apparatus for providing haptic feedback from multi-actuated waveform phasing using perimeter actuators.

Those of ordinary skills in the art will realize that the following detailed description of the exemplary embodiment (s) is illustrative only and is not intended to be in any way limiting. Other embodiments will readily suggest themselves to such skilled persons having the benefit of this disclosure. Reference will now be made in detail to implementations of the exemplary embodiment(s) as illustrated in the accompanying drawings. The same reference indicators will be used throughout the drawings and the following detailed description to refer to the same or like parts.

In the interest of clarity, not all of the routine features of the implementations described herein are shown and described. It will, of course, be appreciated that in the development of any such actual implementation, numerous implementation-specific decisions must be made in order to achieve the developer's specific goals, such as compliance with application- and business-related constraints, and that these specific goals will vary from one implementation to another and from one developer to another.

An embodiment(s) of the present invention discloses a haptic device, which is capable of generating haptic feedback over a touch surface using multi-actuated waveform phasing. The device includes a touch surface and a group of haptic actuators, wherein the touch surface is capable of sensing an event. The event, for instance, can be a contact with the touch surface or a movement nearby the device. A portion of the haptic actuators coupled to the touch surface is used to provide haptic feedback in response to the event. Another portion of the haptic actuators is used to minimize unwanted haptic responses on the touch surface.

FIG. **1**(*a*) illustrates a haptic device **150** capable of generating haptic feedback utilizing multi-actuated waveform phasing in accordance with one embodiment of the present invention. Device **150** includes a touch surface **152** and a group of actuators **156** capable of providing haptic feedback using haptic phase actuation. Actuators **156** are coupled to the perimeter of touch surface **152**. Touch surface **152** is also known as touch pad, haptic layer, touch sensitive surface, flexible touch sensitive surface, or the like. It should also be noted that the underlying concept of the exemplary embodiment of the present invention would not change if one or more blocks (circuits or layers) were added to or removed from device **150**.

Touch surface **152**, in one aspect, includes a detecting mechanism capable of sensing an event. The event can be, but not limited to, a surface contact, a movement, an ambient condition, a sound, an optical light, and the like. The ambient condition includes surrounding temperature, light, humidity, radiation, et cetera. For instance, a surface contact has occurred when a depression on the touch surface happens via a push by a user's finger. Alternatively, a contact can be made by a pointed object, such as a stylus or a pen.

Touch surface **152**, in one embodiment, is made of flexible soft material wherein the medium of the flexible soft material is able to transmit haptic waves from a wave-generating source such as actuators **156** to wave-destination such as the contact location. For example, the touch surface **152** may be made of gel-like synthetic polymers or natural substances. The medium of gel-like polymers facilitates the travel of the haptic waveform from a wave-source to a wave-destination via the gel-like polymer or semi-liquid medium.

Device **150** also includes a haptic sensor or a controller, not shown in FIG. **1**(*a*), capable of determining physical location of an event, also known as the location of the interaction on touch surface **152**. The haptic sensor, in one embodiment, is capable of calculating a distance for every actuator between its location and the location of interaction. Upon detecting multiple interactions or events, the haptic sensor is configured to calculate distances between each actuator and the multiple locations of interactions. It should be noted that the haptic sensor or controller can be a part of touch surface **152**. Alternatively, the haptic sensor can be distributed across one or more actuators **156**. The calculated distances between actuators and location(s) are used by actuators **156** for generating haptic feedback as well as haptic phase actuation for canceling unwanted haptic responses. It should also be noted that the haptic sensor does not require the user to have direct contact with the touch surface before making its calculations for haptic responses.

Actuators **156**, in one embodiment, are physically located at the perimeter of touch surface **152**. It should be noted that depending on applications, additional actuators may be placed below or above touch surface **152**. Alternatively, actuators **156** can also be situated in one side, two sides, or three sides of the perimeter of touch surface **152**. Actuators **156**, in one embodiment, work in harmony or in synchrony to intensify the haptic feedback. A portion of haptic actuators **156** is allocated to provide haptic feedback to touch surface **152** in response to the event while another portion of haptic actuators **152** is used to minimize unwanted haptic effect on touch surface **152**. For example, while some actuators **156** located at the perimeter of touch surface **152** send haptic waves to an interactive point or location of the interaction, other actuators **156** emit actuations to cancel unwanted actuation waves.

To intensify haptic feedback at the interaction, various haptic waves generated by a group of actuators **156** arrive at the location of the interaction on touch surface **152** at the same time or substantially the same time. Since the distance between each actuator **156** and the location of interaction can be different, time to activate haptic wave for each actuator **156** is independent from its neighboring actuators thereby all of the haptic waves for generating haptic feedback can arrive at the same time. Similarly, to improve haptic feedback, various haptic actuations generated by another group of actuators **156** are used to cancel unwanted haptic waveforms, unwanted vibrations, or unwanted actuations across touch surface **152**. In one embodiment, actuators are also capable of generating haptic feedback to support multiple interactions in response to multiple touch events. It should be noted that actuators **156** may include one or more of the same or different types of haptic elements, such as fibers (or nanotubes) of electroactive polymers ("EAP"), piezoelectric elements, fiber of shape memory alloys ("SMAs"), plasma actuators, pneumatic actuators, electric actuators, motors, hydraulic cylinders, linear actuators, and the like.

Multi-actuated waveform phasing across the entire surface of touch surface **152** creates areas of greatest haptic actuation (s) at one or more touch points while canceling or reducing any perceived actuations in other areas of touch surface **152**. Touch surface **152** can be actuated through the use of a gel material having aquatic-like or paste-like medium by injecting energy into the medium in a controlled manner thereby various waveforms are produced. An advantage of using the haptic phase actuation for a multi-point touch system is that a user(s) can feel two distinctly different haptic responses in different areas of a touch surface without one response bleeding over into another response. For example, for a touch surface capable of simulating both texture and objects, when a user drags two fingers across the touch surface, he or she can feel a haptic texture with one finger and a haptic virtual button with another finger. It should be noted that haptic sensation