TITLE OF THE INVENTION

Gesture Recognition

BACKGROUND OF THE INVENTION

The invention relates to gesture recognition in particular gesture recognition by processing of time series of positional inputs received by a two-dimensional (2D) touch sensor, such as a capacitive or resistive touch sensor. The invention may also be applied to one-dimensional (1D) touch sensors, and the principles could also be applied to three-dimensional sensors. It may also be applied to proximity sensors, where no physical contact, i.e. touch, with a sensing surface is involved.

The invention can be applied to sensing surfaces operable by a human finger, or a stylus.

1D and 2D capacitive and resistive touch sensors have been in widespread use for many years. Examples include the screens of personal digital assistants (PDAs), MP3 audio player controls, mobile phone keypads and/or displays, and multimedia devices. The touchpad in notebook computers provided in place of a mouse is another form of 2D capacitive touch sensor. 2D sensors are also provided in many white goods such as ovens and blenders.

Detailed descriptions of 2D capacitive sensors have been given many times, for example in patents and patent applications with the inventor Harald Philipp such as US 2005/0041018 A1, US 2007/0247443 A1, US 2007/0257894 A1, and US 2007/0279395 A1, the contents of which are incorporated herein in their entirety.

Other prior art examples of touch screens are as follows.

US 3,593,115 shows a touch element having triangulated shapes for determining object position. However this scheme requires numerous secondary electrode connections as well as two or more layers of construction, increasing construction costs and reducing transparency.

US 5,650,597 shows a 2D sensing method which in its active area requires only one layer but requires large numbers of electrode connections. Resistive strips resolve one axis of position, and the accuracy is dependent on the tolerance of large numbers of resistive strips. This method however does suppress hand shadow effects.

US 6,297,811 describes a touch screen using triangulated wire outline electrode shapes to create field gradients. However this patent suffers from the problem that it is difficult to scale up the screen size, as the number of electrode connections to a sensing circuit is one per triangle. It is desirable to dramatically reduce the number of connections in order to reduce cost and simplify construction. Also it is desirable to use solid shapes rather than wire outlines which are more expensive to construct. This method however does suppress hand shadow effects.

Gesture recognition has also been used for many years in such devices. An early example is character recognition in PDAs, such as the original machines from Palm. Tracking finger motion, and single and double taps on a notebook touchpad is another long used example. More recently, gesture recognition has been incorporated into handheld devices such as the Apple iPhone (RTM). Prior art patent publications on touch screens that involve gesture recognition are also large in number, with significant numbers of publications from Synaptics, Inc. and also more recently Apple Computer, Inc, for example.

US 2007/152984 A1 assigned to Apple Computer, Inc. discloses a portable communication device with multi-touch input which detects one or more multi-touch contacts and motions and performs one or more operations on an object based on the one or more multi-touch contacts and/or motions.

US 2002/015024 A1 assigned to University of Delaware discloses simultaneously tracking multiple finger and palm contacts as hands approach, touch, and slide across a proximity-sensor. Segmentation processing extracts shape, position and surface proximity features for each contact and a persistent path tracker is used to detect individual contact touchdown and liftoff. Combinatorial optimization modules associate each contact's path with a particular fingertip, thumb, or palm of either hand on the basis of biomechanical constraints and contact features. Classification of intuitive hand configurations and motions enables unprecedented integration of typing, resting, pointing, scrolling, 3D manipulation, and handwriting into a versatile, ergonomic computer input device.

US 6028271, US 6414671 and US 6750852 are related patents assigned to Synaptics, Inc. which disclose gesture recognition of an object on a touch-sensor pad and for cursor motion. Tapping, drags, pushes, extended drags and variable drags gestures are recognized by analyzing the position, pressure, and movement of the conductive object on the sensor pad during the time of a suspected gesture, and signals are sent to a host indicating the occurrence of these gestures.

US2007/176906 A1 assigned to Synaptics, Inc. discloses a touch sensor having a signal processor adapted to distinguish between three gestures based on different finger motions on the sensing device by providing a workflow with an idle state and three gesture-specific states referred to as first, second and third result states, as illustrated in Figure 5 of US2007/176906 A1.

Generally, the raw output from the 2D touch sensor will be a time series of x, y coordinates, which are then processed by software, or firmware generated from higher level software, to distinguish the nature of the gesture that has been input. Generally, the raw data is split into contiguous touch segments and then processed to determine what if any gestures can be deduced. The processing of the raw data to identify the gestures may be carried out in the same chip as generates the raw data, or the raw data may be exported to an external chip, for example by transmission over a communication bus to the device's central processing unit (CPU). The former approach is preferred by Synaptics, the latter by Apple as exemplified by US 2006/0066582 A1.

Most of the patent literature is unspecific about how the raw time series data are converted into gestures. The straightforward approach is to write appropriate high level code, for example in C or another suitable programming language, in which the interpretation of the time series data is analysed using conditional statements, such as *if* .. *then* .. *else*.

However, it is difficult to reliably and efficiently add code to identify a new gesture into an existing block of code for distinguishing between a significant number of gestures, for example at least 3 or 4, perhaps 10 to 20. Testing of the code is a particular difficulty. This is because in general at any intermediate point in a time series of x,y,t data the input may relate to a plurality of possible gestures, thereby making the coding for recognising one gesture generally dependent on or linked to the coding for recognising another gesture.

SUMMARY OF THE INVENTION

The invention solves this problem by adopting a state machine approach to designing and writing the gesture recognition algorithm. In particular, the invention relates to a touch sensor device comprising an at least one-dimensional sensor arranged to output a sense signal responsive to proximity of an object, a position processing unit for calculating a position of an interaction with the sensitive area from an analysis of the sense signals and output a time series of data indicative of interaction positions on the sensor, and a gesture processing unit operable to analyse the time series data to distinguish one or more gesture inputs therefrom, wherein the gesture processing unit is coded with gesture recognition code comprising a plurality of linked state modules. The invention also relates to a corresponding signal processing method.

The gesture recognition code can be written in a high level language such as C and then compiled and embedded in a microcontroller chip, or CPU chip as desired. Preferably, the gesture recognition code is loaded into the same chip that interprets the touch signals from the screen and generates the time series data, e.g. a microcontroller, or other programmable logic device such as a field programmable gate array (FPGA). This approach has been used to create reliable testable code both for single-touch data input screens and also multi-touch data input screens. A single-touch screen is one which assumes only one simultaneous touch of the screen, and is designed to output only one x,y coordinate at any one time. A multi-touch screen is one that can sense multiple simultaneous touches, for example up to 2 or 3 simultaneous touches.

The state machine includes an idle state module which is the start state, and also the state which is returned to after a gesture interpretation state module has been exited.

Responsive to a touch, the idle state passes control to a touch state. In a multi-touch environment, there are multiple touch states, one for a single touch, one for a double touch, one for a triple touch etc with control passing to the appropriate touch state based on the number of simultaneous touches defined by the time series data at the time. A touch is usually only output as a valid touch, if certain criteria are satisfied, typically that there are a succession of touch at a stable x,y location or x,y region over multiple time sample increments. If a touch of a duration longer than a threshold duration is sensed in the touch state, then control flow passes to a press state module, wherein the press state is for handling longer touches. The press state is preferably a superstate comprising multiple sub-states to distinguish between different durations of press and/or to allow a very long press to be interpreted as being repeat presses, which may be useful for alphanumeric key entry applications for example.

The state machine preferably also has a plurality of state modules for interpreting higher level gestures, such as one or more states for interpreting double taps, flicks, drags and any other gestures. The gestures include those specifically described in this document as well as other gestures known in the art, specifically all those disclosed in the above-referenced prior art documents.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, and to show how the same may be carried into effect, reference is now made by way of example to the accompanying drawings.

Figure 1 Gesture recognition state machine.

Figure 2 Gesture recognition state machine pressed superstate.

Figure 3 Gesture recognition state machine for single touch gestures.

DETAILED DESCRIPTION

1 Introduction

This document defines a state machine for recognising user gestures on a touch surface.

Section 2 describes the user gestures recognised by the state machine.

Section 3 describes the events generated by the state machine in response to user actions.

Section 4 describes the state machine itself.

2 Gestures

This section lists the gestures recognised by the state machine described in Section 4.

2.1 Tap

A tap happens when the user quickly touches and releases the touch surface. No significant movement takes place while the user's finger is on the touch surface. It is characterised by a short touch duration. This could be used, for example, to activate a hyperlink on a displayed web page.

2.2 Double Tap

A double tap happens when the user quickly touches and releases the touch surface twice in quick succession. No significant movement takes place while the user's finger is on the touch surface, or between successive touches. It is characterised by short touch durations, and a short gap between the first release and the second press. This could be used, for example, to select a word in a displayed document.

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