

bine multiple instances of a particular module or submodule. Furthermore, those skilled in the art will recognize that the operations described in exemplary embodiment are for illustration only. Operations may be combined or the functionality of the operations may be distributed in additional operations in accordance with the invention.

[0106] Thus, an I/O device such as that described herein provides a natural way of interacting with a computer by employing direct mapping that provides for multiple simultaneous inputs and dynamic haptic feedback, in order to enhance a user's interactive experience.

[0107] While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that, based upon the teachings herein, changes and modifications may be made without departing from this invention and its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as are within the true spirit and scope of this invention.

[0108] Moreover, while the invention has been particularly shown and described with reference to these specific embodiments, it will be understood by those skilled in the art that the foregoing and other changes in the form and details may be made therein without departing from the spirit or scope of the invention. For example, there can be an arbitrary number of haptels in the grid. The touchable surface can be divided into multiple distinct areas whose tilt and orientation is varied relative to each other or fixed by the design. Moreover, the individual haptels need not be flat, so long as the surfaces of neighboring haptels form a continuous surface when tiled together. For example, the haptel surfaces can each have a three-dimensional quality (e.g., a slight spherical curve). Such haptels could thus be tiled such that the touchable area forms a section of a sphere, ellipsoid, or other three-dimensional surface. The proximity sensor can be replaced by a linear optical encoder or other type of position sensor. Position measurement can be derived from other sensors, such as by integrating the signal from a velocity sensor. Multiple sensors of different types can be combined, such as a position sensor and an accelerometer, for example. A force sensor can be added to the design, such as a piezoelectric sensor, or other type of force sensor. The spring can be removed and the actuator powered to provide an upward force adequate to keep the haptel at its upper travel limit (or some other position) when no force is applied. The actuator can be replaced with another type of actuator, such as a moving magnet actuator. Alternative bearing designs may also be used (e.g., other types or combinations of bearing materials, or rolling bearing designs, among other possibilities). The haptels can be coordinated in other ways, such as making the feedback force for one haptel or set of haptels equal to the applied force of a different haptel or set of haptels, and vice versa. The touch location sensor can be replaced by another type of sensor, such as a capacitive proximity sensor. The grid of haptels can be covered by a single, flexible touch location sensor, or by multiple, possibly overlapping, flexible touch position sensors. Each haptel could contain multiple touch location sensors, so that more than one touch could be distinguished within the bounds of each haptel. The functionality of the control processor can be implemented by the computer.

[0109] Accordingly, the scope of the invention should be determined not by any of the embodiments illustrated, but with reference to the appended claims and their legal equivalents.

What is claimed is:

1. An input/output device comprising:

a plurality of haptic elements, wherein

each one of said plurality of haptic elements comprises a contact surface,

said contact surfaces of said plurality of haptic elements define a surface, and

at least one of said plurality of haptic elements is configured to produce a haptic effect at a contact surface of said at least one of said plurality of haptic elements in response to said contact surface being touched.

2. The input/output device of claim 1, further comprising:

a sensor coupled to said contact surface of said at least one of said plurality of haptic elements;

a processor, coupled to said sensor and said at least one of said plurality of haptic elements, wherein

said sensor is configured to generate information in response to said contact surface being touched, and

said processor is configured to control said haptic effect provided by said at least one of said plurality of haptic elements based on information received from said sensor;

3. The input/output device of claim 2, wherein said sensor is further configured to generate information based upon a proximity of a pointing device to said contact surface.

4. The input/output device of claim 2, wherein said sensor is a resistive film sensor.

5. The input/output device of claim 2, wherein said sensor is a capacitive proximity sensor.

6. The input/output device of claim 1, wherein each haptic element of said plurality of haptic elements is configured to provide a haptic effect at a contact surface of said haptic element upon said contact surface of said haptic element being touched, and further comprising:

a plurality of sensors, each one of said plurality of sensors coupled to a contact surface of a corresponding one of said plurality of haptic elements, wherein said at least one of said plurality of haptic elements said plurality of sensors; and

a processor, coupled to said plurality of sensors and said plurality of haptic elements, wherein

each one of said plurality of sensors is configured to generate information upon said contact surface of said corresponding one of said plurality of haptic elements being touched,

said processor is configured to control a haptic effect provided by certain ones of said plurality of haptic elements based on information received from ones of said plurality of sensors corresponding to said certain ones of said plurality of haptic elements, and