CONET Newsletter

INFSO-ICT-224053

Issue nr. 1, January 2009

Contents

Editorial

Welcome to the first issue of the CONET newsletter. CONET is the EU FP7 network of excellence on Cooperating Objects, merging the fields of embedded systems for robotics and control, pervasive computing and wireless sensor networks. CONET will focus on establishing the field of Cooperating Objects within the research and industrial community, thus strengthening the position of Europe in the research landscape.

The CONET newsletter will be a vehicle for spreading the activities of the network to the research community. This issue presents a guest column by Prof. John Stankovic from University of Virginia about the proliferation of sensor networks entitled "when sensor and actuator networks cover the world." In this short note he addresses two specific challenges for sensor networks: the extraction of knowledge from the raw sensor data and the necessary openness to increase cooperation and interconnection of different sensor networks.

A recurring section at the newsletter will be a "member profile" where a short description of a CONET member is presented; this issue presents the CISTER research unit from ISEP/IPP, Porto, Portugal. We'll also take the opportunity to present some of the work being done within the CONET consortium in the "Cooperating Objects Roadmap". This issue presents a summary preview of the vision for innovative applications on the Transportation and Healthcare domains. ■

When Sensor and Actuator Networks Cover the World

By John A. Stankovic, University of Virginia

Wireless sensor and actuator networks are proliferating at a prodigious rate pushing the world into the verge of a new revolution.

1. Introduction

In this short note[1] I'd like to provide a glimpse of what happens when Wireless sensor and actuator networks (WSAN) cover the world. I believe that the results will be revolutionary and transform society. In section 2, I briefly discuss one example of such a potential transformation. However, to achieve these results will require new research in many areas. In section 3, I discuss two key research problems that need to be solved. I conclude in section 4.

2. Applications

There will be many new and transformative applications because of WSAN. For example, global scale environmental monitoring and control, social participatory computing and micro-agriculture are three important examples. There are many others. Here I discuss yet another one: **Continuous birth-to-death health care**.

One use of the emerging availability of WSAN is medical care. In the future, it will be possible to create an "account," (e.g., see Google Health and Microsoft's Health Vault) for each person when they are born and via physiological, activity and environmental sensing keep a lifelong record of their health and activities that relate to health. Using such information, preliminary diagnosis can be achieved without a doctor's visit. This will also enable preventative care. As one ages or as one's health deteriorates, specific devices can be included in smart clothes or within the home that ameliorates the condition and/or treats it more effectively. In some cases automatic medical treatment might even be administered. Of course, any such automatic control actions must be

[1] Material in this short note is excerpted from "When Sensor and Actuator Networks Cover the World," J. Stankovic, *ETRI Journal*, Korea, Vol. 30, No. 5, Oct 2008, pp. 627-633. See the full article for a more complete discussion.

guaranteed to be "safe." This holistic and long term health information on individuals will enable dramatic improvements in their care as well as improve our overall understanding of health problems and the effectiveness of treatment. It has been shown that elderly individuals are happier and healthier when participating in social activities. The fact that WSAN will also create social participatory computing will further improve health care. Consequently, it can be expected that many new WSNA applications will synergistically benefit from each other.

3. Challenges

Because of safety, security, privacy and many other requirements, many challenging research problems must be addressed before WSAN of the future are in widespread use. This short note discusses just two of them: from raw data to knowledge, and openness.

When WSAN cover the world a new revolution similar to the Industrial and Internet revolutions will occur.

From Raw Data to Knowledge

With a world covered by WSANs, there will exist a vast amount of raw data being continuously collected. It will be necessary to develop techniques that convert this raw data into usable knowledge. For example, in the medical area, raw streams of sensor values must be converted into semantically meaningful activities performed by or about a person such as eating, poor respiration, high blood pressure, or exhibiting signs of depression. Key challenges for data interpretation and the formation of knowledge include addressing noisy, physical world data and developing new inference techniques. Given that a very large number of WSAN will exist, with each providing many real-time sensor streams, it will be common for a given stream of data to be used in many different ways for many different inference purposes. Enabling streams to act as primitives for unexpected future inferences is an interesting research problem.

Due to the expected pervasiveness of WSAN many individuals will often be in the sensing area of the same sensors. It is necessary to perform correct *data association* ensuring that the collected data and subsequent inferences are associated with the correct individual or individuals. This is a very challenging problem for many situations. However, when users are wearing RFIDs or when cameras with pattern recognition software are used then the problem is conceptually solved. However, in many other situations it will be necessary to combine a set of current sensor readings with a trace of the recent past readings and utilize a history of a given user's activities and personal characteristics to arrive at an accurate data assignment. Very little work has been done on this problem.

Openness

In the past, the majority of sensor based systems have been closed systems. For example, cars, airplanes and ships have had networked sensor systems that operate largely within that vehicle. However, these systems and other WSAN systems are expanding rapidly. Cars are automatically transmitting maintenance information and airplanes are sending real-time jet engine information to manufacturers. WSAN will enable an even greater cooperation and 2-way control on a wide scale: cars (and aircraft) talking to each other and controlling each other to avoid collisions, humans exchanging data automatically when they meet and this possibly affecting their next actions, and physiological data uploaded to doctors in real-time with real-time feedback from the doctor. WSAN require openness to achieve these benefits. However, supporting openness creates many new research problems. All of our current composition techniques, analysis techniques and tools need to be re-thought and developed to account for this openness. At a practical level, new unified communications interfaces will be required to enable efficient information exchange across diverse systems. Openness also causes difficulty with security and privacy. Consequently, openness must provide the correct balance between access to functionality and security and privacy.

4. Conclusions

When WSAN cover the world a new revolution similar to the Industrial and Internet revolutions will occur. Applications such as those mentioned in this note and many others not even conceived of today will appear. New jobs, industries and economic models will emerge. Daily life will be changed in profound ways.

References

D. Arora, S. Ravi, A. Raghunathan and N. Jha, “Secure Embedded Processing through Hardware-assisted Run-time Monitoring.” Proceedings of the Design, Automation and Test in Europe Conference and Exhibition (DATE), 2005.

Q. Cao and J. Stankovic, “An In-Field Maintenance Framework for Wireless Sensor Networks.” DCOSS, June 2008.

A. Cerpa and D. Estrin, “ASCENT: Adaptive Self-Configuring Sensor Networks Topologies.” In Proceedings of the IEEE Infocom, 2002.

P. Kamat, Y. Zhang, W. Trappe, and C. Osturk, “Enhancing Source Location Privacy in Sensor Network Routing,” In Proc. Int. Conf. on Distributed Computing Systems, 2005.

A. Perrig, D. Wagner, and J. Stankovic, “Security in Wireless Sensor Networks.” Invited paper, In CACM, Vol. 47, No.6, June 2004.

B. Przydatek, D. Song, and A. Perrig. “SIA: Secure Information Aggregation in Sensor Networks.” In Proceedings of the 1st ACM International Conference on Embedded Networked Sensor Systems (Sensys), pp. 255-265, 2003.

A. Woo, T. Tong and D. Culler, “Taming the Underlying Challenges of Reliable Multihop Routing in Sensor Networks.” In Proceedings of the 1st ACM International Conference on Embedded Networked Sensor Systems (SenSys), 2003. ■

Member profile: ISEP/IPP

Research Centre in Real-Time Computing Systems

CISTER is a top-ranked Portuguese Research Unit based at the School of Engineering of the Polytechnic Institute of Porto, Portugal.

ⓘ http://www.cister.isep.ipp.pt

The IPP-HURRAY research group, created in mid 1997, is the core and genesis of the CISTER (Real-Time Computing Systems Research Centre) Research Unit. HURRAY stands for **HU**gging **R**eal-time and **R**eliable **A**rchitectures for computing s**Y**stems. Therefore, the research unit focuses its activity in the analysis, design and implementation of real-time and embedded computing systems.

Since it was created, the research unit grown to become one of the leading European research units in the area, contributing with authoritative and even seminal research works in a number of subjects, such as: real-time communication networks and protocols; wireless sensor networks (WSN); real-time programming paradigms and operating systems; distributed embedded real-time systems; cooperative computing and QoS-aware applications; scheduling and schedulability analysis (including multiprocessor/multicore systems); cyber-physical systems (CPS).

Currently, the CISTER research unit is an active member of a number of international networks of research excellence: ArtistDesign (FP7 NoE on Embedded Systems Design); CONET (FP7 NoE on Cooperating Objects) and PT-CMU (on Wireless Sensor Networks and Cyber-Physical Systems). The unit is also involved in a significant number of other international and national R&D projects. Related to CONET’s scientific areas, CISTER is involved in the ARTEMIS Project EMMON (EMbedded MONitoring), led by Critical Software, a high-tech Portuguese company.

Prototype board for Dominance-based MAC protocols developed by CISTER

Researchers at the CISTER research unit have also been driving other initiatives related to Cooperating Objects, Wireless Sensor Networks and Cyber-Physical Systems.

The ART-WiSe (Architecture for Real-Time communications in Wireless Sensor networks, http://artwise.cister-isep.info) research framework aims at using standard and commercial-off-the-shelf (COTS) technology to design a communication architecture fulfilling quality-of-service (QoS) properties such as scalability, reliability, timeliness, mobility, energy-efficiency and cost-effectiveness. Scientific focus was mostly on the analysis, dimensioning and engineering of IEEE 802.15.4/ZigBee Star and Cluster-Tree networks. Several methodologies were proposed that enable an improved performance of these protocols and to compute throughput/message delay bounds for the Guaranteed Time Slot (GTS) mechanism and router's buffer requirements in cluster-tree networks. An open-source toolset for these protocols have been made publicly available (http://www.open-zb-net) that includes the IEEE 802.15.4/ZigBee protocol stack implementation in TinyOS for the MICAz and TelosB motes, featuring 60000 visits to the site and 4000 downloads in 2 years.

CISTER researchers also recognized that no existing communication standard for wireless media performs well for sporadic message streams with real-time requirements. Part of this problem can be tackled by implementing dominance-based MAC protocols in the wireless domain. Interestingly, it turns out that these protocols can also be useful for obtaining functions such as MIN and MAX very efficiently in large-scale, dense sensor networks. In this context, a research framework has been setup developed which exploits dominance-based MAC protocols. The Physical Dynamic Priority Dominance ($(PD)^2$) protocol (http://cister.isep.ipp.pt/PrioMAC/) has been proposed as an important building block for computing aggregate quantities with a low time-complexity. The $(PD)^2$ protocol is an example where communications and computations are tightly coupled with the physical environment. ■

WSN Applications for Healthcare

By Telecom Italia

Devices composed of wearable sensors and remote communications can change the way healthcare services are provided and greatly increase the quality of life of every human, especially disease-impaired people.

The progress of science and medicine during the last years has contributed to significantly increase the average life expectancy. The worldwide population over 65 is projected to increase from 500 million in 2006 to one billion in 2030. This increase of elderly population will have a large impact especially on the health care system.

ICT technologies and in particular Wireless Sensor Networks (WSNs) composed of wearable sensors will contribute to improve the quality of health care services by:

- enabling continuous monitoring of vital signs of patients even outside hospitals or care facilities, thus providing doctors and caregivers with new data about their patients that was not previously available;
- supporting remote therapy and rehabilitation to reduce hospitalization costs;
- allowing to compensate increasing disabilities of an aging person through assisted living services.

WSNs support the provisioning of remote and continuous monitoring services by allowing connectivity of sensor nodes placed on the human body and in the surrounding environment. Health Care applications based on WSNs support prevention, therapy or rehabilitation by monitoring human body parameters, such as heart rate, respiration rate, muscular tension, limbs acceleration. Assisted Living systems provide services to humans in their everyday life, such as monitoring and control of appliances, detection of intrusions, detection and immediate notifications of emergencies. An example of assisted living service is the detection of falls of the elderly and the immediate notification to the emergency care units.

An active area of research that has potential to enable a variety of services in this domain is emotion recognition. So far, the problem of recognizing emotions has been addressed mostly

From the WWW

A 2006 podcast from Bruce Sterling for O'Rilley Media on "**The Internet of things**".
http://www.oreillynet.com/pub/a/network/2006/03/20/distributing-the-future.html

Bruce Sterling, science fiction writer, talks about a world of ubiquitous computing where you can use Google to find your socks in the morning.

in the area of HCI (Human-Computer Interaction) using facial and voice analysis techniques. The capability of Body Sensor Networks (BSNs) to derive physiological parameters has recently enabled several research projects, which aim to understand how physiological parameters measured by wearable sensors, such as heart rate variability, respiration rate and volume, and skin temperature and conductivity, can contribute to determine someone's mental conditions such as emotions, mood, depression, attention level, stress and anxiety. Skin conductivity has been used in several research projects, e.g. at the MIT Media Lab, to measure arousal. Other projects have used sensors that measure heart rate variability, blood volume pulse, breathing rate and volume and obtained preliminary evidence that basic emotions such as fear, anger, sadness and happiness are associated with distinctive patterns of cardio-respiratory activity.

Other very active areas of research are activity monitoring and gait analysis that develop system and algorithms to classify data measured by wearable accelerometers and gyroscopes.

The design of BSN applications is still complex and time-consuming due to the lack of proper abstractions that support interoperability and hide low-level details to application developers. Most applications require advanced algorithms to interpret the sensor data and derive patterns of behavior or health conditions. Classification and pattern recognition techniques have been developed and applied to other application domains. However, implementing them on BSNs introduces new challenges because BSNs are very resource-limited in terms of battery power, memory, and computing power. To meet the application requirements, designers must carefully evaluate implementation tradeoffs regarding the allocation of resources. Hence, it will be essential to develop flexible design frameworks that provide proper abstractions and support fast prototyping. CodeBlue (University of Harvard), Titan (ETH Zurich) and Spine (Open Source project led by Telecom Italia) are examples of frameworks currently under development within the research community.

Several applications enabled by wirelessly connected medical and fitness devices are currently entering the market. However, to fully exploit the potential of WSNs in this domain and target more advanced services, research is needed to further improve WSN systems with respect to requirements such as:

- low energy consumption to maximize battery lifetime;
- wearability to allow patients carry sensor nodes in their daily life;
- privacy and security to ensure that only authorized people, e.g. doctors, relatives and caregivers, can access information on personal health or activities;
- low latency especially in life emergency scenarios;
- reliability, especially for applications monitoring vital parameters;
- accuracy in pattern recognition;
- easiness to extend the platform to other sensors and services, e.g. when new health care needs arise;
- provisioning of service across locations to support continuous monitoring. ■

Vision for Innovative Applications on the Aerial Transportation Domain

By Boeing Research & Technology Europe

Future participants in the aerial transportation domain (e.g., airplanes, control towers) will have an architecture designed for system-wide cooperation instead of disconnected interactions.

Today's computerization and digital technologies have become pervasive in all relevant fields for aerial transportation; the main change expected in the future is the architectural evolution from a set of disconnected systems interacting in a one to one basis to a system of systems designed from the beginning with the aim of cooperation among all systems. Some of the main issues expected are those related to standardization and certification. Interoperability issues will arise and should be managed to ensure smooth transition as aircrafts cross different regions of the earth.

This new future architecture is usually referred to as Network Centric Operations (NCO) and systems affected by this vision are: integrated aircraft systems, Satcom and Broadband satellite systems, Ground receiver systems, Factory/Productions Systems, Flight Test Systems, Flight Line Systems, aircraft Operations and Maintenance, Air Traffic Management (ATM), on-board wired and wireless systems.

In the future we will see airplanes as a securely and seamlessly connected node in the world wide web being each of them a network of hundreds of sensors and actuators controlled by systems with different levels of autonomy. With cost reduction, miniaturization and wireless capabilities, the number of nodes will arise very fast, thus increasing the safety (integrated health management) and the performance of the aircraft.

New services will be offered to passengers and other parties, on-board and at the airport (video on demand, virtual office, telemedicine,…) and time spent at the airport will be reduced.

Maintenance organizations will benefit of more and better data, increasing fleet availability and reducing operational costs.

The System Wide Information Management (SWIM) concept will drastically transform Air Traffic Management infrastructures, allowing new operational concepts. ■

Announcements

Research clusters. CONET has setup eight research clusters: (i) COTS-based Architecture for QoS in Large-Scale Distributed Embedded Systems; (ii) Deployment and Management of Cooperating Objects; (iii) Mobility of Cooperating Objects; (iv) Recognizing Emotions using Wireless Sensor Networks; (v) Resource Management and Adaptation; (vi) Scalable Data Processing; (vii) Testbed and Simulation Platforms for Cooperating Objects; and (viii) Ubiquitous Integration of Cooperating Objects.

ⓘ https://www.cooperating-objects.eu/research-clusters/

Keynote at RTNS´08. Eduardo Tovar (ISEP/IPP) gave a Keynote talk titled "Highly Scalable Aggregate Computations in Cyber-Physical Systems: Physical Environment Meets Communication Protocols" on Cyber-Physical Systems at RTNS´08.

ⓘhttp://www.dei.isep.ipp.pt/~emt/KeynoteTalk RTNS08_EduardoTovar.pdf

Keynote at IT&TC. Manfred Hauswirth (NUIG) gave a keynote talk on “Enabling Networked Knowledge” at the 8th Annual Information Technology & Telecommunication Conference.

ⓘhttp://www.ittconference.ie/mainleft.php?ID2=14

Keynote at CIA-2008. Manfred Hauswirth (NUIG) gave a keynote talk at the 12th International Workshop on Cooperative Information Agents.

ⓘhttp://www-ags.dfki.uni-sb.de/~klusch/cia2008/html/invited_talks.html

Best Demonstrator Award. SELEX has won the Best Demonstrator Award in Commercially Available Systems Category with their Compact Integrated Sensors Processor (CISP) during the Wireless Sensing Demonstrator Showcase organized by the Sensors & Instrumentation Knowledge Transfer Network.

ⓘ http://www.wisig.org/showcase2008

EWSN’09. The 6th European Conference on Wireless Sensor Networks will be held on February 11th-13th in Cork, Ireland. This event is sponsored by CONET.

ⓘ http://www.ewsn.org

MSc/PhD Awards @ EWSN’09. MSc and PhD thesis finished during 2008 at an European University may apply for an award granted by CONET at EWSN’09. The deadline for submission is January 23rd.

ⓘ http://www.ewsn.org/submissions.html

Tutorials @ EWSN’09. Mário Alves (ISEP/IPP) and Luca Mottola (SICS) will be giving two tutorials titled, respectively, “WSN Standards and COTS Landscape: Can we get QoS and Calm Technology?” and “Programming WSNs: From Theory to Practice” at EWSN’09, on February 11th.

ⓘ http://www.ewsn.org/tutorial.html

ETTX’09. The First European TinyOS Technology Exchange will take place in Cork, Ireland, on February 10th, collocated with EWSN’09.

ⓘ http://sites.google.com/site/ettx2009

■

Cooperating Objects NETwork of Excellence

CONET aims at building a strong community in the area of Cooperating Objects capable of conducting the needed research to achieve, in the long run, the vision of Mark Weiser for ubiquitous computing.

http://www.cooperating-objects.eu