[0146] **FIG. 13** is a perspective view of one embodiment **330** providing a translating touchpad surface. Touchpad **332** is moved relative to a housing **334**, such as a laptop or PDA housing, by an actuator **336**. In the described embodiment, the actuator **336** is a rotary actuator, such as a DC motor, having a rotating shaft **338** that is coupled to a linkage **340**. The linkage **340** is coupled to a bracket **342** at its other end, where the bracket **342** is coupled to the underside of the touchpad **332** module. The linkage includes joints and/or flexibility/compliance to allow the rotational motion of the shaft **338** to be converted to linear force on the bracket **342**, thereby causing the touchpad **332** to move laterally as shown by arrows **344**. For example, the linkage can be made of polypropylene, similar to the linkages of the actuator assembly of **FIG. 5**. The laptop housing can serve as a constraining structure for the moving touchpad module.

[0147] For example, a standard DC motor can be used for actuator **336** and a polypropylene linkage assembly for linkage **340**. In one embodiment, the haptic feedback components can reside where optional components for the laptop are normally placed, such as an optional disc drive.

[0148] In other embodiments, the actuator **338** can be located remotely from the touchpad **332**, e.g., wherever space is available in the housing as opposed to directly underneath the touchpad as illustrated in **FIG. 13**. Linkages can be used to locate the actuator(s) remotely from the touchpad, as shown in **FIG. 14** below.

[0149] Translating the entire touchpad in one or two axes may be one good overall haptics approach. Very small displacements (0.2 mm<x<0.5 mm) of the touchpad are desired to provide useful haptics. The power consumption for this embodiment when evaluated within a practical magnitude range can be less than the consumption of currently available inertial mice interface devices, which can receive all needed power over the interface to the host computer, such as USB.

[0150] Some advantages are apparent in this type of embodiment. Feedback experience is direct, well correlated with pointing, and precise. Implementation can be flexible and unobtrusive, and addition of haptic components does not alter how the touchpad is used. The translating surface has a small displacement requirement compared with inertial approaches this can lead to reduced power consumption and manufacturing benefits. In some embodiments, the motion of the touchpad can be oriented at an angle in the x-y plane. Some disadvantages may include use of a DC motor, which are relatively large, a flexible linkage may need a lot of clearance and may cause friction, and power consumption may be relatively high.

[0151] **FIG. 14** illustrates a perspective view of another embodiment **350** of a moving touchpad, in which the touchpad may be moved in both X and Y directions. The touchpad **351** is directly coupled to a first linkage member **351**, which is coupled to a rotating shaft of an actuator **353** by a flexible member **354**, such as polypropelene. Actuator **353** is grounded to the laptop housing. When actuator **353** rotates its shaft, the flexible member **354** converts the rotary motion to linear motion and translates the linkage member **352** in the x-direction, which in turn translates the touchpad as indicated by arrow **355**. At the distal end of the first linkage member **354**, a second linkage member **356** is coupled, e.g. by a flexible coupling.

[0152] A second actuator **358**, grounded to the laptop housing, is coupled to the other end of the second linkage member **356** by a flexible member **357**, where the axis of rotation of the rotating shaft of the actuator **358** is substantially the same as the axis of rotation of the actuator **353**. The rotary force output by the rotating shaft of the actuator **358** is converted to a linear force by the flexible member **357**. This linear force causes the second linkage member **356** to move linearly along its length, which in turn causes the first linkage member **352** to pivot approximately about its end near actuator **353** along the y-axis and cause the touchpad **351** to move approximately along the y-axis. The actuators **353** and **358** can be, for example, DC motors or any other type of actuator, e.g. linear actuators can also be used, as described below in FIGS. **15-17**. The linkage members can be made of any suitable material, e.g. carbon fiber. Preferably, very little energy is absorbed by the grounded structure or by unwanted deformations in the linkage assembly.

[0153] Thus, the mechanism decouples the x- and y-motions; by activating actuator **353**, x-axis motion is provided, and by activating actuator **358**, y-axis motion is provided; both x- and y-axis motion can be provided by activating both motors simultaneously. Both actuators can be driven either together (common mode) or differentially (differential mode) to achieve pure X or Y movement without binding the linkage parts. Furthermore, any combination of drive current will produce a resultant force along any arbitrary axis with the same fidelity and lack of binding.

[0154] One embodiment may use firmware for rapid evaluation and output of X and Y forces, e.g. software running on a local controller such as a microprocessor, or running off the host CPU. In some embodiments, such firmware may be too complex, so that alternatively, a mechanism with an electronic way of switching between the two principle feedback axes can be used. in one embodiment, the two DC motors can be connected in a series circuit with switch that reverses the current through one of the two motors.

[0155] In the embodiment of **FIG. 14**, the user may feel the difference between x- and y-directional forces when moving a finger or object on the touchpad in the x-direction. There is haptic value in having the correlation or alignment of tactile feedback with finger/cursor motion; in some cases, alignment can boost the haptic signal-to-noise ratio. For example, moving the cursor right to left over icons or buttons may feel better and more like real buttons to the user when the feedback is directed horizontally along the x-axis. Less power may be required overall if the feedback is aligned with the cursor direction instead of being omnidirectional or misaligned. In some cases, a weaker aligned haptic effect may be more meaningful than a stronger misaligned effect.

[0156] The touchpad surface with enhanced texture moves relative to a fixed surrounding surface with enhanced texture. The enhanced texture is more rough, corrugated, or otherwise textured, allowing a stronger user contact.

[0157] In some other embodiments, the touchpad surface can be comprised of interdigitated surface features that move relative to each other in x- and/or y- directions. For example, two halves of a touchpad can be driven by actuator(s) to move relative to each other.

[0158] In other embodiments, other actuators can be used to move the touchpad, touchscreen, or other touch device in