Putting the “Touch” in Multi-Touch

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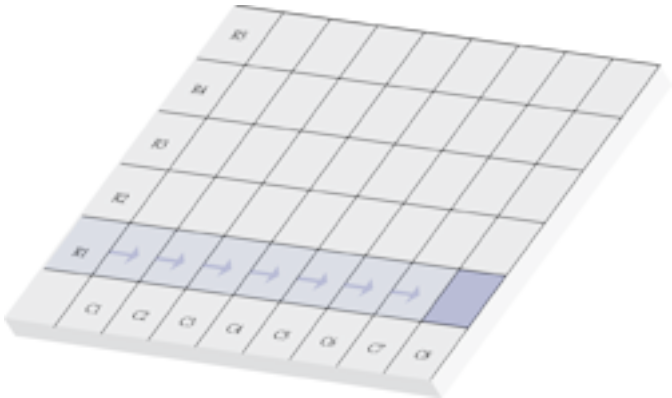
An in-depth look at the future of interactivity

Multi-touch touch screens are fast becoming the standard for touch interface systems. This white paper examines what the term “multi-touch” means, what it does, and how it is used.

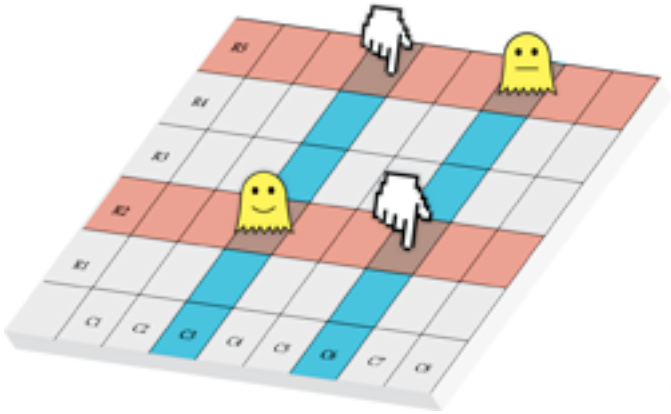
Background
The term multi-touch refers to the ability to simultaneously register more than one touch at the same time on a touch screen. Multi-touch capability is not new. The earliest forms of touch screens -- matrix resistive and IR (infra-red) -- were both capable of generating two coordinates; however, due to “ghosting”, both of these touch technologies registered two touches as an error, instead of making use of the data. It was not until Apple introduced the iPhone that two or more touches became anything more than a problem.

For the last 25 years, the two most common touch technologies -- analog resistive and surface capacitive -- only reported one X, Y touch coordinate. In fact, if there were two touches at the same time, the technology could not even recognize that there were two fingers on the sensor and would instead report the average of the two touches, which was a phantom point. The pseudo-multi-touch systems, most notably the games produced by Merit, made use of the fact that it was actually impossible (or extremely rare) that two people could touch at exactly the same time, so they would extrapolate the second touch from the first.



Scanning
Today, most multi-touch technologies are scanned. This means that the touch sensor (the thing you touch) is made up of rows and columns, most often one row on a top layer and one column on a bottom layer. Each row and column is connected to (at least) one conductive wire which goes to the electronics. The electronic controller will turn on one row and one column at a time and decide if there is a touch occurring at that point. For example, turning on column 1, the controller will start with row 1 and then check row 2 and so on until it has checked all rows for touches which may be occurring on column 1. Then the controller will move to column 2 and check all of the rows again. Once all of the row and column

combinations have been scanned, the process starts over. There are more efficient variations of this row and column scanning method but this is essentially how all of today’s multi-touch systems work.



Two Touch and Ghosting

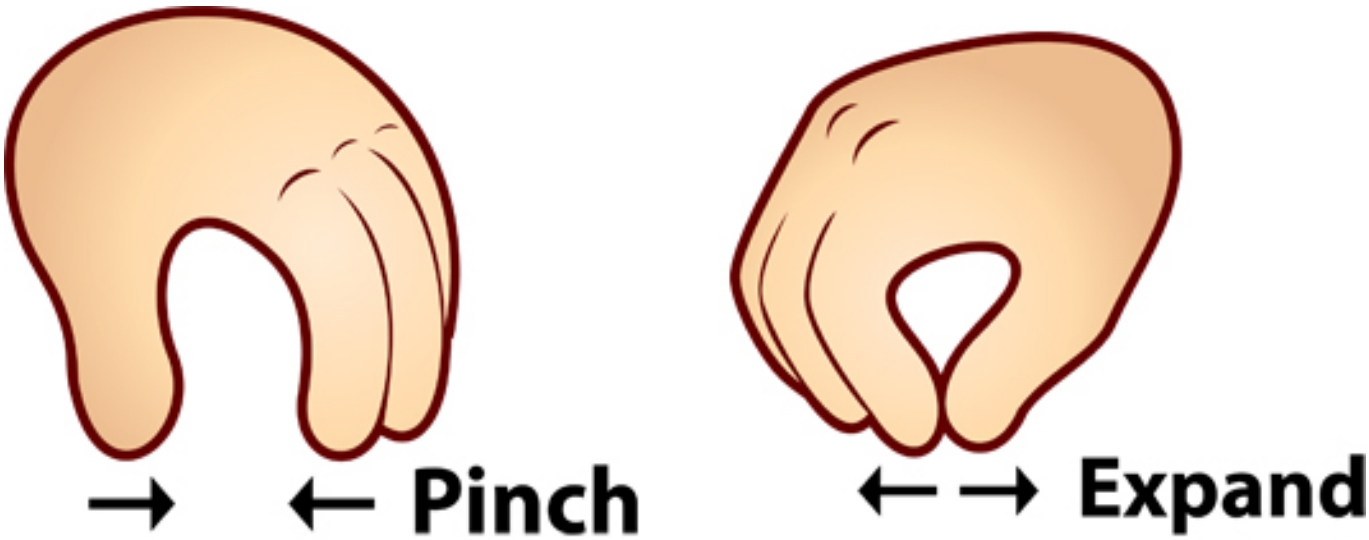
The reason multi-touch took so long to become accepted was because of a phenomena called ghosting. Ghosting means the controller cannot determine which of two coordinate pairs the “right one” is. Ghosting occurs when two touches are diagonal to each other, which is almost always the case. The only time ghosting doesn’t happen is when the two touches are located on the same row or same column. Here is why:

You can see that the touches are on row 5, column 3, and on row 2 column 6. The electronics can sense that rows 5 and 6, and columns 3 and 6 are active, so two touches are occurring. However, the electronics would sense the same rows and columns if the touches were occurring at row 5 and column 6 and row 2 and column 3.

So for 25 years this inability to determine which were the real two points caused customers to reject multi-touch and the touch manufacturers to report two touches as an error state instead of useful data.

The Genius of Apple

It is reported that the first versions of the iPhone multi-touch sensors had a ghosting “problem”. This smartphone made use of two multi-touch gestures -- “pinch” and “expand”. No doubt you are familiar with touching an image and making it larger or smaller by touching the corners and moving your fingers apart to expand, or moving your fingers closer together to pinch. To do this, notice from the drawing above, the electronics do not need to know which two corners are being touched, only that the picture is being pinched or expanded. So this super-cool feature of the iPhone was done from data which previously had been rejected as a problem!



True Multi-Touch
Once Apple had demonstrated the use for having two touches at the same time, the race was on for more applications which could use this feature. Microsoft had already developed a product called “Surface,” for which the applications called for the ability to unambiguously determine the exact location of up to ten touch points at the same time. In the subsequent release of Microsoft Windows® 7 (Tablet version), which supported multi-touch touch screens, the touch coordinates were required to be absolute.

Thus, the term “multi-touch” applies to two or more touches occurring at the same time, with the capability of knowing the exact position of each touch (no ghosting). Most multi-touch systems can demonstrate up to 10 fingers at the same time, but the Microsoft requirement is just two.

Multi-Touch Sensing Technology
Today, there are three technologies in common use that can sense multiple touches. All of these are covered in Touch International’s whitepaper “Choosing the Right Touch Technology.”

The most common multi-touch technology, projective/projected capacitive or pro-cap/ p-cap, is used in all cell phones and e-readers. Projected capacitive is the most widely used because, in addition to sensing multi-touch, the visual appearance of the display is good and the sensor will never wear out.

A second technology is MARS or Multi-Touch Analog Resistive System, also called AMR. This is an older technology which is essentially a 4-wire resistive sensor, cut up into many small 4-wire touch screens. The advantage of this technology is that it works best with pen-input systems because it is pressure sensitive.

The best choice for a very large display is an optical system using cameras. There are two versions, one which uses small cameras in the corners of the flat panel display (SMART/NextWindow), and another which uses an overhead (sometime underneath) camera with a projector (Microsoft Surface).

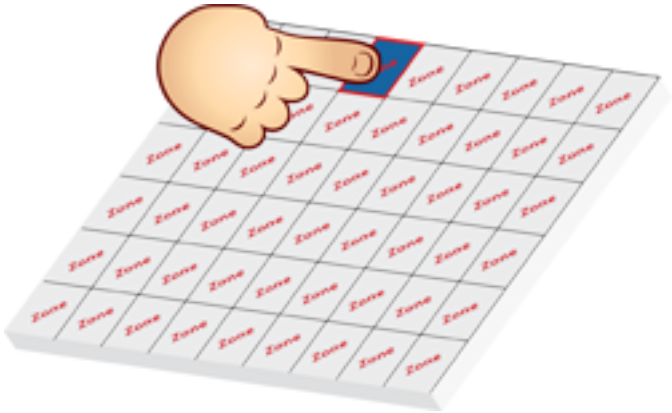
Multi-Touch Resolution and Speed
Most touch screens, including multi-touch sensors, generate a resolution of 1024 x 1024, or ten bit. The way in which the coordinates are generated is different with each of the three multi-touch technologies but all of them require substantial computing power to do this for up to ten fingers at the same time.

Human perception of “instant” is considered to be one-quarter of a second. To allow for the first point to be generated, processed by the computer and then shown on the display, the first touch point needs to be generated in a tenth of a second. This processing requirement is the same for multi-touch systems, which requires increased computing power.

Some users have noticed a delay when ten fingers are simultaneously drawing on the screen. Typically this is not because there is an inherent delay in the touch system, but because the host computer and its video adapter also need to be more powerful to accommodate this increase in data.

Software Interface
An early problem with multi-touch was how to report up to ten touches at the same time. Microsoft resolved (some would say, benevolently dictated) this problem by standardizing the way multiple input points were interpreted by the computer. To make it easy to integrate single touch displays into the computer environment, the X, Y coordinates (which is all that touch screens do) were treated as an “absolute” mouse. A regular mouse is a “relative” device which just tells the computer which direction to move the cursor. As an absolute mouse, the touch screen tells the computer where to move the cursor (under the finger, of course) by acting as though the mouse was manually moved to the touch point.

Multi-touch screens are treated as though they are multiple absolute mice connected to the computer at the same time. Thus, if the touch screen electronics are capable of generating 10 simultaneous touches, then the computer will see ten mice connected to it. Other operating systems, specifically Linux, have also adopted this method.



Multi-touch Zones

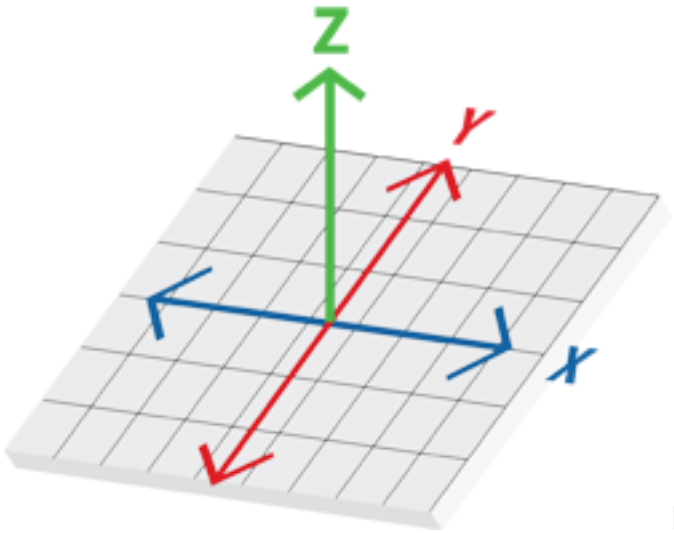
Projected capacitive and MARS systems generate analog (continuous) coordinates from zones formed by rows and columns; this is analog output from digital inputs. The rows and columns are generally 7-10 mm wide which is the best size to generate 1024 x 1024 coordinates quickly. In addition, the zones must be small enough that only one finger will fit in each zone; if the zones are larger, two fingers

can enter one zone, making it impossible for the system to distinguish two separate touches.

Making Multi-Touch Bigger
Most multi-touch applications are for 12.1 inch displays and smaller, excluding camera systems which are typically used for displays 32 inches and larger. Producing multi-touch screens in sizes from 12 to 32 inches presents two problems. First, it takes multiple processors to generate fast touch points. Second, with rows and columns in the 10mm range, there are a large number of connections. These two factors tend to increase the price of multi-touch displays; however, the durability offered to kiosk, point of sale and transaction machines justifies the cost.

Multi-Touch Gestures
A gesture is a description of what happens when two or more touches do “something”. Originally, these actions were coded in the touch controller chip, but now that multi-touch drivers are available in Windows and Linux systems, that function is left to those standard interfaces. Thus, the touch controllers once again just generate coordinates, albeit now there can be simultaneously up to 10 pairs.

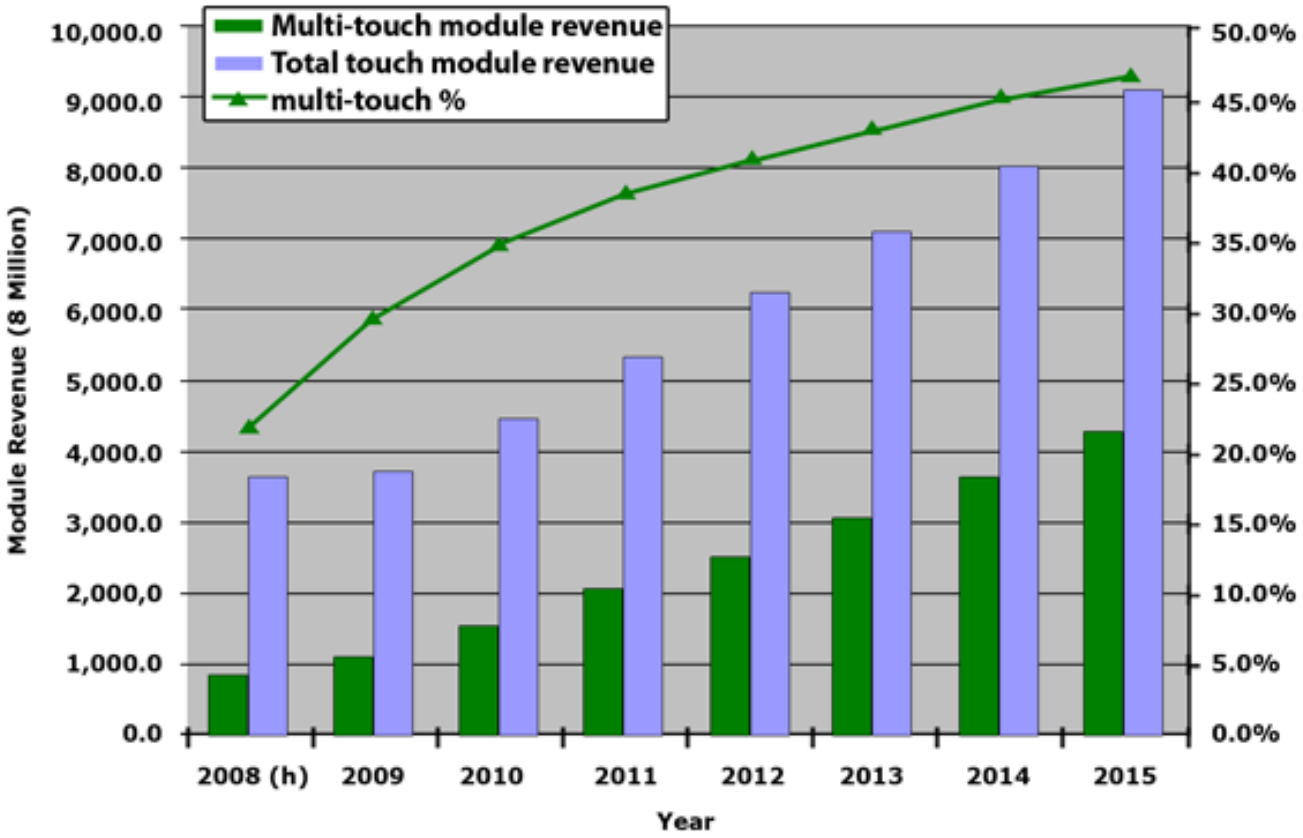
There are only three gestures that are unique to multi-touch systems. They are pinch, expand, and rotate. The others -- flick, hold, tap and pan -- can be done with older technologies but are easier with a projected capacitive system.



Multi-Dimensional Multi-Touch
The future of multi-touch is to add the distance (proximity or “Z”) dimension to touch screens. The now familiar video of Jeff Han (http://www.youtube.com/watch?v=89sz8ExZndc) waving his hands over the display to control the images is coming to smaller devices. Similar actions are common with TV news and sports broadcasts. Some game systems are already using cameras to allow multiple users to control the play without the need for wireless remote controls. This proximity sensing is being built into a number of smaller devices to both detect a presence of a person or to control actions without having to touch the display.

Conclusion
Thanks largely to the iPhone’s widespread success and the release of Windows 7, multi-touch technology has been firmly embedded into the mainstream market and

is here to stay. In the years to come, multi-touch systems are expected to show strong growth due to improved designs, reduced component prices and better software development. Dr. Jennifer K. Colegrove, Director of Display Technologies at DisplaySearch, estimates that by 2015, multi-touch sensor sales will grow to $4.2 billion and account for nearly half of touch screen sales worldwide.



Touch Screen Module Revenue and Multi-Touch Module Revenue Forecast
Source: DisplaySearch and Multi-Touch Module Revenue Forecast

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