Anticipation of Mouse Pointer Movement Using Pressure Sensors

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Abstract
We propose a method of anticipation of mouse cursor movement using pressure sensors. Pressure sensors are embedded in mouse pad. Data from sensors are collected in 10-bit A/D value every 10 ms. From the time series of pressure level, the orientation and distance are anticipated at the moment of starting the mouse movement. Moreover, user's intention and posture can be extracted to some extent by sensing pressure amplitude and latency. In this paper, we present the configurations of our system and the results of experiments for evaluation.
Keywords: mouse, pointing task, pressure sensor, cognitive action, anticipation.

1 Introduction

Human-computer interaction using mouse is mainly performed by sensory-motor and cognitive operations of computer user. It includes the motor operations of moving hand on a flat surface, and the perceptual operations of tracking the mouse pointer as a visual feedback. The pointer movement is usually controlled only by user with fixed rate of response predefined by computer system.

The response of the pointer is typically set to be proportional to the mouse movement, or slightly enhanced to be nonlinear with the speed of mouse movement as mentioned in section 2. It is also described in ISO 9241-9 that the resolution of a mouse should be independent of both the position of the device on the work-surface and the position of the pointer on the display. But in real input tasks, the optimal response and resolution depend on the kind of tasks: pointing; selecting; dragging; tracing, drawing. And they also depend on the distance between the pointer and target, task demands or task loads, level of consciousness, and so on.

In our study, we found that user's intention and posture can be extracted to some extent by sensing pressure amplitude between mouse and mouse-pad. Piezo-resistive film sensors are embedded in mouse-pad. Data from these sensors are collected in 10-bit A/D value every 10 ms. From the time series of pressure level through wavelet filter, the orientation and distance are anticipated at the moment of starting the mouse movement. Modulated response and resolution are performed according to user's posture. In this paper, we present the configurations of our system and the results of experiments for evaluation.

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2 Related work

A number of algorithms have been developed to predict the target of the cursor. Murata (1998) proposed a method for predicting the target using the movement vector and trajectory of cursor. Oirschot and Houtsma (2000) also studied the accuracy of prediction based on trajectory, and they pointed out that the parameters of the prediction algorithm would have to vary across devices and users. Lane et al. (2005) proposed a system for predicting the icon that will be selected by user from an icon toolbar. It was based on not only mouse trajectory but also command use frequency.

Many approaches for facilitating target acquisition include modifying target when the cursor is close enough. This is achieved, for example, by magnifying the target (McGuffin 2002), or by adding a "bubble" around the target (Cockburn, 2003). Fisheye views are also the kinds of target modification methods (Furnas, 1986; Bederson, 2000) etc., and automatic zooming method is a different way for magnifying the detail around the target (Igarashi, 2000). In the case of precise graphical manipulations, "snapping" functions are also effective (Bier 1986; Baudisch, 2005; etc.).

Control-display (C-D) ratio adaptation is another approach for improving target acquisition (MacKenzie 1994; Keyson, 1997; Cockburn, 2003; etc.). Blanch et al. (1994) introduced "Semantic Pointing" to analyze the pointing performance with C-D ratio in terms of Fitts'law (Fitts, 1954; Card, 1983; MacKenzie 1994), and they applied the notion of semantic pointing to the motor and visual sizes of traditional GUI widgets independently.

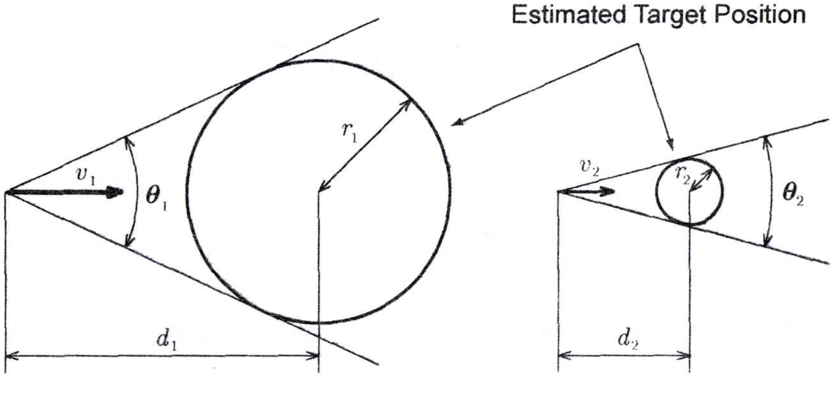
3 Prediction of target using trajectory of cursor

Conventional prediction methods are classified into successive ones and direct ones. In the former methods, for example, the target position is estimated using the velocity of the cursor as shown in Figure 1. The angle, the radius and the distance of the estimated target increase with the velocity. The estimation progresses successively with the cursor movement and it is accomplished when the cursor actually hits the target. Various functions such as snapping, warping, magnetism, or gravity can be applied using this estimation.

In the latter methods, for example, the direction and the peak velocity of cursor are used for the prediction of the target as shown in Figure 2.

Mouse user spontaneously schedules the direction, speed, and trajectory in an instant before starting mouse movement. The mouse movement will be smoothly performed only with expected feedback of every moment. It means the cognitive action is already completed in advance of the physical action, therefore, extracting the cognitive action through supplementary communication channel may enable the operating system to afford adequate feedback to the succeeding physical action.

Supplementary communication channels in daily conversation include, for example, situation, surroundings, context, facial expression, posture, clothes, appearance, and so on. Using these nonverbal channels, we can anticipate the partner's next dialogue and presume the partner's present intention. The pressure level between mouse and mouse-pad can be one of supplementary communication channels in pointing tasks.



if $v_1 > v_2$ **then** $\theta_1 > \theta_2,\ d_1 > d_2,\ r_1 > r_2$

Figure 1: Conventional estimation of the target position in successive method.

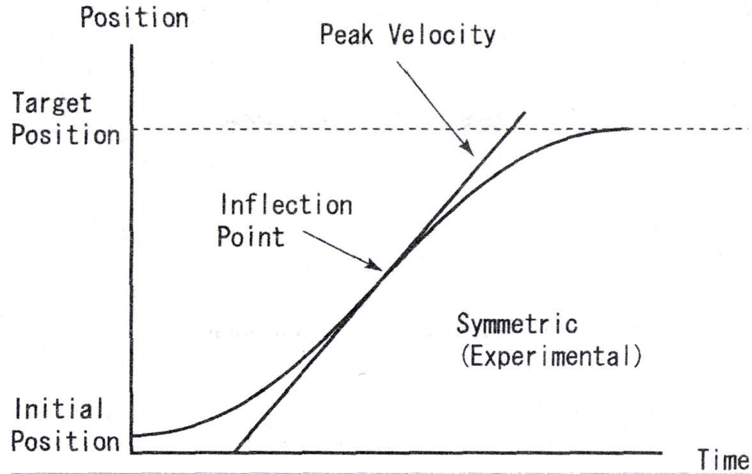


Figure 2: Conventional prediction of target position using peak velocity.

4 System configuration

Figure 3 shows the dimension of mouse pad and four sensors. Piezo-resistive film sensors (Flexiforce by Tekscan, 4.4N-max) are placed on each corner of mouse pad. The sensing elements are embedded between acrylate panel and silicon rubber as shown in Figures 4-5. Measured data are transferred to PC every 10 ms through 10 bit A/D converter, micro-controller, and USB controller (Figure 6).

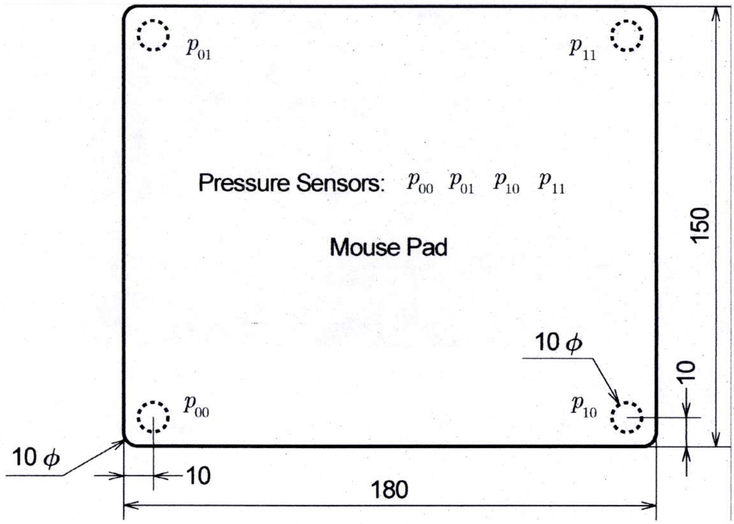


Figure 3: Dimension of mouse pad and sensors.

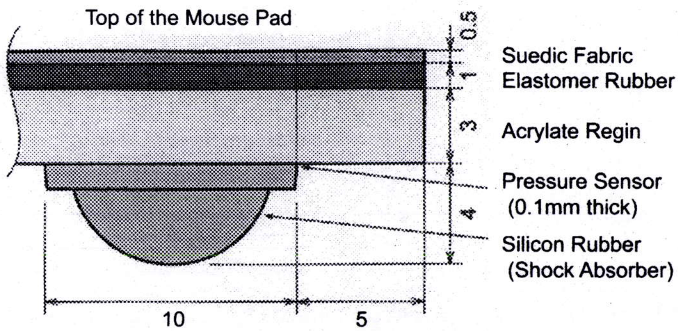


Figure 4: Dimension of sensing element.

After applying successive wavelet filter, the pressure level is calculated as approximation by quadratic polynomial:

$$p = \sum_{i,j=0,1} (p_{ij} + \varepsilon_{ij} p_{ij}^2) \qquad \text{unit: [pl]},$$

where, ε_{ij} are set empirically by calibration.

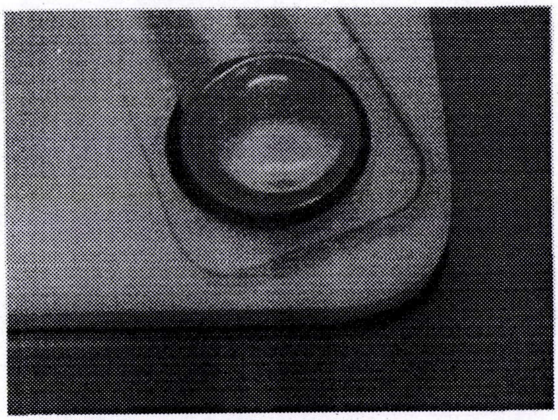


Figure 5: Photograph of sensing element.

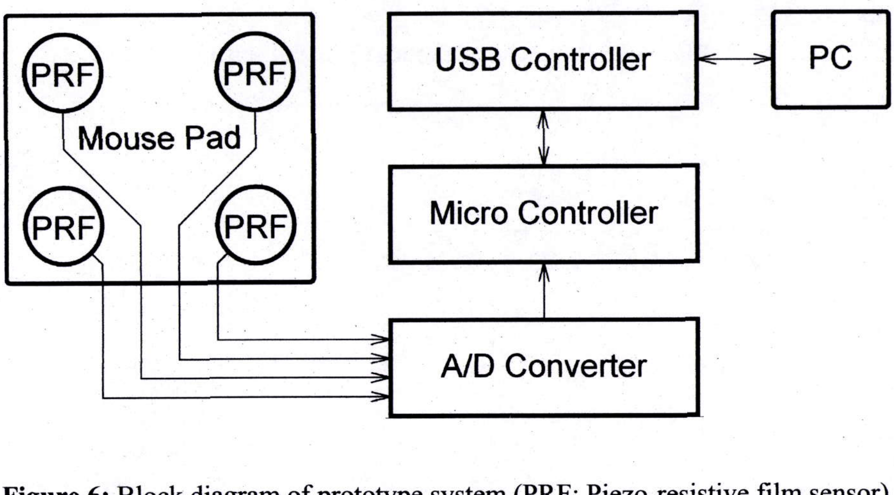


Figure 6: Block diagram of prototype system (PRF: Piezo-resistive film sensor).

5 Measurement examples

Figure 7 shows the measurement example of pressure level when a mouse is placed on a mouse pad and when user's hand is put on the mouse. Horizontal axis stands for the time elapsed in ms, and vertical axis stands for pressure level in pl. Obviously the condition of mouse pad is reflected in the data of pressure level.

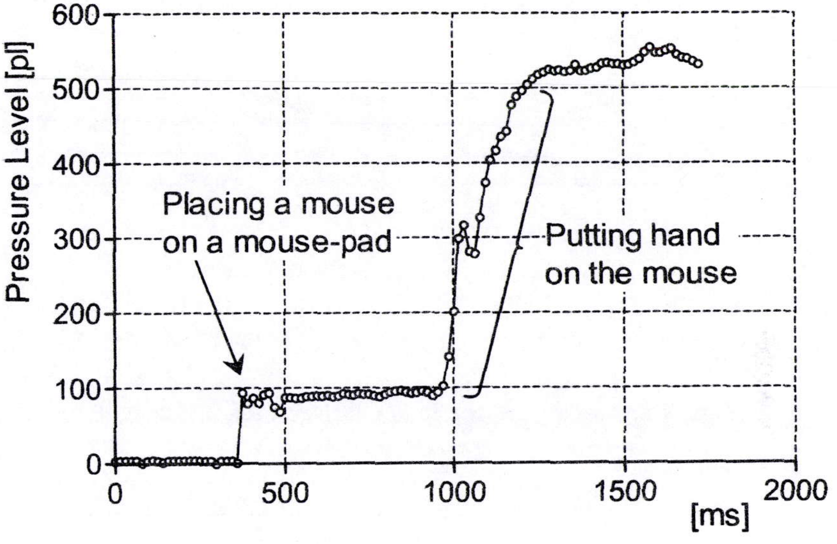


Figure 7: Calculation of pressure level

Figures 8 – 11 are the results of pressure level measurement in various conditions:

- Moving an icon to the trash box (Figure 8),
- Ranging by rubber band (Figure 9),
- Accessing an icon (Figure 10),
- Moving outside a window (figure 11).

In Figure 8, the pressure level remains high during moving cursor. It represents that the movement is careful dragging. In Figure 9, the pressure level is smoothly decreases and restored. It indicates that the movement is slightly rough but steady because the operation is dragging. In Figures 10 and 11, pressure level apparently decreases during cursor is moving, and especially, the transition is rapid in the latter case. Moreover, in Figure 11, pressure level starts to decrease about 300 ms before the beginning of cursor movement. It suggests that the latency of pressure level increases with the cursor speed and movement distance, therefore, the cursor speed and movement distance can be anticipated in advance of cursor movement.

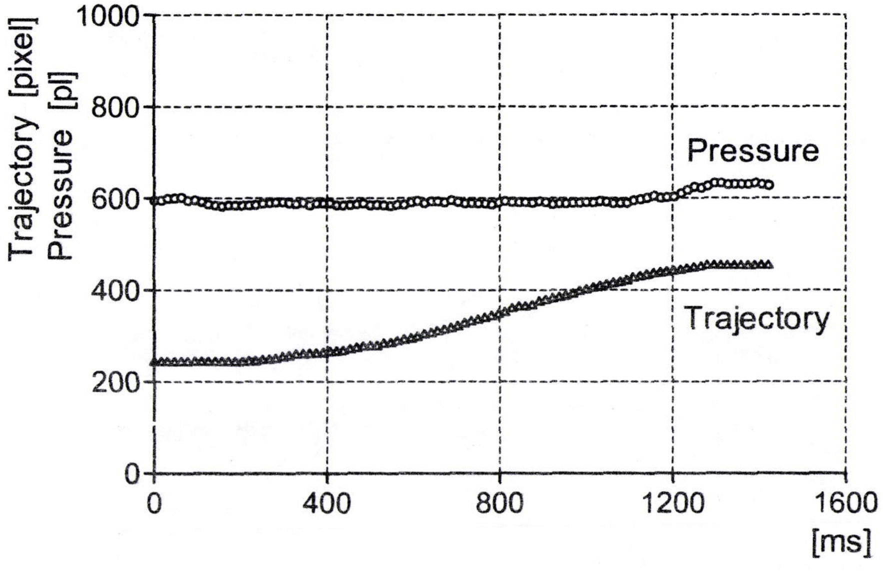


Figure 8: Moving an icon to the trash box (careful dragging).

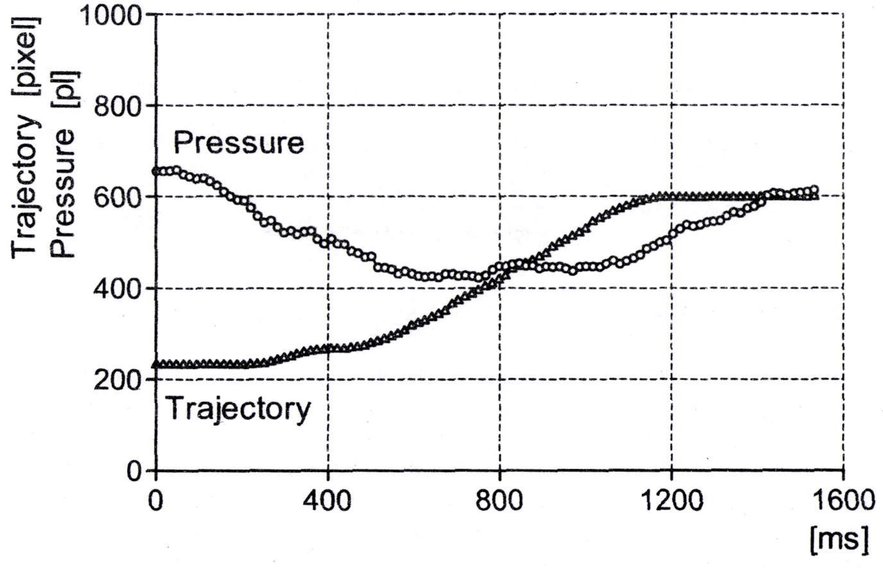


Figure 9: Ranging by rubber band (rough dragging).

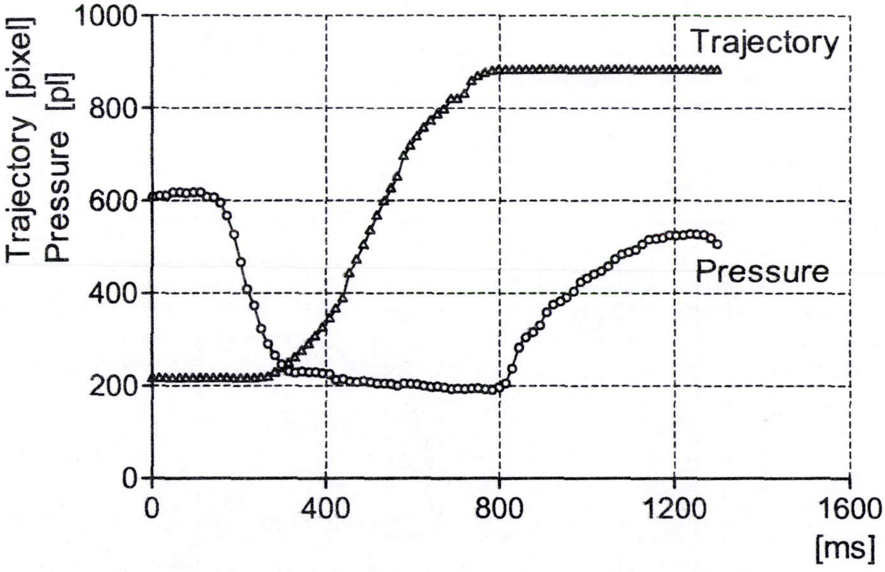


Figure 10: Accessing an icon (moving and pointing).

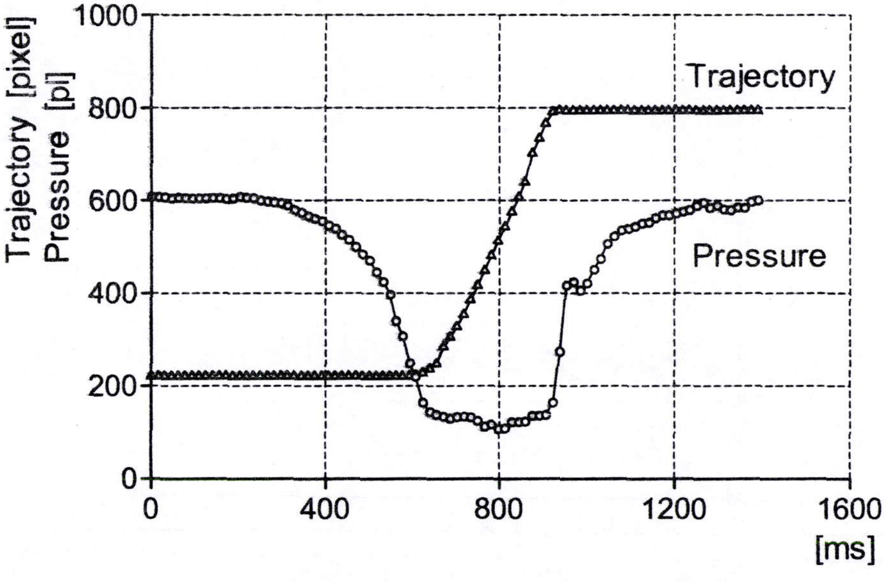


Figure 11: Moving outside a window (rough moving).

6 Experiment

We examined the correlation between the distance (D) of cursor movement and two parameters: latency (τ) / pressure level (ϕ). The meanings of the two parameters are indicated in Figure 12.

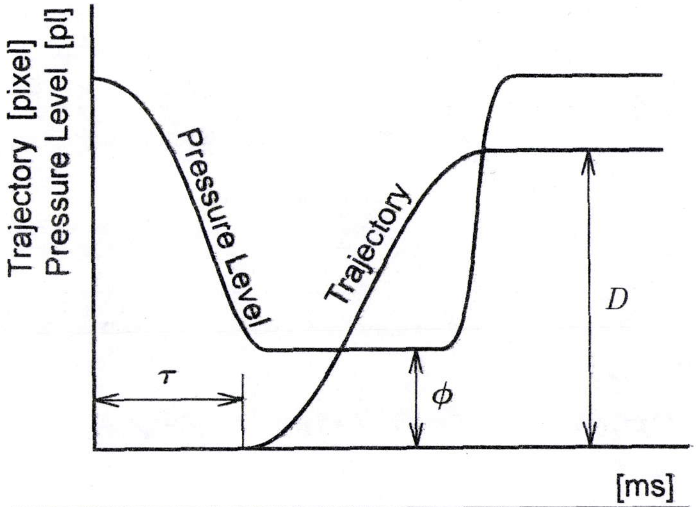


Figure 12: Measured parameters: D, τ, and ϕ

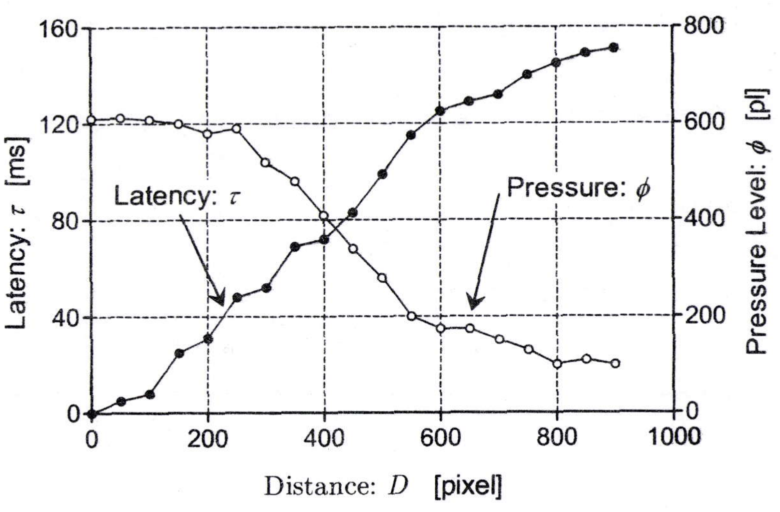


Figure 13: Correlation between the distance (D) and the latency (τ)/pressure level (ϕ)

Latency and pressure level as functions of distance are plotted in Figure 13. Each value is the average of 100 trials of pseudo-random repetitive tasks for one subject. It is obviously observed that latency increases with distance, and pressure level decreases with distance. The result suggests that both parameters are available for anticipation of movement distance and target to acquire.

We also examined the pressure level during various conditions assuming ordinary tasks with graphical user interface:

- Free pointer moving,
- Web browsing,
- Operating a pull-down menu,
- Technical drawing.

Pressure level is measured for 1 minute with sampling rate 100 Hz. Figure 14 shows the result by the histogram of percentage for each condition. Similarly, the proportion of pressure level is depicted in Figure 15. The result suggests that measurement of pressure level is applicable to detecting user's intention and following user's context.

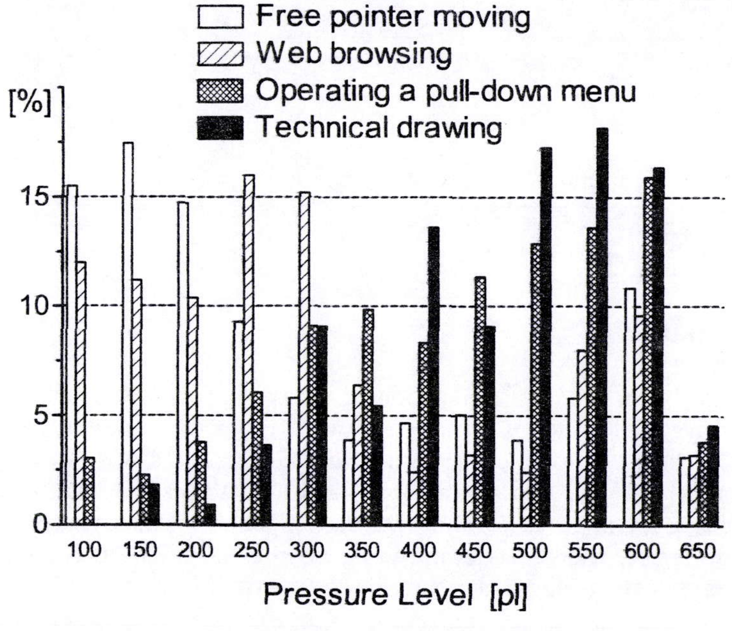


Figure 14: Results of measurement during various tasks.

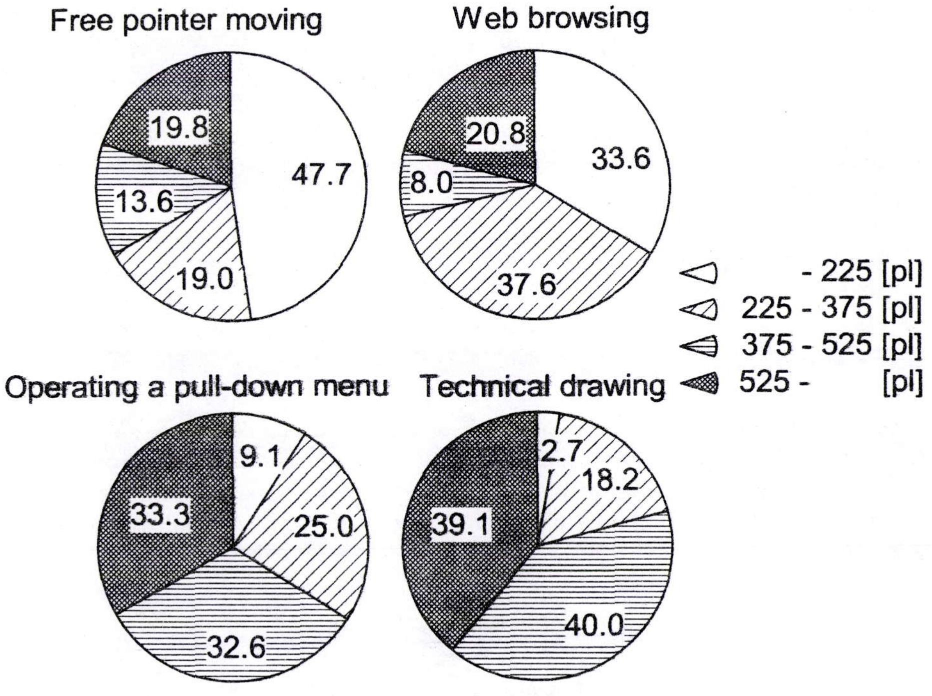


Figure 15: Proportion of pressure level during various ordinary tasks.

7 Conclusion

We proposed a method of anticipation of mouse cursor movement using pressure sensors, and we constructed a prototype system. From the experimental results, we found that the distance of cursor movement can be anticipated with pressure level and duration time of latency. The results also suggest that pressure level is effective to detecting user's intention and following user's context. Further considerations of individual differences and variety of operating environment are needed. Development of user assistance system using pressure level is underway.

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