

trollers (DACs), analog to digital controllers (ADCs), and other components, as is well known to those skilled in the art.

[0072] In some of the implementations herein, the actuator has the ability to apply short duration force sensation on the housing or manipulandum of the device, or via moving an inertial mass. This short duration force sensation can be described as a “pulse.” The “pulse” can be directed substantially along a particular direction in some embodiments. In some embodiments, the magnitude of the “pulse” can be controlled; the sense of the “pulse” can be controlled, either positive or negative biased; a “periodic force sensation” can be applied and can have a magnitude and a frequency, e.g. the periodic sensation can be selectable among a sine wave, square wave, saw-toothed-up wave, saw-toothed-down, and triangle wave; an envelope can be applied to the period signal, allowing for variation in magnitude over time. The wave forms can be “streamed” from the host to the device, as described in copending application Ser. No. 09/687,744, incorporated herein by reference in its entirety, or can be conveyed through high level commands that include parameters such as magnitude, frequency, and duration.

[0073] Other input devices **118** can be included in device **12** and send input signals to microprocessor **110** or to host **14** when manipulated by the user. Such input devices include buttons, dials, switches, scroll wheels, knobs, or other controls or mechanisms. Power supply **120** can optionally be included in device **12** coupled to actuator interface **116** and/or actuator **18** to provide electrical power to the actuator. Alternatively, power can be drawn from a power supply separate from device **12**, or power can be received across bus **20**. Also, received power can be stored and regulated by device **12** (and/or host **14**) and thus used when needed to drive actuator **18** or used in a supplementary fashion.

[0074] The interface device **12** can be any of a variety of types; some embodiments are described further below. The touchpads or touchscreen described herein can be provided on a variety of types of devices, such as gamepads, joysticks, steering wheels, touchpads, spherical controllers, finger pads, knobs, track balls, remote control device, cell phone, personal digital assistant, etc.

Specific Embodiments

[0075] The present invention presents a variety of embodiments in which haptic feedback is provided to a user of a laptop computer or other portable computing device, and/or to the user of any computing device having a touchpad or similar input device.

[0076] Some embodiments are based on displacing the skin of a user's finger when it is in contact with a touchpad. These embodiments deliver high fidelity sensations while offering a good correlation between input and output right at the user's fingertip. Actuator and linkage solutions are described to drive any of the translation embodiments. Other embodiments are based on the stimulation of palm surfaces of the user that are normally in contact with the laptop computer **10**. These surfaces can provide haptic sensations based on inertially coupled forces or translation of the palm surfaces. Translations of surfaces in plane with the upper surface of the touchpad or laptop (i.e. in the X and/or Y axes) are as effective at conveying haptic information as vibrations or displacements in the Z axis (those normal to the touchpad

or laptop upper surface). This can be important when the volumetric constraints of a laptop are considered.

[0077] In many of the embodiments described herein, it is also advantageous that contact of the user is detected by a touch input device. Since haptic feedback need only be output when the user is contacting the touch device, this detection allows haptic feedback to be stopped (actuators “turned off”) when no objects are contacting the touch input device. This feature can conserve battery power for portable devices. If a local touch device microprocessor (or similar circuitry) is being used in the computer, such a microprocessor can turn off actuator output when no user contact is sensed, thus alleviating the host processor of additional computational burden until touch is again detected, when the actuator output is resumed.

[0078] In many preferred embodiments, haptics are added to a laptop computer or other device in a way that does not force the user to relearn how to control the laptop or force the manufacturer to stretch design and manufacturing too far from existing designs to provide the haptic content. For example, in laptop embodiments, as the user moves his or her finger across the touchpad, a cursor displayed on the laptop screen is correspondingly moved. Haptic effects can be output on the touchpad or other laptop component contacted by the user when the cursor interacts with a graphical object or area, when an event occurs, etc. In other applications, haptic effects can be output when events or interactions occur in a game or other application running on the laptop.

[0079] Other embodiments and descriptions of touchpads, devices, applications, and other components suitable for use with the present invention are described in copending patent application Ser. No. 09/487,737, filed Jan. 19, 2000, which is incorporated herein by reference in its entirety. Many types of actuators, sensors, linkages, amplification transmissions, etc. can be used with the present invention.

[0080] A touchpad surface, as manufactured currently, typically is coupled to a printed circuit board (PCB) that includes necessary electronics and standard connections for connecting and operating the touchpad in a laptop. Thus, when forces are applied to the touchpad, they are also applied to the PCB that is often directly coupled to the touchpad, e.g. underneath the touchpad.

[0081] The embodiments herein are designed with particular guidelines and characteristics. For example, the particular haptic experiences that feel compelling in a certain embodiment, the location where the tactile content is focused or located physically, the spatial correlation of the haptic feedback with the pointing of the user's finger on the touchpad, e.g. the feedback can be right under the finger, or originate somewhere in the case/housing of the laptop, the required force strength and power for compelling feedback, the way the user interacts with the device and effect on quality and content of the feedback (angle of finger contact, etc), and which actuators and mechanisms that can fit into the laptop form factor/housing are most desirable.

[0082] Preferably, existing haptic feedback software and drivers can be used with the embodiments described herein, such as TouchSense software from Immersion Corp. A standardized module, such as a particular touchpad, that works for many different types of products is desirable, such as PDAs, laptops, cell phones, and remote controls.