TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

01st January 2016

1. INGESTIBLE VITAL SIGNS MONITORING

Vital signs are crucial indicators of an individual's physical condition and can provide key information with respect to the need and suitable type of intervention.

Conventional methods of measuring a person's vital signs (such as heart rate, respiration rate, body temperature, blood pressure) include electrocardiography, pulse oximetry, blood pressure cuffs or blood pressure sensors, and stethoscopes. Such devices can be inconvenient for individuals, as contact with the skin is required. Moreover, wearable monitoring devices can be uncomfortable.

There is keen, deep interest in developing and commercializing ingestible sensors for monitoring vital signs or detecting an individual's medication adherence. Ingestible sensors can allow for improved, real-time monitoring of an individual's key physiological parameters, as well as more efficient healthcare by enabling remote monitoring of patient health. The types of ingestible sensors that have been developed or are under development, include, ingestible temperature sensors, ingestible gas sensors, ingestible pressure sensors, ingestible camera pills, and ingestible medication adherence trackers.

Researchers affiliated with Massachusetts Institute of Technology (MIT) have advanced the field of ingestible sensing by designing an ingestible sensor that has potential to measure heart rate and respiratory rate, from within the human gastrointestinal digestive tract.

Promising applications for the sensor could include evaluation of the condition of trauma patients, monitoring soldiers in combat, assessment of patients with chronic illnesses, or enhanced training of athletes. For example, the ingestible sensing device could be beneficial in monitoring soldiers for fatigue, dehydration, tachycardia (heart rate exceeding the normal resting rate), or shock. In combination with a temperature sensor, the device could, moreover, detect hypothermia, hyperthermia, or fever from infections.

The ingestible sensor calculates heart and breathing rates from the distinctive acoustic waves generated by heartbeats and the inhalation and exhalation of the lungs. The researchers were able to accurately measure heart rate and respiration rate by characterizing the sound waves recorded from different parts of the gastrointestinal (GI) tract.

The researchers essentially created a very small, swallowable stethoscope. A single sensor can collect heart sounds and lung sounds. Signal processing systems were created to distinguish the acoustic signals generated by the heart from those produced by the lungs, as well as from signals generated by the background noise from the digestive tract or other parts of the body.

The ingestible sensor, which is about the size of a multi-vitamin pill, is comprised of a tiny microphone packaged in a silicon capsule, which also includes electronics that process the sound and wirelessly transmit radio signals to an external receiver over a range of about 3 meters. In testing in the GI tract of pigs, the ingestible sensing device was able to accurately detect heart rate and respiration rate, even when the amount of food being digested was varied.

The ingestible sensor is envisioned to remain in the digestive tract for about one or two days, and new capsules would need to be swallowed for longer term monitoring.

The researchers also envision creating sensors for diagnostics and drug treatment delivery; for example, sensors to detect particular molecules or a pathogen and then deliver an antibiotic.

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2. ENHANCEMENTS IN FLEXO-ELECTRIC NANOMATERIALS

Piezoelectric materials embody the piezoelectric effect and are able to generate a voltage when subjected to mechanical stress. Such materials also exhibit the reverse piezoelectric effect and are able to deform (become mechanically stressed) in response to an applied voltage. Piezoelectric ceramic materials can become susceptible to drawbacks in such areas as stability (due to aging), electrical/voltage shortcomings (exposure to a strong electric field, of opposite polarity to that of the polarizing field, can depolarize a piezoelectric material); ability to withstand mechanical stress; operating temperature limits; mechanical stress limitations (high mechanical stress can depolarize a piezoelectric ceramic).

Furthermore, PZT (lead zirconate titanate) piezoelectric materials, a commonly used piezo ceramic material, comprise more than 60% lead. The piezoelectric effect in piezoelectric materials decreases as the material is made thinner.

Researchers at the Netherlands-based University of Twente's MESA+ research institute, along with researchers from several other institutions (the Catalan Institute of Nanoscience and Nanotechnology and Cornell University), have developed a flexo-electric nanomaterial, which can enable non-piezoelectric materials to gain piezoelectric properties. Such flexo-electric material features built-in mechanical tension that changes shape when an electrical voltage is applied, or generates electricity when its shape is changed. The flexo-electric effect strengthens as the material is made thinner. The material has potential in interesting and key applications, such as recharging of a pacemaker within the human body or very sensitive sensors. Ceramic or quartz piezoelectric materials are used in sensors to detect various parameters, such as pressure, acceleration/vibration, force, strain, or in ultrasound sensing.

The researchers have been able to develop a flexo-electric nano system that is only 70 nanometers thick. Although the flexo-electric effect is weak, the thinner the material is made, the stronger the effect is manifested. They fabricated a silicon-compatible thin-film cantilever actuator with a single flexo-electrically active layer of strontium titanate with a figure of merit comparable to that of state-of-the-art piezoelectric bimorph cantilevers.

The researchers have shown that flexoelectricity, which allows a dielectric material to polarize in response to a mechanical bending moment and, conversely, to bend in response to an electric field, could be viable for the creation of led-free microelectromechanical and nanoelectromechanical systems.

The researchers envision the possibility over time of creating ultra-thin flexo-electric materials having a thickness of only a few atomic layers. Such capability could enable innovative applications, such as ultra-sensitive sensors capable of detecting a single molecule. For instance, a molecule landing on a vibration sensor would make the sensor fractionally heavier, slightly slowing the vibration. The flexo-electric effect could then be used to measure the reduction in frequency. Another potential area for such flexo-electric materials is difficult-to-access applications that require a limited amount of power, such as pacemakers or cochlear implants in the human body.

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3. ADVANCEMENTS IN CONTEXT-AWARE SENSING

The proliferation of mobile computing devices, such as cell phones or smart wearable devices has driven intense interest in context-awareness. Context awareness refers to enabling mobile computing or handheld electronic devices to provide different functions or services based on different contexts, locations, and environments. In context-awareness, sensors are vital to provide information about the activities and events in the real world and to determine the user’s context.

Researchers at Carnegie Mellon University and Disney Research have devised the EM-Sense technique, which leverages the conductivity of the human body to elegantly enable context and activity sensing by detecting interaction with objects. In this approach, the human body serves as an antenna. Objects can be identified solely by their electromagnetic (EM) signatures.

As noted in "EM-Sense: Touch Recognition of Uninstrumented, Electrical and Electromechanical Objects," published in *UIST ’15 Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology*, the approach takes advantage of the small amount of electromagnetic noise that is emitted from many electrical or electromechanical objects during their operation, such as kitchen appliances (for example, refrigerators or stoves), computing devices (for example, touch screens), power tools, cars. Moreover, electronic devices, particularly such devices driven by motors or switching power supplies can generate significant levels of EM noise, which propagate as radio frequency signals. EM noise is also generated from varied sources such as AC electricity and power line devices. Furthermore, non-electromechanical objects can generate EM signatures, such as large metallic structures, doors, ladders, furniture, and so on.

The EM signals propagate through the user when he/she contacts the object, due to the natural electrical conductivity of the human body. The EM-Sense technique allows for detecting whether an individual is touching an electrical or electromechanical device and can automatically identify an object based on the distinctive electromagnetic noise that it emits.

The researchers modified a software-defined radio to detect and classify EM signals in real time, enabling on-touch object detection. A software-defined radio can transmit and receive widely different radio protocols based only on the software used. In the software-defined radio, some or all of the physical layer functions are software defined.

The researchers created a highly innovative approach that does not require any instrumentation of objects (using such technologies as RFID tags, barcodes, or Bluetooth Low Energy beacons) or the environment. They built a proof-of-concept smart watch to implement the E-M Sense capabilities and demonstrated the feasibility of discriminating among dozens of objects, irrespective of the wearer, the time or the surrounding environment. The EM-Sense technology has potential to allow smart watches to automatically recognize the particular object that an individual is touching to facilitate improved context awareness.

In the proof-of-concept smart watch implementation, the researchers modified a software-defined radio receiver to serve as an analog-to-digital converter. When the user contacts an electrical or electromechanical object, the object's EM signal propagates through the body and is sensed by a wrist-worn conducting electrode. Real-time signal analysis is used to extract the EM signals produced from physically touching an object.

A smart watch equipped with EM-Sense technology would provide a more detailed understanding of the user's activities in relation to the environment. Such an EM-Sense enabled device could allow functions such as automatically starting a timer when the wearer uses an electric toothbrush. It could also allow user authorization of a computer without using a password, enable touch screens to differentiate inputs from different users as a result of knowing when each user contacts the screen, automatically detect one's mode of transportation and provide a route overview; or, as a result of detecting patterns of appliance touches, play the latest news when breakfast is being prepared.

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4. PRECISE DETERMINATION OF POWER LINE SHORT CIRCUITS

There is a vital need for very reliable, proactive monitoring of electric utility distribution as well as transmission power lines in order to provide improved identification and communications about incipient outages and increased safety and grid utilization. Enhanced power line monitoring solutions can, furthermore, enable quicker line restoration and reduction in costs by eliminating or reducing the need to send work crews to discover problems in the power line.

Sensors to detect key parameters, such as fault current, fault location, voltage, as well as the temperature of the conductor are becoming more widely used on distribution lines to provide more accurate timely detection and prevention of power line faults and outages. It is important for fault current sensors to not be vulnerable to false alarms and to not equate a switching event with a power outage.

There is also a pressing need to monitor the condition of transmission lines, which are higher voltage, high value, critical lines that are more complex and costly to repair or replace.

Researchers at the Ecole Polytechnique Fédérale de Lausanne (EPFL) Distributed Electrical Systems and Electromagnetic Compatibility Laboratories in Switzerland have devised a method to precisely pinpoint the exact location of a short circuit in a power grid, which could alleviate the need for sending a technician to visually inspect the line to find the location of the fault. The approach is based on electromagnetic time reversal (EMTR), which has certain benefits in fault location, such as straightforward applicability to inhomogeneous media (mixed overhead and coaxial power cable lines), use of a single measurement point, and robustness against the type of fault and fault impedance.

As noted in "A New Method to Locate Faults in Power Networks Based on Electromagnetic Time Reversal," published in 2012 IEEE 13th International Workshop on Signal Processing Advances in Wireless Communications (SPAWC), the EMTR technique for locating sources of electromagnetic transients of currents and voltages exploits the wave equation. The approach allows for time-reversing the transients observed in specific points of the system to focus the energy that originated the transient at the location of the source. The EMTR technique is mainly used in an inhomogeneous medium to focus the wave into a specific point and to locate sources that have generated disturbances. This technique has been especially efficient when the system is space limited. The aforementioned document, authored by individuals from EPFL's Distributed Electrical Systems Laboratory and Electromagnetic Compatibility Laboratory, discussed the theoretical demonstration of the applicability of the EMTR technique to electromagnetic transients associated with traveling waves in transmission lines. The line is assumed to be terminated at both ends on power transformers represented with high impedances.

The researchers developed an embedded hardware platform hosting the fault location algorithm connected to the primary substation on the grid. In the event of a short circuit, the system analyzes the resulting waveforms at the measurement point. The fault location platform then time-reverses the waveforms and reinjects them into the grid model simulated in the platform. The back-injected signals converge towards the fault location.

The researchers posit that the EMTR technology, which has been implemented in a chip-scale real-time simulator, can provide faster and more efficient fault location compared to conventional fault indicators. The entire power grid can be covered from one observation point, potentially eliminating the need for installing numerous sensors power lines that span very long distances (for example, hundreds of kilometers). The technique is very suitable and beneficial for large-scale power grids that have complex topology and for hybrid or mixed power networks that combine high-voltage lines and coaxial cables. The platform, moreover, facilitates large-scale integration of renewable energy sources. The realization of such grids with complex topologies will be given impetus by the ability to identify the exact fault location within a very short time using a single measurement point.

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5. RECENT PATENTS IN THE FIELD OF THREE-DIMENSIONAL IMAGING SENSORS

Three-dimensional (3D) image sensors are able to capture in-depth information to provide a 3D image. Three-dimensional vision systems have been used for machine vision and surveillance, with potential in robotics. The technology has received considerable attention in recent times because of its applicability in the huge consumer electronics sector.

In an industrial or warehouse setup, 3D images enable better identification and handling of materials. 3D gesture recognition is more accurate than 2D gesture recognition, as 3D depth measurement can separate the foreground from the background. 3D machine vision can be used in robotics to enable a better sense of the environment in robots, including, depth sensing.

A recent patent in 3D imaging sensor is powered by plurality of pixels (US20150123173). The patent is assigned to SILICON OPTRONICS, Inc., which has been classified as semiconductor components sensitive to shorter wavelengths of radiation such as infra-red and electromagnetic radiation.

The key growth driver is the sense of depth in images and videos, enabling better visualization. This factor is expected to drive the industry through the long term. The immersive computing and augmented reality user experiences are enabled using 3D image sensors, which would drive the industry through the long term. 3D image sensors have a wide application scope, ranging from healthcare to consumer electronics and automotive.

According to the patent filing scenario, it can be said that there is an increased interest in gesture recognition and this will enable higher adoption of 3D image sensors that employ the time-of-flight principle. Promising applications for 3D TOF sensors include industrial human machine interfaces, smart advertising/digital signage, healthcare, and so on.

Some of the companies in 3D image sensing are Pelican Imaging, Fuel3D, Matterport, Infineon, Velodyne, and Fastree3D.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
3D STACKED IMAGE SENSOR WITH PMOS COMPONENTS	07.05.2015; US20150123173	SILICON OPTRONICS, INC.	Xinping He	An active pixel sensor comprises a sensor die and a circuit die. The sensor die comprises a plurality of pixels, wherein each pixel includes a light sensitive element and a transfer gate, a floating diffusion region, wherein the plurality of pixels include at least one reset gate. The circuit die comprises a plurality of processing and amplification circuits associated with the reset gates of the sensor die. The sensor die is interconnected with the circuit die utilizing a plurality of inter-die interconnects each coupled to a source node of a reset gate on the sensor die and a node of a processing and amplification circuit on the circuit die. The plurality of processing and amplification circuits each comprises a source follower transistor, wherein the source follower transistor uses a PMOS.
PIXEL UNIT OF 3D CMOS IMAGE SENSOR	07.05.2015; WO/2015/062141	SHANGHAI IC R&D CENTER CO., LTD.	CHEN, Jiayin	Provided is a pixel array of a 3D CMOS image sensor, which belongs to the field of integrated circuits. From bottom to top, the pixel array comprises in sequence: a substrate, a sensor layer being provided in the substrate and being used for conducting a photoelectric conversion on incident light in an optical channel; a metal layer which is used for transmitting an electrical signal, on which the photoelectric conversion is conducted, to a peripheral circuit for processing; a micro-lens layer which is used for focusing light rays which are irradiated into the optical channel to form the incident light; and a light shading layer which is used for enabling the direction of the incident light sensed by a sensing layer in each pixel in an odd column and the direction of the incident light sensed by a sensing layer in each pixel in an even column to be distributed at two sides of a normal direction of a pixel array respectively, so that digital images which simulate left and right eye channels are formed by way of the processing of the peripheral circuit. In the present invention, based on a monolithic image sensor, the 3D stereoscopic vision is achieved, and the costs of the 3D stereoscopic vision are reduced.
SYSTEM AND METHOD FOR FABRICATING 3D IMAGE SENSOR STRUCTURE	09.04.2015; KR1020150039171	Taiwan Semiconductor Company Limited conductor menu pack chyeoring	KAO MIN FENGKAO MIN FENG	This disclosure provides, among other things, a microfluidic device for detecting an analyte in a liquid, comprising: a substrate; a fluidic channel on a surface of the substrate; and a nanosensor at a location of the channel, the nanosensor comprising: a nanostructure, the nanostructure comprising at least one nanostructure element, each element comprising at least two metallic structures that are separated by a gap, and a capture agent deposited on a surface of the nanostructure, wherein the capture agent specifically binds to the analyte. The nanosensor amplifies a light signal to and/or from the analyte or a light label attached to the analyte, when the analyte is bound or in proximity to the capture agent.
IMAGE SENSOR WITH 3D STACK STRUCTURE	26.02.2015; US20150053846	SILICONFILE TECHNOLOGIES INC.	BYUN Kyung Su	Disclosed is an image sensor with a 3D stack structure, in which pixels of a top plate are realized as image pixels and pixels of a bottom plate are realized as pixels for realizing a phase difference AF, so that the phase difference AF is realized without loss of resolution. In the image sensor with a 3D stack structure, a problem of the reduction of resolution, which is a disadvantage of an existing imaging surface phase difference AF device, is solved, so that a fast phase difference AF is realized while maintaining high resolution without a separate phase difference AF module.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Indoor robot vision hand-eye relation calibration method based on 3D image sensor	16.07.2014; CN103925879	HEFEI INSTITUTES OF PHYSICAL SCIENCE, CHINESE ACADEMY OF SCIENCES	KONG LINGCHENG	The invention provides an indoor robot vision hand-eye relation calibration method based on a 3D image sensor. The method comprises the following steps: S1, marking a plurality of marking points on hand grabbing tail end joints of a robot, acquiring point cloud image information of the hand grabbing tail end joints through the 3D vision sensor of the robot, and acquiring a plurality of sets of three-dimensional coordinate values relative to a visual sensor coordinate system; S2, acquiring the three-dimensional coordinate values of the multiple marking points of the hand grabbing tail end joints under the world coordinate system through an external three-dimensional measurement device, wherein the values are acquired through an arm-base coordinate system of the robot; S3, acquiring the coordinate values through the step S1 and the step S2 and obtaining a hand-eye calibration array. The indoor robot vision hand-eye relation calibration method based on the 3D image sensor simplifies the calibration process, the measurement precision is high, and the requirement for indoor robot hand-eye calibration can be effectively met.
3D IMAGE SENSOR AND METHOD OF FABRICATING SAME	23.04.2014; KR1020140047934	SAMSUNG ELECTRONICS CO., LTD.	LEE, KWANG MIN	Provided are a 3D image sensor and a method of fabricating the same. In the 3D image sensor, because the thickness of a second transmission gate and the gate insulating layer of a drain gate is thinner than that of other gate insulating layers, the operation voltage of the second transmission gate and the drain gate can be lowered. Thereby, the power consumption of the 3D image sensor can be reduced. COPYRIGHT KIPO 2014
IMAGE SENSOR OF A 3D CAMERA FOR OBTAINING A 3D IMAGE BY ONE CAMERA	27.02.2013; KR1020130019583	FIBER OPTIC KOREA CO., LTD.	KIM, YANG GON	PURPOSE: An image sensor of a 3D camera is provided to change configuration of arrangement of a Bayer pattern in the image sensor, thereby receiving a visible light area and an infrared area in one camera. CONSTITUTION: A 3D camera includes a light source, a plurality of pixels, and a light detection element. The plurality of pixels is arranged in an array of a 2x2 pixel group. The array includes a pixel in which a red light filter is arranged; a pixel in which a green light filter is arranged; a pixel in which a blue light filter is arranged; and a pixel in which an infrared filter is arranged. COPYRIGHT KIPO 2013 null

Exhibit 1 lists some of the patents related to 3D imaging sensors.

Picture Credit: Frost & Sullivan

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