[0013] A number of devices having dynamic force feedback exist. Most of these lack a direct mapping between the hand and the device (e.g. force-feedback joysticks). Others have a direct mapping but are primarily designed for use in three-dimensional applications such as virtual reality or tele-operation. Most productive work done on computers is two-dimensional in nature, such as spreadsheets and page layout. These productivity applications would not enjoy significant benefits from the use of a three-dimensional input device. These devices have additional drawbacks, as outlined below.

User interaction is encumbered or impeded

[0014] Many input devices encumber the user by requiring them to move at least a portion of the input device during use. For example, the time it takes to move the cursor across the screen with a mouse is increased because the user must accelerate and decelerate the mass of the mouse, in addition to the mass of their hand. Other input devices do not add inertia but impede the user in other ways. With a trackball, for example, multiple sweeping motions are required to move the cursor large distances, which is awkward and time consuming. With a joystick, for example, the force applied relates to the speed of the cursor on the screen, which may require the user to wait when the cursor is moving relatively large distances.

[0015] Any input device which must be located and/or manipulated before use suffers from such problems to at least a certain extent (e.g., mice and some force reflecting interfaces, among others). For example, if a person not currently using a computer and wants to press a graphical button on computer's display, they must find and grasp the mouse, move the mouse to position the cursor over the button, and then click the button. In contrast, a touch screen leaves the user unencumbered. They can reach out and press a graphical button on the display directly, with no intermediate steps. A touch screen, however, suffers from the previously-described infirmity of lacking haptic feedback.

Insufficient support for multiple interactions

[0016] Most input devices, such as the mouse, trackball, joystick, the Synaptics TouchPad and the IBM TrackPoint ®, only support a single interaction at a time. However, people have two hands which they are innately able to use together. Two single-interaction devices have been combined to provide two points of control, but confusion can arise because the correspondence between screen cursors and pointing devices is not apparent. Because these devices lack a direct mapping to the screen, their physical positions cannot resolve the correspondence between an input device and its cursor. Moreover, no provision is made for the interaction of multiple users. With a single input device, only a single user may "own" the device at any given time, and (given a single input device) users must take turns interacting with the computer. This is obviously a cumbersome and awkward technique when multiple users wish to work collaboratively on a given project.

SUMMARY OF THE INVENTION

[0017] Embodiments of the present invention overcomes conventional limitations by providing a device having a direct mapping, for example, between the touching portion of a user's hand and the position of a cursor on a display and an output in the form of dynamic haptic feedback, without encumbering or impeding the user and allowing a large number of simultaneous interactions. The device provides direct mapping to reduce the conscious effort required for relatively pedestrian tasks such as interacting with a graphical user interface (GUI). The user's interaction with the device is not hampered by a need to laterally move any portion of the device.

[0018] The device provides dynamic haptic feedback. Haptic feedback is termed herein as being dynamic to indicate that the haptic feedback can be altered over time (e.g. by means a software application) in order to provide additional information to a user. In the previous example, a disabled button would have a different feel from that of an enabled button, allowing a user to discern that a graphical button was not enabled, using their sense of touch. The device also supports multiple interactions. Having more than two points of control is useful when multiple users collaborate at the same computer. Allowing a large number of interactions at once allows multiple users to interact with the computer simultaneously. Another benefit of having more than two points of control is the ability of a user to employ multiple fingers for pointing purposes, even in combination.

[0019] Embodiments of the present invention take the form of an input and output device for a processor. In one embodiment, an input/output device has a horizontal two-dimensional area which can be touched simultaneously (e.g., with the hands) in multiple places. The location of each touch is measured and the area surrounding each touch moves vertically and provides dynamic haptic feedback to the user. The device has a control processor that communicates with another processor on which software applications are executed. The control processor continually sends the current attributes of all touches in progress, and receives commands which specify the type of haptic response each touch should exhibit.

[0020] The touchable area is comprised of a grid of haptic elements, referred to herein as haptels. Haptel is used herein to describe a haptic feedback device with linear motion having a touchable surface substantially perpendicular to the direction of motion. A haptic feedback device is used herein to describe an input and output device with a moving portion manipulated by a user, one or more sensors that measure the position and/or various derivatives of position and/or the forces applied to the moving portion, one or more effectors which can apply forces to the moving portion, and a processor which measures the sensors, computes a response, and drives the effectors to create a range of haptic effects.

[0021] In one embodiment, each haptel includes a position sensor to measure the vertical position of the surface within its range of travel, an electromagnetic linear actuator to provide a controllable vertical bi-directional feedback force, and a touch location sensor to measure the coordinates of a single touch within its bounds. Preferably, the haptel grid is covered by a single sheet of flexible material that protects the haptels and hides the grid from view.

[0022] The haptels have their sensors and effectors interfaced to a control processor. The control processor measures the position of haptel surfaces and allows information such as velocity, acceleration, and applied force to be derived. Alternatively, sensors can be included in each haptel to