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Survey on Sensor Application

Elham Khalesi*

Department of Tehran Standard and Industerial Research, Iran

***Corresponding author:** Elham Khalesi, Department of Tehran Standard and Industerial Research, ISIRI, Tehran, Iran

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ABSTRACT

Measurement is a very important topic in every technical system. If we cannot measure some physical property in our system (temperature, pressure, humidity, force, torque, liquid level, etc.) with a desired precision and other characteristics, we cannot expect to have good control over the system. It is therefore very important to know how we can measure the desired property, what sensor principles we can use, what accuracy can we expect, where to place sensors to obtain correct readings, etc. The proper application of any process-monitoring device requires a good understanding of how sensors work and their advantages as well as their limitations. A chemical sensor is a self-contained device that is capable of providing realtime analytical information about a test sample. By chemical information we understand here the concentration of one or more chemical species in the sample. Ion sensors were the first type of chemical sensors to be developed and produced on a large scale. The pH glass electrode was the first widely used ion sensor. Enzymes form an important class of recognition receptors utilized in chemical sensors. Although isolated enzymes were initially used, it was soon realized that enzymes incorporated in biological materials (such as cells or tissues) can perform better due to the fact that they are in their natural environment.

Keywords: Component; Formatting; Style; Styling; Sensors; Chemical Sensors; Enzyms; Nano Robots; Physical Sensors; Cell Manipulation

Abbreviations: GANs: Generative Adversarial Networks; VAEs: Variational Autoencoders; RNNs: Recurrent Neural Networks; CAE: Computer-Aided Engi Neering; LED: Light Emitting Diode; PVDF: Polyvi Nylidene Fluoride

Introduction

A sensor is a device that transfers the measured physical property into some output signal that can be processed or displayed. Today's sensors use mostly electrical output signals; however, some other possibilities exist like mechanical, pneumatic or hydraulic signals. The sensor is then usually placed in a measuring chain where we can find the sensor, signal processing (like filters, amplifiers, etc.) and gauges (voltmeter, ampere meter, etc.). A chemical sensor is a self-contained device that is capable of providing realtime analytical information about a test sample. By chemical information we understand here the concentration of one or more chemical species in the sample. A target species is commonly termed the analyte or determinand. Besides chemical species, micro-organisms and viruses can be traced by means of specific biocompounds such their nucleic acid or membrane components. Physical sensors are devices used to measure physical quantities such as force, pressure, temperature, speed, and many others. The first (and also best known) chemical sensor is the glass electrode for pH determination, which indicates the activity of the hydrogen ion in a solution. When operated, a chemical sensor performs two functions, recognition and transduction.

Ion sensors were the first type of chemical sensors to be developed and produced on a large scale. The pH glass electrode was the first widely used ion sensor. It is based on the pioneering work of F. Haber and Z. Klemensiewicz (1908) and became commercially available by 1936 along with the Beckman pH-meter. Sensors for other ions (cations or anions) have been developed further. Enzymes form an important class of recognition receptors utilized in chemical sensors. Although isolated enzymes were initially used, it was soon realized that enzymes incorporated in biological materials (such as cells or tissues) can perform better due to the fact that they are in their natural environment. This leads to the development of a new class of chemical sensor in which the recognition is performed by cells or tissues of biological origin. Synthetic sensor data generation using deep learning techniques involves training a model to generate data that closely resembles real-world sensor data. This is achieved by feeding the model large amounts of real-world data and using it to learn the underlying patterns and structures in the data. Once trained, the model can generate data that are similar in quality and complexity to the original data, but with added variations and noise to increase diversity and realism. Several deep learning techniques such as generative adversarial networks (GANs), variational autoencoders (VAEs), recurrent neural networks (RNNs) have shown impressive results in generating synthetic data for a range of sensors.

Piezoelectric Sensor and Actuator Devices

Nowadays, computer simulations play a key role in the design, optimization, and characterization of piezoelectric sensor and actuator devices. The primary reason for this lies in the fact that simulations as an important step in computer-aided engineering (CAE) allow to predict the device behavior without fabricating expensive prototypes. Consequently, we can accelerate the device design, which goes hand in hand with reduced development costs and a reduced time to market. Simulations allow, furthermore, to determine quantities (e.g., inside a material), which cannot be measured at reasonable expense. In order to demonstrate the idea of the FE method, let us consider a one-dimensional (1-D) hyperbolic partial differential equation. Such partial different equation com monlyoccurs for mechanical problems. It comprises derivations with respect to time as well as to space. The starting point of the FE method is the strong formulation of the PDE. Within Galerkin's Method,thespatial computational domainissubdividedintocells, the so-called finite elements. In case of the studied 1-D hyperbolic PDE, we divide the domain [a,b] into M sufficiently small intervals x_{i-1}, x_i $\forall i = 1,...,M$ where each interval border x_i is a node. In book " Piezoelectric Sensors and Actuators Fundamentals and Applications" , all methods for simulation and designing of this sonsor has described.

Nano Robotics and Nano Sensors

Nanorobotics being a promising research and development era has gained acute attention and response from Govt. as well as industries. For long term future application; the characterization and manufacturing techniques of Nano robots is yet to be much more developed. Apart from biomedical applications its potential use in defense, automotive &aerospace, automation of production industry,molecular chemistry, material science research and electronics-communication engineering could be estimated to visualize its tremendous accuracy, precession, smaller size, lesser weight, accessibility and efficiency. Chemical sensors have been used onboard to transmit vital biological environment inside the operating body. RF based resonators and nanoelectronics circuitry are claimed to be the power generators in the range of 1.7mA at 3.3V form the inductively coupled vibration waves transferred from outside. One of the biggest challenges concerned with nanobots are incorporation of organic/inorganic & biotic/abiotic species with sensors & actuators which requires tremendous precision control, advanced wireless telecommunication, remote power supply or generation procedure. The researchers have been able to position nanoscale parts on to a surface with precision with the help of sintering instead of previously used chemical gluing or pushing (by AFM tip).

As discussed above, biomedical sector expects maximum benefit from nanobots. Protecting our body cells from pathogens seems to be one of the precious implementations. Nanobots made of diamond coating and fullerene nanocomposites parts shows inertness inside human body from the immune systems. Successful simulation model of such nanobots are still waiting for practical application in near future. Energy sources for such nanobots are expected to be bodily acoustic vibration, metabolization of glucose cells. Nano computing devices installed onboard, function as the navigators and signal transmitters. They help to distinguish between cells, orient their way to desired organs, transmit feedbacks to doctors regarding the conditions of the cell and receive commands from the operator to perform exact medication to that cell. Chemotactic nano sensors chipped onto these nanobots analyze the surface antigen of the bio cells and distinguish between other nanobots and particular human cell (which needs medication). The nanobots could be introduced inside body by mouth or nose pretty easily. When their job is over, nanobots are designed to be extracted by active scavenger system or defused through our excretory channels.

Nanorobotics has so far proved its incredible future potential in various area i.e. medical, surgery, defense, aerospace research, automotive, molecular manufacturing, nanoelectronicsand micro/nano electro mechanical systems. Technologies like molecular manufacturing, self-assembly, bottom up building are some of the cutting edge topics which hold the rein to success for nanorobotics. Force sensors were integrated with micropipette for injection force measurement and control. Cell mechanical prop erties can be calculated based on the indentation depth and the applied force. Characterizing the intracellular structures is of vital importance to study the natural cellular process, disease progression, and drug effects. A majority of robotic systems have been developed to either extract the contents of living cells or directly conduct measurement in situ with minimal invasiveness and high efficiency.

Robotics for Cell Manipulation and Characterization

In 2002, a microrobot with three degrees of freedom (DOFs) was first developed to automate single cell injection using a micropipette [1]. In the mid-2000s, force sensors were integrated on the end effectors to either measure or control the force during cell manipulation. Glass micropipettes are commonly used for cell aspiration and injection. The diameter of a micropipette ranges from submicrometers to a few hundred micrometers. To perform cell manipulation, micropipettes are connected to a pneumatic or hydraulic pump for pressure control at the micropipette tip. The polished glass micropipettes have a large and smooth contact area, which reduces the friction and pressure applied to the target cells, causing minimal cell damage. To improve the throughput, nanos traws have been used with microfluidic devices. Cells are patterned in the microfluidic device and multiple nanostraws are used for extraction from a high number of cells at the same time. The extraction process can last for several days for an extended period of real-time cell monitoring. Many other approaches, including the injection of nanoparticles, fluorescent 13 Introduction of robotics for cell manipulation and characterization markers or MEMS sensorsinto cells, can be used for intracellular measurement. These approaches provide high signal-to-noise ratio, but are usually limited to prespecified targets [2].

Robotic microinjection adopts automation techniques to deliver foreign materials into living cells with a fine needle. Robot microinjection systems mainly include a piercing mechanism (including precise positioning manipulator and microinjector), cell holder (e.g., petri dish or micropipette), injection control loop, machine vision and other sensors, user interface, and an environment control system for adjusting cell cultivation conditions (e.g., temperature, pH value, and humidity) . By contrast, force sensor-based microinjection can offer real-time force feedback, which can be used to overcome the aforementioned disadvantages and achieve reliable control process. Thus, force-assisted robotic microinjection is vital for scenarios where large amounts of cells need to be injected in a limited time with accurate operation. The vision-based force sensors have been widely used owing to three dis tinct advantages. First, they can offer global force (rather than local force) feedback generated by contact force sensors. Second, for some specific conditions, vision-based force sensors are irreplaceable when the contact force sensors find it challenging or impossible to detect the microinjection force. Third, by making use of the microscope in the microinjection system, they can provide the force information without an additional equipment [3].

Many researchers focus on the development of microforce sensors for cell microinjection. There are mainly five prevalent types of microforce sensors. It is notable that the microinjection force of suspended cell generally lies in the μN-mN range . As microinjection is usually performed under the field of view of a micro scope, visual feedback is the most widely adopted sensing method in current microinjection systems. Vision-based force sensors employ image processing and an accurate cell model to detect the microinjection force. Image processing is mainly adopted to detect the deformation of soft objects, such as cell membrane, cell hold devices, and microinjector. The measured deformation is applied as the input of a force estimation algorithm, and then, the microinjection force can be obtained by an appropriate cell model. In the following, several popular image processing methods and cell models are presented. Optical-based force sensors generally use a light source (e.g., light emitting diode [LED], laser, or halogen lamp) to illuminate a load-sensitive medium 32 Robotics for cell manipulation and characterization (e.g., microcantilever or grating) [4]. A photodetector (e.g., photodiode or CCD camera) is adopted to measure the ranks of illumination, refractive index, or spectrum of the reflected light from the load-sensitive medium. The force can be computed from the change of measured results along with some known properties.

In comparison with conventional piezoelectric force sensors and strain gauge sensors, capacitive force sensors are more stable and more sensitive, and exhibit no hysteresis. As compared with AFM, they are also more stable and more compact. In particular, MEMS capacitive force sensors offer several outstanding properties, such as wide force range, multi-DOF measurement, compact size, and high sensitivity. Nevertheless, the fabrication process is relatively complicated, which imposes high requirements in terms of equipment, resulting in relatively high cost per unit. Furthermore, MEMS capacitive force sensors are very fragile and would be broken in case of any mistake or uncontrolled accident. In addition, the MEMS capacitive force sensors can only be used to manipulate the cells rather than injecting foreign materials into the cells, because they cannot integrate the required injection equipment due to their low load-bearing ability [5]. Concerning the piezoelectric force sensors for cell microinjection, polyvinylidene fluoride (PVDF) film is the most widely used material in sensing the microinjection force. The PVDF film works based on the forward piezo electric effect to generate electric charge under the applied force. Currently, there are mainly three types of PVDF force sensors, that is, cantilever-PVDF sensor, simply supported PVDF sensor, and fixed-guided PVDF sensor [6].

Conclusion

In this survey, I have tried in glossary present new kinds of sensors, mechanical and chemical. In my references, you can see the details of design new kinds of sensors.

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