simpler and more reliable than in computer vision approaches to free-space hand tracking such as S. Alimad, "A Usable Real-Time 3D Hand Tracker," Proceedings of the 28th Asilomar Conference on Signals, Systems, and Computers—Part 2, vol. 2, IEEE (1994) or Y. Cui and J. Wang, "Hand Segmentation Using Learning-Based Prediction and Verification for Hand Sign Recognition," Proceedings of the 1996 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, pp. 88-93 (1996). However, parts of the hand such as intermediate finger joints and the center of the palms do not show up in capacitive proximity images at all if the hand is not flattened on the surface. Without these intermediate linkages between fingertips and palms the overall hand structure can only be guessed at, making hand contact identification very difficult. Hence the optical flow and contour tracking techniques which have been applied to free-space hand sign language recognition as in F. Quek, "Unencumbered Gestural Interaction," IEEE Multimedia, vol. 3, pp. 36-47 (1996), do not address the special challenges of proximity image tracking.

[0024] Synaptics Corp. has successfully fabricated their electrode array on flexible mylar film rather than stiff circuit board. This is suitable for conforming to the contours of special products, but does not provide significant finger cushioning for large surfaces. Even if a cushion was placed under the film, the lack of stretchability in the film, leads, and electrodes would limit the compliance afforded by the compressible material. Boie et al suggests that placing cornressihle insulators on top of the electrode array cushions finger impact. However, an insulator more than about one millimeter thick would seriously attenuate the measured finger-electrode capacitances. Thus there exists a need in the art for a method to transfer finger capacitance influences through an arbitrarily thick cushion.

SUMMARY OF THE INVENTION

[0025] It is a primary object of the present invention to provide a system and method for integrating different types of manual input such as typing, multiple degree-of-freedom manipulation, and handwriting on a multi-touch surface.

[0026] It is also an object of the present invention to provide a system and method for distinguishing different types of manual input such as typing, multiple degree-of-freedom manipulation, and handwriting on a multi-touch surface, via different hand configurations which are easy for the user to learn and easy for the system to recognize.

[0027] It is a further object of the present invention to provide an improved capacitance-transducing apparatus that is cheaply implemented near each electrode so that two-dimensional sensor arrays of arbitrary size and resolution can be built without degradation in signal to noise.

[0028] It is a further object of the present invention to provide an electronic system which minimizes the number of sensing electrodes necessary to obtain proximity images with such resolution that a variety of hand configurations can be distinguished.

[0029] Yet another object of the present invention is to provide a multi-touch surface apparatus which is compliant and contoured to be comfortable and ergonomic under extended use.

[0030] Yet another object of the present invention is to provide tactile key or hand position feedback without impeding hand resting on the surface or smooth, accurate sliding across the surface.

[0031] It is a further object of the present invention to provide an electronic system which can provide images of flesh proximity to an array of sensors with such resolution that a variety of hand configurations can be distinguished.

[0032] It is another object of the present invention to provide an improved method for invoking cursor motion continuation only when the user wants it by not invoking it when significant deceleration is detected.

[0033] Another object of the present invention is to identify different hand parts as they contact the surface so that a variety of hand configurations can be recognized and used to distinguish different kinds of input activity.

[0034] Yet another object of the present invention is to reliably extract rotation and scaling as well as translation degrees of freedom from the motion of two or more hand contacts to aid in navigation and manipulation of two-dimensional electronic documents.

[0035] It is a further object of the present invention to reliably extract tilt and roll degrees of freedom from hand pressure differences to aid in navigation and manipulation of three-dimensional environments.

[0036] Additional objects and advantages of the invention will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

[0037] To achieve the objects and in accordance with the purpose of the invention, as embodied and broadly described herein, the invention comprises a sensing device that is sensitive to changes in self-capacitance brought about by changes in proximity of a touch device to the sensing device, the sensing device comprising: two electrical switching means connected together in series having a common node, an input node, and an output node; a dielectric-covered sensing electrode connected to the common node between the two switching means; a power supply providing an approximately constant voltage connected to the input node of the series-connected switching means; an integrating capacitor to accumulate charge transferred during multiple consecutive switchings of the series connected switching means; another switching means connected in parallel across the integrating capacitor to deplete its residual charge; and a voltage-to-voltage translation device connected to the output node of the series-connected switching means which produces a voltage representing the magnitude of the self-capacitance of the sensing device. Alternatively, the sensing device comprises: two electrical switching means connected together in series having a common node, an input node, and an output node; a dielectric-covered sensing electrode connected to the common node between the two switching means; a power supply providing an approximately constant voltage connected to the input node of the series-connected switching means; and an integrating current-to-voltage translation device connected to the output node of the series connected switching means, the current-to-voltage transla-