TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

31st October 2014

1. PRINTED SENSORS TO MONITOR FLOODS

According the National Weather Service of the US government, approximately 1500 people died in the hurricane Katrina in 2005. Over the years, flood incidents have been reported in many places, becoming fatal for many people because of the lack of early warning. Conventional solutions to monitor floods, such as, satellite imagery, can be too inaccurate and expensive to detect floods. There is a need for a cost-efficient and accurate device that can monitor floods in real time.

To address the above-mentioned challenge, researchers from the King Abdullah University of Science and Technology (KAUST) have developed a printed wireless sensor for flood monitoring. The substrate also employs a three dimensional (3D) antenna.

The researchers have developed a wireless sensor using an inkjet printing technique. The electronic sensor weighing 1.8 grams is embedded on the substrate. A small paper cube with a size of 13mm × 13mm × 13mm is used to print the sensor and the 3D antenna. The antenna is employed to provide a signal to the base station. This printed device is fixed to the unmanned aerial vehicle using a special type of glue. The unmanned aerial vehicle is used to drop the printed sensor over an area that needs to be monitored. When the sensors are dropped on the water, they start floating with the direction of the flood. As the sensors move along the water, the antenna sends the signal to the central fixed station about the direction of flood. This information is further used to warn authorities and the public about the extent of the flood. In this way, the printed sensor helps to monitor the extent of the flood.

Once the project is fully developed, the sensor will be used for flood monitoring. With further advances in the technology in the future, it will also be used in detecting harmful gases in the environment. This will further help to monitor environmental conditions in remote locations. During catastrophic events, this technology will not only enable greater safety for individuals, but also assist in creating smart houses and environment. The cost to manufacture the wireless printed sensor is very low, and the device provides information with high accuracy.

The project was funded by the King Abdullah University of Science and Technology. It was supported by other associate professors in electrical engineering. The researchers are currently working on identifying the different applications of wireless sensors integrated with the unmanned aerial vehicle. The device is expected to become commercialized in one to two years. It would have potential to get a good response from the governments of different countries for monitoring floods.

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2. NOVEL HEAT FLUX SENSOR TECHNOLOGY

Heat flux sensing (which generates an electrical signal proportional to the total heat rate applied to the sensor's surface) is among the fundamental technologies for measurement of heat in several industries, including, industrial process control. However, heat flux sensing equipment available in the market faces certain challenges, such as slow response time because of the thickness of the sensor. Response time is directly proportional to the thickness of the sensor. There is a need for heat flux sensing with high accuracy and good thermal conductivity. The device should be easy to use and cost efficient.

To address the above-mentioned challenges, researchers from Netherlands-based company Hukseflux Thermal Sensors B.V. have developed a heat flux sensor that integrates a thermopile sensor element in a heat flux sensing device. The device is made of ceramic plastic.

Hukseflux's technology enables a highly sensitive and thin product as a sensing element. The outer body of the device is made of ceramic plasti, which enables lowering thermal resistance. The thermopile is used to measure the temperature difference across the ceramic plastic body. The temperature difference generates an output voltage that is proportional to the local heat flux. The difference in electrical voltage causes thermoelectric effect. The principle of sensing is based on a thermoelectric phenomenon known as the Seebeck effect. This technology has been used by Hukseflux to develop a range of heat flux sensors, enabling different applications.

The heat flux sensor developed by Hukseflux will be used to detect different forms of heat flux, such as, conduction, radiation, and convection. The heat flux sensing technology of Hukseflux serves several different applications, such as, building physics, laser power measurement, calorimetric measurements, and solar measurements. The technology will also be used in the biotechnology industry to measure the core temperature of the body. The company is able to scale the technology to develop products with different specifications. The heat flux technology developed by the company provides valuable insights and deeper understanding about variations in heat. For example, the sensor reads out units for the measurement apparatus in a laboratory.

The researchers are currently working on exploring the possibility of applying the technology in various untapped sectors. The project was self-funded by the company. Hukseflux's heat flux sensors are already available in the market with the temperature range of -30 degrees C to +70 degrees C. In control systems and thermal measurements, heat flux sensors are deployed to provide a fast and precise response. Hukseflux products are able to provide cost benefits to customers in multiple industries, such as, building automation, biotechnology, and industrial automation. Hukseflux has a standard product line of heat flux sensors, and is also engaged in the development of customized sensors for specific applications. Hukseflux is enabling new products with increased functionality in applications such as energy harvesting.

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3. ROBOTIC HAND FOR TACTILE SENSING AND LOAD SENSING

In robotics industry force sensing is the significant technology. Robots strengthen the grip of the object based on the level of force. Robots with force sensing technology can be used in many different industries such as manufacturing. The force sensing equipment available in the market use one-dimensional sensing to grip the object. One-dimensional sensors sense the force from just one direction. This information is not enough for the robot to sense the shape and weight of the object and conform its grip according to the shape.Hence, there is a need for a device, which uses tactile sensing to sense the shape of the object and change itself with respect to the object. In addition, there is also a need for a device, which can sense the load of the object and adjust the grip of the robotic hand accordingly. The device should be easy to use and cost efficient.

To address the above challenge, researchers from London based company Shadow Robot have developed a robotic hand with three-dimensional (3D) cameras and pressure sensors. It has been named as "Dexterous Hand." The Dexterous hand is designed to sense the force of the object from multiple directions. The robotic hand takes into consideration direction and magnitude of the force to achieve tactile and load sensing.

The Dexterous Hand can analyze the shape of the object and then decide the best way to grip the object. The finger tip of the robotic hand is mounted with the pressure sensors. The sensors help the hand to judge the amount of force needed to grasp an object. The 3D cameras help a robotic hand to determine the shape of the object. A specially designed algorithm determines the arrangement of the fingers for optimal grip. Touch sensors integrated on the robotic hand continuously monitor the stability of the object in the hand. Thus, the Dexterous Hand conforms itself according the shape, weight, and texture of the object.

The Dexterous Hand serves two main applications--tactile sensing and load sensing. The sensors use tactile sensing to cause the robot’s fingers to conform according to shape of the object. The robotic hand can be used to grip a variety of solid objects and thus has potential for usage in various industries. The sensors use load sensing to tighten the grip depending on the load. Shadow Robot’s force sensing technology can also be used in prosthetic applications in

the health-care industry, and it is useful in the rehabilitation process for people with disabilities.

The project was self-funded by the company. The researchers are currently working toward scaling the product to commercial scale. At present, the company has two distributing partners in China and Japan. The Dexterous Hand has opportunities to get good response from the health-care industry, especially in prosthetics. To embed multiple sensors in a single robot is a very expensive and complicated process. In comparison, the robotic hand manufactured by Shadow Robot is very cost efficient.

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4. RECENT PATENTS IN THE FIELD OF FORCE SENSORS IN ROBOTICS

The force sensing technology currently available in the market can use a one-dimensional sensor that provides data about force in one direction. To obtain data from more than one direction, multidimensional sensors can be employed. Deploying multidimensional sensors or multiple sensors to measure the force might be very expensive.

A recent patent in the force sensing (CN103507070) assigned to Fanuc Ltd. pertains to a robot control device with a three-axis force sensor.

From 1960 to October 2014, approximately 2706 patents have been registered in this domain. From 1986 to July 2014, approximately 134 patents have been registered with the title force sensing and abstract robotics.

Three dimensional axis force sensing technology is expected to have a significant impact on the robotics industry. The sensor technology is beneficial for giving robotic limbs a sense of touch as well as a sense of grip, which allows the robotic limbs to be utilized in multiple application sectors. Apart from influencing the robotics industry, the technology is also applicable in various other industries, such as, industrial automation, packaging, and healthcare.

Recent trends suggest that inventors and investors are purely focusing on industrial applications of robotics that uses multidimensional force sensing. The trends also indicate that industries will slowly move toward a greater number of axes, such as, from three to six axes. Companies are also capitalizing on the performance of force sensing technology in robotics by

developing products with different specifications. Force sensing technology in robotics will provide high cost benefits to customers not only in the robotics industry but in other industries as well, such as, healthcare, packaging, and automotive.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Robot control device carrying out force control through three-axis force sensor	15.01.2014; CN103507070	Fanuc Ltd.	Takayuki Sato	The invention provides a robot control device (11). A tool (4) is driven to move relative to a workpiece (W) by the front end portion of a hand of a robot (1) or the workpiece (W) is driven to move relative to the tool (4) by the front end portion of the hand of the robot (1), so that force applied to the tool and the workpiece is controlled. The robot control device is provided with a force detection part (3), a force estimation point setting part (12) and a force estimation part (13). The force detection part (3) detects force in the direction of a single axis and the torque around axes in two axial orthogonal directions, wherein the direction of the single axis and the two axial directions are respectively orthogonal. The force estimation point setting part (12) is used for setting a force estimation point used for estimating the force applied to the tool (4) and the workpiece (W). The force estimation part (13) is used for estimating the force in the two axial directions or further estimating the torque around the single axis based on the single-axis-direction force detected through the force detection part, the two-axial-direction torque, around the axes, detected through the force detection part and the force set through the force estimation point setting part. Therefore, force and torque which can not be detected through a three-axis force sensor can be estimated.
Force sensor and robot arm including force sensor	15.01.2014; CN103512694	Canon Inc.	Shuichi Sato	A force sensor that detects external force includes a sheath, a pressure member configured to be provided on the sheath, a sensor unit configured to detect force applied to the pressure member, and a slip ring unit configured to supply power or transmit signals through a contact between a rotating body and a static body. The sensor unit and the slip ring unit are stored in the sheath, and power is supplied or signals are transmitted between the slip ring unit and the sensor unit. Further included is a robot arm including the force sensor
ROBOT FOR MINIMALLY INVASIVE SURGERY WITH FORCE SENSOR	07.01.2014; KR1020140001365	KOREA ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY	LEE, JUNG JU	A robot for minimally invasive surgery with a force sensor which is capable of providing a feed back to an operator by precisely measuring a force which is generated in the end of the surgical instrument and comprises: a shaft which has a shape of a hollow container in the inside; a fixed end member which is installed as a fixed status in the end of the shaft; an operating end member which is installed in order to operate to approach or distant toward the fixed end member of the end of the shaft; a driving case which is installed by being connected to the other side of the end of the shaft; a driving reel which is installed in the inside of the driving case; a driving wire which delivers the rotatory power of the driving reel to the operating end member by connecting the driving reel and the operating end member; a sheath member in which the driving wire is installed by being inserted in the inside, and both sides of the sheath member are fixed in both sides of the shaft; a force sensor which is installed in the shaft, and detects the variation of the force which acts to the shaft. COPYRIGHT KIPO 2014
ROBOT CONTROLLER WHICH CONDUCTS A FORCE CONTROL BY USING A THREE-AXIAL FORCE SENSOR	19.12.2013; US20130338832	SATO Takashi	SATO Takashi	A robot controller (**11**) which moves either a tool (**4**) or a workpiece (W) relative to another one with a hand unit, controls the force acting between the tool and the workpiece, comprising a force detector unit (**3**) for detecting a force in one axial direction and moments about the axes in two axial directions that are at right angles with the one axis and are, further, at right angles with each other; a force-presuming point setting unit (**12**) for setting a force-presuming point at where a force acting between the tool and the workpiece is presumed; and a force-presuming unit (**13**) for presuming forces in the two axial directions and a moment about the one axis based upon the force in the one axial direction and the moments about the axes in the two axial directions, and upon the position of the force-presuming point.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
PHYSICAL STRENGTH INCREASING ROBOT FOR ESTIMATING THE INTENSION OF A USER USING A FORCE-TORQUE SENSOR AND A CONTROL METHOD THEREOF CAPABLE OF PRECISELY AND NATURALLY CONTROLLING THE OPERATION OF THE ROBOT	15.10.2013; KR1020130113062	NT RESEARCH. INC.	KIM, KYUNG HWAN	PURPOSE: A physical strength increasing robot for estimating the intension of a user using a force-torque sensor and a control method thereof are provided to enable the natural operation of the robot even if a user wears the robot by minimizing the restriction of operation. CONSTITUTION: A physical strength increasing robot for estimating the intension of a user using a force-torque sensor comprises a restriction tool (10), a force-torque sensor, and a robot control unit. The restriction tool surrounds the body of a user. The force-torque sensor is installed between the restriction tool and a skeleton element adjacent to the restriction tool. The robot control unit estimates the intension of the user using the value outputted from the force-torque sensor and controls the posture of the robot according to the estimated intension. COPYRIGHT KIPO 2013 null
SENSOR MODULE, A FORCE SENSOR, AND A ROBOT CAPABLE OF DETECTING A FORCE COMPONENT	23.09.2013; KR1020130103431	SEIKO EPSON CORPORATION	KAWAI HIROKI	PURPOSE: A sensor module, a force sensor, and a robot are provided to accurately detect a contact force with obstacles generated in the middle of predetermined motions and a contact force with a target object with the force sensor and provide a robot control device on the data, thereby precisely and safely performing a task. CONSTITUTION: A sensor module (10) includes a sensor element, a first member (12), a second member (34), a first plate (70), a second plate (80), and a joining unit (86). The sensor element is formed by laminating piezoelectric bodies and electrodes. The first member includes a first a concave unit (30) in which the sensor element is arranged. The second member is bonded to the first member and closes the first concave unit of the first member. The first plate is in contact with the second member. The second plate is in contact with the first member. The joining unit joins the first and second plates. The distance from a contact surface of the first member and the sensor element to a bonded surface of the first and second members is formed larger than a dimension of the sensor element in direction in which the piezoelectric bodies and the electrodes are laminated. COPYRIGHT KIPO 2013 null
FORCE SENSOR FOR A ROBOT EFFICIENTLY SENSING THE MOVEMENT OF A USER AND AN EXOSKELETON ROBOT USING THE SAME	26.06.2013; KR101279285		KIM, KAB IL	PURPOSE: A force sensor for a robot and an exoskeleton robot using the same are provided to save a production cost of the exoskeleton robot by simplifying structure of the force sensor required to manufacture the exoskeleton robot. CONSTITUTION: A force sensor(100) for a robot comprises a first sensor unit(130), a second sensor unit(140), first cases(110,120), and a second case. The first sensor unit includes a vertical penetration hole and a horizontal penetration hole in one part. One end of the second sensor unit is connected to the first sensor unit, includes a vertical penetration hole in one part, is arranged to the direction intersecting with the first sensor unit. The first case covers the upper surface of the first sensor unit and the second sensor unit. The second case covers the lower surface of the first sensor unit and the second sensor unit. COPYRIGHT KIPO 2013 null

Exhibit 1 lists some of the patents related to force sensors used in robotics.

Picture Credit: Frost & Sullivan

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