Editorial
Distributed Intelligence and Data Fusion for Sensor Systems

L. Shu1 J. Lloret2 J.J.P.C. Rodrigues3 M. Chen4

1Department of Multimedia Engineering, Graduate School of Information, Science and Technology, Osaka University, Japan
2Integrated Management Coastal Research Institute, Universidad Politécnica de Valencia, Spain
3Instituto de Telecomunicacões, University of Beira Interior, Portugal
4School of Computer Science and Engineering, Seoul National University, Korea
E-mail: lei.shu@ist.osaka-u.ac.jp; jlloret@dcom.upv.es; joeljr@ieee.org; minchen@ece.ubc.ca

Abstract: Sensor systems can monitor any type of parameter which is ideal for gathering information from the real world. The next step is to promote the research of distribute intelligence in sensor systems in order to let the sensors be smart and take their own decisions, and propose new data fusion techniques and methods in order to obtain the appropriate data and accurate results. In this paper we summarise a Special Issue that tackles the distributed intelligence and data fusion for sensor systems from the perspective of coding and channel allocation, data aggregation and data storage, routing, security, mobility and distributed services. This paper introduces the reader to those main hot topics and summarises the recent advances provided by the papers published in this Special Issue.

1 Introduction
Use of intelligence, data mining and data fusion has provided new momentum in the use of sensors. They have converted Wireless Sensor Networks (WSNs) into a new brand of dynamic, autonomous and intelligent distributed sensor systems. These features enable new smart sensors to play new roles as intelligent nodes gathering, manipulating and decimating data for more reliable and secure communication whilst performing more efficiently using less energy and number crunching. How to improve power saving and energy optimisation techniques is one of the main issues in WSNs [1], thus distributed intelligence and data fusion can enhance this techniques. They can be used to improve coding and channel allocation, data aggregation and data storage, routing, security, mobility and distributed services (see Fig. 1). Their application to each field contributes to the sensor systems enrichment. Some examples of how they can be applied to the aforementioned research fields are:

1. While transmitting sensory data from local sensors to the fusion center [2], the status of wireless channels will have impact on the performance of data fusion. Intelligent coding and channel allocation reduces the energy consumption while decreasing the data distortion.
2. Efficient data aggregation solutions may be used to avoid redundant data collection and raw data storage and the amount of data transmitted on WSNs [3]. Data fusion approaches applied to data aggregation and data storage can improve the network performance and prolong WSNs lifetime.
3. Gathered sensory data should be efficiently sent to the base station, which requires intelligent routing path exploration. Data fusion in-network-processing can help to reduce the size of the sensory data that to be transmitted [4].
4. Attacks may be launched when using wireless links to delivered fused data due to the lack of physical security in WSNs [5]. Meanwhile, various security/privacy issues can be involved during the process of data fusion.
5. With mobile sensors, users can easily and more efficiently gather sensory data. The fusion task can be done in various mobile devices. Mobility models and mobile path planning of mobile devices have considerable impacts on the performance of sensory data gathering and data fusion [6].
6. Self-organising and mobile sensor networks have several problems related with mobility, dispersion, weak and intermittent disconnection, dynamic reconfiguration, and limited power availability. Appropriate distributed services can solve these problems and represent a strong impact on the information distribution [7].

In order to achieve these goals sensors systems may make use of innovative protocols and algorithms, appropriate cross-layer design, network management protocols, distributed security and privacy, distributed QoS provisioning, context sensing and context awareness, Intelligence and cognitive techniques, and collaborative in-network processing and...

The paper ‘Evolutionary Game Based Data Aggregation in Multi-Replication Data Centric Storage Systems for Wireless Sensor and Actor Networks’, Cuevas et al. introduce a novel type of sensor network, the Autonomous Wireless Sensor and Actor Network (AWSAN), in which sensor and actor nodes collaborate together in a fully distributed way to achieve a predefined goal without any central base station that manages the network. AWSAN could be deployed in remote isolated areas where difficult access for humans although other deployment scenarios are also possible. In addition, a multi-replication Data Centric Storage as the best data storage and delivery technology for AWSAN, leading to the novel concept of AWSAN-DCS networks is proposed. Furthermore, authors define an AWSAN-DCS application taxonomy.

The paper ‘Monitoring and control Sensor System for Fish Feeding in Marine Fish Farms’, presented by Garcia et al., shows a feeding control system for marine fish farms. It mixes data obtained from group of sensors and takes the appropriate decisions to perform an exhaustive control on the feeding process, being able to reduce the costs and decrease the environmental impact given by residuals level accumulated in the seabed. The system takes into account the behaviour of the fishes, and some parameters from the water, and fuses the data obtained in order to decide if the fish is hungry or not.

In the paper ‘Modelling Data-Aggregation in Multi-Replication Data Centric Storage Systems for Wireless Sensor and Actor Networks’, Cuevas et al. introduce a novel type of sensor network, the Autonomous Wireless Sensor and Actor Network (AWSAN), in which sensor and actor nodes collaborate together in a fully distributed way to achieve a predefined goal without any central base station that manages the network. AWSAN could be deployed in remote isolated areas where difficult access for humans although other deployment scenarios are also possible. In addition, a multi-replication Data Centric Storage as the best data storage and delivery technology for AWSAN, leading to the novel concept of AWSAN-DCS networks is proposed. Furthermore, authors define an AWSAN-DCS application taxonomy.

The paper ‘Monitoring and control Sensor System for Fish Feeding in Marine Fish Farms’, presented by Garcia et al., shows a feeding control system for marine fish farms. It mixes data obtained from group of sensors and takes the appropriate decisions to perform an exhaustive control on the feeding process, being able to reduce the costs and decrease the environmental impact given by residuals level accumulated in the seabed. The system takes into account the behaviour of the fishes, and some parameters from the water, and fuses the data obtained in order to decide if the fish is hungry or not.

In the paper ‘Evolutionary Game Based Data Aggregation Model for Wireless Sensor Networks’, by Jiawen Lin et al., an evolutionary game theory is employed to establish a common model, which is independent of the specific application environments, for solving the multi-source data aggregation problem of WSNs. Guided by the model, the competition and cooperation in aggregation procedure is map into games, and then the adaptive weighting method for pixel-level aggregation with homogeneous sensors can be achieved. The experimental result shows that the proposed
model helps to achieve the efficient data aggregation process, improve the information precision, while also telling the feasibility to some extent.

2.3 Routing

Tseng et al. present ‘On QoS Guaranteed Cluster-based Multihop Wireless Ad Hoc Sensor Networks’. This paper proposes a quality of service (QoS) guaranteed scheduling algorithm based on distributed intelligence. Its aim is to schedule packet transmissions in both intra-cluster and inter-cluster connections in a cluster-based multihop wireless ad hoc sensor network. It uses a prioritised polling token and a local synchronisation scheme in order to analyse the maximum jitters for inter-cluster and intra-cluster constant bit rate connections and the maximum delays for intra-cluster variable bit rate connections incurred in each Cluster head. The analysed maximum jitters and delays are further used as the connection admission criterion for each newly requested connection. Both numerical and simulation results show that by using their proposal the QoS requirements of all admitted intra-cluster and inter-cluster connections are guaranteed.

Paper ‘Towards Intelligent Contention-Based Geographic Forwarding in Wireless Sensor Networks’, authored by Cheng et al., proposes a protocol to improve the Contention-Based Geographic Forwarding routing performance in lossy links. It combats the channel variation and combines the advantages of both cooperative and contention-based forwarding. It improves the transmission reliability and avoids packet duplications by involving multiple neighbours into cooperation and sending one additional control message on demand. Simulations demonstrate that their proposal improves the routing performance by decreasing the end-to-end hop counts, so it improves the end-to-end energy efficiency, latency and packet loss ratio.

2.4 Security


Paper ‘On Centralised Conference Key Mechanism with Elliptic Curve Cryptography and Lagrange Interpolation for Sensor Networks’, is contributed by Ming-Huang Guo and Der-Jiunn Deng. In this paper, the authors introduced the centralised conference key management mechanism with Elliptic Curve Cryptography and Lagrange Interpolation. The analysis showed that the proposal defeats the security attacks, and costs the control center less computation than other approaches.

In paper ‘Geomorphic Zonalisation of Wireless Sensor Networks Based on Prevalent Jamming Effects’, Misra et al. propose a scheme that demarcates the geographical extent of Wireless Sensor Networks under attack of a jammer into different zones as per the severity of jamming experienced by various nodes of the network. The proposed scheme performance is studied by the authors in detail and they do not have any inherent inaccuracies.

In the paper entitled by ‘Efficient Sensor Node Authentication in 3G-WSN Integrated Networks’ Hysuk, et al. propose an authentication and key agreement protocol that efficiently reduces the overall computational and communication costs in the next generation converged network. The advent of converged environment merged with wireless sensor networks and mobile networks can have the possibility on enabling us to experience variety of ubiquitous applications based on multi-sensor attached smartphones. The enhanced security procedures are operated through the mobile network in order to maximise the lifetime of the sensor networks and to apply the combined capabilities of both networks.

RFID-based sensor systems are emerging as a new generation of wireless sensor networks by inherently integrating identification, sensing, communications and computation capabilities. Security and privacy problems are critical issues in dealing with a large amount of identified and sensed data. In the paper entitled by ‘Scalable and Distributed Key Array Authentication Protocol in RFID-based Sensor Systems’ Huansheng Ning, et al. propose a distributed Key Array Authentication Protocol (KAAP) with index-pseudonym and partial identifier for intelligent security management. KAAP is comprehensively analysed in three aspects: logic, security and performance. The protocol is feasible and scalable in ubiquitous RFID-based sensor systems for intelligent management.

2.5 Mobility

Over the last decade, mobile agent (MA) systems for multimedia and surveillance applications in wireless sensor networks have gained much attention. In the paper ‘Multiple Mobile Agents Itinerary Planning in Wireless Sensor Networks: Survey and Evaluation’ by Wang et al., the itinerary planning issues for using multiple Mobile Agents (MAs) in WSNs are discussed, including deciding the number of MAs to be dispatched, grouping of source nodes for each MA, routing of each MA for its assigned source nodes and etc. And also the authors survey the existing algorithms for these issues and evaluate their performance by OPNET.

2.6 Distributed services

In paper ‘Distributed Service Integration for Disaster Monitoring Sensor Systems’, Liu et al. propose new architectural model of dynamic distributed service integration for disaster monitoring sensor systems which can proactively self-adapt to changes and evolution occurring in the provision of search and rescue capabilities in a dynamic environment. They demonstrated through simulations that the proposed model can achieve enhanced performance for the provision of rescue capability in a scenario of disaster area monitoring.

3 Conclusion and future trends

We have seen in this Special Issue how distributed intelligence and data fusion can be applied to sensor systems by means of coding and channel allocation, data aggregation and data storage, routing, security, mobility and distributed services. Distributed intelligence and data fusion techniques have provided many benefits to the field of sensor systems, by making them more adaptable, flexible, smart, secure and scalable while improve their performance. Future trends in sensor systems are focused in adding cognitive science at all communication levels. We have observed many research works introducing cognitive science at the physical and MAC communication layer and it is expected to be added in higher layers, in security and in cross-layer optimisation techniques.
Lei Shu (M’07), is a currently Specially Assigned Researcher in Department of Multimedia Engineering, Graduate School of Information Science and Technology, Osaka University, Japan. He received the B.Sc. degree in Computer Science from South Central University for Nationalities, China, 2002, and the M.Sc. degree in Computer Engineering from Kyung Hee University, Korea, 2005, and the PhD degree in Digital Enterprise Research Institute, NUIIG, in 2010. He has published over 90 papers in related conferences, journals, and books. He had been awarded the Globecom 2010 Best Paper Award. He has served as editors of Wiley, European Transactions on Telecommunications, IET Communications, Wiley Wireless Communication and Mobile Computing, KSII Transactions on Internet and Information Systems (TIIS), Journal of Communications, etc. He has served as various Co-Chair for international conferences, e.g., ICC, ISCC, and IWCMC; TPC members of more conferences, e.g., MASS, ICCCN, ICC, Globecom, and WCNC. His research interests include wireless sensor network, security, and multimedia communications. He is a member of IEEE and IEEE ComSoc.

Jaime Lloret (M’07 – SM’10), received his M.Sc. in Physics in 1997, his M.Sc. in electronic Engineering in 2003 and his Ph.D. in telecommunication engineering (Dr. Ing.) in 2006. He is a CCNP Instructor. He is Associate Professor in the Polytechnic University of Valencia and he is the research line coordinator of the ‘communications and remote sensing’ of the Integrated Management Coastal Research Institute. He is currently the Cognitive Networks Technical Committee (IEEE Communications Society) Vice-chair for the Europe/Africa Region. He more than 210 research and educational papers published in national and international conferences, international journals (most of them with Impact Factor in Journal Citation Report), and books. He has been the co-editor of 15 conference proceedings and guest editor of several international books and journals. He is editor-in-chief of the international journal ‘Networks Protocols and Algorithms’, of ‘Advances in Network and Communications’, IARIA Journals Board Chair, and he is associate editor of several international journals. He has been involved in more than 150 Program committees of international conferences and in several organisation and steering committees. He has been the general chair of SENSORCOMM 2007, UBICOMM 2008, ICNS 2009 and ICWMC 2010 and co-chairman of ICAS 2009 and INTERNET 2010. He is the co-chairman of IEEE MASS 2011 and SCPA 2011. He is IEEE Senior Member and IARIA Fellow Member.

Joel J. P. C. Rodrigues (S’01 – M’06 – SM’06), received a five-year B.S. degree (llicentiate) in Informatics Engineering from the University of Coimbra, Portugal and the M.Sc. degree and Ph.D. degree in Informatics Engineering from the University of Beira Interior, Covilhã, Portugal, and a Researcher at the Instituto de Telecomunicações, Portugal. He has authored or coauthored over 170 technical papers in refereed international journals and conferences, a book, and a patent. He is the editor-in-chief of the International Journal on E-Health and Medical Communications and served several Special Issues as a Guest Editor. He has served as General Chair, Technical Program Committee Chair, and symposium Chair for many international conferences. He is a member of many international TPCs and several editorial review boards. His main research interests include sensor networks, high-speed networks, delay-tolerant networks, e-health, e-learning, and mobile and ubiquitous computing. He is a licensed professional engineer (as senior member), and he is member of ACM SIGCOMM, a member of the Internet Society, an IARIA fellow, and a senior member of IEEE.

Min Chen (M’08 – SM’09), is an assistant professor in School of Computer Science and Engineering at Seoul National University (SNU). He has worked as a Post-Doctoral Fellow in Dept. of Electrical and Computer Engineering at UBC for three years since Mar. 2009. Before joining UBC, he was a Post-Doctoral Fellow at SNU for one and half years. He has published more than 120 technical papers. Dr. Chen received the Best Paper Runner-up Award from QShine 2008. He serves as editor or associate editor for Wiley I. J. of Wireless Communication and Mobile Computing, Wiley I. J. of Security and Communication Networks, Journal of Internet Technology, KSII Transactions on Internet and Information Systems, IJSNet, etc. He is a managing editor for IJACCS. He was a TPC co-chair of BodyNets 2010. He is a symposia co-chair and workshop chair of CHINACOM 2010. He was co-chair of MMASN-09 and UBSN-10. He was the TPC chair of ASIT-09, ASIT 2010, TPC co-chair of PCSI-09 and PCSI-10. He is a symposia co-chair for IEEE ICC 2012 and IEEE ICC 2013. He is an IEEE senior member.

4 References


1636
© The Institution of Engineering and Technology 2011
IET Commun., 2011, Vol. 5, Iss. 12, pp. 1633–1636