TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

30th October 2015

1. PAPER SENSOR FOR ENHANCED DETECTION OF PESTICIDES

The ability to reliably detect pesticides in the environment and in foods is vital for safeguarding the health of individuals as well as for protecting agriculture. Pesticides are often detected using expensive, cumbersome and time-consuming equipment, such as gas chromatography-mass spectroscopy (GC-MS) or high-performance liquid chromatography (HPLC).

In contrast, paper is an appealing material for devices for pesticide detection as it is relatively inexpensive, abundant, disposable, and has a high volume-to-surface ratio, and is compatible with chemicals and biochemicals. However, paper-based sensors for analytical applications have had limitations in accuracy and sensitivity. Furthermore, smaller paper sensors may not be able to generate sufficiently strong signals for detection purposes.

In a development that has promise for enhancing paper sensor-based pesticide detection, researchers at Hefei University of Technology in China and the National University of Singapore, have developed a smartphone-based detection system that uses a paper sensor containing nanoparticles that produce sufficiently strong signals to detect small concentrations of the pesticide thiram. Thiram belongs to the ethylene bisdithiocarbamate (EBDC) class of chemicals, which are fungicides used to prevent crop damage in the field and to protect harvested crops from deterioration in storage or transport. Thiram is highly toxic if inhaled.

The pesticide detection system includes nanoparticles (in the form of upconversion nanocrystals) to detect the pesticide and emit a fluorescent signal on the paper; a 3D printed equipment comprising a cell phone attached to a mini laser; an optical filter and mini-cavity; and software that runs on the Android mobile operating system. Upconversion nanocrystals are attracting keen interest due to their ability to convert near-infrared photons to visible or even ultraviolet emissions. These optical nanomaterials also offer promise for use in optoelectronic devices.

In the pesticide detection system, the upconversion nanocrystal nanoparticles are decorated with copper ions and fixed onto the paper. When the sample is then put on the paper, the pesticide molecules attach to the copper ions on the nanoparticles. Light is shined onto the paper, and using specially developed software, the smartphone reads the fluorescent light emitted from the nanoparticles. The fluorescent light differs based on the amount of pesticide in the sample, and the software translates the fluorescent light signal into the level of pesticide concentration. The system is able to provide a reliable and accurate reading at low concentrations of 0.1 micrometer.

The use of a smartphone allows more readily accessible, convenient, and lower-cost pesticide detection. Although the system was tested on pesticide molecules, the researchers envision that it could be used to detect any type of molecule, including drugs, proteins, or antibodies. The researchers are further developing the technology, which is at the prototype stage, to detect different molecules and plan to use the technology for multiplex detection (detection of multiple molecules simultaneously) for applications such as testing of food quality.

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2. ADVANCEMENTS IN FINGERPRINT SENSORS

Fingerprint identification is a very well-established form of biometric identification. Fingerprints are unique and may be readily acquired for identification, although the quality of print can differ from person to person and from finger to finger. Moreover, the fingerprint sensor can be fooled, resulting in false acceptances or false rejects. For example, fingerprints can be flattened due to old age or damaged from manual work or extreme sports. Fingerprint identification systems can also be fooled by fake fingerprints. There are opportunities for enhancing the performance of fingerprint sensors, such as reducing distortion or noise in the captured image.

Various types of sensing technologies are used to collect information from a fingerprint surface, such as optical, capacitive, ultrasound, and thermal. The most popular and common type of fingerprint sensor has been optical sensors that take an image of the fingerprint.

Researchers from The Langevin Institute in France, Claude Bocarra, a professor specializing in scientific instruments and Egidijus Auksorius, postdoctoral researcher, have built an innovative fingerprint imaging system. It uses full field optical coherence tomography and a camera and looks inside a finger to capture an image or picture, thereby offering a more reliable and secure means of identifying individuals. Moreover, the device can be more streamlined and is quicker and less expensive than other technologies that have been used to image inside fingers.

Optical fingerprint sensors typically generate images by reflecting light from areas where skin does not come in contact with a glass plate. This technique captures fingerprint details from only the very top layer of the skin. On the other hand, the internal fingerprint sensor developed at The Langevin Institute is able to image the internal fingerprints, which have an identical pattern to external fingerprints, but are around one-half inch beneath the skin's surface. Furthermore, the internal fingerprints provide a master template from which the surface, when damaged, is able to regrow.

The internal fingerprint sensor uses optical coherence tomography (OCT), a non-invasive optical diagnostic technique used in clinical, diagnostic, and biological applications that detects backscattered light from a tissue or biological sample. OCT can be an effective tool for accurate and sensitive detection of, for example, false fingerprints. While standard OCT systems collect 3D data and use sophisticated lasers and light detectors, the internal fingerprint sensing system uses full-field OCT (FF-OCT), which enables in-depth, high-resolution tissue imaging at the cellular level and allows simplifying of the internal fingerprint sensing system. Bocarra is a co-inventor of the FFOCT technique.

The FF-OCT system is able to take a 2D image of the fingerprint directly, which saves time and renders the data processing simpler and less expensive. Furthermore, as the internal fingerprints of individuals are located at different depths, the researchers devised a method to initially take an image of the fingertip at an angle. The initial image is used to determine the depth of the internal fingerprint. Subsequently, a second image of the fingerprint is taken. The system is also able to image sweat pores, which provide an additional means of identification.

The researchers are working to shrink the internal fingerprint sensor system, which is presently about the size of a shoebox. The specialized infrared camera that has been used in the system costs around $40,000. The team, however, obtained comparable images using a camera that is less than 20% the cost of the IR camera. It is envisioned that a complete device using the new camera could be built for under $10,000. Such a device could find opportunities in imaging problematic fingerprints or in applications where security is a vital concern.

The team is further enhancing the system's imaging speed and depth capabilities and plans to test the device in Turkey by scanning the fingerprints of 100 people.

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3. SKIN INSPIRED ORGANIC MECHANORECEPTOR

The skin is the largest organ in our body. It is also an individual interface with the external world. The ability to build synthetic skin that can mimic the function of touch will enable us to not only restore the sense of touch medically but also enable tremendous opportunities in inspiring new electronic material development and new forms of electronic devices which will find application in wearable electronics, automobile, robotics, displays and implantable devices. Flexible plastic materials are the key enablers of wearable devices and can be easily applied on the user's body, and such devices conform to the varied geometries of the human body. The plastic material currently available can help develop sensitive touch sensors but the electrical signals that are emitted from the sensor may not be in the right format for the brain to interpret.

To address this challenge, researchers from Stanford University have developed flexible artificial skin with the help of a plastic material to sense touch and detect pressure. The sensations from the detected pressure are sent to the brain cells as short pulses of electricity which are very easy to read and interpret. In the latest research, the output of the sensors was used to stimulate optogenetically engineered mouse somatosensory neurons of a mouse cortex in vitro.

The researchers have employed plastic material, sensors and carbon nanotubes to develop the artificial skin that can sense touch and generate an electrical signal which is further used to communicate with the brain. Touch sensing is accomplished using thousands of sensors called mechanoreceptors that are distributed in the skin. The mechanoreceptor produces electrical pulses in response to the pressure. The electrical pulses are transmitted to the brain where the signal is interpreted. The pressure determines how frequently the electrical pulses are produced. Small pulses induce only few electrical pulses per second while larger pulses produce electrical pulses more frequently--about several hundred pulses per second, Artificial mechanoreceptors mimic this process by coupling the pressure sensor with the flexible circuit layer that produces the electrical pulses. The sensors are made of a pyramid structure of insulating rubber filled with conductive carbon nanotubes. As the pressure on the sensor is increased, the carbon nanotubes move closer together and more electricity can flow through the sensor. Beneath that layer is an inkjet-printed circuit. An oscillator is employed to turn the variable current into a train of pulses. With more pressure and more current, the rate of the pulses goes up. The inkjet printing process is developed at PARC, a Xerox Company.

The artificial skin developed with the help of the plastic material has potential to eventually be used on prosthetic limbs. In the near-term, the sensors will be employed in wearable devices. The sensors are very thin, flexible and stretchable and can be mounted on the skin to detect vital signs such as heartbeat and blood pressure. At the heart of the device is a flexible layer of rubbery polymer which is shaped into tiny pyramids and tied with carbon nanotubes. When the sensor gets squashed, this semi-conductive layer offers a read-out of the pressure.

To communicate a signal reliably with the nervous system, the researchers have adopted a technique called optogenetics. Optogenetics uses biological neurons to detect electronic signals; it is a combination of genetics and optics. The artificial skin generates a sensory output which is compatible with the nerve cells. The researchers are currently working on identifying other methods to read the electrical signal and use it in real prosthetics. The researchers envision that this artificial mechanoreceptor concept will inspire a technology that can be utilized for enabling brain responsive prosthetics, providing the most important sense of touch.

In the future, stem cell technology could generate an optogenetic interface for technologies such as the new sensors. Companies and universities are working toward developing soft electrodes exploring optogenetics as an alternative to electrical stimulation which will offer better bio-interfaces.

The key to adoption and disruption is accessibility and affordability. For wearable artificial skin sensors to become ubiquitous, they need to be affordable. Hence, it is essential to make the product and all associated technologies extremely economical. Sacrificing profit for market penetration will be critical at least initially. The industry will need to focus on driving adoption and affecting a paradigm shift before turning attention on revenue. For artificial skin sensors to be successful, vendors will have to forge alliances and partnerships with cross-industry stakeholders. Such synergistic convergence will unlock doors to new application areas. Wearable artificial skin will be used to provide emergency alerts on the medical condition of workers working in hazardous conditions by constantly monitoring parameters such as heart rate.

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4. INTERPRETING SIGN LANGUAGE USING SENSOR FUSION

American Sign Language has more than 150 finger spelled words and signs. For a deaf person, it is very important to learn all the signs and their respective meaning to bridge the gap in communication. Sometimes, even when the user is able to learn finger-spelled words and their meanings, it is very difficult to match the speed of gestures and interpret the gestures in the given time. Many different universities are working towards addressing this challenge. One of the most recent initiatives is to employ cameras to capture gesture. However, this method has some drawbacks; for instance, under poor lighting conditions, the quality and accuracy of image capturing diminishes, and it does not convert the signs and finger-spelled words into exact words. In addition, the system always needs the storyteller in front of the camera.

To address the above challenge, researchers from Texas A&M University have developed a prototype of a high-tech sign language recognition system with the help of sensors and Bluetooth to bridge the communication gap between people who do not use sign language. The device fuses data from motion and muscle activities to achieve highly accurate and more efficient interpretation.

The researchers have developed a wearable device with the help of two sensors and one Bluetooth protocol. The two different types of sensors employed by the researchers are an inertial sensor and an electromyographic sensor. The inertial sensor is employed to detect the motion of the user and consists of a gyroscope and an accelerometer. With the help of the gyroscope and accelerometer, the sensor is able to measure the angular velocities and acceleration at which the hand and arm of the user are moving. It helps to distinguish between the user's arm and hand movements. The second sensor used by the researchers to develop the high-tech sign language recognition system is the electromyographic sensor. This sensor is employed to detect the muscle activities and measure the electrical potential of the activities. The researchers have employed the electromyographic sensor to distinguish between two partly similar types of signs to provide accurate interpretation. The data from the inertial and electromyographic sensors are converged and fed to the complex algorithm on the laptop via Bluetooth. The algorithm helps to interpret the exact representation of the finger spelled words.

The researchers have managed to achieve an approximately 96 percent accuracy with this system. In addition, the system at present is only able to identify 40 American finger spelled words. The researchers are currently working on increasing the number of signs recognized by the system. In addition, they are planning to make the system more compact by merging the hardware and software into one wearable device which will perform the complete operation.

The project is supported by Texas Instruments. At present, the researchers have demonstrated the system prototype in the relevant lab environment. The system will be capable of identifying all finger spelled words in one to two years' time. Once the system is fully completed, it has opportunities to elicit good response from consumer electronics companies for activating home devices with the help of context aware wearables.

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5. RECENT PATENTS IN THE FIELD OF SMART HOME SENSING

Smart homes are residences that can use a single, central controller to integrate their home automation systems onto one grid and then monitor them from the controller. A smart home is equipped with lighting, heating, and various electronic devices that are able to be controlled remotely via a mobile phone or computer. Smart homes are typically equipped with a large number of networked wireless sensors. The collected data are then processed to make deductions about the state of key automated systems as well as to monitor the daily activities of the residents.

The key sensing technologies used in smart homes include motion sensors, occupancy sensors, gas detectors, humidity sensors, temperature sensors, magnetic field sensors, accelerometers, and cameras. ZigBee and Z-Wave are the key wireless sensor networking technologies being used so far in smart homes. Emerging technologies such as WiFi and 6LoWPAN have opportunities to be adopted widely.

With affordable smart home services, the ubiquity of smart mobile devices and consumer cost saving features, smart homes are set to increasingly impact consumer lifestyles within this decade. The growing demand for smart energy management solutions, security and healthcare will significantly increase the adoption of smart homes in the coming years. Home energy management and home automation companies already cater to the wealthier niches of the smart home market. Collaboration between different providers of devices and services is needed for mass market adoption.

With the help of patent filing trends, it can be said that the US smart home industry is clearly expanding with increasing consumer interest for smart devices and applications. Lighting, home entertainment, and security systems are among the applications generating interest. Smart, Internet-connected thermostats also have opportunities. In Europe, Germany is a leading smart home market; and UK and Italy have also shown interest in smart home adoption.

One of the growing segments in the smart home arena is home entertainment. Energy management features can be incorporated by controlling lighting, home appliances and air heating/conditioning. Based on an occupancy sensor, the lights in a smart home can be turned on and off automatically. Sensor-based smart home systems are already established for entertainment applications, enhancing user comfort, as well as security. By controlling lights and heating, ventilating, and air conditioning (HVAC), the smart home system holds the potential to converge with smart grid systems. Smart utility meters automatically send electronic meter readings about the customer’s electricity consumption to the energy supplier Smart home convergence with the telecommunications and healthcare industries holds immense potential for mobile health in the future.

Some of the stakeholders in smart home sensor systems include Google, SNUPI Technologies, Creston, Control4 and many more.

A recent patent in smart home sensing powered by occupancy sensors (US20150260581) is assigned to Google Inc., which pertains to a smart home device that includes an occupancy sensor, button cap component, and a lighting component.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Selectable lens button for a smart home device and method therefor	17.09.2015; US20150260581	Google Inc.	Anthony Michael Fadell	According to one embodiment, a smart home device includes a front casing that is coupleable with a back plate to define a housing having an interior region within which one or more components of the smart home device are contained. The smart home device also includes an occupancy sensor that is disposed within the interior region of the smart home device and a button cap component that is positioned axially in front of the occupancy sensor. The button cap component is pressable by a user to actuate a switch that is disposed axially behind the button cap component. The smart home device further includes a lighting component that is positioned axially behind the button cap component. The lighting component is configured to disperse light circumferentially around the button cap component so as to provide a visual halo effect around the button cap component.
Smart home impleme ntation system and method, home gatew ay and computer storage medium	13.08.2015; WO/2015/117487	ZTE Corporation	Zhang, Xueqian	Disclosed are a smart home implementation system and method, a home gateway and a computer storage medium. The method comprises: collecting sensorinformation related to a home environment; analysing the collected sensor information, and determining a task needing to be executed; and controlling a corresponding home device to execute the task needing to be executed. The home gateway comprises: an environment proxy module which is configured to collectsensor information related to a home environment; a management proxy module which is configured to analyse the sensor information collected by the environment proxy module, determine a task needing to be executed, and control an execution proxy module to execute same; and an execution proxy module which is configured to control a corresponding home device to execute the task needing to be executed which is determined by the management proxy module.
Smart-home hazard detector providing non-alarm status signals at opportune moments	02.07.2015; US20150187200	Google Inc.	Anthony M. Fadell	In various embodiments, a hazard detector is presented. The hazard detector may include a hazard detection sensor that detects a presence of a type of hazard. The hazard detector may include a light and a light sensor that senses a brightness level in an ambient environment of the hazard detector. The hazard detector may include a processing system configured to receive an indication of the brightness level in the ambient environment of the hazard detector from the light sensor. The processing system may determine the brightness level in the ambient environment of the hazard detector has reached a threshold value. A status check of one or more components of the hazard detector may be performed. The processing system may cause the light to illuminate using a selected illumination state in response to the determining the brightness level in the ambient environment of the hazard detector has reached the threshold value.
Smart home display system with energy-saving effect	03.06.2015; CN104678979	Chengdu Player World Network Technology Co. Ltd.	YE ZHAN	The invention relates to the field of smart homes, and discloses a smart home display system with an energy-saving effect. The smart home display system with the energy-saving effect comprises display equipment (1). The smart home display system is characterized by further comprising a control module (2) and an infraredsensor (3) for detecting areas in front of the display equipment (1), wherein the control module (2) is connected with the display equipment (1) and the infraredsensor (3). By adopting the smart home display system, behaviors of a watcher can be automatically sensed, energy-saving control can be automatically realized according to the behaviors of the watcher, no human being engagement is needed, and relatively good user experience can be achieved.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Safe smart home sys tem based on ZigBee technology	22.04.2015; CN104537794	Sichuan Zonten Technology Co., Ltd.	Yu Lin	The invention provides a safe smart home system based on zigbee technology. The safe smart home system comprises a zigbee wireless gateway and a power module connected with the zigbee wireless gateway, as well as CC2530 for communication with the zigbee wireless gateway; the system further comprises a pyroelectric infrared sensor for detecting the current environment in real time, a smoke detection integrated circuit for detecting the smoke gas concentration of the current environment, a carbon dioxide sensor for detecting the concentration of carbon dioxide, and a gas sensitive sensor for collecting combustible gases in a room; each detection circuit and each sensor are connected with the power module and in signal connection with the CC2530; the system further comprises an intelligent device for receiving digital environment information transmitted by the zigbee wireless gateway, and a processing device configured for each detection device. The safe smart home system based on the zigbee technology is capable of automatically detecting the current environment and giving an alarm, and transmitting the environment data information in the environment to the intelligent device in real time. The casualty rate caused by fire accidents can be greatly reduced and the immovable properties in the current environment can be indirectly protected.
Status indication triggering and user interfacing in a smart-home hazard detector	09.04.2015; US20150097685	Google Inc.	David Sloo	In various embodiments, a hazard detector may be presented. The hazard detector may include at least one hazard detection sensor that detects a presence of at least one type of hazard. The hazard detector may include a speaker, a light, and a motion detection sensor that detects motion in an ambient environment of the hazard detector. A processing system of the hazard detector may be configured to select an illumination state based on a determined status. The processing system may cause the light to illuminate based on the selected illumination state. The processing system may determine a gesture has been performed in the ambient environment of the hazard detector following the light being illuminated based on the selected illumination state. The processing system may output a detail of the status via the speaker corresponding to the illumination state in response to determining the gesture has been performed.
Embedded wireless smart home monitoring system	25.03.2015; CN104460333	Guangdong Institute of Science & Technology	Feng Zhirong	An embedded wireless smart home monitoring system comprises a control terminal, indoor sensors, a wireless transmission module, a master control wireless module, a wireless receiving module and a wireless receiving control module, wherein the indoor sensors are used for monitoring indoor environments, the wireless transmission module is used for sending signals transmitted by the indoor sensors to the control terminal through a GSM network and receiving feedback signals of the control terminal, the master control wireless module is used for monitoring indoor environment factors and giving out corresponding control instructions, the wireless receiving module is used for receiving signals of the master control wireless module, and the wireless receiving control module is used for receiving and executing signals sent by the wireless receiving module. The mode that an ARM embedded control system and a GSM are combined through short messages and self-adaptive control of various sensors are adopted by the embedded wireless smart home monitoring system to achieve intelligentization of homes.

Exhibit 1 lists some of the patents related to smart home sensing.

Picture Credit: Frost & Sullivan

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