

[0064] FIG. 8A shows an exemplary system that incorporates a sensory feedback array 820 for implementing the reconfigurable keyboard 110 shown in FIG. 1. In the context of the present disclosure, a sensory feedback array generally comprises a collection of sensory feedback elements providing various touch-related and vision-related indicators associated with the emulated hard keys of a reconfigurable keyboard. A first group of such sensory feedback elements collectively provides one keypad surface area equivalent to one emulated hard key. Several such groups of adjacent sensory feedback elements are used to emulate multiple hard keys.

[0065] In a first exemplary embodiment, each of the sensory feedback elements includes a vibrator such as a piezo-electric crystal or a nano-device. Keyboard emulator controller 115 provides an electrical stimulus to the first group of sensory feedback elements corresponding to the emulated hard key. The electrical stimulus causes the sensory feedback elements to vibrate with a first vibration characteristic, for example, a low frequency vibration. This vibration can be felt through the user's fingertips when the user places his or her finger against these vibrating sensory feedback elements, thereby indicating the presence of an emulated hard key. On the other hand, the sensory feedback elements of the inactive surface of the keyboard do not provide such a vibration.

[0066] Three sensory feedback elements 805, 810, and 815 are shown in FIG. 8A, with sensory feedback element 810 configured to provide sensory feedback associated with an emulated hard key. In this example, sensory feedback elements 805 and 815 are not configured to provide sensory feedback because they are not associated with an emulated hard key. Therefore, when the user places his or her finger against these two sensory feedback elements no sensory feedback is provided. On the other hand, when the user places his or her finger upon sensory feedback element 810, which is a part of the first group of sensory feedback elements corresponding to the emulated hard key, sensory feedback is provided via the first vibration.

[0067] A pressure sensor (not shown) is located under or above sensory feedback element 810. When the user applies finger pressure to operate the emulated hard key, the pressure sensor is used to detect finger pressure greater than a preset threshold. When the finger pressure is greater than the preset threshold, the pressure sensor communicates this information to keyboard emulator controller 115. Keyboard emulator controller 115 then provides a second electrical stimulus to the group of sensory feedback elements, including sensory feedback element 810. The second electrical stimulus causes the sensory feedback elements to vibrate with a second vibration characteristic, for example, a high frequency vibration. This vibration can be felt through the user's fingertips and is indicative of key operation. The second vibration additionally provides tactile feedback to the user because the second vibration is generated only when finger pressure corresponding to key operation is applied upon the emulated hard key.

[0068] In a second exemplary embodiment, each of the sensory feedback elements 805, 810, and 815 comprises an electrode that provides an electric charge under control of the keyboard emulator controller 115. In the example shown in FIG. 8A, sensory feedback element 810 provides such a

charge. Consequently, when the user places his or her finger against sensory feedback element 810, the electric charge provides an electrical stimulus that is felt as a mild electric shock by the user, thereby indicating the presence of an emulated hard key. Here again, a pressure sensor is used to detect a finger pressure greater than a preset threshold. When the finger pressure is greater than the preset threshold, which is indicative of a key operation, keyboard emulator controller 115 provides a stimulus to the sensory feedback elements for generating a second sensory feedback such as a vibration, a temperature change, a change in visual appearance, change in size etc. The second sensory feedback additionally provides tactile feedback to the user because the second sensory feedback is generated only when the user operates the emulated hard key.

[0069] In a third exemplary embodiment, the temperature of each of the sensory feedback elements 805, 810, and 815 is controlled by keyboard emulator controller 115. In the example shown in FIG. 8A, sensory feedback element 810 is configured to provide first sensory feedback in the form of a first temperature. Consequently, when the user places his or her finger against sensory feedback element 810, heat is transferred between sensory feedback element 810 and the user's finger thereby indicating the presence of the emulated hard key.

[0070] Furthermore, in the third exemplary embodiment, a pressure sensor is used to detect a finger pressure greater than a preset threshold which indicates key operation of the emulated hard key. When the finger pressure is greater than the preset threshold, keyboard emulator controller 115 provides a stimulus to the sensory feedback elements for generating a second sensory feedback such as a vibration, a temperature change, a change in visual appearance, change in size etc. This second sensory feedback additionally provides tactile feedback to the user because the second sensory feedback is generated only when the user operates the emulated hard key.

[0071] In a fourth exemplary embodiment, the appearance of each of the sensory feedback elements 805, 810, and 815 is controlled by the keyboard emulator controller 115. In the example shown in FIG. 8A, sensory feedback element 810 provides a first visual appearance indicative of the presence of an emulated hard key. For example, sensory feedback element 810 displays a blue color indicative of the presence of the emulated hard key, while sensory feedback elements 805 and 815 each display a gray color indicative of the inactive surface of the reconfigurable keyboard. As described above, a pressure sensor is used to detect key operation, and initiate second sensory feedback, for example, by changing the color of sensory feedback element 810 from the blue color to a red color thereby indicating key operation. The red color additionally provides tactile feedback indicating key operation.

[0072] It will be understood that various combinations of emulated hard key presence and emulated hard key operation indicators are used in various embodiments. For example, a vibrator may be used as the presence indicator of an emulated hard key, together with a visual indicator for indicating key operation.

[0073] FIGS. 8B and 8C illustrate a first example of a sensory feedback array 820 configured as a telephone keypad 800. In this exemplary embodiment each of the 12