

may combine the EAP, piezoelectric elements, and/or SMA to achieve a specific haptic sensation.

[0032] Deforming mechanism 106 provides a pulling and/or pushing force to translate elements in the haptic substrate 104 causing flexible surface 102 to deform. For example, when deforming mechanism 106 creates a vacuum between flexible surface 102 and haptic substrate 104, flexible surface 102 is pushed against haptic substrate 104 causing flexible surface 102 to show the texture of flexible surface 102 in accordance with the surface pattern of haptic substrate 104. In other words, once a surface pattern of haptic substrate 104 is generated, flexible surface is pulled or pushed against haptic substrate 104 to reveal the pattern of haptic substrate 104 through the deformed surface of flexible surface 102. In one embodiment, haptic substrate 104 and deforming mechanism 106 are constructed in the same or substantially the same layer.

[0033] Upon receipt of a first activating signal, haptic substrate 104 generates a first surface pattern. After formation of the surface pattern of haptic substrate 104, deforming mechanism 106 is subsequently activated to change surface texture of flexible surface 102 in response to the surface pattern of haptic substrate 104. Alternatively, if haptic substrate 104 receives a second activating signal, it generates a second pattern.

[0034] Haptic substrate 104 further includes multiple tactile regions wherein each region can be independently activated to form a surface pattern of the substrate. Haptic substrate 104 is also capable of generating a confirmation feedback to confirm an input selection entered by a user. Deforming mechanism 106 is configured to deform the surface texture of flexible surface 102 from a first surface characteristic to a second surface characteristic. It should be noted that haptic device further includes a sensor, which is capable of activating the device when the sensor detects a touch on flexible surface 102. Deforming mechanism 106 may be a vacuum generator, which is capable of causing flexible surface 102 to collapse against the first surface pattern to transform its surface configuration in accordance with the configuration of first pattern of haptic substrate 104.

[0035] FIG. 1(b) shows a 3D diagram illustrating a haptic structure 130 using a haptic substrate and a flexible surface in accordance with one embodiment of the present invention. Structure 130 includes a flexible surface 102, a haptic substrate 134, and a deforming mechanism 106. In one embodiment, haptic structure 130 is an article of haptic fabric or cloth capable of communicating with the user via haptic feedback. It should be noted that the underlying concept of the exemplary embodiment of the present invention would not change if additional blocks (circuits or layers) were added to or removed from structure 130.

[0036] Haptic substrate 134 is similar or substantially similar to haptic substrate 104 illustrated in FIG. 1(a) except that tactile regions 136 and 139 are activated. Tactile regions 136 and 139 are raised in a z-axis direction. Upon receipt of one or more activating signals, haptic substrate 134 identifies a surface pattern in accordance with the activating signals. Haptic substrate 134 provides identified pattern by activating various tactile regions such as regions 136 and 139 to generate the pattern. It should be noted that tactile regions 136 and 139 imitate two buttons or keys. In another embodiment, tactile region 136 or 139 includes multiple haptic bits wherein each bit can be controlled for activating or deactivating.

[0037] FIG. 1(c) shows a 3D diagram illustrating a haptic material or structure 140 using a haptic substrate and a flexible surface in accordance with one embodiment of the present invention. Structure 140 includes a flexible surface 142, a haptic substrate 134, and a deforming mechanism 106. It should be noted that haptic substrate 134 and deforming mechanism 106 are the same or substantially the same elements. In one embodiment, flexible structure 140 is an article of haptic fabric or cloth capable of changing patterns in response to the haptic feedback. It should be further noted that the underlying concept of the exemplary embodiment of the present invention would not change if additional blocks were added to or removed from structure 140.

[0038] When deforming mechanism 106 is activated, flexible surface 142 collapses over haptic substrate 134, which, as illustrated in FIG. 1(b), has two activated tactile regions 136 and 139, to form two bumps 156 and 159. Bumps 156 and 159, in one example, imitate two buttons. For example, haptic substrate 134 is capable of detecting a contact on button 156 or 159 and providing a haptic feedback to confirm which button had been depressed. Alternatively, haptic substrate 134 is capable of generating one of many unique physical patterns in response to one or more signals. As such, flexible surface 102 can be reconfigured to different patterns in accordance with the pattern or patterns provided by haptic substrate 134. The surface texture of flexible surface can be configured to a telephone key pad, a calculator buttons, computer key pad, radio panel, PDA interfaces, or the like.

[0039] FIG. 1(d) shows examples of haptic substrates 150-170 illustrating different patterns generated by haptic effect in accordance with one embodiment of the present invention. Substrate 150 illustrates an array of tactile regions 152 wherein each region can be independently controlled and activated. Substrate 160 illustrates that nine (9) tactile regions 162 situated in the mid-section of substrate 160 are activated and raised. Also, two sections 172-174 of haptic substrate 170 have been raised to provide a different surface pattern. It should be noted that different patterns can be generated from the array of tactile regions in response to the various control signals. It should be further noted that substrate can change over time, which causes flexible surface 102 to change as well.

[0040] FIG. 1(e) illustrates a haptic device 180 using haptic substrates and flexible surfaces in accordance with one embodiment of the present invention. Device 180 includes a flexible screen and an array of actuator 186 wherein the flexible screen is capable of combining haptic sensation with computer graphics. The flexible screen, for example, illustrates the terrain and/or texture of a mountain 182 as well as a watery sensation or texture of a lake 184. When a computer displays a graphical representation of a mountain terrain and a lake, device 180 provides realistic sensation of mountain terrain for the mountain and watery texture for the lake. For example, a user feels a watery sensation when he or she touches lake 184 or feels a rocky sensation if he or she touches mountain 182. When the computer, however, displays another graphical representation, such as a beach, device 180 will change its surface characteristic to illustrate the beach or sandy sensation. It should be noted that haptic substrate 104 may be used to replace actuator array 186 in device 180.

[0041] FIG. 2(a) is a diagram 200 illustrating a cross section view of haptic device capable of generating haptic feedback using plasma actuator in accordance with one embodiment of the present invention. Diagram 200 shows a device