Tactile Sensors

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Tactile sensing is a field that is rapidly progressing and becoming more useful. One major use of tactile sensing is minimally invasive surgery. This technology will allow surgeons to make smaller incisions and use sensors to virtually feel and look at the internal organs of a patient. A highly developed tactile sensor could even detect cancerous cells from healthy cells[1]. Tactile sensing can also be used in different interfaces with touchscreens. For example, the iPhone uses touch technology and Microsoft has introduced Microsoft Surface[2], a multi-touch interactive table-top that uses a combination of different technologies, including infra-red sensors, to detect touch. Similarly, hp's TouchSmart[3] is using single-touch technology to change the way we use computers today. Eventually, touch technology could be used to develop prosthetics with touch feedback. The apple trackpad also uses touch technology to understand the different ways of touching the mousepad into different actions[4].

Today, there is a new boom in tactile sensing research. Historically, visual sensing has been the more widespread technology. Now, the potential of tactile technology is becoming more evident. Robert D. Howe from Harvard and Mark Cutkosky from Stanford University have published many papers about tactile sensors, and are the leaders in this area of research. Another similar area of research is haptic technology, which has been explored in more depth.

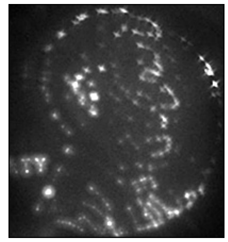
The University of Tokyo has developed an artificial skin that can be used on robots[5]. The technology uses organic

[1] http://www.livescience.com/strangenews/060608_robot_touch.html
[2] http://www.microsoft.com/surface/index.html
[3] http://www.hp.com/united-states/campaigns/touchsmart/#/Main/
[4] http://www.macworld.com/article/134343/2008/07/maclaptop_trackpad.html
[5] http://www.trnmag.com/Stories/2004/092204/Flexible_sensors_make_robot_skin%20_092204.html

field-effect transistors made of carbon chains to create a large, flexible, potentially ultra-low cost pressure-sensor array The arrays have 16 sensors per square centimeter, as opposed to 1,500 in the human fingertip. Takao Someya, one of the principal researchers, foresees many future applications of this technology, including drivers seats, hospitals, and many more. Someya thinks the product could be available for practical use by 2010.The comparative ease of development and manufacturing makes these potential applications much more likely.

Robotic hand and skin - fig1
http://www.ntech.t.u-tokyo.ac.jp/Archive/Archive_download/Archive_download_en.html

Vivek Maheshwari and Ravi Saraf from the University of Nebraska have also developed a different type of tactile sensing. The sensor is made of layers of semiconductive material: when these layers are pressed together, it releases light and a measurable electrical current. The sensor is a very thin film, yet is high resolution; when pressed against a penny, the image is clear enough to read the word "liberty."[1]



http://news.bbc.co.uk/2/hi/science/nature/5056434.stm

The challenge of creating a touch or tactile sensor lies in mimicking the touch sensitivity of the human finger. In the newly expanding field of robotics, tactile sensing allows robots to respond to their environment, as well as explore and manipulate the environment. Robots can be programmed to complete intricate tasks, but if the device cannot sense when it has hit a surface, it may damage itself. Touch and tactile sensing allow robots to understand their environment by feeling an object and determining what that object is. Minimally invasive surgeries already use this kind of sensing – the surgeon is able to virtually "feel" the tissue inside the patient without actually needing to make large incisions. According to Dr. Richard Crowler, "The development of tactile sensor is one of the key technical challenges in advanced robotics and minimal access surgery."[6]

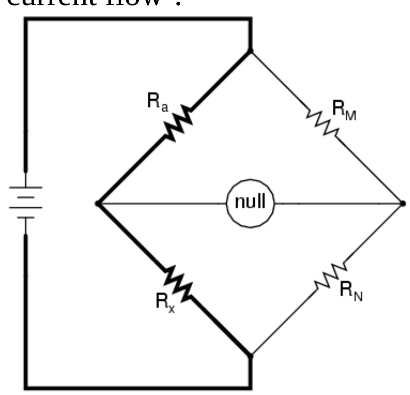
There are two types of tactile sensing – kinesthetic sensing, which primarily detects internal forces, and cutaneous sensing, which, like skin, detects external forces. An example of kinesthetic sensing is human perception of muscle motion. Cutaneous sensing refers to skin-sensing – determining the feel and contours of an object. This paper focuses on the different types of cutaneous sensors.

Creating a sensor as sensitive as the human finger is a difficult task – the human hand has about 17,000 different mechanoreceptors[6]. Nerve endings respond to touch, pressure, temperature, pain,

[6] Howe "Tactile Sensing and…." COME BACK AND FIX ME!!!!!!!!

liquidity, and other stimuli. One of the most difficult senses to reproduce is perception of touch and force. Many factors must be considered when determining which sensors will best suit one's needs. Some important factors to think about are whether the sensor needs to be able to detect the amount of pressure, or simply whether it is touching something. Spatial resolution must also be considered; how accurately must the sensor detect position? Similarly, one must consider temporal resolution and how quickly the sensor must respond to a trigger. Activation force should also be taken into consideration. A sensor may be very sensitive, but only in a certain range of pressure.

Piezoresistive pressure sensors are the oldest and most highly-used pressure sensors[7]. The sensors consist of four resistors imbedded into a micro-machined silicon diaphragm in a Wheatstone Bridge, which is a setup that accurately measures electrical resistance. Two resistors are oriented to sense stress in the direction of current, and two are placed perpendicularly to their current flow[8].

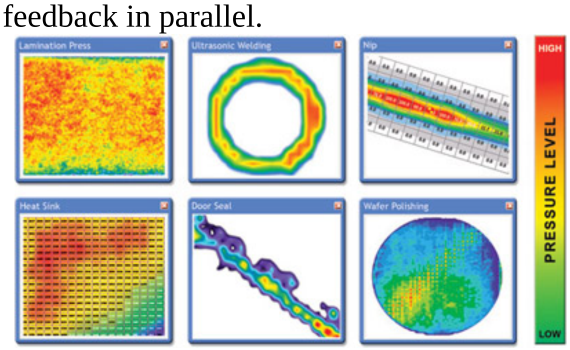


http://www.eng.cam.ac.uk/DesignOffice/mdp/electric_web/DC/00420.png

This way, resistance change of each pair is opposite to the other piezoresistive pair. The electrical resistance of crystalline silicon changes under mechanical stress, and virtually never breaks. When a stress or pressure is applied, the diaphragm flexes, inducing a stress on both the diaphragm and the resistors. Response time can be as rapid as one millisecond. The simplicity of imbedding the resistors straight into homogenous crystalline silicon creates a very stable sensor[9].

The sensors are very thin, and the sensitivity can be changed depending on the resistor used in the circuit. Piezoresistive sensors are also quite inexpensive. Force sensing resistors, or FSRs, use the piezoresistive effect to determine pressure applied. Interlink Electronics is a company that is the biggest FSR manufacturer. FSRs respond to any stimuli, not just skin, and have been used in Microsoft game controllers.[10] When a force is applied to the sensor, the resistance decreases.

The Tactilus product is an incredibly user friendly sensor from Sensor Products[11] Inc that uses piezoresistive technology to create arrays of sensors for surface pressure mapping. Tactilus products can only be purchased with the accompanying software, which includes extensive imaging, etc. The company can customize sensors to any specific needs, allowing the sensors to conform to difficult shapes. Tactilus free form are smaller piezoresistive sensors that can be run simultaneously, and give feedback in parallel.



http://www.sensorprod.com/tactilus.php

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[7] http://www.sensorland.com/HowPage004.html

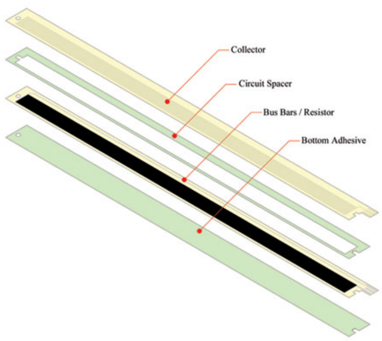
[8] http://www.magnet.fsu.edu/education/tutorials/java/wheatstonebridge/index.html

[9] http://www.maxim-ic.com/appnotes.cfm/an_pk/871

[10] http://www.interlinkelectronics.com

[11] http://www.sensorprod.com

The SoftPot sensor from Spectra Symbol[12] is a strip potentiometer that changes resistance depending on where it is pressed, and can therefore be used to determine where it is being pressed.



http://robosavvy.com/store/product_info.php?currency=EUR&products_id=416

The Tekscan[13] also uses their self-developed resistive-based technology developed to determine the shape of an object. In order to purchase an iScan sensor, you must also purchase the software. The software includes advanced realtime 2D and 3D color images, among many other features. The company offers over 200 different sensors, but is willing to help design and manufacture a custom sensor. Tekscan products have been used in a wide variety of industrial, mental, and dental applications.

Capacitance is another technology in touch sensors[14]. The sensor includes an overlay on top, which is usually 3mm or less, though scientists are striving towards making thicker and less flexible overlays without compromising the sensitivity. A current goal is to make a sensor that is able to have 10mm thick glass as its overlay.

Right now, many touch screens such as the iPod and iPhone use capacitance based technology. The human body has a certain electrical potential and there are electrolytes present which could conduct electricity. The human skin is a dielectric (non-conductive) material. When a finger comes into contact with the sensor, it brings with it the accumulated charge of the human body. As the distance between the body of charge and the sensor decreases, so does the capacitance of the sensor. Change in capacitance can be used to determine if something has been touched.

Most touch screens nowadays have a transparent metallic film over some other transparent substance (like glass or plastic) for rigidity. A low voltage is distributed through the metallic film. Receptors, which monitor the voltage, are located at the corners of the film and occasionally on the edges. When a finger of or source of charge comes into contact with the screen it creates a voltage drop and therefore draws current. The current flow to the receptors is proportional to the distance from the receptors.

The basic design of an optical sensor consists of a surface off of which light is reflected. When pressure is added to this surface, it deforms and thus changes some property of the light, typically the direction. Optical sensors utilizes four main methods to detect variations in pressure, total internal reflection, surface plasmon resonance, and interferometry. Total internal reflection is a

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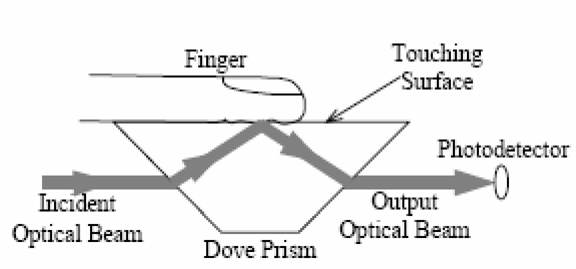
[12] http://spectrasymbol.com/typo3/site/en/softpotsplash.html

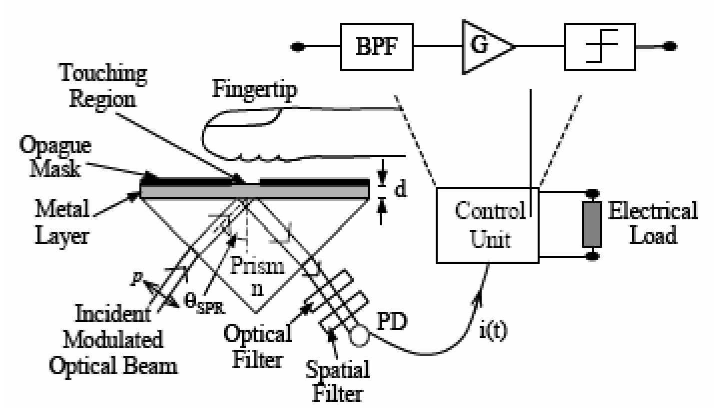
[13] http://www.tekscan.com

[14] http://www.planetanalog.com/showArticle.jhtml?articleID=181401898

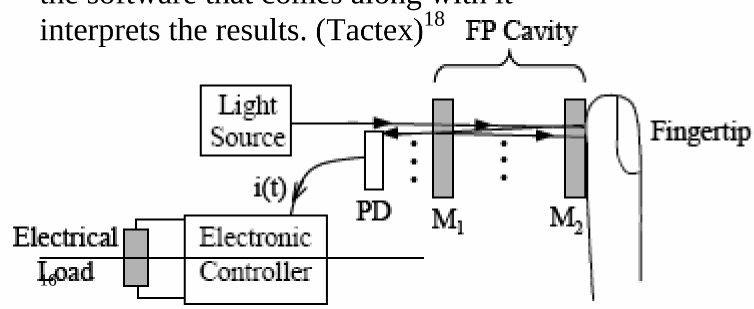
phenomenon that occurs when light travels from a more optically dense into a less optically dense medium. Because of refraction, the beam of light bends away from the norm (the path of light if it traveled in a straight line). At once point the angle of incidence becomes so great that the light bounces back into the denser medium. At this point, the surface where the two mediums come into contact acts like a mirror, and reflects the light. When a force is exerted on this surface, the output beam bounces back at a different angle. The photodetector can detect what the percentage of light is striking, which helps it infer the angle at which the light is coming from. (Amarit, Ratthasart) [15]



Surface plasmon resonance occurs when surface plasmons interact with light, which increases their level of excitation. Surface plasmons are electromagnetic waves that occur parallel to the boundary layer between a metal and a dielectric material. When the surface is disturbed, so is the boundary layer, which in turn changes the direction surface plasmons. Two polarized light beams of different frequencies are emitted and go on to excite the surface plasmons. The polarized light beams are reflected back at a different frequency. A detector receives both of these light beams, and can then deduce what the image of the surface was. Force sensors using this technology have not yet been made commercially available. (Lin, Chu-Wann)[16]



Interferometry is a way to detect changes in the properties of light. It superpositions of two (or more) intersecting light beams and how they reflect off of a surface. When the surface is shifted, the differing beams of light give information on the light beam. Occasionally, only one light source is used and then broken up using partial mirrors or grating. (S. Kusamran) [17] The Kinotex sensor from Tactex uses its own modification of this technology. There are various taxels (receivers – the number depends on what size the array is) and at least two laser light sources. Each of the taxels pick up a different signal from the light sources. When pressure is applied, the signal received by each of the taxels changes, and the software that comes along with it interprets the results. (Tactex)[18]



[15] http://ieeexplore.ieee.org/iel5/10387/33016/01548254.pdf

[16] http://www.patentstorm.us/patents/6661520/claims.html

[17] http://www.tijsat.tu.ac.th/issues/1996/no1/1996_V1_No1_2.PDF

[18] http://www.tactex.com/large_arrays.php

"Large Array Sensor" from Tactex using Kinotex technology.

http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1896101#R10

http://www.patentstorm.us/patents/6661520/claims.html Lin, Chu-Wann

http://www.tijsat.tu.ac.th/issues/1996/no1/1996_V1_No1_2.PDF S. Kusamran

http://www.tactex.com/large_arrays.php

http://ieeexplore.ieee.org/iel5/10387/33016/01548254.pdf

TIF
SPR
Interferometry
TIR + Scattering

Diagrams, products and drawings circuit diagrams
Citations, terms
How the sensors actually work, versus the technology that goes into.
DLR head sketchup