Touch technologies for large-format applications

by Geoff Walker

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This article compares touch technologies that are used in large-format (> 30-inch) touch-display applications such as interactive digital signage, wayfinding, kiosks, education, and conference rooms.

There are more than a dozen touch-screen technologies in current or emerging use. These technologies can be classified in a number of different ways, such as by optical properties, degree of patent protection, number of years in the market, response to various touch objects, multi-touch capability, and many others. One simple classification method is by size range, as shown in Table 1.

Note 1: Once touchscreen sizes exceed 100 inches, "maximum size" becomes more a matter of bragging rights than significance. 167 and 150 inches are the largest pro-cap and infrared touchscreens (respectively) of which the author is aware; the former is made by Visual Planet (http://www.visualplanet.biz); the latter is made by IRTouch (http://www.irtouch.com).

Touch Technology (in order by maximum size)	Size Range (inches)
Projected Capacitive (Wires)	6-167 (note 1)
Traditional Infrared	6-150 (note 1)
Optical	15-120 (note 1)
Vision-Based (Projection)	30-100 (note 1)
Surface Acoustic Wave	10-52
Acoustic Pulse Recognition (APR from Elo)	3-52
Force Sensing	5-48
Dispersive Signal Technology (DST from 3M)	32-46
Surface Capacitive	6-32
LCD In-Cell (Voltage-Sensing)	3-26
LCD In-Cell & On-Cell (Charge-Sensing)	3-24
Analog Resistive	1-24
Multi-Touch (Digital) Resistive	2-22
Projected Capacitive (ITO)	2-22
LCD In-Cell (Light-Sensing)	3-20
Waveguide Infrared (from RPO)	3-19

Table 1: Touch technologies in order of their maximum size. Technologies greater than 32 inches are in green; see the text regarding the technologies in yellow.

Touch Technologies: Since this article is focused on technologies that are used in large-format applications, only the technologies shown in green in Table 1 are considered in the remainder of this article. The list is simplified slightly by eliminating two technologies – force-sensing, which is not yet available in production quantities larger than 30 inches, and vision-based, which requires a camera that takes an image of the entire screen from a distance. That leaves a total of six technologies to be compared. How each technology works is briefly described in the following paragraphs.

1. Projected Capacitive: Wire-based projected-capacitive touch screens consist of a two-layer, X-Y grid of 10-micron wires attached to the back surface of a film or glass substrate. The grid is energized with an AC signal that creates a three-dimensional electrostatic field. A controller measures the change in the field caused by the presence of a conductive finger at a small distance from the X-Y grid and calculates the point of touch.

2. Traditional Infrared: Infrared touch screens consist of a frame surrounding a glass or other flat substrate (or no substrate at all). Two adjacent sides of the frame contain a series of very closely spaced infrared LED transmitters; the other two sides of the frame contain a matching series of infrared photodiode receivers. The transmitters and receivers create an X-Y grid of infrared light beams just above the surface of the substrate. When a finger or other object enters the grid, it interrupts the light beams; a controller senses the interruption and calculates the point of touch.
3. Optical: Optical touch screens consist of a plain sheet of glass or other flat substrate (or no substrate at all), with two or more line-scanning optical sensors located at the corners of the substrate. Infrared light is distributed evenly across the surface of the substrate via a passive method with illuminated borders on the three facing edges. When a finger or other object touches the substrate, it blocks the light seen by the optical sensors. A controller analyzes the resulting optical information and uses triangulation to calculate the point of touch.
4. Surface Acoustic Wave: In surface acoustic wave (SAW) touch screens, ultrasonic sound waves emitted by transducers in two corners of a glass substrate are distributed across the surface in X and Y directions by reflectors formed on the edge of the glass. Ultrasonic transducers in the other two corners receive the sound waves via a second set of reflectors. When a finger (or any sound-absorbing object) touches the substrate, it interferes with (damps) the sound-wave propagation in both directions. A controller analyzes the changes and calculates the point of touch.
5. Bending-Wave (APR & DST): Bending-wave touch screens consist of a plain sheet of glass with four piezoelectric transducers attached to the back surface near the corners. When a finger or any object touches the substrate, minute vibrations (bending waves) occur within the substrate. A controller compares the "signature" of the vibrations against a stored list of signatures (in APR from Elo TouchSystems) or analyzes the vibrations in real time (in DST from 3M) and calculates the point of touch.

Touch Characteristics: Table 2 below lists 19 characteristics that can be used to compare touch technologies. These are not the only characteristics that can be used (the available total is over 40); however, this list include those characteristics that tend to be more significant in evaluating large-format touch screens. The following paragraphs briefly explain the rating of each characteristic in Table 2.

- Touch with Any Object: Projected capacitive (pro-cap) can only be touched with a finger; SAW can only be touched with a soft (sound-absorbing) object; the others have no restriction. Unless there are specific application reasons for limiting the touch object (e.g., regulated gaming), more is better.
- Touch with a Small Object: Infrared (IR) and pro-cap require the largest touch-object size (typically over 5 mm); optical and SAW requires a touch object in the 3-5 mm range; bending wave (APR & DST) have no restriction. The smaller the touch object can be, the easier it is to use a stylus.
- Light Touch: SAW typically requires a touch force of 80 grams; APR requires a noticeable "tap" (unspecified force; enough to generate some bending waves); DST requires a very light touch (less than 10 grams); optical and IR don't require any force; pro-cap's touch activation force is adjustable and can be set to sense a finger above the screen (this is called "proximity sensing"). SAW's relatively high touch force can become tiring after long use; APR's need for a "tap" makes it inappropriate for "shy" users in public (those who barely touch the screen because they're unsure of what to do).
- No Unintended Touch: An "unintended touch" occurs when a touch is sensed above the substrate; it's also called "pre-touch". IR has the greatest amount of pre-touch (often more than 3 mm); optical has a moderate amount (1-2 mm); the others have none. In applications that involve the transfer of money (e.g., gambling), unintended touch is undesirable.

- Multi-Touch: SAW, APR and DST do not currently support multi-touch in sizes above 30 inches (Elo TouchSystems has announced two-touch SAW in 22 inches only); optical and IR both currently support a limited number of multiple simultaneous touches; pro-cap technically can support an unlimited number of touches, although none of the current implementations on the market support more than two touches. The need for multi-touch in large-format applications is primarily for multiple users rather than multiple fingers on a single user.
- Touch-and-Hold: Touch-and-hold refers to the ability to drag something on the screen, pause (while holding your finger on the screen) and then continue to drag. Neither APR nor DST have this capability because when the touching object stops moving, no more bending waves are generated and the driver must execute a mouse-up since it can't tell if the user is still touching the screen. Touch-and-hold is required to use any version of Windows.

Characteristic	Optical	Infrared	Projected Capacitive	SAW	APR	DST
Touch with any object	H	H	L	M	H	H
Touch with a small object	M	L	L	M	H	H
Light touch	H	H	H	L	M	H
No unintended touch	M	L	H	H	H	H
Multi-touch	M	M	M	L	L	L
Touch-and-hold	H	H	H	H	L	L
Object size recognition	H	L	M	L	L	L
Measures Z-axis	M	L	M	H	L	L
High optical performance	H	H	M	H	H	H
Flush surface (low profile)	M	L	H	M	H	H
Resistant to contaminants	M	M	H	L	H	H
Insensitive to EMI and RFI	H	H	L	H	H	H
Insensitive to ambient infrared	M	M	H	H	H	H
Works with plastic substrate	H	H	H	L	L	L
Works on curved substrate	L	L	H	L	L	L
Scalable	H	L	M	M	H	H
Simple sensor manufacturing	H	M	L	M	H	H
High MTBF	H	L	M	M	H	M
Multiple sources	H	H	H	H	L	L

Table 2: Ratings of 19 characteristics of six touch technologies used in large-format applications.
***H** (Green) = **H**igh or Best; **M** (Yellow) = **M**edium or OK; **L** (Red) = **L**ow or Worst*

- Object Size Recognition: IR, SAW, APR and DST are not able to sense the size of a touching object. Optical and pro-cap can, although the mechanisms are different. Optical triangulates four edges of a touching object and can therefore estimate the outline of the touching object; this is useful for automatically determining whether the touching object is (for example) a pen, a paintbrush, or an eraser and acting accordingly. Pro-cap can approximate the size of a touching object by measuring how many wire intersections are covered by the object; however, since the touching object must be part of a human being (i.e., have significant capacitance to ground), this is not particularly useful.
- Measures Z-axis: Measuring the Z-axis means being able to detect how much pressure the touch object is exerting against the touch screen. Of these six technologies, only SAW has the actual ability to measure pressure – and it's very low resolution (not more than about 4 bits). Pro-cap and optical can

simulate the measurement of pressure for a single user by estimating the touch-object size (pressing harder flattens your finger), but that method doesn't work with multiple users with varying finger-sizes.

- High Optical Performance: Pro-cap is the only technology of the six that inserts something other than plain glass between the user and the display; it uses 10-micron wires attached to plastic film (e.g., PET) or glass. The wires are barely visible to the human eye; in intermittent-use large-format applications, this isn't a problem. In continuous-use applications the visibility of the wires can become annoying to a user. Optical and IR are capable of the best optical performance, since they don't actually require any substrate at all.
- Flush Surface: The ability to have edge-to-edge glass (a totally flush top surface) on a product can be a desirable industrial design feature. Pro-cap, APR and DST are all capable of flush surfaces, since the sensing elements are on the rear of the glass. This also allows these technologies to be vandal-proofed to a greater extent than the others. Optical and SAW have a profile height of 1-3 mm; IR's profile height is typically in the 3-5 mm range.
- Resistant to Contaminants: Pro-cap, APR and DST are resistant to contaminants due to their sensing mechanisms; pro-cap is generally considered to be the most resistant. This same resistance makes pro-cap the technology most suited for use in rain, snow and ice. Optical and IR are susceptible to contaminants blocking the IR light beams; SAW is the most susceptible to contaminants of the six technologies – for example, water on the surface of a SAW touch screen creates a dead spot.
- Insensitive to EMI and RFI: Only pro-cap is sensitive to EMI and RFI. As a result, it can be difficult to mount a pro-cap touch screen directly on top of an LCD or plasma screen due to the noise generated by the display; some amount of air gap is usually used.
- Insensitive to Ambient Infrared: Only optical and IR are sensitive to ambient infrared, since they both use IR-sensitive photo sensors. This can be an issue in outdoor use, especially near the equator.
- Works with Plastic Substrate: SAW, APR and DST all rely on the particular characteristics of a glass substrate; pro-cap works equally well with plastic or glass; and as previously mentioned, optical and IR can be used with no substrate at all.
- Works on Curved Substrate: Because it uses plastic film as a substrate, pro-cap is the only technology of the six that can be applied to a curved (2D) surface. The others require a flat surface.
- Scalable: Optical is the most scalable of the six technologies because it can be made larger by simply increasing the length of the reflective border on three sides of the screen. APR and DST are scalable because the size of the glass can be increased (within their maximum size limits of 52 and 46 inches respectively) without changing anything else. Pro-cap and SAW are less scalable, since expanding them requires adding more wires (pro-cap) or more reflectors (SAW). IR is the least scalable of all because of the circuit board that surrounds the entire screen; every added inch means adding more IR transmitter-receiver pairs.
- Simple Sensor Manufacturing: Optical, APR and DST all have relatively simple-to-manufacture sensors, requiring only the attachment of minimal hardware to the glass (and printing a few low-resolution conductors for APR and DST). IR and SAW require more substrate processing; pro-cap requires the most processing in order to attached the 10-micron wires to the film or glass in the proper pattern.
- High MTBF: The number of components in a touch-screen system can be translated into mean time between failures (MTBF). Because of the numerous IR transmitter-receiver pairs surrounding the screen, IR has the most components, which means the lowest MTBF. Pro-cap, SAW, and DST all have fairly complex controllers, which increases the component count. Optical and APR have the simplest systems and thus the least number of components.

- Multiple Sources: APR and DST are sole-sourced from Elo TouchSystems and 3M respectively; the other four technologies are all available from multiple suppliers. The ability to purchase from multiple suppliers can reduce a project's risk.

Conclusions: The clear message of Table 2 is that "there is no perfect touch technology"! None of the six columns have a majority of green. Every technology has distinct strengths and weaknesses; this means that each application must be carefully analyzed to determine its specific requirements before selecting the best technology for that application.

When selecting the best technology for a given application, it is appropriate to weight each of the factors in Table 2. In a real-world situation, one factor can easily be two or three times more important than another factor. But since that weighting is application-dependent, this article can only weight all the factors equally. Assigning a value of 3 to green, 2 to yellow and 1 to red produces the following ranking for the six technologies:

Touch Technology	Total Points
Optical	47
Projected Capacitive	43
APR	42
DST	42
SAW	39
Traditional Infrared	37

Optical being at the top of the list (i.e., having the most number of desirable characteristics for large-format applications) is not a surprise. In their 4Q-2009 market research report entitled "Touch-Screen Interfaces Continue to Drive Growth in Signage and Professional Applications", iSuppli forecasted that optical touch would grow to be the biggest large-format touch technology in both units (25%) and revenue (33%) by 2013. Optical touch is definitely worth considering!