TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

18th December 2015

1. CAMERA-BASED PRECISION LOCALIZATION FOR SELF-DRIVING VEHICLES

Self-driving vehicles, which are able to sense their environment and navigate without human input or intervention, typically use information from the GPS (global positioning system) and an inertial navigation system (including accelerometers and gyros) to localize themselves, as well as data from sensors, such as Lidar (light detection and ranging) systems to refine the determination of the vehicle's position and help build a 3D image of the vehicle's environment.

Lidar systems can be compromised. For instance, a device similar to a laser pointer with a pulse generator could spoof numerous objects to conduct a denial of service attack on the tracking system, impeding its ability to track real objects. Due to its being fooled into sensing objects that do not actually exist, the vehicle could be made to slow down or even come to a total stop.

Researchers at Southwest Research Institute (SwRI) in the US have developed a patented, relatively low-cost technique to enable very precise localization and navigation for automated vehicles. Ranger uses a ground-facing camera and localization algorithms to create highly precise position and orientation information. Ranger technology is able to image the unique fingerprint of a road surface, enabling precise automated driving within two centimeters. While this level of localization is similar to that of highly accurate and expensive global positioning systems, Ranger is able to operate in surroundings where a GPS is subject to poor performance or can fail.

RANGER functions by matching thousands of distinguishing features on the ground to corresponding features that are collected and stored in a map. The features include large-scale characteristics such as cracks, road markings, oil stains, as well as small, subtle features such as exposed aggregate and contrast variations. The composition of features on any portion of the ground is unique, similar to a fingerprint. Only a small percentage of such features is necessary for Ranger to be able to match in order to accurately determine the location of the vehicle.

The RANGER solution can perform effectively under varied illumination conditions and in adverse weather conditions, such as rain or fog. The camera-based approach with controlled illumination can attain greater precision than sensor-based localization techniques.

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2. ENHANCEMENTS IN ION SENSING

Ion-selective electrodes, a sub-category of electrochemical sensors, are widely used in applications such as chemical analysis. Moreover, such sensors have opportunities in diverse areas such as, healthcare, environmental monitoring, or as wearable sensors for applications such as tracking fitness activities or athletic performance. Ion-selective electrodes can provide convenient, portable, relatively low-cost ion measurement in liquid media. However, conventional ion-selective electrodes can be subject to limitations in detection limit, linear measurement range, and selectivity due to interference from other, undesired ions.

Imec and Holst Centre (established by Imec and TNO) have developed and demonstrated a prototype of a single-chip electrochemical sensor for simultaneous detection of multiple ions in fluids. The technology can help enable the realization of compact cost-efficient detection systems for applications such as agriculture, healthcare, food quality monitoring, and water management.

Imec and Holst Centre's enhanced ion sensor solution embodies a generic platform that can be configured for particular applications. The sensor allows efficient and cost-effective monitoring of, for example, nutrient concentrations in surface and waste water, for agricultural and water quality applications. For example, there is potential for nitrate ion measurement to address a vital need for detection of elevated nitrate levels caused by activities such as farming (through the use of fertilizers such as ammonium nitrate) and industrial process plant discharge from nitrogen-containing processes.

In healthcare or lifestyle applications, the ion sensor can provide disposable point-of-care diagnostics, or a flexible, conformable solution for integration into patches. Depending on the application and form factor, the ion sensor can be mass produced via microfabrication or screen-printing on economical substrates, such as glass or foil. Compared to commercial ion sensors, the sensor developed by Imec and Holst Centre can offer such benefits as low-cost manufacturability and compact and convenient size. In addition, the sensor can be tailored to detect additional ions by altering the selective membranes on the electrodes.

The handheld prototype integrates a single-chip sensor with different electrodes to detect pH levels in a range from 2 to 10 at 0.1 pH accuracy. The sensor provides a 10% detection accuracy for chloride, sodium, potassium, and nitrate,-ranging from 10-4 M to 1 M ions. Imec's prototype device demonstrated comparable sensitivity and accuracy for a versatile multiple-ion solution when benchmarked against other available single-ion sensors.

The development of small, autonomous, smart sensors that are able to adapt to and wirelessly communicate with the environment and one another facilitates Imec’s objective to create key building blocks, enabling an intuitive Internet of Things (IoT) scenario. Imec will help further drive enhancements in smart, connected systems by improving the sensor platform, developing sensors for other ions, integrating additional sensors into a single system, and extending the lifetime of the sensor. There are opportunities to partner to jointly develop new ion sensing applications and commercialize the technology.

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3. ADVANCEMENTS IN MICROFLUIDIC DEVICES FOR DIAGNOSIS

Microfluidics technology manipulates and controls small volumes of fluids, using channels with tiny dimensions. Lab-on-chip technology, which uses microfluidics to help scale down highly multiplexed laboratory steps into a more efficient, higher-throughput chip format, allows for performing microscale chemistry or biochemical analytical tasks using less volume of fluids with reduced manual labor. Key applications for lab-on-chip technology include point-of-care diagnostics and clinical research. Promising applications include patient monitoring and drug delivery.

Acoustic tweezers enable control of the movement of objects via sound waves. Accurate manipulation of objects using sound waves can be achieved by controlling the position of the minimum or maximum acoustic pressure regions.

Researchers from The Pennsylvania State University (Penn State), under the direction of Tony Huang, professor of engineering science and mathematics, have developed acoustic tweezers, based on gentle acoustic vibrations, for which a patent has been filed. The reusable microfluidic device, facilitating the sortation and manipulation of cells and other micro/nano meter scale objects, has opportunities to make biomedical diagnosis of diseases less expensive and more convenient in geographic regions with limited medical facilities or where such costs can be prohibitive.

The newly developed acoustic tweezers can have opportunities in diagnostics as well as in therapeutic applications. In contrast to diagnostic devices that need to be disposed of after a single use, the Penn State researchers have devised a means to separate the fluid-containing component of the device from the more expensive ultrasound-generating piezoelectric substrate. This approach enables disposable acoustic tweezers.

The disposable plastic portion of the new acoustic tweezers is envisioned to be manufactured for as little as 25 cents per unit. A complete permanent system that can be used repeatedly with easy replacement of the plastic microfluidic channels that include electronics for diagnosis are envisioned to be capable of being manufactured for a few US dollars.

In a previous device, the microfluidic channel was permanently bound to the substrate and the ultrasound signals would be radiated directly into the fluid. Although the newly developed device has an intervening layer, the ultrasound force is sufficiently strong to manipulate the cells and pattern them.

The patterning of cells is particularly crucial in the investigation of cell-to-cell communication in biology labs or for drug screening.

In drug screening, using acoustic tweezers, one can create high throughput of single cells and view how they respond to drugs; or one can create varied types of cell assemblies and perceive how they respond to drugs. The acoustic tweezers could facilitate improved understanding of how drugs would work inside the human body.

The acoustic tweezers are viewed as having opportunities in diagnosing diseases such as HIV and tuberculosis, which are prevalent in geographic regions with poor resources. The technology is also anticipated to be significantly used in hospitals, clinics, biology labs, and in homes.

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4. PRINTABLE, CONFORMABLE TEMPERATURE SENSOR

Sensors for measuring and monitoring human body temperature are well-established, generally reasonably accurate and can be relatively inexpensive. For example, thermistors, which use temperature-sensitive, semiconductor materials, and thermocouples, which depend on a current generated when dissimilar metals are joined, tend to be sufficiently accurate for clinical applications while being sufficiently inexpensive for disposability. However, the signals from such types of sensors are inherently non-linear and require linearization via calibrated compensating electronic circuits.

Passive infrared temperature sensors, which rely on the infrared energy emitted from varied surfaces above zero degrees, can be used in a non-contact mode to measure the temperature of the skin surface without touching the surface, and can be accurate and relatively inexpensive. Core temperature can be measured when the infrared signals are obtained from the tympanic membrane. However, such infrared systems tend to be too large to fit more than a few mm into the aural canal and do not see any areas near the tympanic membrane. Infrared systems have tended to be insufficiently accurate for clinical use.

Reflecting expanding opportunities for printable, highly flexible sensors, a research group at The University of Tokyo's Graduate School of Engineering, led by professor Takao Someya and Tomoyuki Yokota, research associate, has developed a thin, flexible, lightweight sensor that is able to respond quickly and accurately to minute changes in human body temperature. The printable sensor, which is sufficiently thin and flexible to wrap around a pencil or to accommodate the form of the human body or another substrate, has opportunities in healthcare applications, such as monitoring body temperature in newborn infants or patients in an intensive care unit.

Wearable, flexible sensors elicited significant R&D efforts and have opportunities in healthcare and wellness applications, such as temperature monitoring, or monitoring key parameters such as gases, fluids, or heart rate. However, low-cost flexible sensors developed for monitoring body temperature have tended to require external circuitry to amplify the sensor's signal to provide accurate temperature measurement.

The University of Tokyo research group has developed a printable, light-weight temperature sensor that exhibits a strong change in electrical resistance of up to 100,000 times over a narrow range of five degrees centigrade. Such capability enables accurate temperature measurement without requiring additional complicated display circuitry.

The researchers are able to precisely control the sensor's target temperature. The sensor is comprised of graphite and a semicrystalline acrylate polymer consisting of two monomers, molecules that bond together to form a polymer chain. By altering the proportions of the two monomers, one can select the target temperature range at which the sensor is most precise. A target temperature range of between 25 and 50 degrees C, which includes average human body temperature, has been achieved. The researchers simultaneously achieved a response time of less than 100 milliseconds and temperature sensitivity of 0.02 degrees C. The device, moreover, showed stability in the context of physiological conditions, with the ability to provide up to 1,800 repeated readings.

In testing, researchers printed a flexible thermal monitoring device, which was placed directly on the lung of a rat to measure lung temperature. The device demonstrated the ability to successfully measure cyclic changes in lung temperature of only 0.1 degrees centigrade as the animal breathed, thereby indicating its suitability for monitoring body vital signs in physiological conditions.

A printed array of such sensors could allow for measuring surface temperature over a large area. Such an array could be attached to biological skin (or other biological tissue) to provide precise monitoring in healthcare applications. The sensor can open up new or innovative applications, as its large response to temperature fluctuations allows for simplifying the sensor circuitry. For example, this capability allows for printing the sensors onto adhesive plasters to monitor body temperature. The plaster, applied directly to a wound or after surgery, could detect local changes in temperature due to inflammation, thereby warning of infection. In addition, the sensor has the potential to be applied beneath fabric in wearable electronic apparel to measure temperature during sports or other activities.

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5. RECENT PATENTS IN THE FIELD OF NANOSENSORS

Nanosensors are very minute devices built on the nanoscale, which are capable of detecting stimuli such as biological or chemical substances and physical stimuli such as pressure at the nanoscale, that is, with the dimension on the order of a billionth of a meter.

Nanosensors can offer key benefits in diverse application fields, including chemical sensing or bio sensing. Such benefits can include superior sensitivity, reduced size and power consumption, faster response, and ability to be configured in large-scale arrays. The different methods employed in manufacturing nanosensors include molecular self-assembly, bottom-up assembly, top-down lithography or with the use of carbon nanotubes (CNTs). CNTs have exceptional properties, such as high mechanical strength and high length to radius ratio, but nanosensors based on changes in electrical conductance can be limited by the poor charge transfer with CNTs.

The key growth driver in the nanosensors arena is the demand for improved detection mechanisms in specific sensing applications. Nanomaterials possess very high surface-to-volume ratios; a large surface area is available for analytes to interact with the sensor components. Nanosensors could serve as the enabling technology for performing certain detection activities which cannot be adequately obtained by employing other technology configurations. For example, optical nanosensors that are designed for monitoring changes and performing certain quantitative measurements within the intracellular environment can provide better understanding of a cell's response to certain stimuli, which includes environmental changes, ultraviolet (UV) radiation, microorganisms, and other potential sources of harm to the cell

According to the patent filing scenario, research institutes and universities are te organizations mainly publishing patents in this field. This shows a strong focus on the research activities in nanosensors and nanotechnology. Nanotechnology research has been quite strong in North America in areas such as chemical and biological agent detection. European universities and organizations are actively involved in developing and commercializing nanotechnology-based sensing devices.

Some of the companies that have been involved in nanosensors include Samsung, Boeing, Dow Corning, IBM, Motorola, Lockheed Martin, and Agilent Technologies, Altair Nanotechnologies, Nanomix. Some of key universities involved in this research are Zhejiang University, Tianjin University, Jilin University, and Korea Institute of Science and Technology.

A recent patent in nanosensors is powered by nano conductive polymers and nanowires (US20150288002), assigned to Lawrence Livermore National Security LLC, pertains to a nanoconverter or nanosensor capable of generating electricity from molecules and for batteryless sensing.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
NANODEVICES FOR GENERATING POWER FROM MOLECULES AND BATTERYLESS SENSING	08.10.2015; US20150288002	LAWRENCE LIVERMORE NATIONAL SECURITY, LLC	Yinmin Wang	A nanoconverter or nanosensor is disclosed capable of directly generating electricity through physisorption interactions with molecules that are dipole containing organic species in a molecule interaction zone. High surface-to-volume ratio semiconductor nanowires or nanotubes (such as ZnO, silicon, carbon, etc.) are grown either aligned or randomly-aligned on a substrate. Epoxy or other nonconductive polymers are used to seal portions of the nanowires or nanotubes to create molecule noninteraction zones. By correlating certain molecule species to voltages generated, a nanosensor may quickly identify which species is detected. Nanoconverters in a series parallel arrangement may be constructed in planar, stacked, or rolled arrays to supply power to nano- and micro-devices without use of external batteries. In some cases breath, from human or other life forms, contain sufficient molecules to power a nanoconverter. A membrane permeable to certain molecules around the molecule interaction zone increases specific molecule nanosensor selectivity response.
NANOSENSOR FOR ASSESSING THROMBIN INHIBITORS	01.10.2015; WO/2015/148622	VIRGINIA COMMONWEALTH UNIVERSITY	DESAI, Umesh, R.	Constructs and monitoring systems to assess the level of molecules that bind to thrombin (e.g. thrombin regulators and inhibitors) are provided. The constructs are nanosensors comprising i) a thrombin molecule to which is bound a reporter ligand comprising a fluorescent label, ii) a fluorescence-quenching metal nanoparticle, and, optionally iii) a fluorescence-quenching dye molecule attached to one or both of the nanoparticle and the thrombin molecule. The binding of a thrombin regulator or inhibitor to the thrombin molecule displaces the reporter ligand, and the signal from the fluorescent label increases. The increase is proportional to the concentration of thrombin-binding molecule in the sample.
Microfluidic Sensors with Enhanced Optical Signals	10.09.2015; US20150253321	THE TRUSTEES OF THE PRINCETON UNIVERSITY	Stephen Y. Chou	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.
HIGH SENSITIVITY MULTICHANNEL DETECTION DEVICE	20.08.2015; WO/2015/121887	ELEMENTS S.R.L.	THEI, Federico	The present invention concerns a detection device (1) of a sample to be examined, comprising a processing module (2), a detecting module (3), connected to said processing module (2), a support (7), in which said sample to be examined can be placed, said support (7) comprising a plurality of sensors, preferably biosensors and/or nanosensors, and being insertable within said detecting module (3), and a containment enclosure (11) comprising a body (12), which is arranged within said processing module (2), and a sensor portion (13), in which said detecting module (3) is arranged, characterized in that said processing module (2) comprises a processing unit (4) having a plurality of processing channels (5) and a processor (6), each one of said processing channels (5) being connected to one respective of said sensors and being adapted to amplify and to filter the signals of said sensors, said processor (6) processing said signals amplified and filtered by said processing channels (5).

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
IMPLANTABLE NANOSENSOR	25.06.2015; US20150173656	Steven Barcelo	Steven Barcelo	An implantable nanosensor includes a stent to be implanted inside a fluid conduit. The stent has a well in a surface of the stent. The implantable nanosensor further includes a nanoscale-patterned sensing substrate disposed in the well. The nanoscale-patterned sensing substrate is to produce an optical scattering response signal indicative of a presence of an analyte in a fluid carried by the fluid conduit when interrogated by an optical stimulus signal.
SCATTERING SPECTROSCOPY NANOSENSOR	10.06.2015; EP2880423	HEWLETT PACKARD DEVELOPMENT CO	GIBSON GARY	A scattering spectroscopy nanosensor indudes a nanoscale-patterned sensing substrate to produce an optical scattering response signal indicative of a presence of an analyte when interrogated by an optical stimulus. The scattering spectroscopy nanosensor further indudes a protective covering to cover and protect the nanoscale-patterned sensing substrate. The protective covering is to be selectably removed by exposure to an optical beam incident on the protective covering. The protective covering is to prevent the analyte from interacting with the nanoscale-patterned sensing substrate prior to being removed.
Highly sensitive detection of biomarkers for diagnostics	21.04.2015; US09013690	The Trustees of Princeton University	Stephen Y. Chou	This disclosure provides, among other things, a nanosensor comprising a substrate and one or a plurality of pillars extending from a surface of the substrate, where the pillars comprise a metallic dot structure, a metal disc, and a metallic back plane. The nanosensor comprises a molecular adhesion layer that covers at least a part of the metallic dot structure, the metal disc, and/or the metallic back plane and a capture agent bound to the molecular adhesion layer. The nanosensor amplifies a light signal from an analyte, when the analyte is specifically bound to the capture agent.

Exhibit 1 lists some of the patents related to nanosensors.

Picture Credit: Frost & Sullivan

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