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Benchmark Analysis of Sensors Used in Modern Smart Phones

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ABSTRACT: Mobile phones are being used extensively in recent times. People's lives are becoming mobile phone centric (esp. smart phone). Today's smart phones provide every feature that is in demand by users all round the globe. Research activities are seen pursued in this area to make sure that user convenience is met through the advent of sensor technology in mobile phones. In this regard, it becomes quite mandatory for mobile vendors to understand sensors and there usage in mobile phones. This chapter gives an understanding on various sensors available on a mobile phone and their sensing paradigms. Analysis on different classifications of a sensor is also made on few of them.

KEYWORDS: Ambient light, Proximity, Surface Acoustic, Touch Screen, Cavity Array, Accelerometer, Gyroscope, GPS System.

I. INTRODUCTION

Emergence of powerful data sensing, data processing, low power and low cost sensors has been possible with the recent technological advancements in the area of wireless communications and electro mechanical systems. These multifunctional sensor nodes are tiny in size and capable of communicating readily over short distances. These significant features of the sensor nodules illustrate the capabilities of the modern sensors and its supremacy over traditional sensors. The mentioned sensor nodules are of two types:

- Sensors which can be deployed far away from the actual phenomenon. Here large sensors having high capacity of sensing and power are used.
- Sensors composing of low power and intelligent spark sensing. Hear tiny sensors which are low in cost are used.

It has been possible for advances to be made in different verticals of an organization by the introduction of sensor nodules. The innovative usage of sensors in mobile phones has let them to act as a sensing device. The key actions performed by sensors present in a mobile phone are:

- Sensing
- Learning
- Informing
- Sharing and
- Persuasion

Mobile phones (especially smart phones) typically comprise of almost 8 different sensors for capturing crucial details [1]. Each of these sensors is classified based on different criteria's. The most important criteria that is taken into account in a mobile phone is the application standard. Fig 1. depicts the various sensors (that includes both trivial and non trivial sensors) available in a mobile phone.

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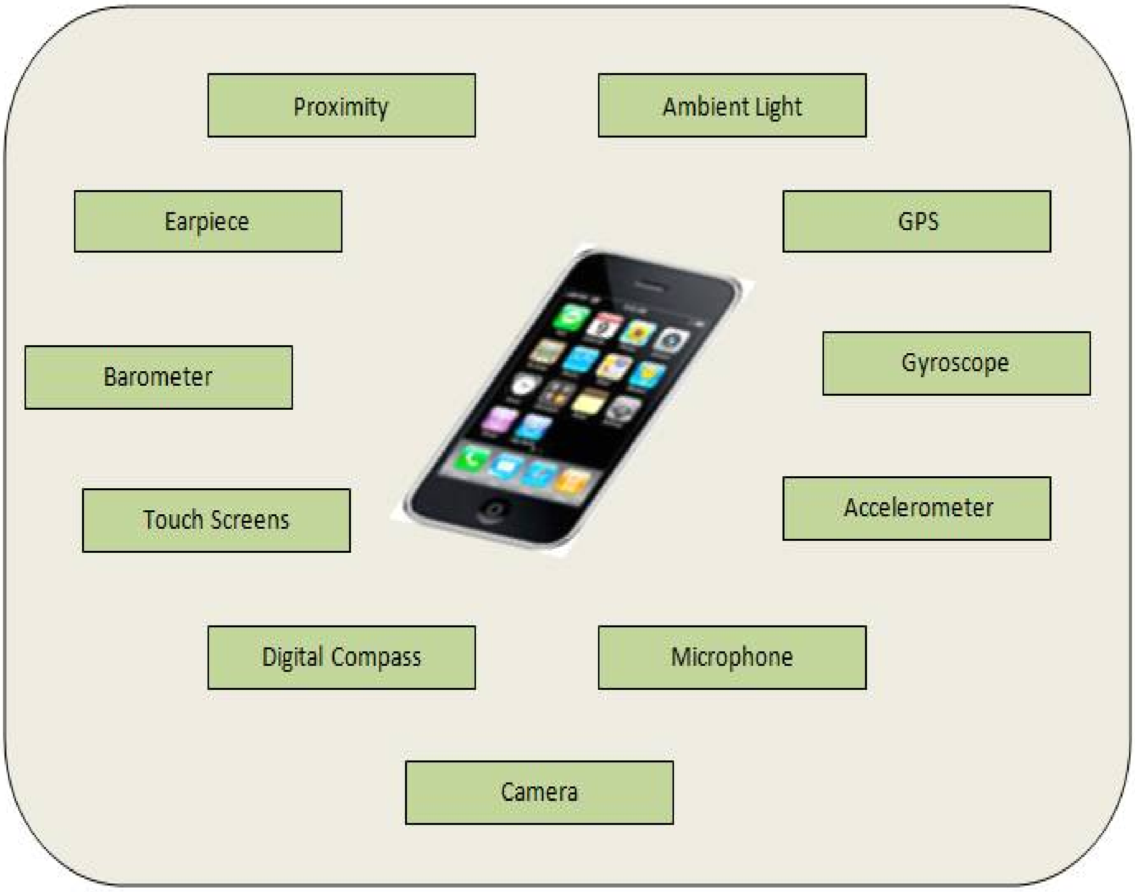

Fig 1: List of commonly available sensors on a typical smart

Analysis on these sensors and benchmarking few of them is done in this chapter. Among the sensors depicted in fig 1, the ambient sensor, accelerometer and gyroscope sensor (orientation based), GPS sensor, earpiece sensor has exceptional sensing capabilities [2].

II. ANALYSIS ON MOBILE PHONE SENSORS

Sensor technology has been serving as a driving factor by providing convenient services in mobile phones to its users. This has enabled many a mobile vendors to deploy the sensor technology in their mobile gadgets by releasing their new versions.

Sensor technologies not only are efficient but also provide convenience in every walk of their usage. Various types of sensors used in mobile devices are enlisted as follows:

2.1 Ambient Light Sensor: Ambient light sensors are used as backlighting controls in many number of LCD display applications from consumer electronics to automotive, and by automatically adjusting display brightness, they can conserve battery life, which is a key benefit in mobile device applications. These sensors have the ability to adjust light on the screens so that it matches up to the sensitivity of the human eye. Types of ambient light sensors and their characteristics are shown in table- 1.

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Table- 1: A Benchmark on types of ambient light sensors

Ambient Light Sensor	Criteria	Description	Links	Names	Rating
Photo Diode	Dispersion	Low dispersion between individual units		ROHM Semi-conductors (White Paper)	5
	Output Current	Low output current due to which an external amplifier is required	[3][4]		
	Sensitivity	The solid state light detector consisting of a shallow diffused P-N junction with connections provided to the outside world determines the sensitivity. Use of Epoxy filters improves the relative spectral sensitivity close to human eye sensitivity.		EXCELITAS Technologies VISHAY Semi-conductors (Application Note)	
Photo Transistor	Dispersion	Large dispersion between individual units and poor temperature characteristics		ROHM Semi-conductors (White Paper)	6
	Output Current	The output current is easily obtainable			
	Sensitivity	The solid state light detectors possess internal gain. This feature makes them more sensitive than photodiodes. Though sensitivity is close to human eye sensitivity. The use of epoxy filter in photo transistor is less compared to that in photo diodes; hence sensitivity parameter is compromised in most of the cases.	[3][4]	EXCELITAS Technologies VISHAY Semi-conductors (Application Note)	

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Photoelectric Cell	Above Mentioned	All the problems concerned to the use of photo diode and photo transistor are overcome using photo cells. The sensitivity in response is similar to human eye, but due to the presence of cadmium sulphide (CdS a prohibited substance) makes photo cells useless in the market.	[3]	ROHM Semi-conductors (White Paper)	3
Photo IC	Above Mentioned	Problems related to Photo cells are eliminated using Photo IC. Advantages are mentioned as below: • Similar to human eye • Output current easily obtained • Low dispersion	[3]	ROHM Semi-conductors (White Paper)	9

Brightness is a term that describes how intense a light source is perceived by the human eye. Brightness is measured in units called "LUX". LUX measures the luminous emittance and calculates the luminous flux per unit area. Light sources with the same LUX level appear at the same brightness to the human eye. The LUX values computed by a light sensor in day are shown as in table- 2.

Table- 2: LUX values of alight sensors in a day

LUX Values	**Day**	Overcast Day	1000 **lx**
		Golden Hour	400 **lx**
		Daylight Noon	130000 **lx**
	Night	Moonless Night	0.002 **lx**
		Night Street	300 **lx**
		Full Moon	0.27 **lx**
	Indoors	Typical Living room	100 **lx**
		Studio	1000 **lx**
		Office Lighting	500 **lx**

2.2 Proximity Sensors: The major function of a proximity sensor is to sense the touch events on smart phone devices (high end devices). This smart detection on a mobile device involves various technologies, which are enlisted as below:

- Electrical (Inductive, Capacitive)
- Optical. (IR, Laser)
- Magnetic

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- Sonar

Among the technologies involved, the most non-intrusive and low-cost module is the optical proximity sensor. These can detect bodies in the vicinity of the device upto 5cm. This is perfect for use on smart-phones.
These available proximity sensors come in combination with the light sensors on smart-phones, which are depicted as shown in fig 2. The light/Proximity sensors are inserted on a GP2A chip close to the speaker on the mobile device. Most of the proximity sensors implemented on a mobile device, are Boolean sensors (i.e., it returns just two values “FAR” and “NEAR”).

- ✓ The fundamental action of a proximity sensor is to disable accidental touch events.
- ✓ On a mobile device, a proximity sensor detects an object coming close to the speaker.
- ✓ A light sensor chip is used for implementing a proximity

Fig 2: Location of a Light/Proximity sensor on a mobile phone

Thresholding is done on the LUX value i.e. the LUX value of the light sensor is compared with a threshold. If LUX-value is more than threshold, then the proximity sensor returns "FAR". Else, the sensor returns "NEAR". The threshold value depends on the sensor-chip being used and its light-response. The above description is tabulated as shown in fig 3.

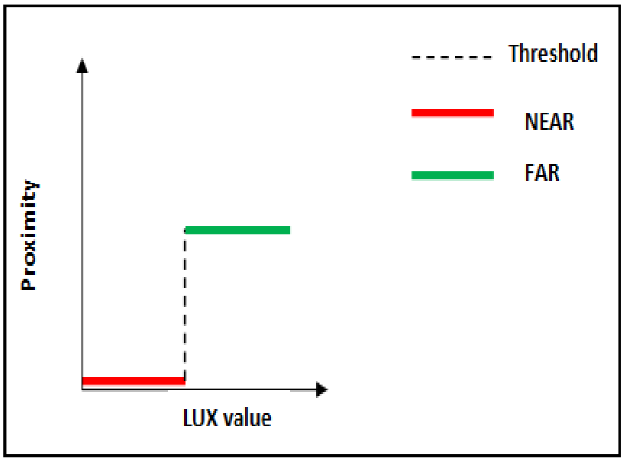

Fig 3: Graph detailing position of an object using the LUX value

A comparison among various types of proximity sensors is made along with their working principles and a benchmarking based on their pros and cons is illustrated in table- 3.

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Table- 3: A Benchmark on types of proximity light sensors

Proximity Sensor	Principle	Description	Rate
Triangulation Proximity Sensor	This proximity sensor emits a thin beam of light using which the location of reflected light (i.e., the target object) can be detected.	**Advantages**: Very accurate results **Disadvantages**: • Limited range • No eye safety	2.5
Optical Proximity Sensors	Hear the presence of a light source and a light sensor is made available. The light source emits infra-red light and the target reflects it, which is sensed by the light sensor and works accordingly.	**Advantages**: • High precision • Highly sensitive to surface reflection • Surface irregularities are detected • Reflected light colours are recognizable **Disadvantages**: • Irresistible to dirt, dust, ambient light colour and intensity • High sensitivity towards every object makes it unsuitable on a mobile phone • Costly	3
	It works on the principle of capacitance. The design principle consists of a plate kept inside the sensor, and this plate acts as one plate of capacitor and the target acts as another plate. A dielectric is developed between the plates. As the target gets nearer to the sensor, a capacitance is developed. Based on the change of capacitance the sensor triggers.	**Advantages:** • It works fine for all the targets having dielectric more than air. • Cost effective • Effective power utilization • Sensitive to any target material	

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Capacitive Proximity Sensor		**Disadvantage:** • High design complexity • Irresistible to dirt, moisture, dust etc. • Results not accurate compared to inductive proximity sensors • Noise sensitive	3
Inductive Proximity Sensor	The working principle involved is based on the magnetic field. In the design principle, we have a coil and an oscillator that creates an electromagnetic field around the sensitive area of the coil. When the target comes near by a fluctuation in the oscillating amplitude is detected and the sensor triggers.	**Advantages:** • Resistible to dirt, dust, moisture etc. • Accurate results • Cost effective **Disadvantages:** The target should only be metallic	2.5
Photoelectric Proximity Sensor	This proximity sensor consists of an emitter and a detector. There are two modes of operations involved in its working. Thru-Beam mode: Hear both the emitter and the detector works independently facing each other. The emitter emits photo light and the detectors receives it. As and when a target comes in between, signal interruption is detected and the sensor triggers. Defuse reflective mode: Hear both the emitter and the detector are coupled together. The emitter continuously emits photo light. When a target gets nearby to the operating range, the light is reflected off and the detector receives it, which enables the sensor to trigger.	**Advantages:** • Varies with signal strength • Sensitive to any target **Disadvantages:** Sensing capacity limited to a very short distance	4.5

The Proximity sensor used on a mobile phone is coupled with the ambient light sensor. Both the sensors are braced together on a mobile phone. From the survey made, the best combination of ambient and proximity sensors suggestible is the Photo IC with the photoelectric proximity sensor. As Photo IC does the ambience sensing and adjusts screen light

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using charge in backup battery storage. The same battery backup storage could be handy in serving the photoelectric proximity sensor, where the emitter could use the same backup device for emitting light. This would improve the effective utilization by enhances the battery backup efficiency. And as they have the best pursuance in their performances, they form the most suitable pair of ambient light and proximity sensors on a mobile phone.

2.3 Touch-Screen Sensors: A touch-screen is an electronic visual display that the user can control through simple or multi-touch gestures by touching the screen with a special stylus/pen and one or more fingers. Some touch-screens use ordinary or specially coated gloves to work while others use a special stylus/pen only. The technology that enables sensing capabilities of touch-screen devices are broadly classified as follows:

- Resistive
- Surface acoustic wave
- Capacitive (Surface Capacitive)
- Infrared Touch Screen Sensor

Resistive: A resistive touch screen is comprised of two layers, the Flex and the Stable layer. These Layers are coated with a thin electrically conductive. These layers are separated by the Spacer layer, as shown in fig 4.

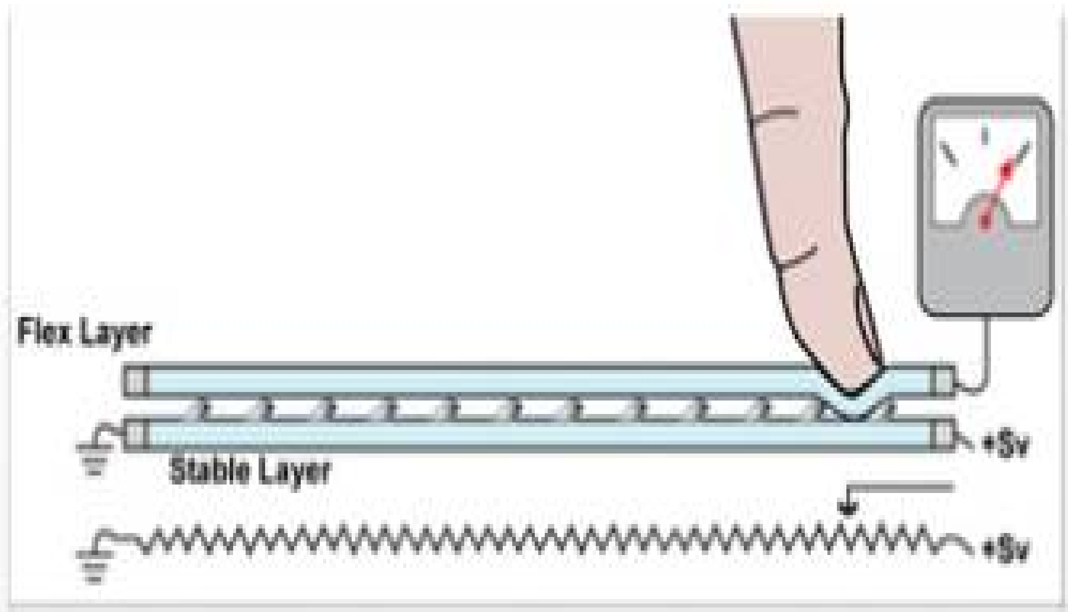

Fig 4: Behaviour of a resistive Touch-Screen Sensor

When touched, the Flex layer comes in contact with the Stable layer. The point of contact creates a voltage divider in the X and Y directions. This voltage is then used to find the relative position of the touch activation. Three basic resistive sensor constructs are 4-wire (Most cost effective), 5-wire (Most durable) and 8-wire (Most flexible). The parameters which decide above mentioned behaviors are tabulated in table 4.

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Table 4: Behaviour of different dimensioned resistive wires Vs variant parameters

Sl. No	Parameters	4 Wire	5 Wire	8 Wire
1	Linearity	Very Good	Least Linear	Very Good
4	Drift Susceptible	Susceptible	Susceptible	Sense and Compensate
7	Suppliers	Many	Many	Few
3	Bus Bar Size	Thin	Medium	Wide
6	Cost	Low	Medium	Medium
2	Power	Low	Medium	Low
5	Durability	Medium	High	Medium

Surface Acoustic Sensors: As the name suggests, an acoustic sensor relies on the modulation of surface acoustic waves (SAW) to sense a physical phenomenon. This sensor, in a mobile phone works on the principle of disruption of acoustic waves that are being transmitted on a glass sheet within the device. In this, surface acoustic wave (SAW) technology makes use of ultrasonic waves for sensing an interruption. The structure of the glass material comprising of transmitting transducer, reflectors and receiving transducers is shown in fig 5.

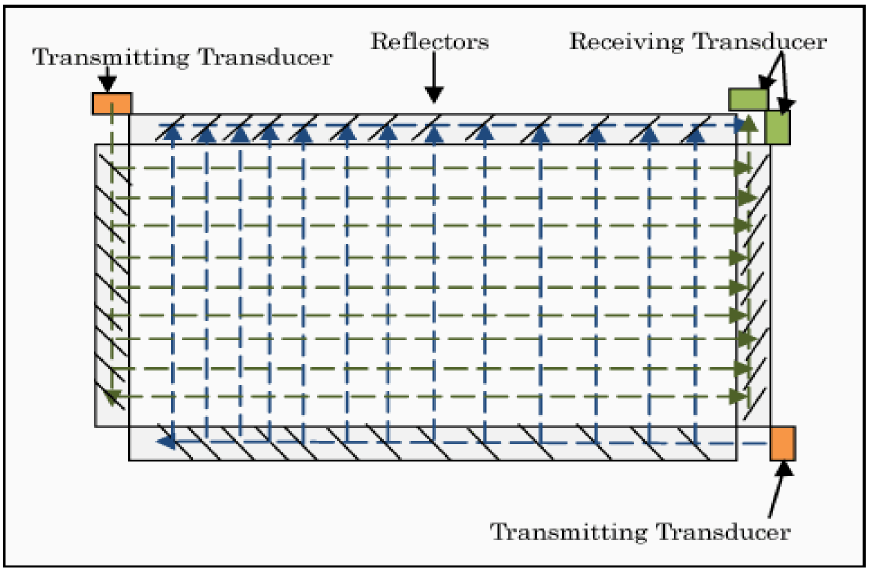

Fig 5: Working principle of a surface acoustic Sensor

The Working principle involves generation of ultra-sonic waves by the transmitting transducers which travel on the edges of the glass surface. The reflectors present on the edges of the panel reflect the waves at 90 degrees to the other

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edge on the panel, where the presence of reflectors redirects the waves onto the edge where receiver transducers are present. These transducers convert the ultra-sonic waves into electric signals. When a touch on the device is made, a distortion in the route of ultra-sonic wave occurs (by absorption of SAW). Note that, different routes are assigned for different ultra sonic waves. Each route has its own distance. If one of the routes is distorted (by a touch) the pulse will be absorbed and the SAW on the route will not be received by the receiving transducers. Thus, the sensor will recognize which route was touched, and then locate the touched point. The benefits and delimits exhibited by SAW on a mobile phone are discussed as follows.

Surface capacitive sensors: The most widely used sensors on mobile phones to detect soft touches are the capacitive sensors. The basic principle involves, use of a capacitor consists of two conductors, e.g. two metal plates, separated by an insulator.

The larger the area of the plates, the larger is the capacitance. The smaller the distance between the two plates, the higher is the capacitance. The insulating material determines the dielectric constant. Table lists some common materials and their permittivity. The conductors (sensor electrodes) are connected to a measurement circuit, which is used to measure the capacitance periodically. A touch on the sensor electrode results an increase in the capacitance, which is detected by the measurement circuit [5]. Fig 6 depicts this scenario. In addition to the above mentioned techniques, that are used to sense the touch on a device, other techniques like infra-red (IR), optical, voltage, and electro-magnetic resonance also exist. Among these the most widely used are resistive and surface capacitive sensors. A detailed comparison of both resistive and capacitive sensors is tabulated in table 5. In a mobile device, an accelerometer is a sensor which measures the tilting motion and orientation of a mobile phone. It is used to measure non gravitational acceleration.

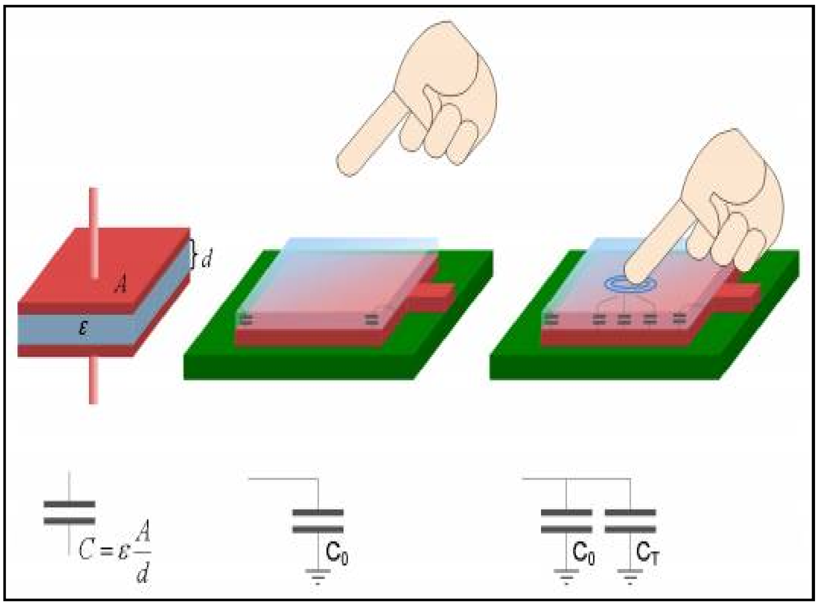

Fig 6: Behaviour of a capacitive sensor with change in capacitance

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Table 5: A comparison between Resistive and Capacitive touch screen sensors

S. No	Parameters	Resistive Touch screen	Capacitive Touch screen
1	Indoor visibility	Very Good	Very Good
2	Visibility in sunlight	Poor	Very Good
3	Touch Sensitivity	A rich pressure is to be applied to a contact with the screens layer	Slightest contact with the screens glass is good enough
4	Cost	Relatively cheap	Costly
5	Accuracy	Comparatively more	Less
6	Robustness	Use of resistive screens makes it vulnerable to scratches and other damages	Use of glass makes it relatively more resistive to minor damages
7	Multi-touch	Not possible	Possible (depends on software and implementation)

Infrared touch sensors: These touch screen sensors work on the principle of interruption technology of light beam. In the design principle a frame is deployed around the screen display. Light emitters and detectors are fixed on either sides of the frame. When a touch is made on the surface on the screen, the invisible light beam gets interrupted causing a drop in the signal received by the detector and then the sensor triggers. The pros and cons involved in the use of infrared sensors are as follows.

The above mentioned four types of touch screen sensors are deployable based on the important parameters that the vendor wants to feature on the smart phone. A benchmarking of these touch screen sensors is tabulated as in table- 6.

Table- 6: A Benchmark on different touch screen sensors

Touch Screen Sensors	Rating	Reasons
Resistive Touch Screen Sensor	2.5	Pros: • Low cost Cons: • Highly susceptible to scratches • Low accuracy • Bad illumination and low visibility • Discloses any object (which is not acceptable on any smart phone)
Surface Acoustic	3	Pros: • Highly accurate • Good illumination Cons: • Highly sensitive to scratches

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Wave Sensor		• Very Expensive • Mild and delicate
Surface Capacitive Touch Sensor	4.5	Pros: • Cost efficient • Unsusceptible to environmental changes Cons: • Sensitive to finger touch only • Reduces brightness
Infrared Touch Screen Sensors	3.5	Pros: • Improves illumination • Detection of blocked objects Cons: • Highly sensitive to false responses • As frame is placed around the screen, the touch detection is made over the screen surface making it sensitive to environmental effects • Susceptible to ambient light • Costly

2.4 Gyroscope Sensor: A gyroscope is a device that uses Earth's gravity to help determine orientation (i.e., it is used to measure/maintain the orientation of the device). Its design consists of a freely-rotating disk called a rotor, mounted onto a spinning axis in the centre of a larger and more stable wheel. As the axis turns, the rotor remains stationary to indicate the central gravitational pull, and thus which way is down. It is frequently used in robotic applications for balancing to send corrections to motors, or for drones to stabilize the flight. Gyroscope is used in mobile phone orientation. The orientations involved in a gyroscope sensor are figured in fig 7. The working principle of it in mobile phones is discussed.

Working Principle:

1. If an object moves along an axis which is rotated on another, then a coriolis force is exerted in the third axis.
2. Gyroscope has a mass oscillating backward, this exerts force in the first axis and plates on either side of the mass in the third direction (direction of the Coriolis force)
3. A change in capacitance occurs when a rotation is detected in the second axis [6].

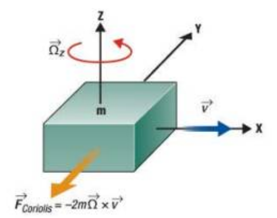
✓ Object moving along X-axis ✓ Object rotated along Z-axis ✓ Coriolis force developed along y-axis	

Fig 7: Working principle involved in a Gyroscope Sensor

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A lot of confusion arises, when referring to accelerometer and gyroscope. There exists a typical difference in the intended functionalities exhibited by these instruments. This variance is clearly reflected in its application on a mobile phone, as shown in table 7. But, coupling of these instruments would make the sensing properties of both acceleration and rotation stronger. When used together, a gyroscope and accelerometer provide a six-axis interpretation of movement through space (3 by accelerometer and 3 by gyroscope). This is especially useful in hand-held devices such as mobile phones, because it can filter the unintended ambient movement and vibration of a user's hand, allowing for a more accurate measurement of intentional movements.

Table 7: Comparison is drawn between an Accelerometer and a Gyroscope sensor

Sl.No	Accelerometer	Gyroscope
1	Only acceleration is measured by an accelerometer	Rate of rotation about an axis is measured by a gyroscope
2	Rotation cannot be sensed	Rotation can be sensed
3	It measures non gravitational acceleration	Orientation is determined using the gravitational acceleration
4	Information about the orientation of a mobile is provided	Information about the orientation, twist and tracking rotation is provided

A gyroscope interprets the shift in position and decides on the orientation. Whereas, an accelerometer interprets the orientation of the phone and changes the display (i.e., from portrait to landscape mode or vice versa) or interprets sudden motions (such as shaking for mobile application interaction).

A gyroscope is applicable in environments where navigation and angular velocity is to be determined. An angular velocity is a rotating in all the 3-axises that measures the rate of change of angular positions of rotating objects [7][8]. A 3 axis gyroscope works with a 3-axis accelerometer to provide a full 6 degree of freedom (DoF) motion tracking system. Rationally gyroscopes are broadly classified into 3 types:

- Rotary Gyroscope
- Vibrating Structure Gyroscope
- Optical Gyroscope

Rotary Gyroscope: It works on the principle that, the angular momentum of a system is constant in both direction and magnitude only if the surface torque acting on it is zero [9]. The design principle involves a spinning disk and a series of gimbals. These gimbals provide an additions degree of rotation to the spinning disk without external torque acting on it and hence the angular momentum is constant and stable.

When an external torque acts on the gyroscope in a direction perpendicular to the spinning disk then a resultant torque is developed in a direction perpendicular to both the spinning disk axis and the input torque axis. This resultant torque causes precision and hence an angular momentum is developed in this direction (output direction). This output axis is fed as an input to the input torque axis where by the spinning disk applies a torque in the opposite direction, cancelling the precision and stabilizing the orientation of the gyroscope [8].

2.5 GPS Sensor: A Global positioning system (GPS) is used to figure out the region of presence. The use of this device in a mobile phone will help in tracking the position of the user. New-generation cell phones combine many devices into

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one. The most convenient of feature is the built-in GPS. Cell phones with GPS receivers communicate with units from among the 30 global positioning satellites in the GPS system. The built-in receiver trilaterates the position using data from at least three GPS satellites and the receiver. GPS can determine your location by performing a calculation based on the intersection point of overlapping spheres determined by the satellites and your phone's GPS receiver. In simple terms, trilateration uses the distance between the satellites and the receiver to create overlapping "spheres" that intersect in a circle. The intersection is the location of device user on the ground. The fig 8. depicts the trilateral triangulated position determined using GPS system.

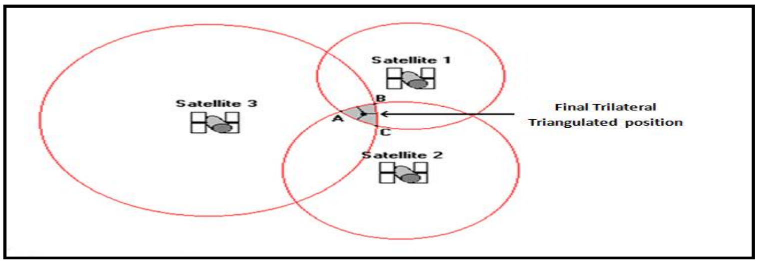

Fig 8: The trilateral triangulated position determined using GPS system

Attainment of uninterrupted and accurate data navigation:

However, accurate and continuous positioning remains as a challenge by the use of a stand- alone GPS. A stand- alone GPS suffers signal masking and reflections of the signal from buildings, large vehicles, and other reflective surfaces. Not only the use of their satellites, but even though four or more satellites are available, strong multipath effect might cause a positioning error of more than 100 m.
In order to obtain uninterrupted navigation, GPS data can be augmented with a complementary navigation system that works continuously in any type of environment. This is known as an integrated navigation system. The use of GPS/ DR (Dead Reckoning) navigation system helps in mitigating the problems like power consumption, cost, weight etc. A GPS/ DR configuration system consists of one gyro for directional measurements and 3D accelerometer. Both the gyro and accelerometers satisfy the requirements for mass market portable consumer devices: low cost, light weight, and low power consumption. This navigation system includes different types of navigation sensors and technologies. The conceptual description of the navigation information sources and data flow is illustrated as in fig 9. Apart from the mentioned sensors, other sensors like camera, Digital Compass, Barometer, Earpiece Speaker, Microphone Speaker etc are also composed in a mobile phone

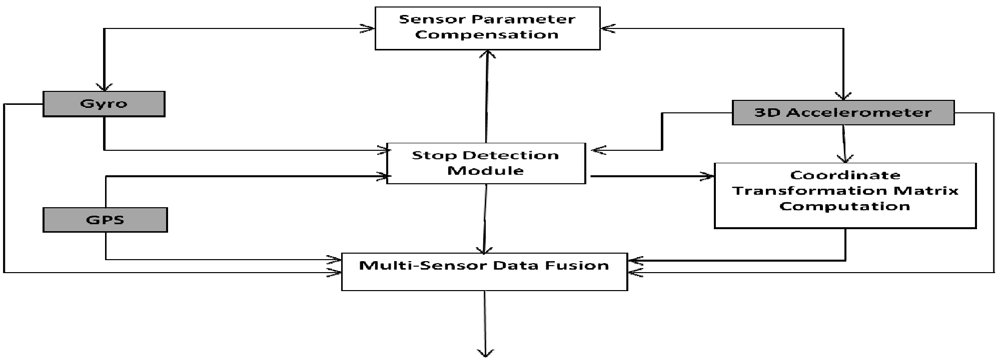

Fig 9: Data flow among sensors present on a mobile phone

2.6 Camera ... the light coming-in through the lens to form an image. This device is called an image sensor. These days, we find the camera sensors even on low end devices. One of the important drivers for this is the introduction of CMOS image sensors

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which have replaced the CCD sensors. This has made it possible for the image sensors to be available at extremely low costs. An illustration of the image sensor used in a camera is shown in fig 10. In this chapter, we discuss in detail about the basic principle involved in the working of an image sensor.

A digital camera uses an array of millions of tiny cavities or photo sites to record an image. As and when the camera shutter opens, the lens comprising of the cavity array is exposed to light, and each of the photo site or cavity stores the photons incident on it. Once the exposure finishes, an assessment of the number of photons available in each cavity is made and sorted into various intensity levels. The fig 11. illustrates only the greyscale images, because the cavities are unable to distinguish how much photons of each colour are captured, only sorting based on the intensity levels is made. For detecting colour images, colour filters on each of the cavity is used which permits only particular colour of light.

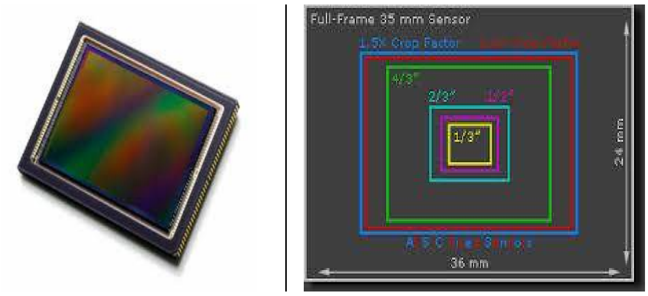

Fig 10: The image sensor lid and its dimensions

As a result only one of the three primary colours is accepted (i.e., 2/3rd is discarded). So, by the use of colour filter approximation of two primary colours in order to have full colour at every pixel is done. Most commonly used colour filter arrays is "Bayer array". A Bayer array consists of alternating rows of red-green and green-blue filters. Therefore, we have twice as many green as red or blue sensors, as illustrated in fig 12. Equal fraction of total area is not distributed to each of the primary colours; the reason for this is that human eyes are more sensitive to green colour than the other two primary colours.

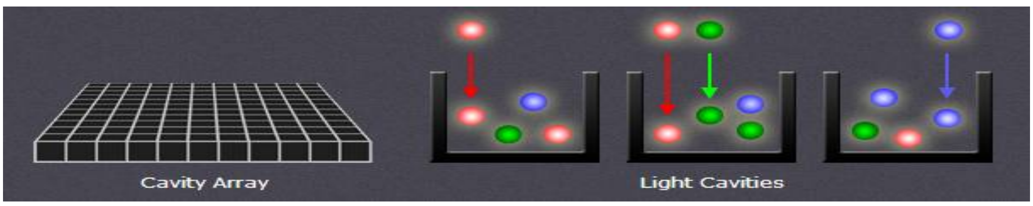

Fig 11: Cavity array for capturing photons in each photo site (cavity)

Redundancy in green pixels produces a noise free image and captures finer details. Bayer demos icing is a process of translating the Bayer array into a final image which contains full colour information at each pixel. The question that arises here is that, how is it possible if the camera is unable to directly measure full colour? One of the most commonly followed methods is to think each of the 2*2 array of red, green, blue as a single full colour cavity. This would enable for determining the full colour of the image. But, using a singe 2*2 array comprising of red, green, blue pixels landed in the same place, only half the resolution in both the directions is achieved. So, instead if a combination of overlapping 2*2 arrays is made, a better resolution of the image can be achieved, which comprises of various combinations. Fig 13, illustrates both single 2*2 arrays and overlapping 2*2 arrays, that captures a full colour image.

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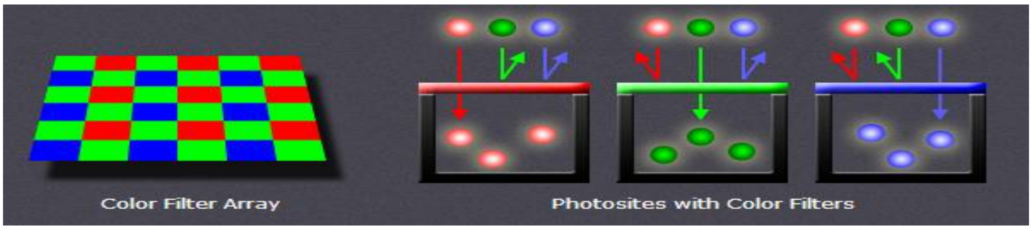


Fig 12: Colour filters over cavity array that capture photons of same intensity

Barometer Sensors: This sensor is found only in some selective smart phones. Contrary to its name, this sensor has nothing to do with measuring the wind speed. This sensor is deployed in the smart phones for assisting the GPS to obtain the altitude data quickly.

Digital Compass Sensors: As the name of the sensor suggests, it is a simple digital compass which is based on a sensor called magnetometer and makes the mobile to work as a simple traditional compass. It provides simple orientation in relation to the magnetic field of our Earth. This sensor is mostly used in the digital maps for letting the user to know about the directions.

Pressure Sensor: A pressure sensor is used for calculating altitude pressures that vary with elevations.

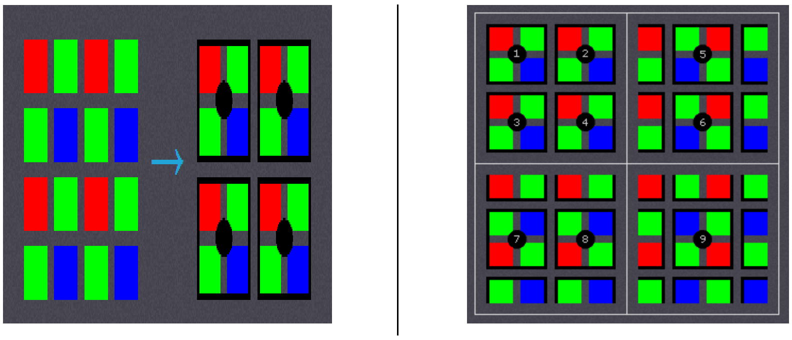
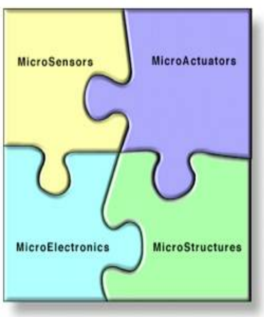


Fig 13: Single and overlapping 2*2 arrays capturing full colour image

For this piezo resistor-equipped MEMS chip is used, which tracks altitude through atmospheric pressure with an uncanny knack for precision; it snitches pressure across floors, which could be more than handy for future iterations of indoor navigation. An MEMS chip is depicted as in fig 14.



- MEMS (Micro-Electro-Mechanical System) is a technology defined as miniaturized mechanical and electro-mechanical elements.
- In MEMS there are at least some elements which have some sort of mechanical functionality whether or not these elements can move.

Fig 14: MEMS Chip used in determining atmospheric pressure

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Microphone Sensors: Micro phones act as an elementary device in call conversations. Smart phones contain tiny microphones based on micro-electro-mechanical systems, commonly called MEMS, as shown in fig 14.

III. CONCLUSION

In this chapter, various sensors present on a mobile phone have been enlisted and analysis on each of them based on their sensing paradigms was made. A benchmark analysis on few of these sensors also has been made based on their principles, characteristics, and some criteria. This analysis helps in understanding what sensors are suitable in sensing a particular scenario.

REFERENCES

[1] Lane, Nicholas D., et al. "A survey of mobile phone sensing." Communications Magazine, IEEE 48.9 (2010): 140-150.
[2] Nokia Research Center (NRC) (2008), "Sensing the World with Mobile Devices", [Online]
Link: https://research.nokia.com/files/NTI_Sensing_-_Dec_2008.pdf
[3] ROHM Semiconductor (2010), "Ambient Light Sensor (ALS) Applications in Portable Electronics" (White Paper), [Online]
Link: http://www.rohm.com/documents/11308/12928/CNA09016_wp.pdf
[4] EXCELITAS Technologies, "Photodiode & Phototransistors for ALS", [Online]
Link: http://www.excelitas.com/pages/product/Photodiodes-and-Phototransistors-for-Ambient-Light-Sensors.aspx
[5] FUJITSU (2012), "Capacitive Touch Sensors" (White Paper), [Online]
Link: http://www.fujitsu.com/downloads/MICRO/fme/articles/fujitsu-whitepaper-capacitive-touch-sensors.pdf
[6] Stanford University, "Sensors and Cellphones", [Online]
Link: http://web.stanford.edu/class/cs75n/Sensors.pdf
[7] E. Miranda and M. Wanderley, New Digital Instruments: Control and Interaction Beyond the Keyboard, A-R Editions, Wisconsin, 2006.
[8] J. Fraden, Handbook of Modern Sensors: Physics, Designs, and Applications. Springer Science Business Media, New York 4th Ed., 2004.
[9] R. Serway, and R. Beichner, Physics for Scientists and Engineers, Thomson Learning Inc., Toronto, 5th Ed., 2000.