PreSenseII: Bi-directional Touch and Pressure Sensing Interactions with Tactile Feedback

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Abstract
This paper introduces a new input device called "*PreSenseII*" that recognizes position, touch and pressure of a user's finger. This input device acts as a normal touchpad, but also senses pressure for additional control. Tactile feedback is provided to indicate the state of the user interface to the user. By sensing the finger contact area, pressure can be treated in two ways. This combination enables various user interactions, including multiple hardware button emulation, map scrolling with continuous scale change, and list scrolling with pressure-based speed control.

Keywords
Input devices, interaction techniques, pressure sensing, tactile feedback

ACM Classification Keywords
H.5.2 User Interfaces -Input devices and strategies, H.5.2 User Interfaces - Haptic I/O, and I.3.6 Methodology and Techniques - Interaction techniques.

Introduction: Pressure-sensing interactions
Pressure sensing has been used for some areas of human-computer interactions. For example, electronic

musical instruments, such as music keyboards, often support pressure-sensing keys to control pitch and other tone parameters. The WACOM tablet stylus senses pressure and pen stroke attributes (thickness, etc.) can be controlled by pressure. It should also be possible to use pressure values in more general domains of human-computer interactions, such as navigation, text input, menu selection, list scrolling etc.

Pressure can be used to control continuous parameters, such as scroll speed, pen-drawing line thickness, music tones, as well as discrete parameters, such as menu selection and (multi-level) button press. Pressure-sensing input devices can add richer interaction without significantly changing a devices' form factor. This is especially beneficial for mobile devices where the physical size of a device is strictly limited.

However, we consider current pressure sensing UIs to be lacking two important features.

Lack of effective feedback:
Users of pressure-sensing interfaces need some type of feedback to know the current pressure value. Except for musical instrument examples, current pressure-sensing user interfaces mainly use on-screen visual feedback, such as a pressure gauge indication on a screen. However, this feedback also consumes screen area. A beep sound for press confirmation can provide confirmation feedback for pressure, but generating sound is not always acceptable.

Lack of bi-directional control:
Most continuous parameter controls are bi-directional. Zooming, for example, has two directions (zoom-in and zoom-out). Other examples include scrolling and volume control. Since pressure is a one-way continuous parameter (from zero to positive), a bi-directional mapping is not trivial. Mode change is the simplest solution but it requires additional mode selection commands and may also cause user's mode-error.

In this paper, we present a new input device, "PreSenseII", which is the successor of our previous PreSense touch-sensing input device [1]. PreSenseII is a combination of a capacitive sensing touch pad for finger-position and finger-contact recognition, and pressure sensors for pressure recognition (Figure 1).

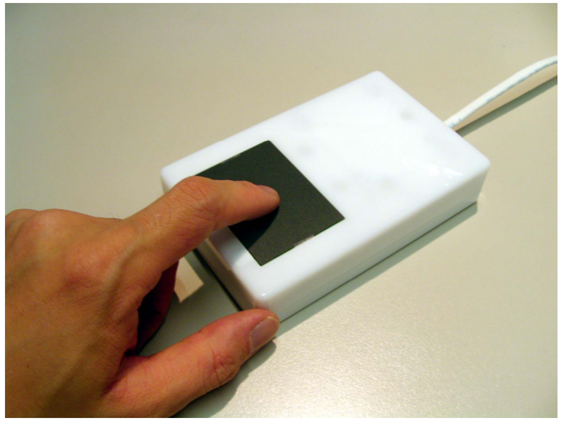


figure 1. PreSenseII pressure sensing input device.

PreSenseII proposes solutions to the above problems. We combine tactile feedback with pressure input for the first problem. For the second problem, we propose an interaction style to treat pressure values in two ways ("positive" and "negative" pressure) by measuring finger pose on a touchpad.

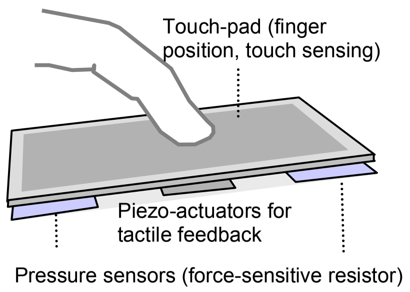


Figure 2. PreSenseII sensor configuration

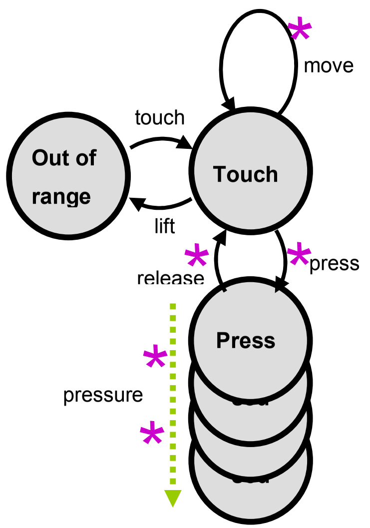


figure 3. State transition of PreSenseII. Asterisc(*) denotes possible positions to cause tactile feedbacks.

PreSenseII

Figure 2 shows the sensor/actuator configuration of PreSenseII. It consists of a capacitive sensing touchpad, pressure sensors, and piezo-ceramic actuator for generating tactile feedback

The pressure sensor is based on resistor sensitive polymer film; it changes its resistance value according to the applied pressure. We use four pressure sensors installed at four corners on the backside of the touchpad. To measure pressure accurately, we also placed a rubber damper between the pressure sensors and the touchpad. Sensed values from the four pressure sensors differ according to the finger position (i.e., a sensor which is close to the finger position reports a bigger pressure value than others). Although it should be possible to estimate finger position by these values, currently we simply use the maximum of the four pressure values to represent the pressure applied to the touchpad.

The *TouchEngine* tactile feedback actuator [2] is also placed under the touchpad. This actuator consists of multi-layer piezo-ceramics and creates vibration according to added voltage. It can generate various types of 'click' sensations by changing vibration patterns.

Figure 3 shows the state transition diagram of PreSenseII. Similar to the previous PreSense, this input device distinguishes the "touch" state from the "pressed" state. This "touch" state is mainly used to show information (typically preview information) before commands are invoked. For example, when a user touches the surface of PreSenseII, menu items appears on a screen, and information about menu item also pops up according to the user's finger position. With this information, users can prospect the result of a command (before activating it).

Unlike PreSense, PreSenseII dose not have mechanical buttons. Instead, it can emulate keypad-type buttons by combining pressure sensing and tactile feedback.

Tactile Feedbacks

Since humans cannot accurately distinguish absolute pressure values, feedback is necessary for most pressure-sensing interfaces. In some cases, feedback is naturally integrated in applications, such as tone change with pressure-sensitive keys of electric musical instruments, but explicit feedback is required for many other applications. PreSenseII's tactile feedback is one such feedback technique. This feedback is used for two purposes.

One is "*state-transition feedback*": This feedback is generated when the pressure value crosses a predefined threshold. The simplest example is button emulation: a tactile 'click' is generated when the pressure level exceeds from "not-pressed" level to "pressed" level. Furthermore, multi-level buttons are also possible. In this case, pressure values are distinguished into three levels ("not-pressed", "light-pressed", and "hard-pressed"). Tactile feedback is generated at the boundaries of these levels (Figure 4). Our informal evaluation reveals that a two-level button is realistic with tactile feedback, but almost impossible to operate without feedback.

The other purpose is "*in-state feedback*": When a user operation is in one mode (e.g., scrolling), tactile feedback can be used to tell status within that mode.

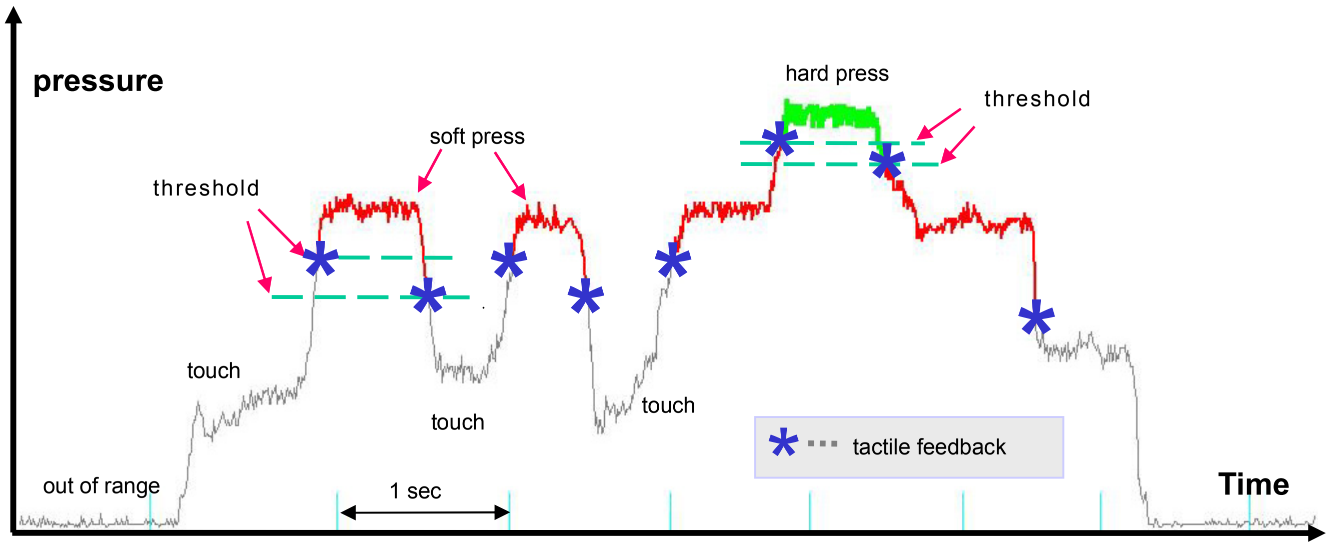


figure 4. Muti-level button operation and corresponding pressure value traces. Note that two threshold values are used to separate states to avoid "chattering" around the boundary of states.

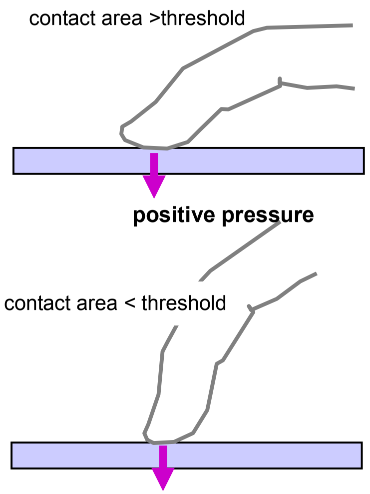
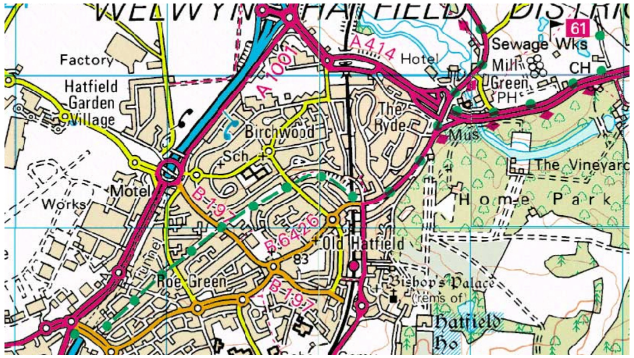


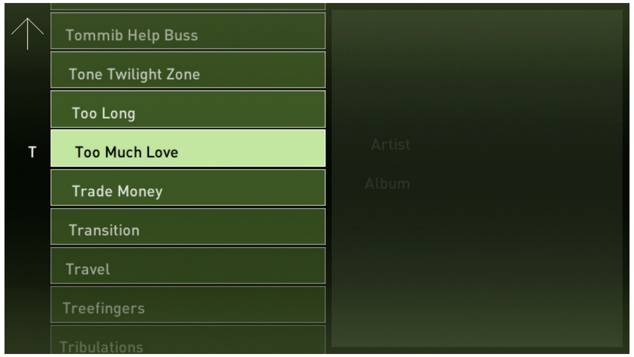
Figure 5. Bi-directional pressure recognition based on finger poses.

For example, when a user is scrolling a list and its scroll speed is controlled by pressure; tactile feedback interval is used to indicate the scroll speed. Without looking at the screen, a user can recognize how fast the item list is scrolling.

Bi-Directional Pressure Control

PreSenseII treats pressure values in two ways, *negative* and *positive*. A zooming interface, for example, requires control of scale parameter in two directions (zoom-in and zoom-out). PreSenseII distinguishes these two modes by measuring finger-contact area based on capacitive sensing. Since PreSenseII is a combination of pressure sensor and capacitive touchpad, it is possible to measure finger contact area as capacitance change [3]. Figure 5 shows finger poses and recognized operation modes. When a finger is placed with the finger cushion touching the touchpad surface, finger pressure is treated as positive value (e.g., zoom-in). On the other hand, when a pointed fingertip touches the surface, the pressure is treated as negative (e.g., zoom-out) value. Users can quickly change these two modes by slightly changing finger pose on a touchpad. This feature is quite effective for operations that require bi-directional zooming with 2D scrolling (e.g., 3D navigation, map browsing).





Example Applications

The screenshots on the left show our experimental applications using PreSenseII. On the top left is a map navigation example. Sliding a finger on a touchpad without adding pressure controls 2D Map scrolling. Zooming (in and out) can be controlled by bi-directional finger pressure. Users of this system do not have to use a mode change command for switching between zoom-in and zoom-out.

A similar technique can also be used to scroll a long item list, such as music titles (left bottom). In this case, users control scrolling by pressing predefined areas of the touchpad. Unlike the jog-wheel of Apple's iPod, this area can be very small, freeing the remaining touchpad area for other purposes. Users are not forced to keep making circular finger motions to scroll through a long item list. Instead, users simply press the scroll area, using a bi-directional technique. Pressure value can be used to control scroll speed and tactile-feedback indicates to the user how fast the list is scrolling.

Related Work

Ramos et al. proposed "Pressure Widgets" [4], which are a set of interaction techniques based on a pressure sensitive pen tablet. For their interaction techniques, a tight binding of pressure and visual feedback is critical. In contrast, in our system the combination of tactile and visual feedback is not always necessary. We consider this difference to be significant when pressure input techniques are applied to mobile devices.

Gummi is a prototype system for "bendable" interactions [5]. Assuming that future computers can consist of flexible circuits and displays, this system uses a degree of "bend" as an input parameter. A notable advantage of "bend" is that it can naturally represent positive and negative values by bending the device to opposite directions. On the other hand, bending typically requires two hands for operation.

A capacitive-based touchpad itself has the capability of sensing finger contact area as analog values. This capacity value can also be regarded as a *pseudo* pressure. Blasko and Feiner proposed a pressure sensitive input device based on this feature [6]. However, based on our experience, regarding capacitive sensing values as pressure is not as reliable as using pressure sensors explicitly. In addition to pressure, capacitance value is also affected by other parameters such as the use of finger (index or thumb), orientation of finger contact.

Our previous PreSense input device is a multi-level input device that distinguishes touch and pressed states [1]. Layered touch panel [7] is a touch-panel that is enhanced by an infrared-grid sensor to distinguish finger proximity and actual touch. It can be regarded as a multi-layer input device. Zeleznik et al. proposed "Pop Through" mouse buttons [8], which are mechanical two-level buttons for the mouse. With this device people can distinguish soft press (*click*) and hard press (*pop*). They also propose various interaction techniques such as a pop-through menu (i.e., "click" to open a first-level menu and "pop" to expand it to include more commands). "Glimpse" is another attempt to introduce multi-level input to support undoable operations [9]. The pressure sensing technique described in this paper can also be used as multi-level buttons and it is easy to implement pop-through interactions. In addition, our approach does not use mechanical buttons, and thus it can be used as analog-pressure control or multi-level buttons, according to the user interface states.

Conclusion

This paper presents PreSenseII, a pressure and touch sensing input device featuring bi-directional pressure control and tactile feedback. Unlike previous pressure sensing interfaces, users can rapidly change pressure modes in two ways by slightly changing their finger pose. Tactile feedback also enables control of pressure without using visual or sound feedback. This feature is useful when screen space is limited or not available, as in the cases of mobile devices.

The prototype PreSenseII is a combination of capacitive-sensing touchpad, pressure sensors, and piezo-actuator. We are also interested in applying this idea to a normal mouse with pressure and touch sensing buttons, and to a one-dimensional "strip" like input device, using pressure sensors that can be attached to the side area of mobile devices.

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