SAVONIA

Sensors in Smartphones

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Abstract

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Abstract

With the booming development of scientific technology, the mobile phone is no longer a simple communication tool, but a portable electronic device with integrated functions. You can use the phone to listen to music, watch movies, take pictures and so on. Mobile phones have gradually entered into human's daily life. In this case, the various sensors are emerged in smartphones. The requirements on smartphones are increasingly high. Telephone, SMS, multimedia, etc., are just basic applications, to be more intelligent and more humanized is the user's goal. Under these conditions, a variety of sensor applications in smartphones are wider.

This thesis focused on a deeper interpretation of various traditional sensors and its applications in smartphones, such as image sensor, fingerprint identification sensors, gravity sensor and so on. Admittedly, the progress of new developing sensors was also mentioned in this thesis. There were some breakthroughs in this field and the newness which had brought better prospects.

This thesis also tracked the marketing of smartphones from statistics and dynamics, then explored the global market and current smartphone services, finally made an evaluation of business future according to the investment and venturing.

In conclusion, this thesis showed the importance of sensors to smartphones. The superiority and usability of sensor were noticed by venders and developers. Moreover, the rising demands of smartphones should not be underestimated.

Keywords
Smartphones, Sensors, Developing Trend, Marketing

CONTENTS

SYMBOLS AND ABBREVIATIONS

PPC	Pocket Personal Computer
PDA	Personal Digital Assistant
3G	Third Generation
4G	Fourth Generation
GPRS	General Packet Radio Service
CDMA	Code division multiple access
WCDMA	Wideband Code Division Multiple Access
HSPA	High Speed Packet Access
LTE	Long Term Evolution
PET	Polyethylene Terephthalate
SCR	Silicon Controlled Rectifier
HD	High Definition
CMOS	Complementary Metal–Oxide–Semiconductor
OEM	Original equipment manufacturers
CCD	Charge-Coupled Device
CP	Content Provider

1 INTRODUCTION

In this day and age, the traditional information and communication tools have changed due to the powerful impetus of mobile devices. Mobile devices such as laptop, MP4, mobile phones can be found everywhere. In various dazzled mobile devices, the smartphones have occupied leading positions and affected the mobile market. A smartphone is a mobile phone with an independent operating program, available setting-up applications and sensitive touchscreen interface which has replaced the outdated keyboard mobile phone. People use them to contact the loved ones and partners, online shopping, to keep in touch with latest news and exchange thoughts on the forums as a portable computer. As the smartphones are gradually integrated into users' daily life, they are looking for advanced services rather than just the basic applications. With increasing requirements of high fluency and humanized services on smartphones, a variety of sensor applications are applied to smartphones.

Inferring the sensors, it is one interesting subject to research. The sensors are important to smartphone. Some of these sensors are hardware-based and some are software-based. Both of them contributed to smartphones and do their functions and so are meeting the goals of customers. From large amount of games depending on the gravity sensor to automatically lock screen during the telephone communications depending on the distance sensor, even the small electronic compass also needs magnetic field sensor to distinguish directions. From overall perspectives, it is interesting to mention that with combination of sensors, the smartphones complement different useful functions. This shows the necessity of sensors in smartphone.

1.1 Objectives of Thesis

The aim of this thesis is to investigate and analyze how the sensors are involved into smartphones and what the functions are expressed. Also, this thesis could track the popularity of smartphones and evaluate the marketing to find out what influences customer to buy and enjoy these products.

Sensors are devices that detect events or changes and provide corresponding output, which are usually signals to control the designated behaviors in smartphones. The systems are equipped with mobile phones that make the phones even more convenient, fluent and fast. Therefore, it is very meaningful to realize that the sensors are brought to smartphones.

1.2 Structure of Thesis

The structure of the thesis is as follows: After the introduction, Chapter 2 covers the introduction to smartphones. Chapter 3 describes the application of sensors in smartphones. In Chapter 4 the developing trends of sensors in smartphones are explained and discovered. Chapter 5 makes an analysis of the marketing of smartphones. Chapter 6 presents the conclusions of this thesis.

Chapter 2 gives an overview of smartphones. It gives an introduction to history of smartphones and presents the definitions of smartphones. It also describes the obvious characteristics of smartphones.

Chapter 3 gives a detailed description of the variety of sensors based on software and hardware. It describes the working principles and functions of each sensor, also it relates to images to explain it clearly.

Chapter 4 lists the arisen sensor applications which have been developed incompletely and will be researched in future. Moreover, it also pictures the blueprints of new sensor applications.

Chapter 5 explores the marketing situation of smartphones as an comparison of different mobile phones. The marketing forecast is examined according to statistics and past databases.

Chapter 6 provides the summary of the results and discusses future smartphones. The main theme is also strengthened again. In addition, some problems and recommendations are referred in this paragraph.

2 INTRODUCTION TO SMARTPHONES

The emerging of smartphones was evolved by the Pocket PC. The earlier Pocket PC was not complemented with communication functions, without a telex-communication conversation. Then, the demanding dependence was growing as users relied on Pocket PC to deal with personal information and daily affairs. However, most of users were not accustomed to bring both mobile phone and PPC devices. Therefore, manufacturers tried to transplant the system of PPC into mobile phones, and based on this concept, the theory of smartphones was picked up.

A simple perspective of Smartphone is 'PPC+ mobile phone= Smartphone'. Generally speaking, smartphones usually contain conversation calls, and are also equipped with the main functions of PDA (personal digital assistant). It especially refers to the personal information management and browser and e-mail services based on the wireless data communications. Smartphones provide users with enough screen size and bandwidth, which is convenient to carry along, but also provide a vast stage for software and 3rd application services. A lot of value-added services can be embarked on which meet human daily life, such as maps, international news, weather, games, shopping, application downloads, music downloads and so on. With the support of 3G and 4G communication networks, the development trend of smartphones is bound to make them become powerful personal handheld devices with integrated functions with calls, text messaging, Internet access, television and entertainment. Also in the future, Integration of 3C (Computer, Communication, Consumer) of smartphones will become the mainstream during the development of mobile phones.

2.1 Brief history of Smartphone

The first smartphone put into the public is said to be IBM's Simon Personal Communicator in 1993. It had the first monochrome touchscreen in the world. It applied Zaurus operating system, and had only one 3rd applicants named Dispatchlt. It had the profound meaning of milestone to later smartphone processor. (Martin 2014.)

Figure 1. IBM's Simon Personal Communicator (pocketnow 2014.)

In the years that followed, Nokia 9000 communicator was considered to be the quintessential smartphone, and later the communicator (the 9500) was the first of Nokia smartphones to carry a color screen. With the following years from 1996 to 2011, the Symbian OS was the leading positions for smartphone operating systems. *(Thenextweb, 2011.)*

Figure 2. Nokia 9500 Communicator(Thenextweb, 2011.)

It was remarkable that when Apple Inc. introduced the iPhone, it was the first real change to show that the market had been changed. After that, Apple Inc. published iphone 3G, by which, it gained further promotion in the market share. Since then, the new era of smartphones was opened by the breakthrough of Apple, and iPhone has gradually become the benchmarking product now. It is interesting to notice that Apple products are welcomed by many countries, and we see its success with the amount of sales, even sometimes the shortage of products also express the popularity of Apple devices. The following Figure 3 shows the evolution of the iPhone.

Figure 3. The evolution of the iPhone (Mashable 2014.)

2.2 Characters of Smartphones

The smartphones have many important characters. However, every smartphone should have the following main five characters.

1) Supplementing with the wireless capability to access the internet. It means that the smartphone could support GPRS under the GSM networks or CDMA1X under CDMA networks. At the same time, it can work under 3G (WCDMA, CDMA-2000, TD-CDMA) networks, even for 4G (HSPA+, FDD-LTE, TDD-LTE).

2) Possessing PDA functions. A PDA, as a pocket PC, is a mobile device that functions as a personal information manager. Usually the PDA functions contain address book, calendar notes, tasks scheduling, multimedia applications and website browsing.

3) Own open operating systems. The smartphone should have independent central processor called CPU and memory to write and read. It allows users to set up applications what they need and has the capability to run the applications smoothly without the mobile evice becoming hot. With the open systems, the functions of smartphones can enlarge endlessly.

4) Humanity. It enables users to extend the machines' functions according to individual needs. For example, users could adjust build-in functions of machines in real time, such as lock screen, and photo enhancer. For sake of safety, users can update their systems to avoid attacks by the viruses. Moreover, smartphones are also equipped with intelligent recognition to software compatibility. At the same time, the software market is also synchronized with current system to achieve user-friendly features.

5) Powerful functions. It has strong scalable performance, and is able to support 3rd-party software. Users are encouraged to discover the potential functions of smartphones, like fingerprint recognitions, interpret the code of product's packing and being intelligent to turn off your lights when you don't use. Nowadays, the smartphone can even talk with users, answer questions and search information for customers.

3 APPLICATIONS OF SENSORS IN SMARTPHONE

Sensors are important to smartphones as hearts to humans. Each sensor performs different functions within a smartphone. There is Figure 4 below showing how many sensors are in a smartphone, and with so many different sensors integrating with each other, a smartphone could be formed.

Figure 4. The description of sensors in a smartphone (Ning 2013.)

3.1 Definition of Sensors

A Sensor is a device that detects the specific events and converts it to signal according to the systematic rules, which are usually the mathematic rules. Generally, it is consisted of sensitive elements and conversion elements. In other words, sensor is a detective device which inspects the measured information and converts it to available output that can be recognized by smartphones. And by this way, the information can

be transmitted, processed, stored, displayed, recorded and controlled in according to the requirements and the designated functions. It is the primary step to automatic detection and automatic control.

Recently, the smartphones are more advanced than the elder smartphones. It can be seen that they are not only accompanying with the high speed of CPU, but also increasing the interactivity with users. With the enlargement of software applications in smartphones, sensors make the users feel more real in the virtual environment. It seems that sensors make users be fascinated with applications and users will not feel passionate about applications without too much interaction and involving in.

In fact, the smartphones are becoming more intelligent by adding various sensors. The interactive responses of acceleration sensors to users make the traditional common input work become new inspired experience in a same way than games brought, and this promotes the willingness of users to commence the smartphones. It is interesting to mention that the comparative point is whether there is an acceleration sensor in smartphones of the old times, but now it turns whether there is three-axis gyroscope in smartphones. In the future, more sensors will be applied to give users a better feeling.

3.2 Touch Screen Sensors

There are two kinds of sensors with touchscreens in smartphones. One is a resistive sensor, and the other is a capacitive sensor. It is popular among children and adults to use capacitive touchscreen smartphones in these days, while the resistive touch screen smartphones are still remaining in use by the elder.

3.2.1 Resistive Touch Screen

Resistive touch screen is a type of passive technology responding to anything that touches it, and a sensor that can convert the physical position of touch point (X, Y) into the relative voltage of X coordinate and Y coordinate.

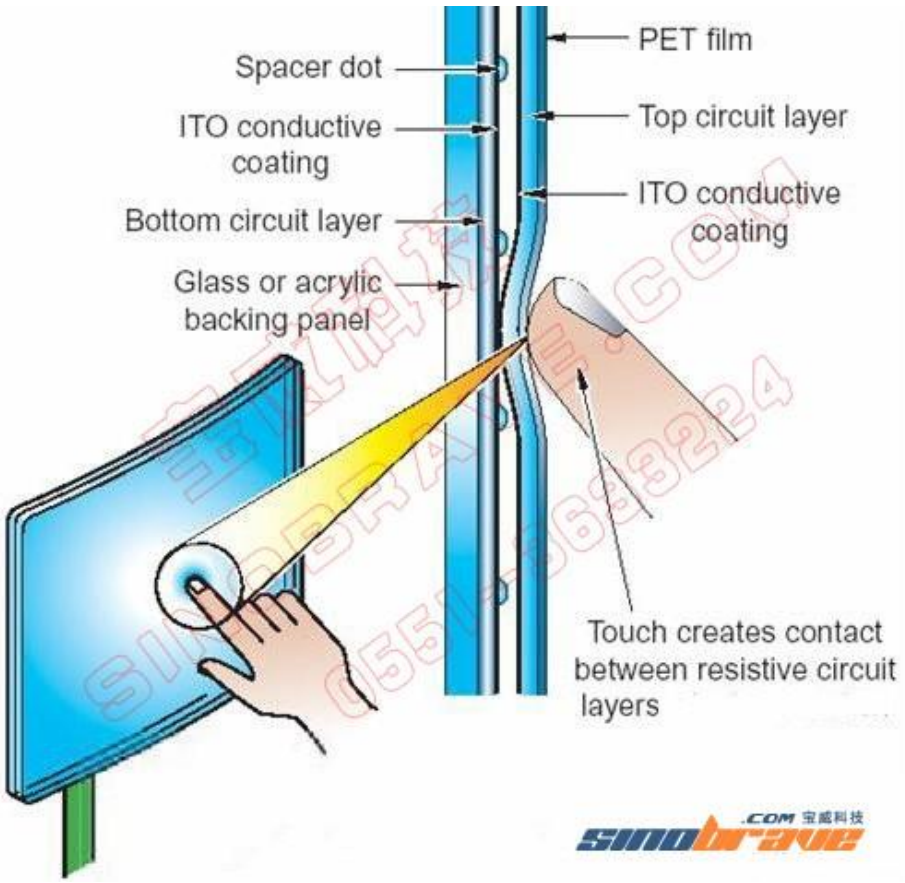

Figure 5. Working principle of four-wire resistive touch screen (Sinobrave 2011.)

The traditional resistive touchscreen is a four-wire resistive touch screen. This is the basic working principle of resistive touchscreen (see Figure 5). The portion of the resistive touch screen is a piece of composite multi-layer film, usually PET (Polyethylene Terephthalate) film. The basic layer is glass or acrylic backing panel as the first sheet. The basic layer is covered by the ITO (Indium Tin Oxide) conductive coating. While the second sheet are PET film, where is cohering ITO conductive coating on the inter layer. The two ITO coatings are representing X coordinate and Y coordinate respectively. And there are tiny transparent spacer dots between the ITO coatings, which aim to separate the two ITO coatings. When the two sheets are pressed together by finger or other stimulants, the connections between two ITO coatings are built, and the resistance is changed. Therefore, the controller can detect the coordinate position according to the changes in the resistance (see Figure 6). Finally, theses information are sent to the processor by simulating the movement of a mouse. *(Sinobrave 2011.)*

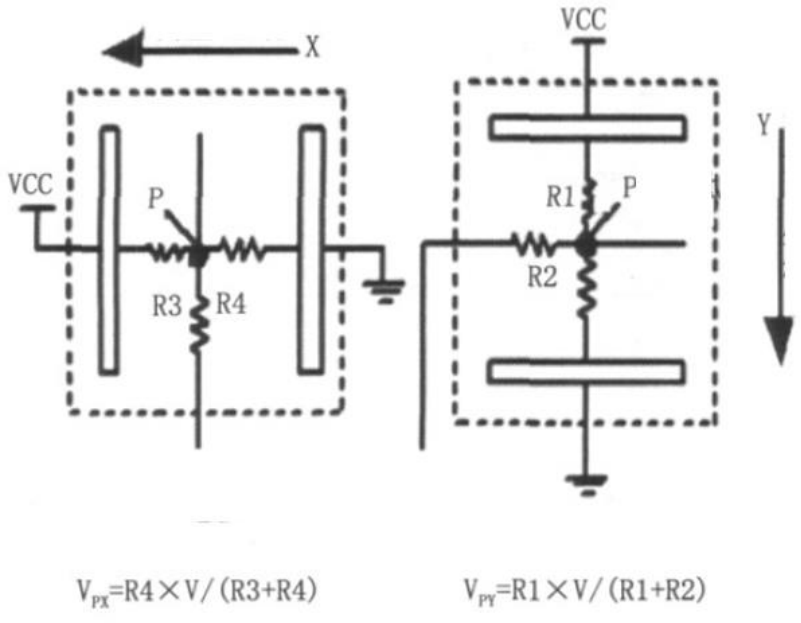

Figure 6. Restistance Changes In Different Directions

In addition, according to number of leading resistance line, it can be divided into four-wire touchscreen, five-wire touchscreen and so on. And the performance is positively correlated with the numbers of lines, but it is also noticed that the more lines, the higher the cost.

3.2.2 Capacitive Touchscreen

Capacitive touch screen is working on by the use of body sensing. It does not require direct contact but only a slight slip on the screen. Thus, it can detect the induced current to locate the touch coordinate.

The following Figure 7 shows that the human body is also an electrical conductor. When a figure touches the outer conductive layer, there is a coupling capacitor due to distortion of the screen's electrostatic field. As a result, the capacitance has changed, with a continuous rescanning of capative signals to determine the location for the touch. Then the location is sent to the controller for processing. Finally, the controller gives the touch coordinate and executes the designated action.

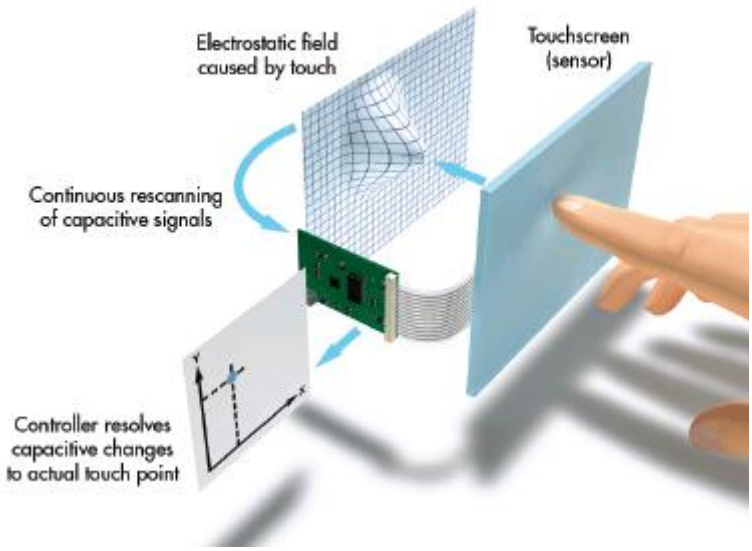

Figure 7. Working Principle of Capacitive Touch Screen (Chinabaike 2013.)

The advantage is having a multi-touch support, better sensitivity and quick response speed. While the disadvantage is that the accuracy is not precise, and it is not stable comparing to resistive touchscreen. The other drawbacks are having the great influence by the environment, and the cost is rather expensive, too.

With the highlight in performance, a capacitive touchscreen is adjusting the drawbacks, the stability is becoming more stable and the display is also better than with the resistive resistance. From the further user experience, capacitive touch screen is the developing trend in the future with excellent fluency and high quality imagery.

3.3 Image Sensor

In each mobile phone, the camera quality is always crucial when users make their choices. With the high demanding for the camera as the standard configuration in recent smartphones, image sensors are becoming popular after the camera with a variety of applications. Using camera to self-shoot and take a photo has became an essential part of many people's entertainment, while, the development of image processing technology enables the image sensors to have a broader application space.

There are two applications that are widely used in smartphones. One is business card recognition, the other is facial recognition.

Business card recognition means using a mobile phone to take a picture of a business card, the image information can be identified by the image processing software. After the background processing is complete, the name, age, telephone and compa-

ny address on the card will be automatically sent into the classification items of phone book. This function has become an advanced application on behalf of business smartphones.

Facial recognition means that users can be simply registered by their faces when first self-photographed. This image will be processed by image sensor software and it records the user's facial features as the later standard to check the user's identity. So that when the user needs to use a safety record of the phone, it does not require a longer complicated password again. Just a self-shoot, an authentication can be made by the smartphones. It is very convenient for users, but also it provides the higher security for the mobile device and user information.

3.4 Fingerprint Recognition Sensor

Users are sensitive to their personal data information, and the requirement of security has a higher demand. Therefore, fingerprint recognition technology is increasingly applied to a wide variety of mobile devices due to the tremendous progress of small size, lower cost and precious accuracy. At present, high-demanded business smartphones are already equipped with a lot of such functions.

Currently in the market, there are two solid fingerprint sensors on the market. They are touch sensors and slide sensors. Touch sensors require relibal figure touch in the fingerprint region for a while to let the sensors to memorize the exact shape of fingers. In contrary, slide sensors need the users just to slide the surface of the sensor. The sensor will collect a specific set of datas. Then it begins a rapid analysis and certification. Both of them are contributing the mobile market. However, accompanying the

advancement in sensor techonology and algorithms, coupled with the requirements of cost-sensitive consumer market, and the inherent requirements of the thin volume within portable devices, slide sensors have become the mainstream in the consumer market.

The main function of fingerprint recognition sensor on the phone is to identify who touches it, which is equivalent to password that only the owner's fingerprint recognition information has been verified and that could be allowed to use this equipment. With the popularity of semiconductor and software technology, the mobile phones will gradually to become a mobile terminal where can get their personal and corporate data can be got anytime and anywhere. Therefore, it is necessary to secure user access to prevent unauthorized access. For example, in e-commerce business, fingerprint recognition application can exempt the multiple tedious operation of users' password, which could simplify the process and create higher security level has been made.

There is also an ingenious idea to apply this fingerprint recognition in different areas, and this application has a far-reaching significance. For example, it could be applied by the police to stop a criminal in the highway who has offended the traffic rules. Just fingerprint required instead of the traditional methods to ask information from suspect, where is the danger that the information provided by suspect is false and unreliable. After gaining fingerprints, the police can scan the fingerprint from the fingerprint database by using smartphones to search on the internet. It will be convenient to obtain information about the true identity of the suspect rather than seeing the ID card or driver's license. Figure 8 shows how fingerprint scanners to help the police to check the people's identities. *(Bbc 2006.)*

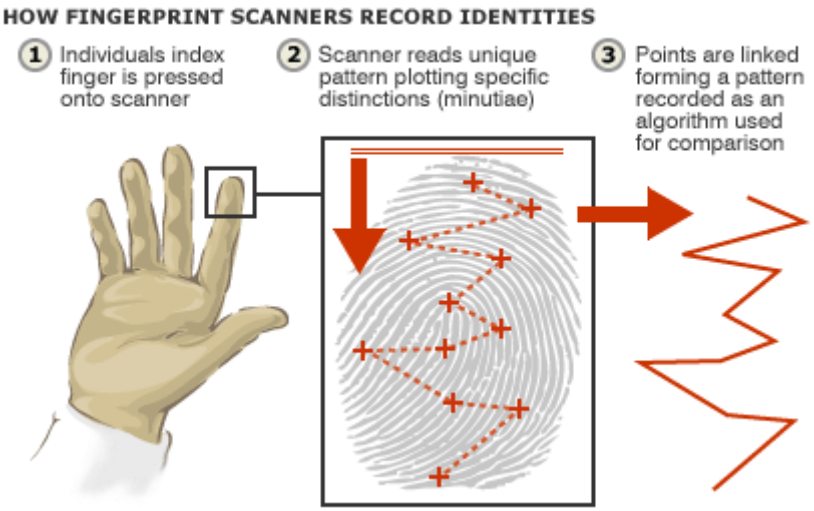

Figure 8. Fignerprint scanner working principle (Bbc 2006.)

3.5 Light Sensor

Light sensors used in smartphones are mainly based on the brightness of the ambient light to determine the users' environment, so it can regulate the smartphones to begin intelligent adjustment to achieve the purpose of energy saving and user-friendly usage. In dark environment, it enables to reduce the backlight brightness to avoid glare. While in the sunshine, it will increase the screen brightness, so it could make the display more clear. When moving the mobile phone into ear to make a phone call, the sensors allow to automatically turn off the screen and backlight. This way could extend mobile phone battery life and close the touch screen. Also it prevents hanging up the phone by users' inadvertent action to contact screen.

Photoresistor is a semiconductor resistor device which is applied in smartphone according to light variables. The normal characteristics contain the high sensitivity, fast response, clear spectral characteristic and consistent resistor value. Even in high temperature and humid environment, it can still maintain strong stability and reliability. There are more wide applications than in smartphones. For example, it can be ap-

plied in cameras, solar garden lights, lawn lights, bank detector, quartz, music mugs and a variety of toys and other light automatic switch control fields. It is still important to find that it can help adjust the brightness of the screen based on the specific indoor and outdoor light intensity, and enables users to see the contents of screen in bright light and in weak light without glare.

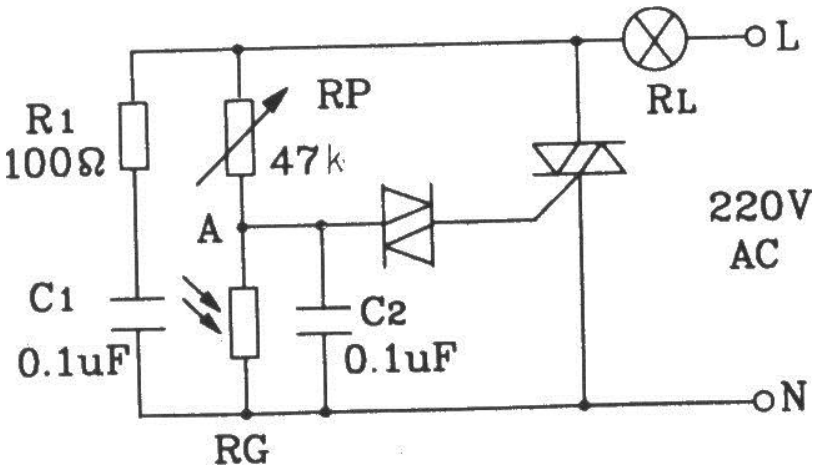

Figure 9. Photoresistor dimming circuit (51base 2010)

Figure 9 is a typical photoresistor dimming circuit. The working principle is that when the ambient light is weak, it causes the photoresistor increasing. Then the voltage of capacitors C_2 increases. It enables the SCR (Silicon Controlled Rectifier) conduction angle to rise, thus the voltage of lamp is levelled up. On the contrary, if the ambient light is bright, the SCR conduction angle becomes smaller, the voltage across the lamp is also decreased. The light is dimmed, so that the circuit can implement the illumination control. *(51base 2010.)*

There is even an interesting application designed by detecting brightness to control the ring volume. It means that the intensity of light in the outside world affects the size of ring tones. For example, when a smartphone is put into the pocket or wallet, the ring is aloud, and when removed out, the ambient light changes, the ring volume

could lower. It is very wise to note that, on the one hand one can avoid picking up later with no rings or low ring tones, on the other hand, the humane creation can meet the requirement of the environment to avert disturbing the others, and it also saves electricity power.

3.6 Acceleration Sensors

There are two kinds of acceleration. One is the static acceleration. When the acceleration sensor is inclined at an angle, a component of the gravitational field is generated in an induction field, through the component, and the inclination angle of the mobile phone can be measured, and thereby to complete the control directions around. The acceleration sensor usually provides three components of acceleration (X, Y, and Z) as seen in figure 10. Another is called dynamic acceleration, which can detect the speed, impact and so on.

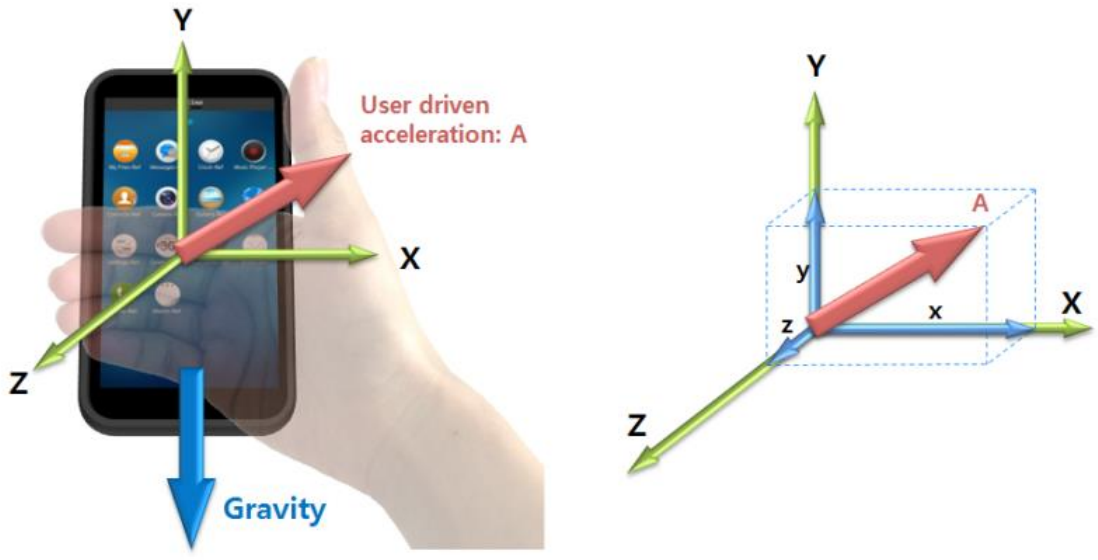

Figure 10. Acceleration sensor vector and axes (Tizen 2010)

3.6.1 Gyroscope

Gyroscope was the firstly applied to Apple products. At the conference of new iPhone 4 and iPod touch 4 in 2010, Apple Company claimed three-axis gyroscope can be used in navigation, orientation recognition and among the various games, in which, three-axis gyroscope is overwhelming defeated gravity sensor in traditional mobile phones (see Figure 11). The scopes applied are more extensive and the directions are able to be indentified more accurately. At the same time, the three-axis could distinguish the users' operation by detecting the directions and angles of inclination even when users stay in bed and are quaking mobile phones freely. The traditional gravity sensors, are always subjecting to the ground. This is the biggest difference between gravity sensors and gyroscope.

Figure 11. 3-Axis Gyroscope and Accelerometer (Patenlyapple 2010.)

Figure 12 shows the structure of three-axis gyroscope. A gyroscope is devices for measuring and maintaining orientation angles, based on the principle of conversation of angular momentum. In a simple world, when a gyro is used at a certain speed, the vertical directions could be able to remain all the time. The measured value is angular momentum by rotating and inclination, the orientation of spin axis are kept fixed.

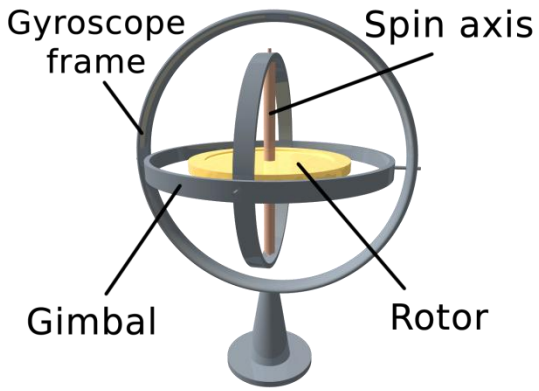

Figure 12. 3-Axis Gyroscope (Wikipedia 2015.)

3.6.2 Applications of Acceleration Sensors

Detecting the angle is the basic function of an acceleration sensor. The information when swinging the phone up and down will be transmitted to central process by an acceleration sensor, and then the operations with menu selection, flipping and image switching could be implemented. Otherwise, when the phone is reversed 90 degrees, the display between vertical screen and horizontal screen can be switched freely for users to use. For example, in racing, skiing and other games, the acceleration sensor can even replace the direction keys, as the customer sway the phones, passing around, accelerating and braking could be realized at the moment, which makes the game more interesting to customer. Figure 13 shows one racing game that applies acceleration sensors.

Figure 13. Racing Games in Smartphone (Wp-seven 2014.)

Acceleration sensors can be used in step counters. It evaluates and records the number of steps to calculate distance. When combined with personal characteristics, such as height, weight and other information, one could calculate calories burned by the software, thus to see the effect of exercise. The phone is also equipped with fitness functions.

A useful function of smartphones is that acceleration sensor can also equip phones with an emergency alarm. If one undergoes a major impact or drop on the road, the acceleration sensor will send the related information immediately to the central processor. If the users do not take actions during a period of time after the accidents, the information can be judged that the users have hurt themselves, and an automatic alarm to police is being sent automatically. Moreover, if there is a GPS in the phones, a GPS can be started automatically to report location information to emergency services for the purpose of emergency activities. There are a growing number of elderly people who could benefit from this function.

The other greater powerful function is complemented by the combination between an acceleration sensor and a geomagnetic sensor. Space perspective technology is mainly realized through a combination of these two sensors. The two sensors are detecting the horizontal displacement, vertical displacement and directions. When the user holds the phone in a building to traverse once, a lot of information about horizontal displacement, vertical displacement and directions are transmitted to the central processor. After the use of image rendering technology, a perspective view of the building will appear to public. Figure 14 shows a structure of one building by this method. In addition, the functions also make a valid GPS navigation supplementation. In particular locations, such as tunnels and high skyscrapers, when the GPS signal is lost, the position cannot be found in time. Then by the acceleration sensor and geomagnetic sensor, through information gained in displacements and directions, the navigation could continue to maintain the trajectory before with the absence of GPS signals. *(Procardy 2013.)*

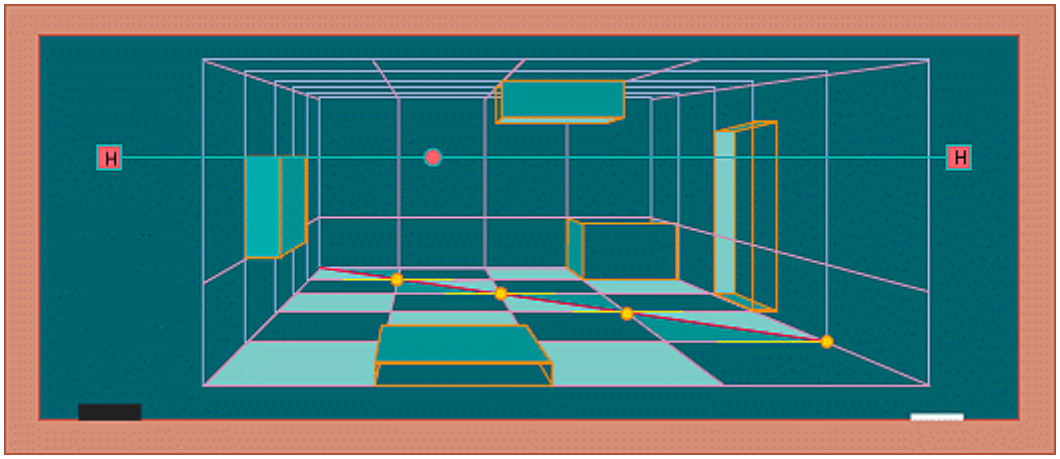

Figure 14. Space Perspective Diagram (Procardy 2013.)

4 THE DEVELOPING TREND OF MOBILE SENSORS

In the future, smartphones will continue to move forward, and this also becomes more tightly bound with the combination of various types of sensors. The appearance of sensors allows users to interact with electronic devices. The feeling is more genuine, and more joyful. At the same time, the interaction between man and smartphones can be more diversified as expected. Plenty of humanized functions and application are gradually achieved by sensors. As in the science fiction movies showing in the future, the more perfect human-machine interaction will definitely depend on this small sensor.

4.1 HD CMOS Image Sensor

In demanding electronics in the modern times, people pay more attention to electronic products, such as digital cameras, in their daily lives. But in different consumer markets, people's purchasing power is different. Digital camera in China could not be afforded by ordinary college students and low-income groups. If a mobile phone can be equipped with higher pixel images and videos dealing, then HD (High Definition) CMOS (Complementary metal–oxide–semiconductor) image sensor is a good research field.

4.1.1 Working Principle of CMOS Image Sensor

Figure 15 indicates the functional diagram of CMOS Image Sensor. Firstly, the external light illuminates the pixel array, and the photoelectric effect occurs. Then the correcting charge is generated in the pixel array. Row selection logic units, strobe the related row pixel units according to the needs. The image signals within row pixel

units and is transferred to responding analog signal processing unit and the A/D converter via individual column signal bus. Therefore they can convert the digital image signal to output. While in the process, the row selection logic unit can scan the pixel array by progress and interlacing. The image window extraction can be achieved by the interaction between row selection logic unit and column selection logic unit. The main function of analog signal processing unit is to amplify the signal processing, and improve signal to noise ratio. *(Wenku 2013.)*

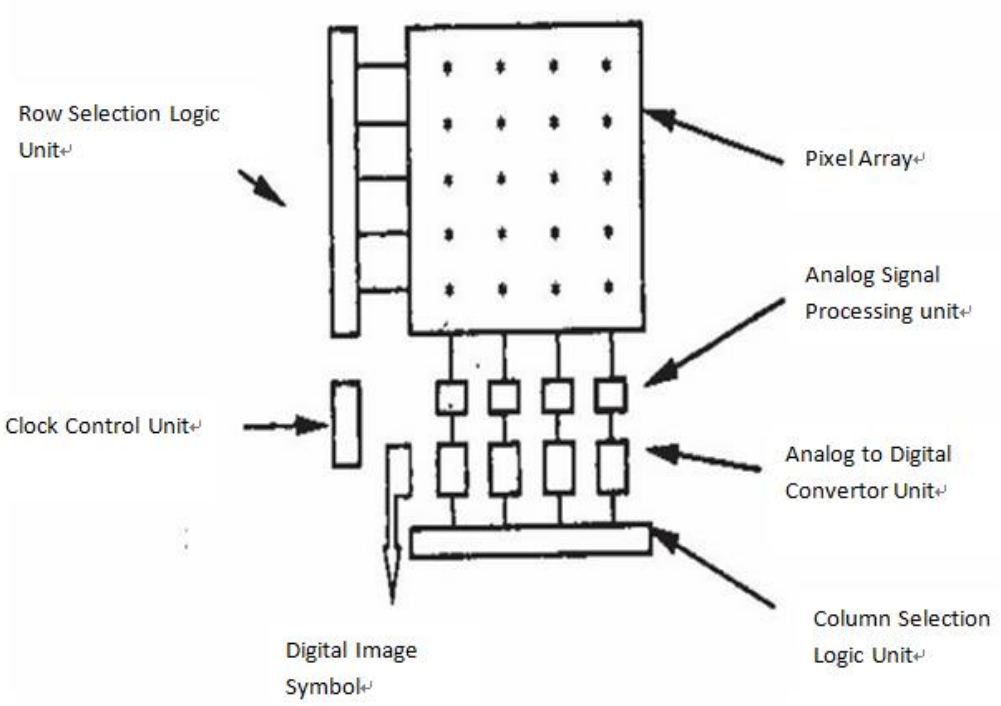

Figure 15. CMOS Image Sensor Functional Diagram(Wenku 2013.)

4.1.2 HD CMOS Image Sensor Development

In the past decade, CMOS image sensor technology has made it shifted from primary services to some high-performance applications through continuous improvement and adjustment. Along with this trend, CMOS image sensors have begun to dominate

the image sensor market, and provide plenty of chances for OEM (Original equipment manufacturers) to achieve differentiation.

The market analysis firm, TSR estimated, in May 2010, CMOS image sensors have occupied more than 90 % market share in high-end digital SLR (DSLR) and mirror-less digital cameras. At the same time, the data released by YouTube indicated that in 2011, the vast majority of videos were uploaded from a mobile device based on CMOS image sensors, especially HD videos. If it takes considerations of various market segments in the entire industry, CMOS technology is undoubtedly the image winner. *(Wenku 2013.)*

Comparing with the CCD (Charge-Coupled Device) image sensors, CMOS image sensors have the following distinct advantages. It relates to good manufacturability, low power consumption, easy integration, low cost and the high quality image. All in all, these inherent advantages have prompted that more competitive OEM developers can better serve end-user imaging systems.

4.1.3 HD CMOS Image Sensor in Smartphones

For smartphones OEM, CMOS image sensors have become the best choice of smartphones and are crucial to acquire higher profits and market shares.

There are obvious examples showing that the smartphone cameras are very important for consumers. The performance of the camera may become the final fact for consumers to direct from which seller to purchase products from which sellers. For example, in July 2010, one report from Pew Reasearch explained that 76 percent of adults surveyed were likely to use the phone camera in their daily life. In contrast, 72 %

of those surveyed sent text messages, 38 % of respondents used a mobile phone to access the Internet. The same survey found that, 34 % of people use their smartphones to record videos. Recently in March 2011, a user report of the frequency to do photo-shoot illustrated that 98 percent of respondents are mobile phone users with some frequency to use their camera phones.

In this market segment, mobile camera and its various triggered camera applications, such as video calls and real-time facetime. This may become distinguished difference from diverse mobile phones. Aptina is a leading innovator of CMOS imaging technology. Aptina Company takes DR-Pix technology to provide high image quality with the best possible noise performance. Aptina DR-Pix technology has two kinds of mode. One is lower conversion gain mode for large charging capacity in bright light scene, the other is a high conversion mode by increasing sensitivity and low read noise for low-scenes. Figure 16 indicates how the DR-Pix technology brought in low light scene is different from the normal pixel image.

Figure 16. DP-Pix Technology in Low Light Scene (Aptina 2008.)

4.2 Smartphone Wireless Charger

Now almost all of the wirelesses charging are unable to take genuine distance charge without a charging dock, but, compared to the traditional way of the line charging, this method is very convenient for picking up a call and replying the information. It will not be constantly troubled without any data lines. If developers can research wireless charging peripherals, it would be useful for users to charge mobile phone in such a convenient pillow, audio and other equipment anytime.

Wireless charging is referring to the battery built-in equipment and charge power devices. They can be charged with the help of the wireless sensors. Wireless charging technology, derived from the wireless power transmission technology, has a basic working principle that uses Faraday law of electromagnetic induction. When the current passes through the coils, it will generate a magnetic field, and the magnetic field generated will form a voltage. After having voltage, the current occurred can charge for powerful devices. There are three ways which could be implemented through electromagnetic induction, radio waves and electromagnetic resonance.

The common wireless charging is based on electromagnetic induction. Current is generated through the induction of primary and secondary coil, thereby energy is transferred from the transmission section to the receiver. Figure 17 shows the work diagram based on electromagnetic induction.

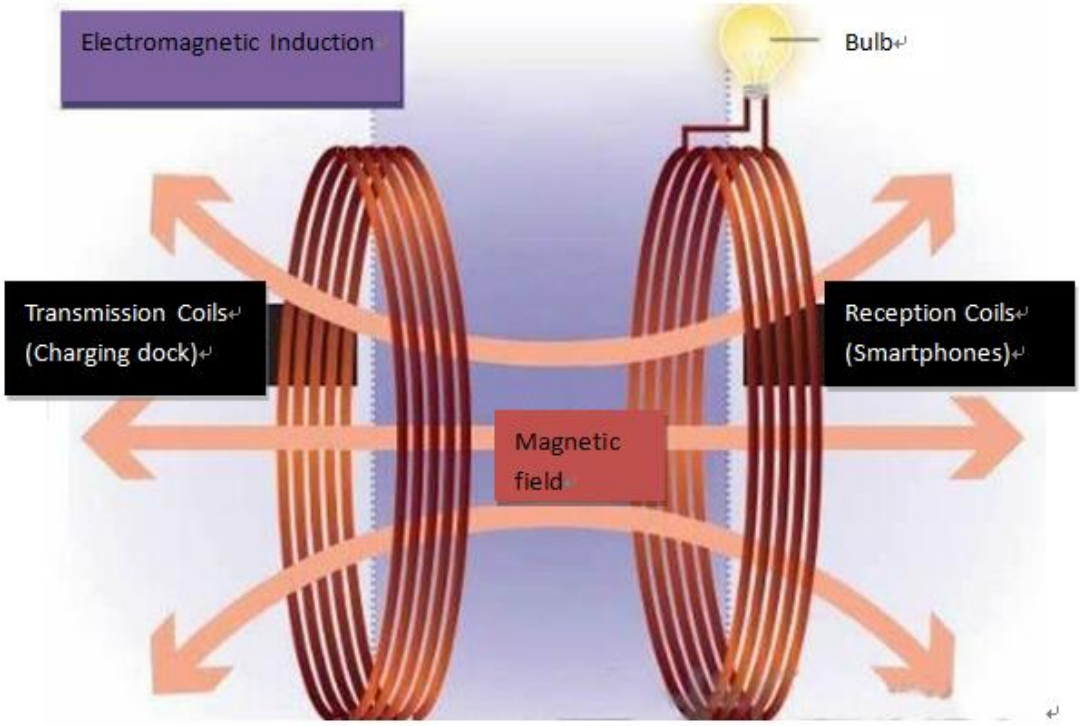

Figure 17. Electromagnetic Induction Wireless Charging (Yesky 2012.)

Electromagnetic induction wireless charging technology can be produced in volume passed through the security department and is able to gain the acknowledgement through proven market. Concerning the production cost, electromagnetic induction technology products have lower costs than other technologies. Next few years, in the field of consumer electronics products such products will show exponential growth. As the initial stage of the new technology, electromagnetic induction has a very obvious drawback. Its distance is too short. As the distance increases, the power loss in the charging process will become very large. *(Yesky 2012.)*

Radio waves, also known as electromagnetic waves, are also able to transmit electrical energy. Such is especially microwave. When it is converted into electrical energy, the conversion efficiency can reach 95 %.

Radio wave wireless charging technology has relatively mature development. Its basic principle is similar to the early use of crystal radio. It can capture energy from the radio waves bouncing off the wall, and maintain a stable DC voltage with the load making adjustments at the same time. Figure 18 shows the working principle of radio wave wireless charging.

Figure 18. Radio Wave Wireless Charging

Current radio wave technology cannot still achieve effectively a long distance transmission. When more electromagnetic energy is concentrated, direction can be guaranteed. Just like a laser in space transmission is subject to refraction of air and dust, resulting very low energy transfer rate.

Magnetic Resonance is a developing technology still under surveying. Resonance is a very efficient way of transferring energy. The same energy can be efficiently transmitted between the two identical objects with same vibration frequency, while there are no effects within different vibration frequency of the objects. Figure 19 illustrates the rules of resonance. *(Yesky 2012.)*

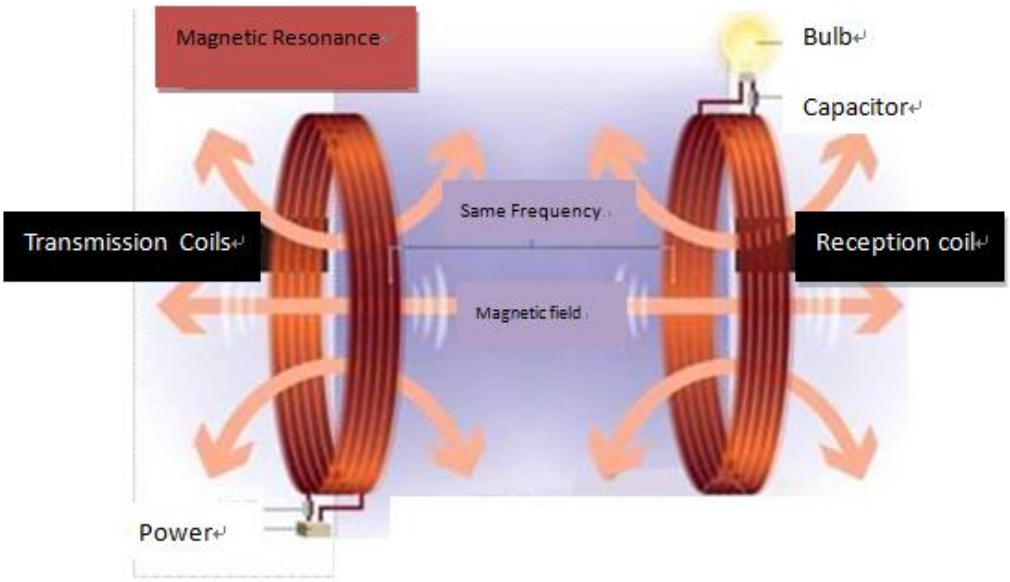

Figure 19.Magnetic Resonance Wireless Charging (Yesky 2012.)

4.3 Body Temperature Testing

Nowadays, human beings express a high concern about their health condition under pressure and everyday life. Everyone hopes to have a healthy body to deal with their daily life activities. Body temperature is an important physiological parameter. It is essential to start monitoring to keep fit. However, nobody could have a thermometer always to measure their body temperature. That would be very inconvenient. If one application could answer this need in smartphones which people usually carry, by applying a better temperature sensor into smartphones.

Figure 20 is ZTP 135SR infrared temperature sensor designed for non-contact measurement of body temperature. It could detect accurately body surface temperature by measuring the infrared radiation on the human body's own energy. Since this wavelength range is not absorbed by air, it could be utilized for measuring tempera-

ture. Also due to its small volume and excellent sensitivity, it is widely suitable for installing in the smartphones and more easier and healthier to care for our bodies in time.

Figure 20. GE ZTP-135SR(Dzsc 2011.)

ZTP135SR sensors are outstanding to satisfy the requirement of customers. It is a linear measuring device based on temperature changes. Equally important is that the infrared sensor used in smartphones is just absorbing infrared radiation from the body rather than any radiation emitted to the human body and radiation damage produced to them. It is better to adapt this to the current smartphone market. By the way, this sensor is not only used in smartphones, but it is a good choice for tablet PCs and ultra-thin laptops to opt for this kind of sensors, too. At the same time, the price is also very cheap and it contributes the development of temperature sensor in the market.

4.4 Smartphone-Based Electrocardiogram Detection

A report from Cnet website says, a new mobile phone called EPI Life from Ephone Company in Singapore aroused much attention. It is the first mobile phone within the market to be able to save lives.

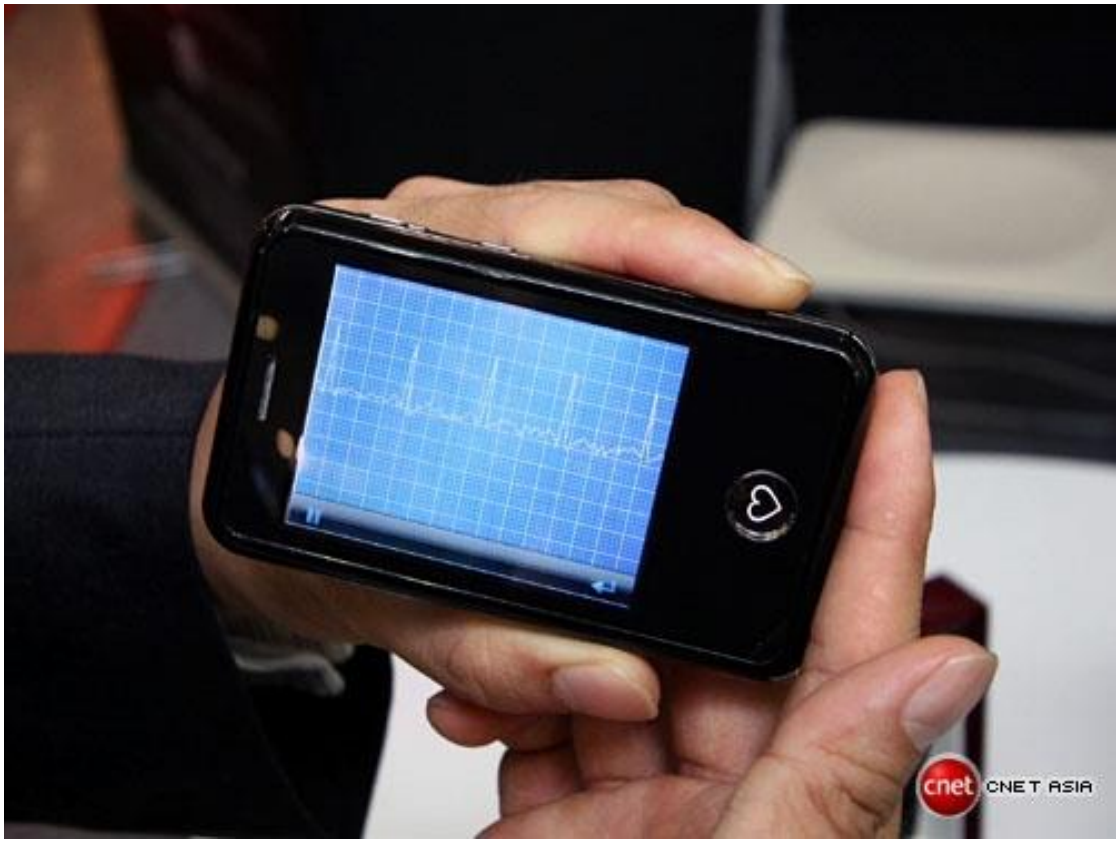

Figure 21. EPI Life-Mobile Doctor (Cnet 2012.)

There is an ECG detection device built in EPI Life. One inspection could be realized within only 30 seconds, and then the data collected will be sent the data centre through the GPRS network. Also Ephone provides emergency service that a group comprised by 10 experts will monitor these data all the time a day. Once there is a life-threatening situation, emergency measures will be launched through a call centre, including an ambulance, rapid response and professional doctors. *(Cnet 2012.)*

This device can also be used to detect blood pressure, blood sugar, cholesterol and other health indictors. Moreover, it is humanized to access to online information to inquire the best solutions or counsel the healthy plan from the doctors for the patients.

There is also an ECG monitoring service platform in China. This system has ECG acquisition box, a smartphone with special transfer software and ECG remote terminal. Five electrodes extending from the ECG acquisition box are attached to the corresponding parts of the patient's body. After starting switch, ECG acquisition box begins to collect data, and human electrophysiological signal is converted into a digital signal. The acquisition box is also equipped with a Bluetooth system that can instantly transfer the digital signal to the smartphone. Remote transmission could be completed by a phone. When the collection box finds the cared object has abnormal fluctuations, such as heartbeat suddenly accelerating, it will automatically collect information and send it. While doctors watch the ECG in the terminal, and once something happens, within three minutes, the doctors would use a mobile phone to send short message to one under supervision about the diagnosis and prescription. If a serious condition appears, the monitoring centre will immediately get in touch with the patient’s family.

5 SMARTPHONE MARKET ANALYSIS

Looking at the smartphone market, not only the competing warfare between both terminal manufacturers, but also operating system vendors, in essence, it is the inevitable result of the market survival of the fittest. At the moment, the mobile phone market, especially in the field of smartphones, is more competitive with new products appearing in booming speed and constant updated terminal iteration.

5.1 Global Smartphone Vendor Market Share in 2014

A glance at Figure 22 reveals the popularity of various global smartphones vendors by occupying the market share in 2014. A report from Q2 2014 indicated that the amount of smartphones is 295.2 million, with a slight increase from last year. One fourth of market share belongs to Samsung, which had been reported to have a decrease than before, largely due to the conflicts of Chinese Brand. The company also had a threat from Apple and the sales of its flagship Galaxy S5 were less than the iPhones. Moreover, some local firms in several countries have gradually entered into the market to gain quiet market, resulting in one of the worst quarterly for the Korea smartphone business in recent times. *(Dazeinfo 2014.)*

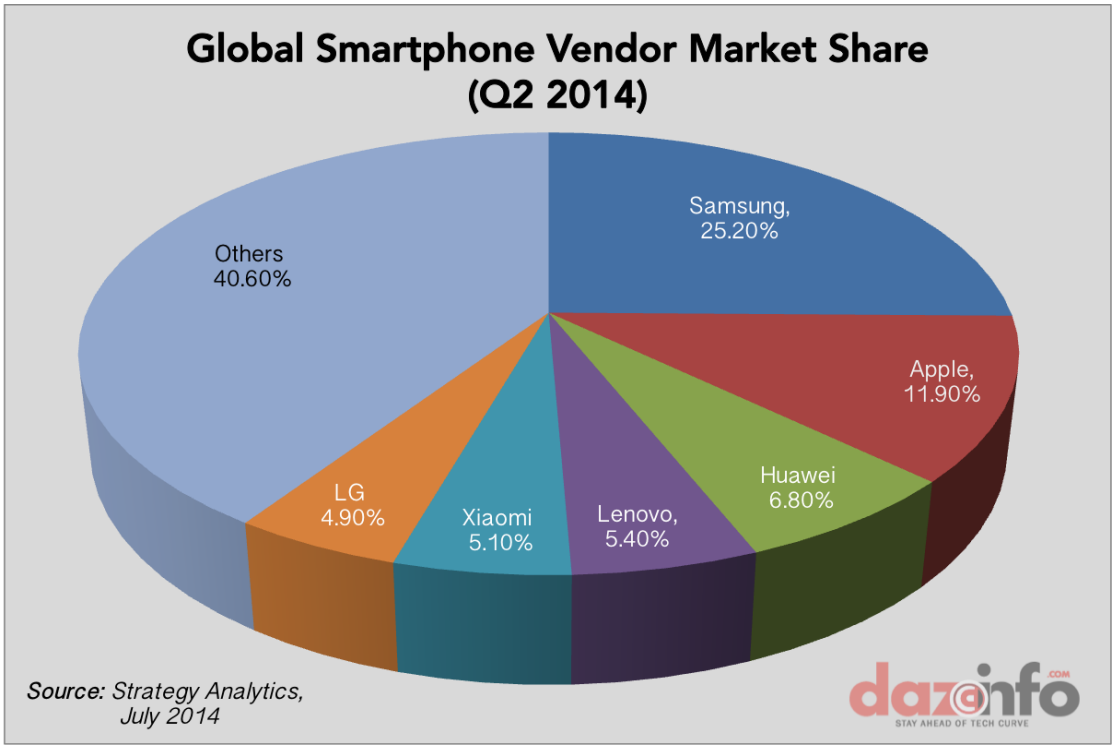

Figure 22. Global Smartphone Vendor Market Share (Dazeinfo 2014.)

Apple sold a total 35.2 million iPhones in Q2 2014, a surprise increase compared to the last year. However, the market share was interpreted to fall down. Without real substantial change in smartphone technology, Apple seems to lose their users more than before. Although it had published new products, the older and cheaper iPhone 4s are preferred by customers with the less income and requirements. According to the situation, it was also exposed the drawbacks of Apple that there was less availability of mid-range category and low-range category. *(Dazeinfo 2014.)*

The remaining three companies in the top are Huawei Technology Co Ltd, Lenovo Groud Limited and Xiaomi. Huawei as the largest telecommunications equipment maker in the world gained the third position with a 6.8 % market share. While Lenovo as the world's largest personal computer vendor also reached the fourth place with a 5.4 % market share. *(Dazeinfo 2014.)*

It is interesting to mention that Xiaomi has acquired a big success recently. After the first release of their smartphones in 2011, it gained the Chinese market and other Asian market surprisingly quickly, and it aimed to expand into the international market later. The new product Mi3 in 2014 has ventured into the Indian Market and got a satisfactory response.

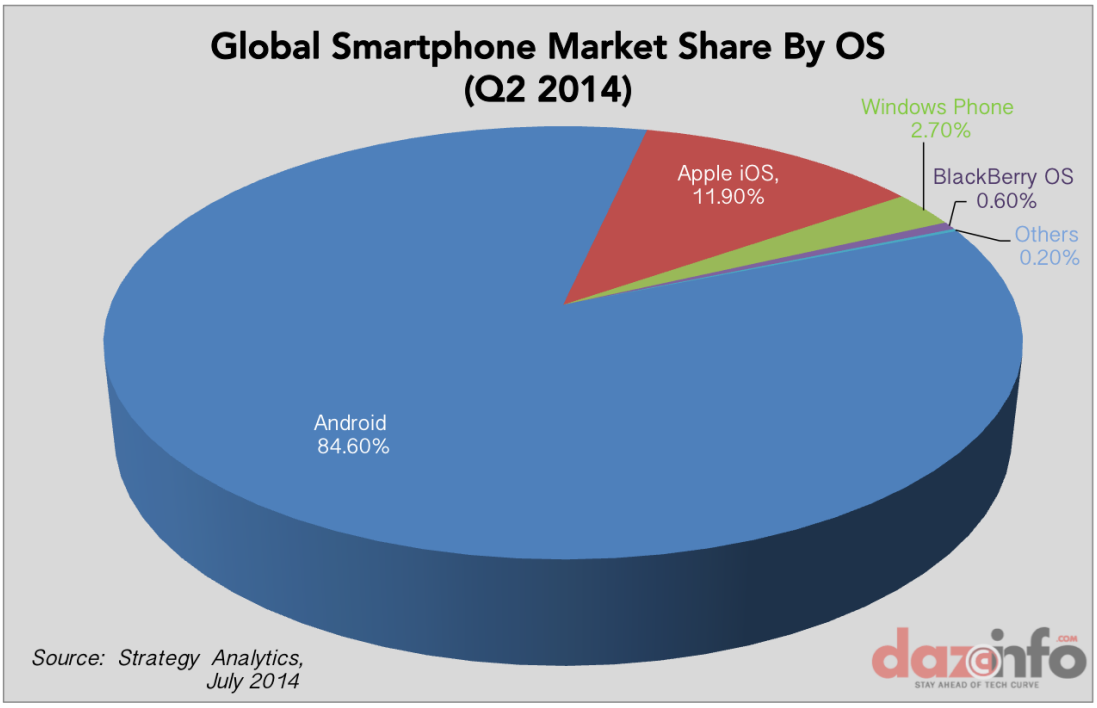

Figure 23. Global Smartphone Market Share By OS (Dazeinfo 2014.)

From other perspectives, as in figure 23, 85 % of all smartphones were shipped by the Android OS. Apple's iOS market share was 11.90 %, and Windows phones shared at 2.7 %. It seems that Android's market could still grow with a variety of vendors investing in the Android systems. Also there is other reasons why Android were popular until now. It provides the low-cost services and user-friendly software, also the free access and many applications based on the Android provided many possible solutions to vendors and users.

5.2 Current Market Performance

Market performance is the behaviour of a security or asset in the marketplace. It refers to under certain market structure and market behaviour, the ultimate economic effects of market operation. It includes the vendor profit margins, industry production capacity and technological progress and production innovation. (Jiang 2014.)

1) Profit margin.

A report released by US market research firm IDC says that the global smartphones shipments were 1.0042 billion in 2013, a 38.4 % increase to the output of 725.3 million in 2012. From the annual data in 2013, Samsung ranked the first in the shipments with 31.3 % market share, comparing to 15.3 % in Apple. The following were by Huawei (4.9 %), LG (4.8 %) and Lenovo (4.5 %). (Jiang 2014.)

However, Apple had a faster growth in the smartphone industry's share of revenues, accounting for nearly 40 %. The profits accounted for 65 % of the smartphone industry. Although Samsung had the largest shipments, the gross profit margin was only 13 %. Thus, industry gross profit margin and the allocation of resources were not ideal. (Jiang 2014.)

2) Industry production capacity

China has now more than 1 billion mobile phone users, and penetration rate of smartphones is about 40 %. While in the global market, the highest penetration rate is in Japan, South Korea is close to or around more than 70 %, so China's smartphone market potential is great; in addition, with the growing popularity of low-

price smartphones, it will further stimulate increasing smartphone shipments. The next few years, penetration rate of China's smartphone can exceed 90 %, even 95 %.(Jiang 2014.)

3) Technological Progress

In terms of technological progress, updated version rate is an effective measurement of market innovation. Update is faster, and then the innovation is stronger. The average update rate of smartphones is quite fast. A new version of Windows Mobile Smartphone is some one year, while Android smartphones can be up to a year with three versions in average, which reflects that in the smartphone industry technological progress is quite rapid.

4) Product innovation

Smartphones have formed path dependence. Product upgrades have been along the existing route to develop, among the bigger screen size, high resolution, faster processor, more cores, thinner body, higher pixel camera and so on. It has been a long time to see the real subversive innovation.

Even for the leading Apple Company, the innovation is also lack and boring. The iPhone 5s just make a change about the colour and little adjustment compared to iPhone 5. The expectation for iPhone 6 is focus on the size of the screen. On the other hand, Samsung's new smartphone S5 is difficult to change the appearance compared to S4, it just increases the functions of waterproof, fingerprint, and heart monitoring. For users, it is also difficult to find a reason to change to new mobile phones.

Therefore, the mobile phone makers must embark on the real innovation and bet on the future, otherwise next stage will change the protagonist.

5.3 Developing Trend of Smartphones

With the enlargement of smartphones in the market share, the mid-range smartphone are blooming (Figure 24). In global mobile phone market, it shows that Asian market is the crucial part within the market, and in order to acquire the favour of them, it is wise to release the mid-range smartphones. There is a growing popularity of smartphones in China especially for mid-stage phones. There are statistics showing that smartphones have higher position, and functional phones are gradually replaced by the smartphones. In order to gain the preference of functional phone users, it is an absolutely good choice for them with the same price but more smart to choose mid-range smartphones.

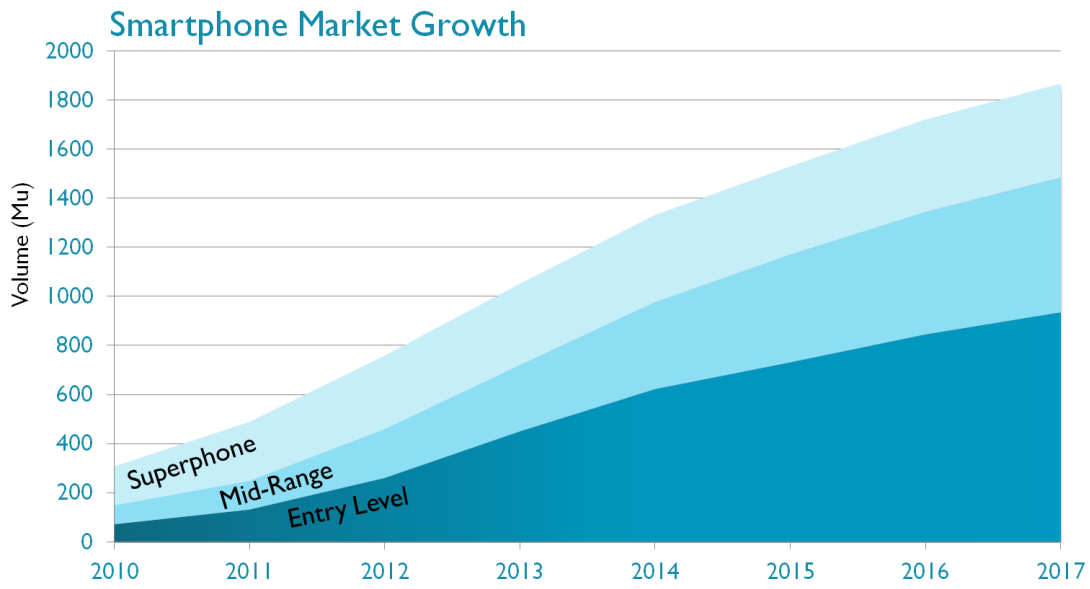

Figure 24. Smartphone Market Growth (Watt, 2012.)

The other clear characteristic is that different industry background is integrating in the market. Traditional smartphones makers and operators continue deepening in the product circle, mastering the new technology and stimulating the innovation. IT vendors also enter this field, not only in the mobile phone terminal, but also in the operating systems. Moreover, the scopes of CP (content provider) are becoming larger than before, and in the future, various filed firms will play a role of CP.

In addition, software application store position is highlighted. With social networks becoming the mainstream of this society, plenty of software developers are developing these fields and aiming to provide first class service for users. Now with the popularity of LTE technology (4G), customers are looking forward to excellent and mature technology brought to them. Moreover, Google, YouTube, Alibaba and other Internet service websites are building their online platform in smartphones. It seems that the application store is occupying more important position than before in the supply chains. Also the intangible pressure is added into the software developing.

6 CONCLUSION

This thesis has introduced the functions of various sensors in smartphones, and discussed the developing trend of sensors in smartphone. Such as fingerprint recognition sensor in terms of security, photoelectric sensors to adjust brightness, gravity sensor gravity sensor and acceleration sensors in specific applications and games to achieve more humanized, as well as other aspects of the image sensor applications. By analyzing the each function of various sensors, so that the sensor in today's rapid development could bring more convenience to the family. Ideas on more and better sensors in smartphones were put forward to meet the needs of people in all aspects. No matter whether sensors in smartphones or in the industrial, medical, aerospace and other aspects, their advantages make it have a very good development prospects, and the application will be more extensive.

There are still some issues to be addressed in the future to solve the limitations of sensors in smartphones. The functional requirements and design will become the focus in the next stage. With the continuous efforts of technical workers, sooner or later, there will be more perfect scheme.

It is also not ignorable that the market of smartphones, the global market has changed all the time. The small vendors and some traditional mobile phones are looking for the new breakthrough. Due to the new requirements and high demands in software applications, lots of new innovations are necessary to win back the heart of users.

There are also unsuitable market performance and market shares. Maintaining the own market share and searching for new opportunities are the long-term strategic

goals. In addition, the competition between different mobile phone brands and network services is increasing sharply. It is a difficult problem how to balance the price and profit, as well as investment and revenue.

All in all, smartphones are important in people's life, and plenty of applications are providing new and convenient services for users. Sensors play essential parts in smartphones. Almost each software application is supported by sensors. It is the mainstream to revise the current sensors and develop new sensors. With the new usage of sensors in smartphones, the market of smartphones is explosive and blooming. Moreover, it is urgent to adjust the current market structures and develop innovative ideas which help to promote the evolution of smartphones.

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