch input with pen input second and mouse input last. More of complex shapes need to be investigated, as it is expected that the results may vary from the one produced for this experiment. Finally posture must be considered as well, when using touch input, especially since there might be additional muscle strain due to the lack of proper support for the user’s arms during the use of touch devices.

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