Introduction to the special issue on Sensors in Technology and Nature

Clemens F. Kaminski, Fernando da Cruz Vasconcellos, and Oliver Hadeler
EPSRC Centre for Doctoral Training in Sensor Technologies and Applications, University of Cambridge.

Welcome to this compendium of articles that reviews sensor research in all its facets, ranging from the physical and chemical nature of sensing at the molecular level, to the monitoring of buildings and human behaviour. The theme of this issue, "Sensors in Technology and Nature", was the theme of the "Sensors Day"[1], a conference organized at the University of Cambridge on the 16th of October 2015, to reflect the diversity of research going on in this field. It was a diverse and highly stimulating event, bringing together experts from all domains of science and technology, academia and industry, to reflect on all aspects of sensors and how they influence our lives. This issue presents a few highlights from the conference, and reflects some of the topics and questions that were discussed at the event in lively debates.

How can sensor technology improve by mimicking nature? Nature has evolved the most sophisticated sensor concepts known to us and much research goes into gaining an understanding on how nature's noses, eyes, and ears reach their unrivalled sensitivities and specificities. The review by Iida et al [2] illuminates this topic from a fascinating angle, focusing on the concept of 'sensor morphology' and arguing how shape, texture, and arrangement of sensory elements have essential functions in the performance of a living sensor system. Why are there structural variations in hair receptors in crickets? Why are rat whiskers oriented in their particular 3D orientation? Understanding these and other sensor morphologies is not only fascinating as a topic in itself, but beginning to inspire technology.

How do we sense what strength is needed to pick up an object, be it smooth, rough, soft, hard, light, or heavy? Building robots with tactile sensing capability is one of the most challenging tasks in the industry today. Wang et al[3], describe the use of electroactive polymer materials that can, like a human hand, perform actuation and sensing tasks in one and the same unit. Physical principles, as well as possible applications, of this emerging technology are discussed.

On a smaller scale, biological cells, the building blocks of life, perform remarkable sensory tasks in tiny volumes. What can we learn by mimicking the chemistry that goes on in such tiny reactor units? The review by Martino et al[4], presents an overview of state-of-the-art technology for the microfluidic generation of encapsulated droplets that act as artificial cells, and in which highly specific and efficient chemistries can be implemented. The format permits rapid screening, sorting, and variation of reaction parameters in femtolitre volumes, and even a capability to sense and translate chemical messages, very much mimicking the processes of life itself.

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[1] http://cdt.sensors.cam.ac.uk/sensors-day-2015
[2] Iida et al.
[3] Wang et al.
[4] Martino et al.

Dhakal et al[5] show how the use of advanced CMOS manufacturing technologies can be used to design sophisticated 'lab on a chip' platforms, which include light sources, waveguides, spectrometers, and detectors. Using evanescent wave sensing and plasmonic structures written directly on top of the waveguides, enhances optical signals and permits the detection of analytes at trace levels, in minute volumes. The methods are highly scalable, permitting mass production of miniature sensor systems, that offer the sophistication of previous bench top instruments.

Advances in nano-synthesis technologies inspire completely new sensor concepts. Miller et al[6] discuss the use of metal-organic frameworks, a self-assembling molecular 'Lego system', with which nanometric fluorescent sensor units can be designed that respond to environmental change or can be used as contrast agents in biological applications, such as MRI and fluorescence imaging. Crucially, the units permit bespoke delivery 'cages' to be constructed, that not only allow therapeutic agents to be delivered to specific locations in an organism, but also report on their location, by acting as environmentally sensitive fluorescent markers.

How do we monitor very large things: buildings, bridges, and even cities? The monitoring of civil infrastructure brings together advances in sensor technologies, wireless communications, and data science in fascinating new ways, as reviewed in Soga et al[7]. The main drivers for innovation in this area are the need to minimize the use of materials, reduce operational cost, and increase the lifespan and safety of buildings. Whilst fibre optic strain and temperature sensors have become standard tools in the field, civil engineers are now looking into computer vision, autonomous sensor networks based on low power devices, and the citizen itself becoming a sensor, with which to obtain an ever more detailed picture of the infrastructure around us.

Finally, a quiet revolution is taking place in laboratories around the world. New and cheaper open hardware technologies permit extremely powerful sensor concepts to be developed at a fraction of the cost of commercial systems. How can we harness this revolution and empower the next generation of leaders in sensor innovation? The final article in the issue describes the development of a sensor unit that monitors living patterns of older people in their own homes[8]. Using open source technologies, a cohort of 10 Masters students, who participate in the EPSRC Centre for Doctoral Training in Sensor Technologies and Applications[9] at the University of Cambridge, developed a highly sophisticated sensor suite to assist older people to live a better and longer independent life in their own homes. In only 12 weeks the students proposed, developed, and implemented a scalable and flexible suite of sensors for assisted living. They had almost no help to complete the task. The project brought out the human side of sensing very much: What do you get when you combine multiple talents, interests, and personalities to evolve a new sensor concept?

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[5] Dhakal et al.
[6] Miller et al.
[7] Soga et al.
[8] Manton et al.
[9] http://cdt.sensors.cam.ac.uk

There was complex connectivity, noise and feedback, trial and error, adaptation and evolution: Hallmarks of nature's best sensor systems.

We hope you enjoy this issue and get a sense of the excitement going on in the field. Take note if that is the case: Sensors Day 2016 is set to take place on the 14th of October 2016.

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