

additional factors of the touch may also be utilized to process a touch, such as the time duration of the touch and the location of the touch.

[0057] A method of determining whether to provide tactile feedback in response to a touch is illustrated in FIG. 8. The method may be carried out by software executed, for example, by the processor 22 and/or the controller 35. Coding of software for carrying out such a method is within the scope of a person of ordinary skill in the art given the present description. Fewer or additional processes may be performed than those shown and described with respect to the flowchart. When a touch is detected 802, the force of the touch is determined 804.

[0058] When the force of the touch exceeds a threshold value 806, tactile feedback is provided 808. This determination may be performed in numerous ways, for example, by correlating the resistance changes in the force sensor 140, e.g., the sensed force, to force values and comparing the correlated value to a threshold force value. Forces in the range of 1 to 5 N, for example, may be utilized as such a threshold force value. When the force of the touch exceeds the force threshold 806, one or more actuators 37 may be actuated by sending a feedback signal to the actuators 37 to provide tactile feedback 808, such as described above. In addition to providing tactile feedback, when the force of the touch exceeds a force threshold 806, a function may be performed 808 that is associated with the location of the touch. A touch that imparts a force that exceeds the threshold 806 may be referred to as a “click” event. Optionally, tactile feedback may not be provided when the location of the touch does not correspond to a virtual button or other selectable feature, even though the force threshold is exceeded.

[0059] The actuators 37 may be any type of motion inducing device, such as a piezoelectric device or hydraulic actuator operably coupled to the touch-sensitive display 33. Multiple actuators 37 may be utilized, which may be, for example, discrete, acoustic, and/or impulse components, piezoelectric sound emitter, buzzer, diaphragm type components, audible emitter, disc-shaped piezoelectric diaphragms of internal or external drive types, such as the 7BB series of components commercially available from Murata Manufacturing Co., Ltd. of Kyoto, Japan. The actuators 37 may be coupled to the touch-sensitive display 33, for example, by direct or indirect coupling. The amplitude and duration of the feedback provided by the actuators 37 may vary, for example, according to the force or the function assigned to a virtual button or other selectable feature associated with the location where the touch is detected.

[0060] When the touch does not exceed a force threshold at 806, a subsequent determination is made 810 whether to perform another function, without providing tactile feedback, such as highlighted as displayed feature such as a virtual button associated with the location of the touch. Tactile feedback or other feedback, such as visual or audible, may optionally be provided, and may be different than the feedback provided at 808. A comparison of the determined force to one or more threshold values may be utilized at 810. By way of example, a force that is less than that a force corresponding to a “click” event for which tactile feedback is provided, but which force meets a lesser threshold force value, may indicate a touch corresponding to a different type of touch function or response, such as a scroll, highlight, text select, drag and drop, pop-up menu, and so forth, which function is performed 812. The location of the touch on the touch-sensitive display

33 may be taken into account in the determination 810 of whether and which function is performed. A force below the force threshold may result in the provision of a visual indicator, for example, associated with a location of the force, such as highlighted of a feature associated with the touch location.

[0061] Optionally, a temporal aspect of the touch may be utilized to determine whether to provide a response. The signal from the force sensor 140 may be monitored for continuity to determine the length of time that a single touch is applied to the touch-sensitive display 33. This time period may be processed in combination with the threshold force values. For example, when a touch is received that meets the threshold force value, but is of duration longer than a predetermined length of time, tactile feedback may not be provided and no function may be performed. This long touch may be result in an optional function corresponding to the force and/or location of the touch on the touch-sensitive display 33. Similarly, optional functions may be performed for shorter durations of touches.

[0062] In another example, two rows of four virtual buttons 130 and 132 may be displayed, such shown in FIG. 2. The lower row of virtual buttons 130 is displayed on the touch-sensitive display 33 at areas corresponding to the four discrete areas 116 of the touch sensor layer 88, as described above. A touch detected at any of the virtual buttons 130 causes a signal to be sent through the associated area 116. When the touch exceeds a force threshold, the actuator(s) 37 may provide tactile feedback, as described above. A location of the touch may be associated with any of the virtual buttons 132 to determine whether an associated function may be performed. When the force of the touch at any of these virtual buttons 132 exceeds a threshold value, e.g., a “click” event, tactile feedback may be provided. For example, when a touch location correspond to a “Contacts” virtual button, the processor 22 determines that such a command is selected based on the x and y components of the location received from the electronic controller 35 and performs the associated function, for example, by opening the Contacts application and providing tactile feedback due to detection of a “click” event.

[0063] While the embodiments described herein illustrate particular implementations of the portable electronic device, other modifications and variations to these embodiments are within the scope of the present disclosure. For example, the size and shape of many of the features, including the patterns of the touch sensors and the force sensors, may vary while still providing the same functions. The touch sensors are not limited to rectangular shapes as shown in the drawings, and may be any suitable shape such as triangles, diamonds, and so forth. With triangularly shaped pads, the location of a touch along the taper may be determined as the resulting capacitance differs based on the width of the respective one of the pads at the touch location, such that only a single capacitive touch sensor layer and dielectric layer may be needed. The touch sensors and force sensors may be located within other layers than described herein, and may be disposed in separate layers. Resistive, optical, or other technology touch-sensitive displays may be utilized to provide alternatives to identify the location of a touch. Many other modifications and variations may occur to those skilled in the art. All such modifications and variations are believed to be within the scope of the present application.

[0064] The present disclosure may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be consid-