Introduction to the Special Theme

The Sensor Web: Bridging the Physical-Digital Divide

by Mark Roantree and Mikko Sallinen

One of the truly multidisciplinary research efforts involving computer scientists revolves around the topic of sensor networks. It brings together chemists who develop the sensors, engineers focusing on wireless platforms and other hardware components, and the computer scientists who develop the services, knowledge layers and middleware. In many cases, research must also include the knowledge workers associated with the specific domain, many of whom are represented in the articles in this issue of ERCIM News. In almost all cases, some aspect of the research will seek to create a bridge or bidirectional channel between the physical world of the planet, its people and the sensors, and the digital world of computers and their software applications.

The emergence of the Sensor Web concept is due to the proliferation of physical devices that are accessible through the internet and thus, act as an extension to the World Wide Web. Through new hardware peripherals, connected directly to the Web, automatically interpreted, integrated and transformed for human interaction, querying and mining, we create the Sensor Web.

The Sensor Web provides a platform for new ideas and applications for different domains. However, each application domain has its own unique characteristics and the concept of a general platform can be developed only for laboratory tests. As a result, development tends to focus on proprietary solutions to meet a varied set of requirements.

The breadth of research in the Sensor Web domain is demonstrated in the articles in this issue of ERCIM News. Wireless networks are necessary to connect to sensor devices that may be physically unreachable. While sensor data is often analysed after sensing has stopped, wireless networks are essential if we are to perform live queries of sensor output, and adapt the behaviour of the sensor in real time. Toolkits for maintaining sensor networks, together with standards for processing and managing sensor data, assist in building more powerful and robust networks. In addition, new technology for developing and integrating smaller nodes enables measuring devices to be placed in a far wider range of products. In an increasing number of applications and projects, data generated by sensor devices is of a confidential nature, perhaps in areas such as personal health or body networks. This requires the appropriate research effort into security for the data transmitted by the many sensor devices inside the networks. Ubiquitous systems will also provide significant data volumes and challenges for the Sensor Web. Similarly, environmental monitoring needs to be continuous, integrated and without loss of data, requiring the specification and deployment of software services for the Sensor Web. Personal health (or pHealth) networks are emerging in many research projects and industrial applications. Wearable sensors transmit a variety of sensed readings from human participants, which are harvested and undergo semantic interpretation to allow domain specialists to make informed decisions on the health and increasingly the performance of individuals in sporting environments. There are several commercial products in this field that enable researchers and companies to develop more advanced solutions for the market. Applications of the Sensor Web covered in this issue include exploration in oil and gas fields, multimedia sensing, life-logging of human actions and interaction, and environmental hazards, demonstrating the multi-disciplinarity of Sensor Web research and highlighting the need to bring expertise from different backgrounds together.

So what issues arise from the articles presented here? There is evidence of a large number of sensor networks in different disciplines, as already discussed. They incorporate both small cheap devices and larger customized, proprietary and highly expensive devices. In general, the sole difference between them is accuracy. As the smaller, less accurate sensors become cheaper, they will quickly represent the significant majority of this device type on the Sensor Web. In many cases, more than one sensor will be required to support decision-making processes. This will demand synchronization and normalization of sensor feeds before integration takes place. While this presents problems, as highlighted in a number of the articles, the power of the Sensor Web is that it provides an infrastructure for harvesting the data. Historically, significant volumes of data generated by sensing devices have been lost, mainly due to a lack of computer scientists in the research project. This illustrates the gap between the physical and digital worlds.

The first step in developing a Sensor Web system is the construction of a simulation for the planned sensor network. This process becomes easier with time as the domains and environments are better understood. However, when designing a new architecture or software service for one of the layers in an architecture, or perhaps for a new domain, precise simulation is of considerable help prior to implementation into real components. A necessary requirement is that all layers are accurately modelled, otherwise the simulation will give misleading results. When this step is completed, the physical process of sensor deployment and sensor network construction can begin.

New ERCIM Working Group on the Sensor Web

A new ERCIM Working Group on the "Sensor Web" was recently established. Representatives from seven ERCIM members (IUA, ICS-FORTH, ISTI-CNR, CRCIM, VTT, SARIT and NTNU), participated in the kick-off meeting on 19 May 2008, or expressed their interest in joining the Working Group.

Objectives

The objectives of the Sensor Web Working Group is to promote and facilitate interactions between various R&D groups inside and outside ERCIM, in multidisciplinary themes relevant to the Sensor Web. The Working Group members cover a wide range of ICT skills (software engineers, information management and databases including information retrieval, wireless applications, networks, security and e-mobility, ambient and ubiquitous computing), and through their collaborators have a broad multidisciplinary base. Areas of interest to the group include both applied and basic research. Examples of deployment areas include personal health, environmental analysis, ambient intelligence, locomotive and large vehicle monitoring, military applications, deployment of personnel in toxic environments, and traffic analysis.

Future Plans

The group intends to establish an ERCIM International Conference on the Sensor Web. This should be of a high quality, with the intention of raising the group's profile, providing a forum for discussing the meaning and scope of the Sensor Web, and attracting new people for future collaborations. The launch of a journal on Sensor Web has also been considered for the longer term. The Working Group is preparing for the next round of FP7 calls and intends to participate fully with ERCIM's Fellowship Programme.

ERCIM Working Groups are open to any researcher in the specific scientific field. Scientists interested in participating in the ERCIM Sensor Web Working Group should contact the coordinator.

Link:
http://wiki.ercim.org/wg/SensorWeb/

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The first task for computer scientists in Sensor Web research is to ensure data crosses safely from the physical to the digital world, where it can be processed and manipulated to better inform us at to how to proceed in the many environments in which sensors now exist. In the past, environmental and personal health sensor networks have generated large volumes of data that were not captured in a digital format. For example, sports scientists have for some time been running sensor-based tests on athletes, in many of which data is recorded manually and on paper. Even complex sporting equipment such as speed gates that record the velocity of players as they move through various sections of a training course, will have their data transmitted wirelessly to a handheld device, which then has no means of transferring the data to a persistent storage mechanism. Eventually, sensor hardware will always provide a means of recording and transferring data but in the meantime, it is the role of data management researchers to devise a means for ensuring that this data is recorded electronically and stored in persistent, query-capable systems.

Analysis of the data and uncovering the essential issues from huge volumes of information is the next step. If data remains in the raw format generated by sensors, many knowledge workers will be unable to express the complex queries that are required to extract knowledge or make the assessments required to adapt the behaviour of sensors within the network. The next challenge for computer scientists is to convert the raw data into a usable format, preferably one that can be queried and updated by standard query languages such as SQL and XPath or XQuery. It is likely that the XML query languages will find widespread use, as data converted to XML has highly interoperable properties. This is crucial when integrating sensor data, both within a single sensor network and with the data generated by other sensor networks.

The final challenge is the identification of the most important issues in each application, eg closing the loop, controlling parameters, devices or actuators or giving instructions. These tasks should all be completed by accurate miniature sensors and nodes, wideband data communication, and the utilization of real-time control with minimum or zero power consumption. This final step demonstrates the path from the original sensor device through the engineering layers required for transmission of data, through the software services and human interaction, and finally back to the sensor, where the knowledge generated is used to make the sensing device more powerful and more accurate. The aspiration for the Sensor Web is that it should continue to evolve and address its limitations, so that the outcomes of the sensor age lead to an improvement in the planet's environment and the health of its citizens.

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