Comparative Study of Various Touchscreen Technologies

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ABSTRACT
First computers became more visual, then they took a step further to understand vocal commands and now they have gone a step further and became 'TOUCHY', that is skin to screen. In this paper we will throw light on significance of touchscreen technology, its types, components, working of different touchscreens, their applications and a comparative study among various types of touchscreen technologies. Recently touchscreen technology is increasingly gaining popularity as these can be seen at ATMs, cellphones, information kiosks etc. Touch screen based system allows an easy navigation around a GUI based environment. As the technology advances, people may be able to operate computers without mice and keyboards.

The touchscreen is an assistive technology. This interface can be beneficial to those that have difficulty in using other input devices such as a mouse or keyboard. When used in conjunction with software such as on-screen keyboards, or other assistive technology, they can help make computing resources more available to people that have difficulty in using computers. Currently various researches are being made to develop touchscreen video projectors. The ability to transform any surface in a touchscreen means lower costs, making the technology more cost effective.

Keywords
Touchscreen Technologies, Resistive Touchscreen, Capacitive, Surface Acoustic Wave.

1. INTRODUCTION
A touchscreen is an electronic visual display that can detect the presence and location of a touch within the display area. The term generally refers to touching the display of the device with a finger or hand. Touch screens can also sense other passive objects, such as a stylus. In other words, a touchscreen is any monitor, based either on LCD (Liquid Crystal Display) or CRT (Cathode Ray Tube) technology that accepts direct onscreen input. The ability for direct onscreen input is facilitated by an external (light pen) or an internal device (touch overlay and controller) that relays the X, Y coordinates to the computer.

The touchscreen has two main attributes. First, it enables one to interact directly with what is displayed, rather than indirectly with a cursor controlled by a mouse or touchpad. Secondly, it lets one do so without requiring any intermediate device that would need to be held in the hand.

Touchscreen technology has the potential to replace most functions of the mouse and keyboard. The touchscreen interface is being used in a wide variety of applications to improve human-computer interaction. As the technology advances, people may be able to operate computers without mice and keyboards. Because of its convenience, touch screen technology solutions has been applied more and more to industries, applications, products and services, such as Kiosks, POS (Point-of-Sale), consumer electronics, tablet PC, moderate to harsh Machine Control, Process Control, System Control/Office Automation and Car PC, etc.

2. TYPES OF TOUCHSCREEN TECHNOLOGY
The touch panels themselves are based around four basic screen technologies: Resistive, Capacitive, Surface Acoustical Wave (SAW) and Infrared (IR). Each of those designs has distinct advantages and disadvantages. The detailed study of each is as follows:

2.1 Resistive
Resistive LCD touchscreen monitors rely on touch overlay, which is composed of a flexible top layer and a rigid bottom layer separated by insulating dots, attached to a touchscreen controller. The inside surface of each of the two layers is coated with a transparent metal oxide coating of Indium Tin Oxide (ITO) that facilitates a gradient across each layer when voltage is applied. Pressing the flexible top sheet creates electrical contact between the resistive layers, producing a switch closing in the circuit. The control electronics alternate voltage between the layers and pass the resulting X and Y touch coordinates to the touchscreen controller. The touchscreen controller data is then passed on to the computer operating system for processing.
Resistive touch screen panels are generally more affordable but offer only 75% clarity and the layer can be damaged by sharp objects. Resistive touch screen panels are not affected by outside elements such as dust or water. Resistive touchscreens are used in food-service; retail Point-Of-Sale (POS), medical monitoring devices, portable and handheld products, industrial process control and instrumentation. Resistive Technology is divided into two broad categories:

2.1.1) 4 -Wire Resistive Touchscreen Technology
Four-wire resistive technology is the simplest to understand and manufacture. It uses both the upper and lower layers in the touchscreen "sandwich" to determine the X and Y coordinates.

Typically constructed with uniform resistive coatings of ITO on the inner sides of the layers and silver buss bars along the edges, the combination sets up lines of equal potential in both X and Y.

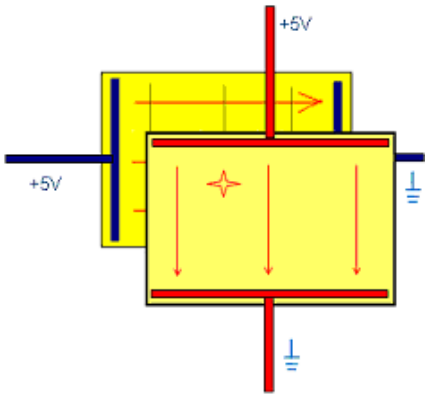

Fig 1:- A simple 4-wire touchscreen

In the illustration below, the controller first applies 5V to the back layer. Upon touch, it probes the analog voltage with the coversheet, reading 2.5V, which represents a left-right position or X axis.

It then flips the process, applying 5V to the coversheet, and probes from the back layer to calculate an up-down position or Y axis. At any time, only three of the four wires are in use.

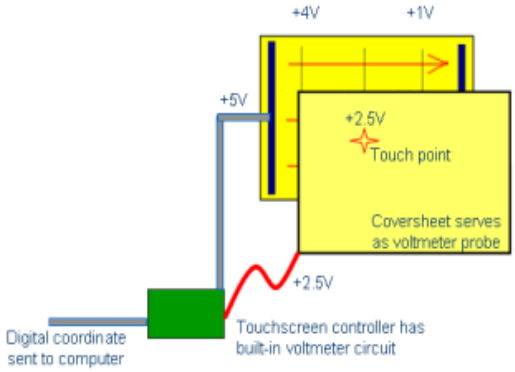

Fig 2:- Working of 4-Wire Touchscreen

The primary drawback of four-wire technology is that one coordinate axis (usually the Y axis), uses the outer layer, the flexible coversheet, as a uniform voltage gradient. The constant flexing that occurs on the outer coversheet with use will eventually cause microscopic cracks in the ITO coating, changing its electrical characteristics (resistance), degrading the linearity and accuracy of this axis.

2.1.2) 5-Wire Resistive Touchscreen Technology

In the five-wire design, one wire goes to the coversheet (E) which serves as the voltage probe for X and Y. Four wires go to corners of the back glass layer (A, B, C, and D). The controller first applies 5V to corners A and B and grounds C and D, causing voltage to flow uniformly across the screen from the top to the bottom. Upon touch, it reads the Y voltage from the coversheet at E. Then the controller applies 5V to corners A and C and grounds B and D, and reads the X voltage from E again.

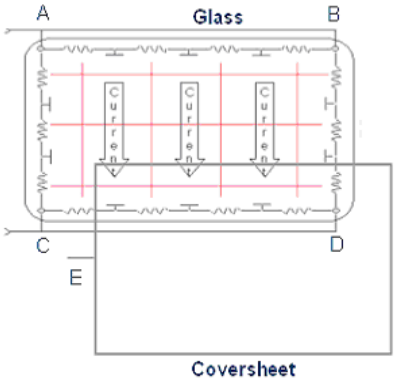

Fig 3:- 5-Wire Resistive Touchscreen

So, a five-wire touchscreen uses the stable bottom layer for both X- and Y-axis measurements. The flexible coversheet acts only as a voltage-measuring probe. This means the touchscreen continues working properly even with non-uniformity in the coversheet's conductive coating. The result is an accurate, durable and more reliable touchscreen over four- and eight-wire designs. Microscopic cracks in the coversheet coating might occur, but they would no longer cause non-linearities as in the case of 4 wire resistive touch screen.

2.2 Capacitive

A capacitive touch screen panel is coated with a material that stores electrical charges. When the panel is touched, a small amount of charge is drawn to the point of contact. Circuits located at each corner of the panel measure the charge and send the information to the controller for processing. Capacitive touch screen panels must be touched with a finger unlike resistive and surface wave panels that can use fingers and stylus.

Capacitive touch screens have excellent clarity, and there are no moving parts to wear out. Liquids, dirt, grease, or other contaminants do not affect them. Unfortunately, gloved fingers will not activate the system. It is divided into two broad categories as follows:

2.2.1) Surface capacitive technology

In this technology, only one side of the insulator is coated with a conductive layer. A small voltage is applied to the layer, resulting in a uniform electrostatic field. When a conductor, such as a human finger, touches the uncoated surface, a capacitor is dynamically formed. The sensor's controller can determine the location of the touch indirectly from the change in the capacitance as measured from the four corners of the panel. As it has no moving parts, it is moderately durable, has limited resolution and is prone to false signals from parasitic capacitive coupling. It is therefore most often used in simple applications such as industrial controls and kiosks.

2.2.2) Projected capacitive technology

Projected Capacitive Touch (PCT) technology is a capacitive technology which permits more accurate and flexible operation, by etching the conductive layer. An X-Y grid is formed either by etching a single layer to form a grid pattern of electrodes, or by etching two separate, perpendicular layers of conductive material with parallel lines or tracks to form the grid. A finger on a grid of conductive traces changes the capacitance of the nearest traces. This change in trace capacitance is measured and finger position is computed.

The use of an X-Y grid permits a higher resolution than resistive technology. Projected capacitive touch screens are clear, durable, solid state, scratch resistant and allow gloved hand use. All these features make them ideal for harsh, industrial, or outdoor applications.

2.3 Infrared

An infrared touchscreen uses an array of X-Y infrared LED and photodetector pairs around the edges of the screen to detect a disruption in the pattern of LED beams. A major benefit of such a system is that it can detect essentially any input including a finger, gloved finger, stylus or pen. It is generally used in outdoor applications and Point-Of-Sale systems which can't rely on a conductor (such as a bare finger) to activate the touchscreen. Unlike capacitive touchscreens, infrared touchscreens do not require any patterning on the glass which increases durability and optical clarity of the overall system.

2.4 Surface Acoustic Wave

The Surface Acoustic Wave (SAW) technology is one of the most advanced touch screen types. The technology is based on two transducers (transmitting and receiving) placed for the both of X and Y axis on the touch panel. The other important element of SAW is placed on the glass, called reflector. The controller sends electrical signal to the transmitting transducer, and transducer converts the signal into ultrasonic waves and emits to reflectors that are lined up along the edge of the panel. After reflectors refract waves to the receiving transducers, the receiving transducer converts the waves into an electrical signal and sends back to the controller. When a finger touches the screen, the waves are absorbed, causing a touch event to be detected at that point.

Compared to Resistive and Capacitive technologies, SAW technology provides superior image clarity, resolution, and higher light transmission. Because the panel is all glass, there are no layers that can be worn, giving this technology the highest durability factor and also the highest clarity. Disadvantages of Surface Acoustic Wave (SAW) technology include the facts that the touch screen must be touched by finger, gloved hand, or soft-tip stylus (something hard like a pen won't work) and that the touchscreen is not completely sealable, can be affected by large amounts of dirt, dust, and / or water in the environment.

The Surface Acoustic Wave technology is recommended for ATMs, Amusement Parks, Banking and Financial Applications, public information kiosks, computer based training, or other high traffic indoor environments. Surface wave touch screen panels are the most advanced of the four types. SAW offers excellent clarity and durability and allows gloved hand use. However, SAW is expensive, is difficult to seal from the environment, and can be activated inadvertently by dirt, grease, or liquids and can be damaged by outside elements.

3. COMPONENTS OF TOUCHSCREEN

A basic touchscreen has three main components: a touch sensor, a controller, and a software driver. The touchscreen is an input device, so it needs to be combined with a display and a PC or other device to make a complete touch input system.

3.1 Touch Sensor

A touch screen sensor is a clear glass panel with a touch responsive surface. The touch sensor/panel is placed over a display screen so that the responsive area of the panel covers the viewable area of the video screen. The sensor generally has an electrical current or signal going through it and touching the screen causes a voltage or signal change. This voltage change is used to determine the location of the touch to the screen.

3.2 Controller

The controller is a small PC card that connects between the touch sensor and the PC. It takes information from the touch sensor and translates it into information that PC can understand. The controller is usually installed inside the monitor for integrated monitors or it is housed in a plastic case for external touch add-ons/overlays. The controller determines what type of interface/connection you will need on the PC. Controllers are available that can connect to a Serial/COM port (PC) or to a USB port (PC or Macintosh). Specialized controllers are also available that work with DVD players and other devices.

3.3 Software Driver

The driver is a software update for the PC system that allows the touchscreen and computer to work together. It tells the computer's operating system how to interpret the touch event information that is sent from the controller. Some equipment such as thin client terminals, DVD players, and specialized computer systems either do not use software drivers or they have their own built-in touch screen driver.

Fig 4:- Components of Toushscreen

4. WORKING OF VARIOUS TOUCHSCREENS

Touchscreens are activated by the insertion or removal of the fingertip or by pressing the controls, active areas or targets with a

Touchscreens are activated by the insertion or removal of the fingertip or by pressing the controls, active areas or targets with a mouthstick, headstick, or other similar device (stylus). Some touchscreens support stylus input and others do not. The difference is in the device's touch sensor technology, of which there are several common types:

- Resistive touchscreens are pressure sensitive, so they can be operated with any input device, including a gloved hand or stylus. However, resistive screens can be easily damaged by sharp objects and they offer only 75% clarity, which may create additional problems for people with low vision.

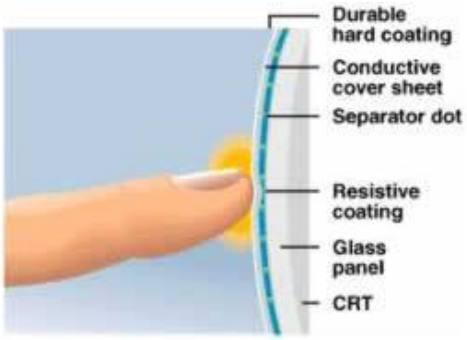

Fig 5:- A cut-away section of a resistive touchscreen

- Capacitive touchscreens offer higher clarity and are more durable, but they do not respond to gloved hands or most styluses (the pointing device must be grounded).

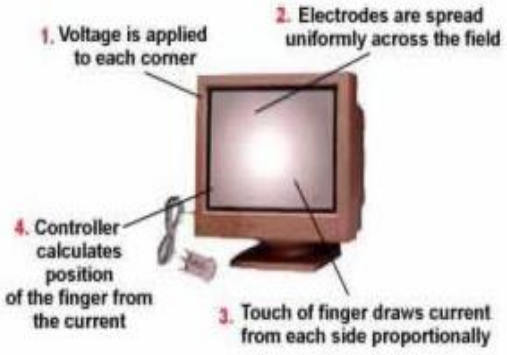

Fig 6:- Working of Capacitive Touchscreen

- Infrared touch screens are based on light-beam interruption technology. Instead of an overlay on the surface, a frame surrounds the display. The frame has light sources, or Light Emitting Diodes (LEDs) on one side and light detectors on the opposite side, creating an optical grid across the screen.
  When an object touches the screen, the invisible light beam is interrupted, causing a drop in the signal received by the photo sensors. These screens can be operated by either human touch or stylus. They also provide high clarity and durability. However, they are more receptive to false responses (by dirt, flying insects, etc.) and do not respond well to users whose fingers hover before pressing a control.

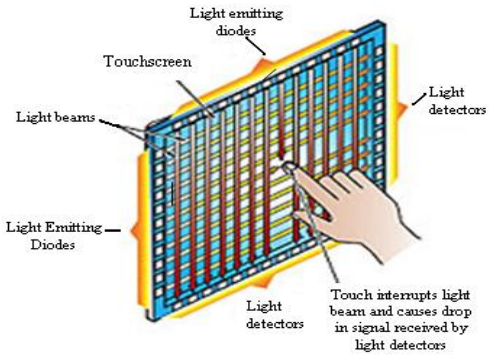

Fig 7:- Working of Infrared Technology

- Surface Acoustic Wave (SAW) is a newer technology that uses ultrasonic waves that pass over the screen . When the panel is touched , there is a change in the frequency of ultrasonic wave and the receiver at end of the panel register this change. Since only glass is used with no coating, there is nothing that wears out.

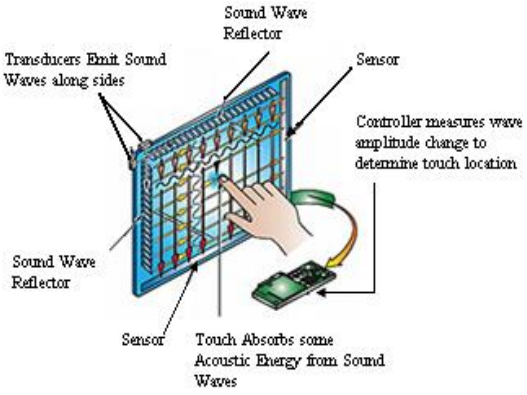

Fig 8:- Working of Surface Acoustic Waves Technology

This technology is a more advanced technology that provides high clarity and durability and can be operated by either human touch or stylus. This technology, however, is considerably more expensive than the more common technologies and is not as well supported.

5. TOUCHSCREEN RESOLUTION

The resolution, or number of touch active points on the touchscreen, affects the level of pointing precision and selection errors. For example, a capacitive screen has a touch resolution of 256 x 256 and an infrared screen has a resolution of 25 x 40 due to limitations on the number of light beams that can be placed around the screens. Therefore, a higher resolution screen provides additional touch points allowing greater pointing precision because the software can average all the points that have been touched and there are less selection errors as touch points are mapped more easily to the targets on the display.

Table 1- Comparison of various Touchscreen Technologies

Properties	4-Wire Resistive	5-Wire Resistive	Surface Acoustic Wave	Capacitive	Infrared
Type	Surface Technique(Electrical)	Surface Technique(Electrical)	Surface Technique(Acoustic)	Surface Technique(Electrical)	Edge Technique(Optical)
Durability	3 Year	5 Year	5 Year	2 Year	5 Year
Transparency	Bad	Bad	Good	Normal	Good
Stability	High	High	Higher	Normal	High
Touch	Anything	Anything	Finger/Pen	Conductive	Finger/Pen
Response time	<10ms	<15ms	10ms	<15ms	<20ms
Sensitivity	Very sensitive to scratch	Very sensitive to scratch	Sensitive to scratch	Sensitive to dirt	ambient light
Following Speed	Good	Good	Low	Good	Good
Chemical Resistance	Alcohol, acetone, grease, and general household detergent	Acetone, Methylene chloride, Turpentine, Isopropyl alcohol, Hexane, Tea, Vinegar, Coffee	Resistant to all chemicals that do not affect glass, such as: Acetone, Toluene, Gasoline, Kerosene, Vinegar	Resistant to all chemicals that do not affect glass, such as: Acetone, Toluene, Gasoline, Kerosene, Vinegar	Alcohol, acetone, grease, and general household detergent
Waterproof	Good	Good	Normal	Good	Normal
Intense light-resistant	Good	Good	Good	Bad	Bad
Multiple Events Support	Yes	No	No	No	No
Installation	Built-in/Onwall	Built-in/Onwall	Built-in/Onwall	Built-in	Onwall
Software Drivers	Windows XP / 2000 / NT / ME / 98 / 95, Linux, Macintosh OS	Windows XP, 2000, NT, ME, 98, 95, 3.1, DOS, Macintosh OS, Linux, Unix (3rd Party)	Windows XP, 2000, NT, ME, 98, 95, 3.1, DOS, Macintosh OS, Linux, Unix (3rd Party)	Windows XP, 2000, NT, ME, 98, 95, 3.1, DOS, Macintosh OS, Linux, Unix (3rd Party)	Windows XP / 2000 / NT / ME / 98 / 95, Linux, Macintosh OS
Monitor option	CRT or LCD	CRT or LCD	CRT or LCD	CRT or LCD or LED	CRT or LCD
Cost	Low cost(for small Sizes)	Low cost (for small sizes)	High	Moderate	High
Advantages	Low cost (for small sizes), can detect any object	Low cost (for small sizes), can detect any object	Can be deployed to a curved surfaces	Moderate cost, good in harsh environments	No overlay, Superior image, can detected any object which blocks
Disadvantages	High costs for large areas, very sensitive to scratch, low fidelity and reduces the visibility of the screen	High costs for large areas, very sensitive to scratch, low fidelity and reduces the visibility of the screen	Delicate, expensive and sensitive to scratch	Finger activation only, reduces illumination, finger must stay in position for detection so no movement	Expensive, detection placed above screen and sensitive to ambient light

6. ADVANTAGES AND DIS-ADVANTAGES OVER OTHER POINTING DEVICES

6.1 Advantages

Touch screens have several advantages over other pointing devices;

- Touching a visual display of choices requires little thinking and is a form of direct manipulation that is easy to learn.
- Touch screens are the fastest pointing devices.
- Touch screens have easier hand eye coordination than mice or keyboards.
- No extra work space is required as with other pointing devices
- Touch screens are durable in public access and in high volume usage.

6.2 Disadvantages

- User's hand may obscure the screen.
- Screens need to be installed at a lower position and tilted to reduce arm fatigue.
- Some reduction in image brightness may occur.
- They cost more than alternative devices.
- Screens get very dirty
- These devices require massive computing power which leads to slow devices and low battery life
- Touchscreen devices usually has no additional keys (see the iPhone) and this means when an application crashes, without crashing the OS, you can't get to the main menu as the whole screen becomes unresponsive

6. APPLICATIONS OF TOUCHSCREEN

The touch screen is one of the simplest PC interfaces to use, making it the interface of choice for a large number of applications. Following are uses of touch screen:

6.1 Public Information Displays

Tourism displays, trade show displays, Information kiosks and other electronic displays are used by large number of people that have little or no computing experience. The touch screen interface is easier to use than other input devices especially for novice users. A touch screen is useful to make your information more easily accessible by allowing users to navigate your presentation by simply touching the display screen.

6.2 Retail and Restaurant Systems

Time is money, especially in a fast paced retail or restaurant environment. In retail or restaurant environment, touch screen systems are easy to use so employees can get work done faster and also training time can be reduced for new employees. As input is present right on the screen, valuable counter space can be saved. Touch screens can be used in order entry stations, cash registers, seating, reservation systems and more.

6.3 Control and Automation Systems

The touch screen device is useful in systems ranging from industrial process control to home automation. Valuable workspace can be saved by integrating the input device with the display. In real-time by simply touching the screen and with a graphical interface, operators can monitor and control complex operations.

6.4 Computer Based Training

The touch screen interface is more user-friendly than other input devices so overall training time for computer novices and therefore training expense can be reduced. It can also more useful to make learning more fun and interactive, which can lead to a more beneficial training experience for both students and educators.

6.5 Assistive Technology

The touch screen interface is very useful for those having difficulty using other input devices such as a mouse or keyboard. When touch screen used with software such as on-screen keyboards or other assistive technology, they can help make computing resources more available to people that have difficulty using computers.

The touch screen interface is being used in a wide variety of applications to improve human-computer interaction. Touchscreens are the most common means of input in Personal Digital Assistants (PDAs). Other applications include digital jukeboxes, computerized gaming, student registration systems, multimedia software, financial and scientific applications and more.

7. CONCLUSION AND FUTURE SCOPE

The touch screen interface is easier to use than other input devices. It is useful to make information more easily accessible by allowing user to navigate by simply touching the display screen.

Currently the touch screens in the laptops mostly have single-touch technology. This means that the computer understands instructions a single touch at a time. Some laptops do include multi-touch capabilities; however, these capabilities are very limited and not really useful. More advanced technology like the one from Japanese Company Wacom, would bring multi-touch capabilities where people can work on more than one object simultaneously. This would bring the touch screen laptop computer capabilities nearer to the real world where people can work with their both hands with great coordination. These laptops with touch screen would allow you to touch, drag, rotate many applications or objects simultaneously, increasing the work productivity. This would help people to work naturally rather than with input devices like mice and keyboard

which can become a bit cumbersome specially when creating images.

Touchscreens can suffer from the problem of fingerprints on the display. This can be mitigated by the use of materials with optical coatings designed to reduce the visible effects of fingerprint oils, such as the oleophobic coating used in the iPhone 3G, or by reducing skin contact by using a fingernail or stylus.

The future of touch surface is touchscreen video projectors. In a restaurant, for e.g., you can place your order using the surface of the table as the touch interface, instead of using a touch screen laptop. The ability to transform any surface in a touchscreen means lower costs, making the technology more cost effective.

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