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A brief review of biomedical sensors and robotics sensors

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ABSTRACT: *In this paper, we present a brief review of biomedical sensors and robotics sensors. More specifically, we will review the cochlear sensors and retinal sensors in the category of biomedical sensors and ultrasonic Sensors and infrared motion detection sensors in the category of robotic sensors. Our goal is to familiarize readers with the common sensors used in the fields of both biomedical engineering and robotics. In addition, we will provide a list of some suppliers of those common sensors.*

Keyword: *Biomedical sensors, cochlear sensors, retinal sensors, robotics sensors, ultrasonic sensors*

I. BIOMEDICAL SENSORS

With the advance of computer and information technology, computers and computerized systems play an increasing role in our daily life. As a result, medical doctors and professionals routinely use biomedical sensors, computers, and associated software to perform medical diagnosis, examine wounded areas, and monitor critical vital signals. For example, eye doctors use advanced software systems for detection and staging of papilledema and other eye diseases automatically [Echegaray et al 2011]. To make accurate diagnosis of various diseases, medical doctors need to have high quality biomedical signals taken from different human organs. Therefore, biomedical sensors, as the interface between human organism and computer systems, are very important in the modern medical diagnosis systems that are used to acquire medical information. For example, electrocardiogram (ECG) measurement, ultrasonic, and CT scan images are all taken by sophisticated computerized systems with advanced biomedical sensors.

Biomedical sensors serve as a gateway between a biological system and an electronic system. As such, it takes biological signals such as body temperature, blood pressure, heart beat rates, the presence of certain chemical compounds, or chemical activities in the human body as inputs and converts them into electronic signals in digital forms for processing by microcontrollers or powerful computers. Depending on what a biomedical sensor measures, it can be classified into two major categories: physical sensors or chemical sensors. A physical sensor measures physical quantities in the human body such as blood pressure and heart beat rates. A chemical sensor examines chemical components or activities in the body such as chemical concentrations and enzyme-substrate. Some sensors, for example, the ones used to measure the blood pressure in a clinic setting, are noninvasive while others that need to be surgically implanted in the body are invasive in nature.

There are many biomedical sensors available such as those designed for eye, ear, brain, heart, and lung implants. Here two popular ones, cochlear sensors and retinal sensors, will be presented because of their widespread usage. It should be pointed out that many new biomedical sensors are in the development and testing phase and may be available soon in the market. For example, it was reported that ultrasensitive artificial skin [Patel 2010] and electronic skin [McCormick 2012] were under successful development and testing. Some of those synthetic skins can feel the lightest touch (up to less than 1k pascal) and can be used for prosthetics and robots.

II. COCHLEAR SENSORS

A cochlear sensor is the main component used in a cochlear implant that is arguably the most widely used and successful neural prosthesis. Cochlear implants have given hundreds of thousands of people worldwide partial hearing so that they can live a normal life. It is extremely important for little children to have cochlear implants in the early age so that they can hear and develop normal language skills.

A cochlear implant typically consists of two units: one external unit and one internal unit as shown in Figure 1 [Zeng et al 2008].

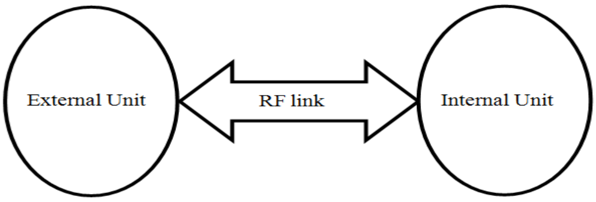

Figure1. Illustration of a cochlear implant

The external unit is usually placed behind-the-ear with an ear hook while the internal unit sits under the skin behind the ear. The main function of the external unit is to pick up outside sound, process it, convert it into a digital signal, and send it to the internal unit via a radio frequency (RF) link. The internal unit then converts the received signal into electric currents that will be used by the electrodes to simulate the auditory nerve. The electrical impulses generated by the auditory nerve are passed to the central nervous system for interpretation as sound. It should be mentioned that the parameters of a cochlear implant can be adjusted by computer software for each individual when the external unit is connected to a computer.

III. RETINAL SENSORS

Similar to the cochlear implant, a retinal implant comprises an external unit and an internal unit as well. The external unit includes a microcontroller with a graphic user interface to adjust the parameters of the current pulses generated by the internal unit such as strength, duration, and frequency [Kelly et al 2011]. The internal unit has a custom Application Specific Integrated Circuit (ASIC) that converts an image into current pulses with aforementioned programmable parameters (strength, duration, and frequency). The external unit and internal unit communicate with each other via near-field inductive coupling as shown in Figure 2.

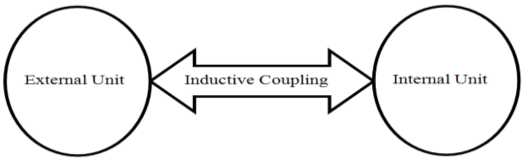

Figure2. Illustration of a retinal implant

In another study, researchers showed that both actively biased photoconductive and passive photovoltaic circuits could play an important role in developing high-resolution optoelectronic retinal prostheses [Loudin et al 2011]. For biomedical sensors, low power and security are two important design considerations. Ideally, a biomedical implant should be able to function continuously through a patient's life time without the need of being replaced or changing its battery. As for the security, a biomedical device should be able to withstand malicious manipulation or attacks from outside attackers. This is especially critical when a biomedical device contains programmable units that can be controlled wirelessly. For example, it was demonstrated that a hacker can remotely take control of insulin pumps and kill patients [Ngak 2011].

IV. ROBOTICS SENSORS

Robots have been widely used in many fields nowadays. For example, The National Aeronautics and Space Administration (NASA) uses robotic cars to search for the evidence of life in the Red Planet Mars. A recent example is the Mars rover Curiosity's landing on the Red Planet using technologies such as radar and dead reckoning [Everett 1995]. The Defense Advanced Research Projects Agency (DARPA) grand challenge promotes the design and implementation of driverless vehicles that can be used to rescue soldiers and deliver suppliers in dangerous regions. Google also joined the force to create a new generation of autonomous cars. Sony designed QRIO (QRIO stands for quest for curiosity) robots as personal assistants that can talk, dance, and even conduct an orchestra. In addition, many different kinds of robots were being created to suit special needs in various fields such as environmental monitoring, health, safety, and electronics. It was also known that robots were being used to infiltrate hard-to-reach areas such as nuclear plants after a disaster.

Regardless of what a robot is used for, it must have a very critical component: Sensors. Without sensors, a robot cannot see, feel, and move around accurately to complete its mission. A robot relies on its sensors to interact with outside world and monitor its own inner status and parameters. With its sensors, a robot can sense its environment and adapt its actions on that basis. Sensors provide a robot the possibility of having artificial intelligence. Without sensors, a robot can at most perform some fixed movements, conducting the same repetitive routines again and again.

Hundreds of types of sensors were created over years for robots to perform different tasks. Some of the popular ones include: odometry sensors, tactile sensors, proximity sensors, ultrasonic sensors, motion detection sensors, light sensors, sound sensors, touch sensors, temperature and humidity sensors, force sensors,accelerometers, inclination and tilt sensors, digital compass sensors, vision sensors, WiFi sensors, RFID sensors, current and voltage sensors, inertial motion sensors, stretch and bend sensors, gas sensors, radiation detection sensors, radar sensors, and GPS sensors. In this chapter, two common ones: ultrasonic sensors and infrared motion detection sensors, will be discussed. It should be mentioned that new sensors are in active development. For example, it was reported that ultrasensitive artificial skin [Patel 2010] and electronic skin [McCormick 2012] can feel the lightest touch (up to 3 pascals) and can be used for robots as pressure sensors.

V. ULTRASONIC SENSORS

An ultrasonic sensor measures the round-trip time required for a pulse of sound waves in the ultrasonic range (above the normal range of human hearing) to reach to a reflecting object and echo back to the sensor. Assume that v is the propagation speed of the sound wave and t is the elapsed time between sending the sound wave and receiving its echo. The distance d between the ultrasonic sensor and the reflecting object could be calculated as follows.

$$d = v * t / 2 \qquad \text{……………. (1)}$$

Ultrasonic sensors are also known as transceivers when they both send and receive the sound waves, as shown below.

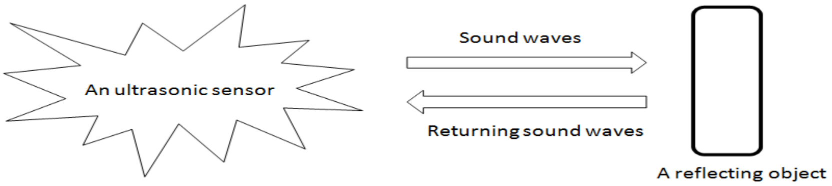

Figure3. Illustration of an ultrasonic sensor acting as a transceiver

In some applications such as ranging application, an ultrasonic sensor can also use both a transmitter and a receiver to measure the distance of a remote object from the sensor, as illustrated below.

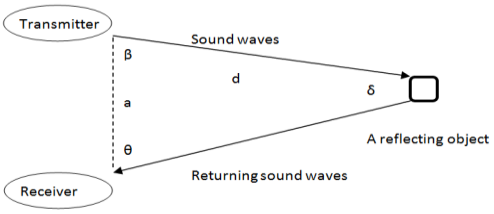

Figure4. Illustration of an ultrasonic sensor consisting of a transmitter and receiver

The desired distance d can be calculated by applying the basic Law of Sines to the triangle whose vertices include the transmitter, the receiver, and the reflecting object, as follows.

$$d = a\frac{\sin q}{\sin d} = a\frac{\sin q}{\sin(q+b)} \qquad \text{……………. (2)}$$

It should be mentioned that ultrasonic waves can also be used to detect flaws in a metal structure such as in a pipe [Bond 2012]. Any flaw in the metal structure will reflect part of the guided wave back toward the sensor that pulses ultrasonic waves through the material to be examined.

VI. INFRARED MOTION DETECTION SENSORS

An infrared motion detection sensor can be used to sense the movement of various objects such as people, animals, and other moving objects. It usually utilizes a passive infrared (PIR) sensor to measure infrared energy radiated from moving objects in its field of view. When a moving object, such as a person, passes through a given location, the temperature at that point will fluctuate, rising from the room temperature to the body temperature first and then dropping down to the room temperature again. This rapid change in temperature will signal the existence of a moving object.

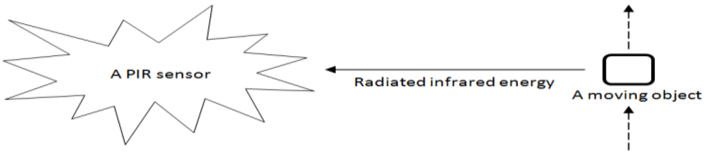

Figure5. Illustration of a passive infrared (PIR) sensor

A PIR sensor detects an object's temperature based on the fact that all objects with an absolutetemperature above 0^{o}K emit radiant energy in accordance with the following Stephan-Boltzman equation [Buschling 1994]:

$$W = es\,T^{4} \qquad \text{…………….} (3)$$

where:
W =emitted energy from an object
e=emissivity
s = Stephan-Boltzman constant (5.670373 * 10^{-8} $watts\ m^{-2}\ K^{-4}$)
T =absolute temperature of the object in degrees K

Emissivity is a measure of an object's ability to either emit or absorb radiant energy [Buschling 1994]. As shown in the above equation, the emissivity e and the absolute temperature T of an object determine the amount of its emitted radiation energy. In should be mentioned that researchers also implemented a PIR-based remote thermometer using a PIR based circuit to measure the temperature of a remote object [Tsai and Young 2003].

VII. CONCLUSION

In this paper, we presented a brief review of biomedical sensors, including cochlear sensors and retinal sensors, and robotics sensors, including ultrasonic sensors and infrared motion detection sensors. It is our hope that through this paper, readers become familiar with common sensors used in the fields of both biomedical engineering and robotics. In the appendix, we provided a list of some suppliers of the aforementioned sensors, from which the interested readers should be able to obtain those common sensors in order to conduct their research.

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[12].

Appendix

PARTIAL LIST OF SUPPLIERS FOR BIOMEDICAL SENSORS:
Advanced Bionics Corporation (*http://www.advancedbionics.com/*)
Med-El Corporation (*http://www.medel.com/us/*)
Cochlear Corporation (*http://www.cochlear.com/*)
Nurotron Biotechnology Inc. (*http://www.nurotron.com*)

PARTIAL LIST OF SUPPLIERS FOR ROBOTICS SENSORS:
SICK (*http://www.sick.com*)
Figaro Engineering Inc. (*http://www.figarosensor.com*)
RobotShop (*http://www.robotshop.com*)
Intelligent Agent (*http://www.intelligentagent.no*)
Dexter industries (*http://dexterindustries.com*)