CSIC Cambridge Centre for Smart Infrastructure and Construction






The Cambridge Conference on

Wireless Sensor Network for Civil Engineering and Infrastructure Monitoring

29 – 30 June 2015

UNIVERSITY OF CAMBRIDGE

EPSRC Pioneering research and skills

Technology Strategy Board Driving Innovation

Conference Organisers

The Conference is organised and hosted by the Cambridge Centre for Smart Infrastructure and Construction, an Innovation and Knowledge Centre at the University of Cambridge.

Organisers

Professor Kenichi Soga
Professor Bill Spencer
Professor Yozo Fujino

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AGENDA

Monday 29 June

8.00 – 9.00	*Registration*
9.00 – 9.20	Welcome Professor Robert Mair – Principal Investigator of CSIC Dr Jennifer Schooling – Director of CSIC Professor Kenichi Soga – Conference Chair
9.20 – 10.00	Professor Bill Spencer, University of Illinois at Urbana-Champaign "Next Generation Wireless Sensors for Monitoring Civil Infrastructure"
10.00 – 10.20	Professor Shirley Dyke, Purdue University "Benchmark problem in active structural control with wireless sensor network"
10.20 – 10.40	Professor Branko Kerkez, University of Michigan "An ultra-low power wireless platform for the measure of environmental systems"
10.40 – 11.10	*Refreshments – Exhibitor presentations*
11.10 – 11.30	Professor James Brownjohn, University of Exeter "Wireless sensor network for structural condition assessment: laboratory and field trials"
11.30 – 11.50	Professor Songye Zhu, Hong Kong Polytechnic University "Towards novel integration of vibration damping, energy harvesting and wireless sensing"
11.50 – 12.10	Professor Yang Wang, Georgia Institute of Technology "Development and large-scale validation of martlet - a next-generation wireless sensing platform"
12.10 – 12.30	Professor Jeong-Tae Kim, Pukyong National University "Wireless monitoring of cable-stayed bridge under back-to-back typhoons via imote2-platformed sensor networks"
12.30 – 13.15	*Lunch – Exhibitor presentations*
13.15 – 13.35	Professor Gul Agha, University of Illinois at Urbana Champaign "A service oriented architecture for structural health monitoring software"
13.35 – 13.55	Professor Jiannong Cao, Hong Kong Polytechnic University "Structural health monitoring using Wireless Sensor Networks: Challenges and opportunities"
13.55 – 14.15	Professor Elena Gaura, Coventry University "ReStructure: adding new value to monitoring of civil engineering structures with WSNs"
14.15 – 14.35	Dr Orfeas Kypris, University of Oxford "Magneto inductive sensor networks for structural and ground health monitoring"
14.35 – 14.55	*Refreshments – Exhibitor presentations*
14.55 – 15.15	Professor Gui Yun Tian, Newcastle University "Electromagnetic NDE-based structural health monitoring"
15.15 – 15.35	Professor Hui Li, Harbin Institute of Technology "Movable wireless sensors and data packet loss recovery algorithms"
15.35 – 15.55	Dr Ivan Stoianov, Imperial College "@@"

15.55 – 16.15 Dr Nemanja Popovic, EMPA
"Event driven monitoring with wireless sensor networks"

16.15 – 16.35 Professor Tomonori Nagayama, University of Tokyo
"Dynamic response intelligent monitoring of infrastructure"

18.00 – 19.00 **CSIC Annual Lecture by Dr Keith Bowers of the London Underground Ltd**

20.00 – 22.00 **Dinner at Jesus College**

Tuesday 30 June

8.50 – 9.10 Professor Yozo Fujino, Yokohama National University
"Infrastructure condition in Japan and a new R&D program - Infrastructure maintenance, renovation and management"

9.10 – 9.30 Professor Kerop Janoyan, Clarkson University
"Development of a Sensor Network to Monitor, Maintain and Control Critical Civil Infrastructure"

9.30 – 9.50 Professor Tomás Fernandez-Steeger, RWTH Aachen University
"Challenges in remote construction site monitoring using WSN"

9.50 – 10.10 Professor Hongki Jo, University of Arizona
"Real-time image processing for non-contact dynamic displacement monitoring using smartphone technologies"

10.10 – 10.30 Dr Elena Barton, NPL
"Keep London ground stable"

10.30 – 11.00 Refreshments

11.00 – 11.20 Professor Daniele Zonta, Trento University
"Wireless technology for seismic protection of buildings"

11.20 – 11.40 Professor Jian Li, University of Kansas
"Fatigue crack monitoring of steel bridges using wireless soft elastomeric capacitor sensor networks"

11.40 – 12.00 Professor Yasunori Miyamori, Kitami Institute of Technology
"Vibration characteristics of a damaged pedestrian overpass measured by dense wireless sensor array"

12.00 – 12.20 Professor Yan Yu, Dalian University of Technology
"Research on wireless distributed monitoring and adaptive control integration systems for Cable-stayed bridges"

12.20 – 12.40 Professor Neil Hoult, Queens University
"Wireless monitoring to assess civil infrastructure assets: a challenging undertaking"

12.40 - 13.10 Closure
Professor Kenichi Soga, University of Cambridge
"Recent progress in WSN monitoring technologies at CSIC"

13.10 – 14.00 Lunch

CSIC Workshop on Monitoring of civil engineering infrastructure with wireless sensor network technology – Best Practice Guide

14.00 – 15.00 Introduction and Reading time
15.00 – 16.00 Workshop 1 - Review
16.00 – 16.30 Workshop 2 – Case Studies

ABSTRACTS

Next Generation Wireless Sensors for Monitoring Civil Infrastructure

Billie F. Spencer Jr., Kirill A. Mechitov and Gul Agha

This paper presents the recent development of a next-generation wireless smart sensor hardware and software framework to enable a more accurate, inexpensive, and greatly simplified method of instrumenting structures for structural health monitoring. The modular hardware supports interchangeable sensor boards capable of measuring: (i) three-axes acceleration for global response monitoring (ii) strain for local response monitoring, and (iii) temperature. The device supports a 24-bit high-precision, analog-to-digital converter with eight differential channels of external analog input, and programmable antialiasing filters. The smart sensor will provide the multi-scale sensed information needed for the SHM algorithms. Communication with a variable power ZigBee radio can be achieved at distances of up to 1 km. The software follows a middleware framework to facilitate the creation of distributed SHM applications. The middleware framework employs a service-oriented architecture (SOA) approach and provides a suite of modular, reusable and extensible services suitable for WSSN applications. This framework addresses critical SHM needs: enabling tightly synchronized sensing, addressing data loss, and efficiently implementing the demanding numerical algorithms required for system identification and damage detection on sensor nodes with limited resources.

B.F. Spencer, Jr. received his Ph.D. in theoretical and applied mechanics from the University of Illinois at Urbana-Champaign in 1985. He worked on the faculty at the University of Notre Dame for 17 years before returning to the University of Illinois at Urbana-Champaign, where he currently holds the Nathan M. and Anne M. Newmark Endowed Chair in Civil Engineering and is the Director of the Newmark Structural Engineering Laboratory. His research has been primarily in the areas of smart structures, stochastic fatigue, stochastic computational mechanics, and natural hazard mitigation. He is a Fellow of ASCE, a Foreign Member of the Polish Academy of Sciences, the North American Editor in Chief of Smart Structures and Systems, and the past president of the Asia-Pacific Network of Centers for Research in Smart Structures Technology.

Benchmark problem in active structural control with wireless sensor network

Z Sun[1], B Li[2], S J Dyke[1], C Lu[2], L Linderman[3]
[1]Purdue University, [2]Washington University, [3]University of Minnesota

Wireless structural control systems that utilize wireless nodes for sensing, communication and control have drawn increased attention due to the flexible installation, rapid deployment and reduced cost. Although there are studies of wireless control systems for civil structures, a benchmark problem which captures the realistic feature of a wireless network would enable research in this area. In this paper, a wireless structural control benchmark problem is proposed to allow the research community, through simulation, to examine the use of wireless sensors to provide feedback to the active control system. This numerical testbed with a sample controller provided will enable researchers to realistically examine the influence of issues in wireless control such as network induced delay, data loss, available sensor measurements, measurement noise and control constraints. Evaluation criteria have been provided to examine resources and control performances.

Shirley J. Dyke is a professor of mechanical engineering and a professor of civil engineering at Purdue University. She received her B.S. in Aeronautical and Astronautical Engineering from the University of Illinois, Champaign-Urbana and her Ph.D. degree in Civil Engineering from the University of Notre Dame in 1996. Dr. Dyke's research efforts have addressed a variety of issues related to the development and implementation of "smart" structures, including innovative control technologies, structural health monitoring and real-time hybrid simulation methods. Dr Dyke also directs the Intelligent Infrastructure Systems Lab at Purdue's Bowen Lab.

An ultra-low power wireless platform for the measure of environmental systems

Branko Kerkez, University of Michigan

We discuss the architecture and performance of a low-power wireless mesh platform, which has been designed for long-term, real-time measurements in harsh and remote environments. This FPGA-based platform features an ultra-low power *ARM-Cortex M3* processors, 20-bit low-noise, analog to digital converter, gigabytes of on-board storage, variable low-noise power supplies, and an industrially rated TDMA-based wireless module. The performance of this platform is discussed across a suite of applications, ranging from remote mountain watershed measurements, to the control of urban water systems.

Branko Kerkez an assistant professor and Berker and Gokyigit Faculty Scholar in the Civil and Environmental Engineering department at the University of Michigan. He received his M.S. and Ph.D. in Civil and Environmental Engineering, and an M.S. in Electrical Engineering and Computer Science, all from UC Berkeley. His research interests include water, data and sensors. He heads the *Real-time Water Systems Lab*, where his group is presently working on a spectrum of applications, spanning from the water balance and water quality of the Great Lakes, to the control of urban hydraulic systems.

Wireless Sensor Network for Structural Condition Assessment: Laboratory and Field Trials

James Brownjohn, University of Exeter

Condition assessment of civil structures under tight timing constraints requires sensors that are quick and easy to deploy. After experiences with research-grade WSNs, we have trialled wireless sensors originally developed for bio-mechanical applications. Such sensors are reasonably priced, available off the shelf, their on board data storage makes them easy to use/deploy on site and they provide additional capability that is more useful to our application than on-board processing or high-spec power management. We have used them in controlled laboratory conditions and on a range of structures around Exeter to explore limitations of synchronisation and resolution.

James Brownjohn is a member of the Vibration Engineering Section which is the international leader in research in vibration serviceability of civil structures under human dynamic loading. His research and professional interests include wind engineering, earthquake engineering, structural health monitoring, vibration serviceability, system identification and biomechanics. James is also a founding director of Full Scale Dynamics Ltd which provides a range of exotic and problematic structures worldwide to play with and try out all kinds of research toys.

Towards Novel Integration of Vibration Damping, Energy Harvesting and Wireless Sensing

Songye Zhu, The Hong Kong Polytechnic University

Power supply issue associated with wireless sensors motivates the development of an emerging area—energy harvesting from ambient vibration. In spite of the apparently complementary nature of vibration control and wireless sensing systems in terms of energy, very limited effort has been made so far to search an appealing strategy that integrates vibration damping, energy harvesting and wireless monitoring systems. This study proposes a novel solution – utilizing regenerative electromagnetic dampers for simultaneous vibration control and energy harvesting. The system consists of three interconnected components, namely electromagnetic dampers (EMD), energy harvesting circuit (EHC), and wireless smart sensors (WSS). This study summarizes a series of theoretical, numerical and experimental work on the proposed self-powered vibration control and monitoring system. The system provides a promising solution to the power supply problem associated with wireless sensing technology.

Dr. Songye ZHU is an Associate Professor in the Department of Civil and Environmental Engineering at The Hong Kong Polytechnic University. He received his B.Sc. and M.Sc. degrees in Structural Engineering from Tongji University (China) and his Ph.D. degree in Civil Engineering from Lehigh University (USA). He is currently an Editor of *Advances in Structural Engineering,* and the Director of ASCE – Hong Kong Section. He has published 38 peer-reviewed journal papers and over 60 conference papers. His major research interests include structural vibration control, structural health monitoring, smart materials and structures, and energy harvesting.

Development and Large-scale Validation of Martlet

Yang Wang, Georgia Institute of Technology

The adoption of wireless sensing technology by the structural health monitoring community has shown advantages over the cable-based systems, such as convenient sensor installation and low system cost. Recently, one new generation of wireless sensing platform, named *Martlet*, has been collaboratively developed by researchers at the University Michigan, Georgia Tech, and Michigan Tech. *Martlet* adopts a Texas Instruments Piccolo microcontroller running up to 90 MHz clock frequency, which enables *Martlet* to support high-frequency data acquisition and high-speed onboard computation. Meanwhile, the extensible design of the *Martlet* node conveniently allows incorporation of multiple sensor boards, so that structural response data can be simultaneously collected from a heterogeneous set of sensors.

Dr. Yang Wang is an Associate Professor in the School of Civil and Environmental Engineering at the Georgia Institute of Technology. After completing a B.S. and an M.S. degree in Civil Engineering at Tsinghua University in Beijing, China, he received a Ph.D. degree in Civil Engineering and an M.S. degree in Electrical Engineering at Stanford University in 2007. Dr. Wang's research interests include structural health monitoring and damage detection, decentralized structural control, wireless and mobile sensors, and structural dynamics. He has published over 100 journal and conference papers in the topic areas. Dr. Wang received an NSF Early Faculty Career Development (CAREER) Award in 2012 and a Young Investigator Award from the Air Force Office of Scientific Research (AFOSR) in 2013. Since 2011, he has served as an Associate Editor for the *ASCE (American Society of Civil Engineers) Journal of Bridge Engineering*.

Wireless monitoring of cable-stayed bridge under back-to-back typhoons via imote2-platformed sensor networks

JT Kim, TH Kim, KS Lee, and TC Huynh

Pukyong National University

Typhoon-induced variation of dynamic characteristics of a cable-stayed bridge is wirelessly monitored by Imote2-platformed sensor networks. Firstly, a cable-stayed bridge with the wireless monitoring system is described. Wireless vibration sensor nodes are utilized to measure acceleration responses from bridge deck and stay cables. Secondly, the cable-stayed bridge under the attack of two consecutive typhoons are analyzed from the estimation of the relationship between wind velocity and the dynamic characteristics. Wind-induced variations of deck and cable vibration responses are examined based on the field measurements recorded during the typhoons, Bolaven and Tembin. Finally, time-frequency analyses are performed to investigate non-stationary random properties of the dynamic responses under the typhoons.

Jeong-Tae Kim is a professor and department head of ocean engineering at Pukyong National University, Korea. He received his Ph.D. in civil (structural) engineering from Texas A&M University, USA, in 1993. He has led BK21Plus graduate education program granted by Korean Government for the last 10 years. He currently serves as an editor-in-chief of Structural Monitoring and Maintenance, an international journal, Techno-Press. Dr. Kim's research has been primarily in the area of damage detection and system identification theories, structural health monitoring techniques, smart sensors and wireless networks, and application of SHM techniques to civil infrastructures. Dr. Kim has been awarded as PKNU Academic Award of 2015, Premier Professor of the Year 2008-2013 from Pukyong National University.

A Service Oriented Architecture for Structural Health Monitoring Software

Gul Agha, University of Illinois

The emergence of small energy-efficient processors, digital sensors and actuators has stimulated research in cyberphysical applications. Cyberphysical applications are implemented on networks of heterogeneous devices (sensor nodes, microcontrollers, mobile devices, operating systems, etc.). Portability and interoperation are major considerations in applications on heterogeneous devices. The Illinois Structural Health Monitoring (ISHM) Project has developed a service-oriented software architecture for WSN middleware services. The ISHM Toolsuite facilitates the rapid creation of portable and reliable applications in heterogeneous cyberphysical systems. Our service-oriented architecture is built using light-weight and flexible local and remote service interaction. The presentation will describe the ISHM Toolsuite and its application to SHM.

Gul Agha is Professor of Computer Science and Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign. Dr. Agha's research is in programming models and languages for open distributed and embedded computation. Dr. Agha is a Fellow of the IEEE. He served as Editor-in-Chief of IEEE Concurrency: Parallel, Distributed and Mobile Computing (1994-98), and EIC of the ACM Computing Surveys (1999-2007). He has published over 200 research articles and supervised 20 PhD dissertations. His book on Actors, published by MIT Press, is among the most widely cited works. Dr. Agha is a co-founder of Embedor Technologies, a company providing solutions for Automated SHM and the Internet of Things.

Structural health monitoring using Wireless Sensor Networks: Challenges and opportunities

Professor Jiannong Cao**,** Hong Kong Polytechnic University

Wireless sensor networks (WSNs) has emerged as a promising paradigm for wireless structural health monitoring (SHM). Compared with traditional wired systems, monitoring of large civil infrastructure using wireless sensor networks is more economical, convenient, and scalable. It also offers new functionalities such as dynamic and real-time monitoring. Recent years have witnessed increasing research projects, even real-world deployments of WSN-based SHM systems. However, some limitations of WSNs, like low-bandwidth and unstable wireless communication, scarce resources on wireless sensor nodes remain to be addressed before WSN-based SHM systems become practical. In this presentation, I will identify the critical issues associated with WSN-based SHM systems and provide an overview of associated recent research on these issues. I will also talk about our on-goings work on WSN-based SHM systems, particularly in terms of system framework design, in-network processing and deployment.

Dr Cao is currently a chair professor and head of the Department of Computing at Hong Kong Polytechnic University, Hung Hom, Hong Kong. His research interests include parallel and distributed computing, computer networks, mobile and pervasive computing, fault tolerance, and middleware. He has co-authored 3 books, co-edited 9 books, and published over 300 papers in major international journals and conference proceedings. He is a fellow of IEEE, a senior member of China Computer Federation, and a member of ACM. He was the Chair of the Technical Committee on Distributed Computing of IEEE Computer Society from 2012 - 2014. Dr Cao has served as an associate editor and a member of the editorial boards of many international journals, including ACM Transactions on Sensor Networks, IEEE Transacitons on Computers, IEEE Transactions on Parallel and Distributed Systems, IEEE Networks, Pervasive and Mobile Computing Journal, and Peer-to-Peer Networking and Applications. He has also served as a chair and member of organizing / program committees for many international conferences, including PERCOM, INFOCOM, ICDCS, IPDPS, ICPP, RTSS, DSN, ICNP, SRDS, MASS, PRDC, ICC, GLOBECOM, and WCNC. Dr. Cao received the BSc degree in computer science from Nanjing University, Nanjing, China, and the MSc and the Ph.D degrees in computer science from Washington State University, Pullman, WA, USA.

ReStructure: adding new value to monitoring of civil engineering structures with WSNs

Dr M Allen[1], Professor A J Whittle[2], Dr R Wilkins[1], Professor E Gaura[1], Dr J Brusey[1], [1] Coventry University, [2] MIT

ReStructure investigates the feasibility of applying wireless sensor networks (WSNs) to monitoring support structures on construction projects that involve excavation. Monitoring is important to ensure structures are operating within specifications, but measurements are expensive to make. WSNs have the potential to support dense, cheap real-time measurements, allowing structural models to be updated during the construction process.
The goals of ReStructure are to develop sensing capabilities and determine how best to meet the application's informational and longevity needs. A prototype WSN has been designed, implemented and lab validated, and is currently undergoing field deployment on an excavation site in Singapore. Findings indicate dense deployment is a necessity for communication and care must be taken to ensure appropriate compensation of measurements in response to environmental conditions.

Professor Gaura received her PhD in Intelligent Sensor Systems in 2000 (Coventry University), was appointed as inaugural director of the Coventry University's Cogent Computing Applied Research Centre in 2006 and was awarded a Professorship in Pervasive Computing in 2009. Presently she is the Associate Dean for Research at Coventry University's Faculty of Engineering and Computing.

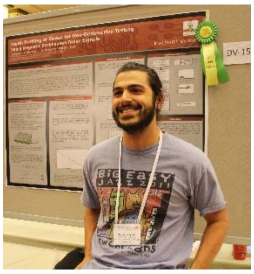
During her research career, Elena has accrued a sturdy academic reputation in the area of MEMS based smart sensing systems in general and wireless sensor networks (WSNs) in particular. She is an active disseminator of research both to the academic community and industry. She is a frequent organiser of Smart Sensing and Wireless Sensor Networks events, and chaired the UK KTN Wireless Intelligent Sensing Interest Group (WiSIG) throughout its lifetime. Her research has spurred world-first innovations including real-time on-body posture monitoring and movement analytics; and industrial scale low-power, robust, unobtrusive energy and home monitoring solutions.

A particular strength in her research has been working with application area specialists and end-users of WSN systems. She is actively involved with the European Commission and regional government organizations to shape and promote knowledge transfer from academia to industry and society at large, focusing on the use of sensing technologies to improve people's life and towards the adoption of wireless technologies for fulfilling UK's carbon footprint reduction targets in Transportation and the Built Environment. Elena was honoured in 2013 to receive the UK Housing Innovation award for Most Innovative Consultant.

Magneto inductive sensor networks for structural and ground health monitoring

Orfeas Kypris and Andrew Markham, University of Oxford

Catastrophic failure of large civil structures like bridges, dams, embankments and buildings can result in fatal, costly and environmentally detrimental consequences. The objective of this research is to develop a low-cost, wireless, embeddable sensing technology that can measure structural deformations in 3-D from deep within a structure, its foundations and surrounding ground. Via magnetic induction one can realize wireless positioning, communication and power transfer among a self-organizing sensor network mixed in with the concrete pour. Preliminary results show that a positioning accuracy of 20 micrometers is achievable, and can be increased further by using more elaborate modulation schemes.



Orfeas Kypris received the BEng degree in Electrical and Electronic Engineering in 2009, and the MSc degree in Magnetics in 2010 from Cardiff University, Cardiff, U.K. He then joined the Magnetics Research Group at the Department of Electrical and Computer Engineering at Iowa State University, U.S.A., where he obtained his Ph.D. in 2015. He is now a postdoctoral research assistant in the Sensor Networks Group at the Department of Computer Science at Oxford University. His research focus is nondestructive evaluation and structural health monitoring using low-frequency magnetic fields.

Electromagnetic NDE-based structural health monitoring

Gui Yun Tian, Newcastle University

This talk introduces novel wireless sensor networks (WSN) to bridge the gaps between non-destructive testing and evaluation (NDT&E) and structural health monitoring (SHM). After a review of the state-of-the art and challenges of WSNs for monitoring of safety critical infrastructure, some of the electromagnetic NDT&E research ongoing in Newcastle with be presented, with particular focus on Electromagnetic sensors, PFID sensors based monitoring system. Two case studies of corrosion monitoring under coating, and crack monitoring for railways will be discussed in the talk.

Professor Gui Yun Tian is Chair in Sensor Technologies in the School of Electrical and Electronic Engineering, Newcastle University. He is PI of the EPSRC-funded AISP (Autonomous Intelligent System Partnership) project of Novel Sensing Networks for Intelligent Monitoring in collaboration with Sheffield and York Universities, and various industrial partners including BAE systems, Network Rail, Scisys, Sellafield Ltd, Cisco etc. Currently, he is also a coordinator of two FP7 projects in collaboration with several leading research centres e.g. MIT, Fraunhofer, Tsinghua University etc. As a chair in sensor technologies, he has published over 230 papers and books with more than 4000 citations with h-index of 34. His current research interests include non-destructive testing and evaluation, structural health monitoring, sensors, wireless sensor network, condition monitoring and lifecycle assessment for safety critical systems e.g. aerospace, railway, renewable energy systems, funded by the Engineering and Physical Science Research Council, the Royal Society, FP7 and industrial worldwide. Currently, he is an adjunct professor with the school of automation engineering, University of Electronic Science and Technology of China.

Moveable wireless sensors and data packet loss recovery algorithms

Hui Li, Yuequan Bao and Dongyu Zhang, Harbin Institute of Technology

Three movable wireless sensor technologies (MWS) were proposed: movable base station in wireless sensor network (MWS-BS), movable wireless nodes (MWS-N), and smart phones-based wireless sensors network and the performance is validated on bridges. For MWS-BS, wireless nodes are densely pre-installed on bridges; the nodes automatically collect data of bridges and the data are deposited in the nodes; only one base station is installed on a car, when the car passes over the bridges, the base station on the car commends the nearest nodes to send data to it. Then the condition of bridges is assessed using the data in base station. For MWS-N, a group of nodes taken by robotics automatically collect data on a local area of bridges and then move to another local area of bridges. In this way, only a group of nodes can obtain responses of many locations at bridges. Most people have smart phones. Smart phones have sensing, data acquisition, process and transmission functions. We proposed to use smart phones to collect acceleration and images of structures. The condition can be assessed using the monitored data and automatically sent to the users by short message, Wechat and email.

Data packet loss frequently occurs during wireless transmission. We proposed a series of compressive sensing-based data packet loss recovery algorithms. First algorithm: the data in sensor node is linearly mapped into another vector. Then the transformed data vector rather than raw data is sent to base station. Data packet may loss during the transmission between node and base station. The loss data packet is viewed as compressed data and the raw data can be recovered by the CS (below right). Second algorithm: to reduce the calculation cost, the product of random demodulation and integration quantization is selected as the random measurement matrix Φ in CS. The data packet loss is recovered by CS. Third algorithm: a data packet loss recovery algorithm without reconstruction error was proposed using a pair of compression and expansion operation on data.

Professor Hui LI is the Cheung Kong Scholars professor in civil engineering at the Harbin Institute of Technology (HIT), China. She is the founding director of the Key Lab of Smart Civil Engineering of the Ministry of Industrial and Information Technology of China.

Dr Li started the study on structural health monitoring (SHM) since 1997. She has research interests primarily in the areas of smart sensor technology and data science and technology of SHM. She is the author of 200 Journal papers, keynote lectures and conference papers.

Dr Li serves as the chairman of Transportation Infrastructure Division in High-tech Program in the Ministry of Science and Technology of China (MOST) and serves on NSFC panel.

Event driven monitoring with wireless sensor networks

Nemanja Popovic and Glauco Feltrin, EMPA

Many monitoring applications in civil engineering benefit from an event driven data acquisition policy since events are often characterized by unpredictable occurrence and short time duration. A representative example is the monitoring of vibrations or strains on bridges during the crossing of trains or trucks. Similar to tethered monitoring systems, wireless sensor networks use triggering mechanisms to implement event driven monitoring policies. The talk presents self-triggering and alerting node triggering approaches for event detection and discusses their performance with respect to data quality, energy efficiency and system reliability based on results of field tests on bridges.

Nemanja Popovic is currently working at EMPA (Swiss Federal Laboratories for Materials Science and Technology) with interests in structural monitoring applications using wireless sensor networks. Other areas of interest include Wireless sensor networks, Hardware design, Software development, Sensors, Signal processing, TinyOS, PCB, Low power applications and Data analysis in MATLab.

Dynamic Response Intelligent Monitoring of Infrastructure

Tomonori Nagayama, University of Tokyo

Wireless sensor networks are expected to reduce the installation cost and time allowing for dense and frequent monitoring of structures. Elemental techniques such as multihop communication, synchronized sensing, low noise acceleration measurement have been addressed. Several applications of wireless sensor networks to bridge response measurements are introduced. In addition, road condition monitoring using probe vehicle vibration measurements are introduced.

Tomonori Nagayama obtained his B.S. (2000) and M.S. (2002) in civil engineering from the University of Tokyo and his Ph.D. (2007) in civil and environmental engineering from the University of Illinois at Urbana-Champaign. He is currently an associate professor at the Department of Civil Engineering at the University of Tokyo. His research interests include smart sensor technology, structural monitoring, infrastructure monitoring using probe vehicles, and local vibration mode analysis.

Infrastructure condition in Japan and a new R&D program - Infrastructure maintenance, renovation and management

Professor Yozo Fujino, Yokohama National University

The economic sustainability, security and well-being of a nation *depend* heavily on the reliable functioning of *infrastructure.* After five decades of development, Japanese stocks of infrastructure have reached enormous amount of over US$7000 billion. Built between the 1960s and 1980s, majority of infrastructure have stood for three to four decades. Most works on highways started in late 1960s, bridges in early 1970s, dams and harbors in early 1980s.

Some of the infrastructures are not in good condition now. Demand for rapid availability of infrastructure in the past might have led to poor design; poor construction quality or structures built using undeveloped technology. Some of bridges are deteriorating due to increasing traffic volumes, the use of anti-freezing salts and humid environment. The collapse of Sasago Tunnel on the Chuo Expressway near Tokyo in 2012 has brought public attention to the issue of infrastructure degradation and led to doubts about their current quality and safety.

Realizing this condition, Japanese government decided to invest on research and development for efficient infrastructure management. A new R&D program named “Infrastructure maintenance, renovation and management” was launched in 2013 under the Japanese Council of Science, Technology and Innovation (CSTI)‘s Strategic Innovation Program (SIP). The 5-years program covers various subjects with key technologies in condition assessment, non-destructive testing, monitoring and robotics; long-term performance prediction, development of high-quality durable material for repair and replacement, and infrastructure management using advanced information and communication technologies (ICT). The program consists of over 60 research projects involving universities, research institutes and industries. This initiative is expected to prevent further accidents and setting an example for efficient infrastructure maintenance by reducing the burden of maintenance works and cost.

Dr Yozo FUJINO was Professor of Civil Engineering, University of Tokyo from 1990 to 2014 and now Distinguished YNU Professor of Institute of Advanced Sciences, Yokohama National University (YNU). His area of expertise comprises dynamics, control and monitoring of bridges and structures, earthquake- and wind-effects on structures.

He was recently appointed to be a policy adviser in the Council of Science, Technology and Innovation(CSTI), Cabinet Office and he is in charge of a 5-years large R&D project (approx. 170 M$US) “Infrastructure maintenance, renovation and management”.

Development of a sensor network to monitor, Maintain and control critical civil infrastructure

Kerop Janoyan, Clarkson University

Clarkson University recently started a new project to gather data for the Ogdensburg Bridge and Port Authority (OBPA) through the use of trend-setting building information modelling and geographic information systems (BIM and GIS) techniques with advanced sensing technologies, and monitoring capabilities. This project's goal is to go beyond sensor development and deployment and focus on how the data is incorporated into the various infrastructure condition assessment and visualization frameworks.
The Ogdensburg-Prescott International Bridge, the testbed for this project, is a vital link in the infrastructure that connects Northern New York with Canada. The project is envisioned to be a multi-year effort, with the first year effort focusing on the development of a robust BIM model of the bridge that is validated for structural analysis efforts. This model will be used and revised throughout the project and will serve as the basis of future research and facility management. It will also provide the bridge owner with 3D visualization of the various elements of the bridge structure to better understand and capture the overall facility needs. Wireless sensors networks will be deployed to gather bridge response data. The data will be used to calibrate and validate analytical model at both local and global levels. Such work will require development of frameworks to seamlessly generate Finite Element Models of the bridge based on BIM models that incorporate the sensor data collected.

Professor Kerop Janoyan received his Bachelor of Science, Master of Science, Engineer, and Ph.D. degrees in civil engineering from the University of California at Los Angeles (UCLA). He is a Registered Professional Engineer (PE) in California.
He currently serves as the Director of Distance Learning in the Office of the Provost at Clarkson University. He is a Professor in the Department of Civil and Environmental Engineering where he also served as Executive Officer from 2010 through end of 2014.

Janoyan's research and development expertise covers a broad range of related topics with a strong focus on aspects of intelligent infrastructure systems. He is the co-director of Clarkson's Center for the Evaluation of Clean Energy Technology (CECET) Blade Testing Facility and the director of the Laboratory for Intelligent Infrastructure and Transportation Technologies.

He has been recognized numerous times by the Coulter School of Engineering for his excellence in teaching undergraduate and graduate courses. He recently received the Albert D. Merrill Award and was inducted into Phalanx, Clarkson University's highest honor society.

Challenges in remote construction site monitoring using WSN

Tomás Fernandez-Steeger

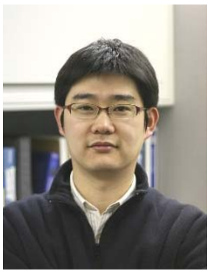
Wireless Sensor Networks (WSNs) are envisioned to be flexible systems providing dense and cost-effective monitoring infrastructures without extensive cabling. From this perspective they are a perfect monitoring tool for construction site or landslide monitoring. However, up to now WSN are still at the level of research and not stand alone monitoring systems. One reason is that a technology simple and powerful as a smartphone is expected and WSN are right the opposite. Another reason is that we often forget that a construction site is an extreme environment for radio communication as well as electronic devices. Furthermore, in project evaluations the data quality is often not considered. In the presentation experiences from deployments and research needs will be discussed.

Tomás Fernandez-Steeger holds a diploma degree in Geology from the Karlsruhe University (now Karlsruhe Institute of Technology KIT). He did his PhD in the DFG-Research Training Group «Natural Disasters» at the University of Karlsruhe (TH) in 2002. Thereafter, he worked for 3 years as Data Mining Manager at a staff division for a German publishing group. In 2004 he returned to university as Assistant Professor at the Department of Engineering Geology and Hydrogeology at RWTH Aachen University. Today he is senior lecturer and leads the group for "Engineering Geology of Soil and Rock" at the Department. His present research is focused on monitoring technologies to enhance rock characterization and improve understanding of spatially and temporally distributed geological processes, especially for hazard monitoring and early warning.

Real-time image processing for non-contact dynamic displacement monitoring using smartphone technologies

Hongki Jo, University of Arizona

Many of the available approaches for Structural Health Monitoring (SHM) can benefit from the availability of dynamic displacement measurements. However, current SHM technologies rarely support dynamic displacement monitoring, primarily due to the difficulty in measuring absolute displacements. The newly developed smartphone application in this study allows measuring absolute dynamic displacements in real time using state-of-the-art smartphone technologies, such as high-performance graphics processing unit (GPU), in addition to already powerful CPU and memories, embedded high-speed/resolution camera, and open-source computer vision libraries. A carefully designed color-patterned target and user-adjustable crop filter enable accurate and fast image processing, allowing up to 120Hz frame rate for complete displacement calculation. The performances of the developed smartphone application are experimentally validated, showing comparable results with those of conventional laser displacement sensor.



Dr. Hongki Jo received the B.S. and M.S. degree in civil engineering from the KAIST, Korea, in 1999 and 2001, respectively and then worked as a bridge engineer in Seoyeong Engineering Co., Ltd, Korea, for 7 years before he started his PhD study. He received the Ph.D. degree from the University of Illinois, Urbana in 2013. He joined the civil engineering and engineering mechanics department at the University of Arizona, Tucson, as an Assistant Professor in 2013. As part of the PhD research, he developed various multi-metric sensor boards for wireless structural health monitoring (SHM) applications: more than 350 units of the sensors are currently being used in 17 research/academic institutes in 5 countries. He has authored or co-authored 17 papers in journals. His current research interests include wireless sensor hardware and software development for SHM applications, hybrid SHM, smartphone network for SHM, and advanced sensing for civil engineering applications.

Keep London ground stable

Elena Barton, NPL

This talk introduces a recently completed project looking at technical capability and commercial feasibility of potential integrated solutions based on sensor data to support management of large scale infrastructure and surrounding areas https://artes-apps.esa.int/projects/tim. A new approach will be described that will help to move from individual structures to asset portfolio management and create an information service for the 21st century city.

After graduation Dr Elena Barton worked at Marconi Research centre modelling novel optical integrated semiconductor devices for applications in telecommunications. In 2007, she moved to DeepSea Monitoring Solutions and validated optical monitoring systems for applications in oil and gas industry. She joined the area of structural health monitoring at NPL in September 2008 and moved to the area of mathematical and statistical modelling in 2012. Her main scientific interests are focused on numerical and analytical methods for asset monitoring using heterogeneous sensor networks and remote sensing including data validation, performance indicators and information extraction.

Wireless technology for seismic protection of buildings

Daniele Zonta, University of Trento

Between 2008 and 2012 a consortium of eleven industries and research institutions from seven countries was involved in MEMSCON, a project co-funded by the European Commission, addressing the development of a system for seismic protection of reinforced concrete buildings. The system consists of a wireless sensor network deployed within the building and linked to a remote center where data is processed and interpreted. Sensor devices include Micro-Electro-Mechanical System (MEMS) strain gauges and accelerometers, both designed and fabricated for the specific application. I will offer an overview of the MEMSCON technology and discuss its performance based on the outcomes of a laboratory validation.

Daniele Zonta achieved his Doctorate in Structural Mechanics at the University of Bologna in 2000, and worked as a Post-Doctorate researcher at the University of California, San Diego, in the period 2000-2001. He is Associate Professor at University of Trento, where he teaches Structural Design and Structural Health Monitoring. In addition, he holds a joint appointment at the Institute for Photonics and Nanotechnologies of the National Research Council and has been, in the past years, a visiting scholars at the University of California, San Diego, Princeton University and the University of Michigan. His research activity includes: Bridge Management; Reliability Evaluation; Structural Health Monitoring (SHM); Sensor and Information Technology; all as applied to civil infrastructure. Dr. Zonta is an active member of SPIE, SEM, IABMAS, where he serves in the SHM committee; he is the chair of the Memscon Series Workshops, of the IEEE EESMS workshop and of the annual Int'l Summer School on Smart Materials and Structures; he serves in the editorial board or as a reviewer in most of the journals of the Structural Health Monitoring community. He is cofounder of Intelligent Infrastructure Innovation, a startup company of the University of Trento. In 2014, Dr. Zonta was awarded Person of the Year by the SAGE SHM editorial board for his contribution to the field of SHM. He is author of over 150 technical publications.

Fatigue Crack Monitoring of Steel Bridges using Wireless Soft Elastomeric Capacitor Sensor Networks

Jian Li, University of Kansas

The initiation and propagation of fatigue cracks is one of the primary concerns for steel bridges. Measuring strain in the area surrounding fatigue cracks has been shown an effective way of monitoring crack activities. However, traditional metal foil gauges are not effective in capturing fatigue cracks due to their limited measurement range, small size, and high failure rate under harsh environment. In this presentation, an on-going Transportation Pooled Fund project will be introduced, which aims at developing a strain-based wireless sensor network for fatigue crack monitoring with soft elastomeric capacitor (SEC) sensors. The SECs are able to provide strain measurements over a large area and will be integrated with wireless sensors to form an autonomous sensor network for long-term continuous fatigue crack monitoring.

Jian Li is an Assistant Professor in the Department of Civil, Environmental, and Architectural Engineering at the University of Kansas. He holds a B.S. and M.S. in civil engineering (Harbin Institute of Technology 2005, 2007) and a Ph.D. in civil engineering (University of Illinois at Urbana-Champaign 2013). His research interests are primarily in the area of structural dynamics and earthquake engineering, with particular emphasis on vibration-based structural health monitoring, wireless smart sensor networks, substructure hybrid simulation, advanced fragility analysis, and seismic risk assessment. He is a member of several professional organizations including ASCE, EERI, SPIE, ASEE, and CUREE.

Vibration characteristics of a damaged pedestrian overpass measured by dense wireless sensor array

Yasunori Miyamori, Kitami Institute of Technology

A fundamental study for structural health monitoring was performed on a damaged pedestrian overpass. The pedestrian overpass had local damage on its girder. The vibration measurement was repeated before and after the repair work of the girder with 14 Imote2 wireless sensors. From measurement results, natural frequencies of each mode did not change by the repair work. Mode amplitudes were slightly changed in several vibration modes. A detailed FE model was constructed to reproduce the measured vibration characteristics with satisfactory accuracy for SHM. Effect of local damage in dynamic characteristics was discussed in both experimental result and analytical model.

Yasunori Miyamori, born 1975, received his PhD degree from Hokkaido University, Japan. He is an associate professor at Department of Civil and Environmental Engineering, Kitami Institute of Technology, Japan. His main area of interest is bridge engineering and dynamic responses of structures.

Research on wireless distributed monitoring and adaptive control integration systems for Cable-stayed bridges

At Present, the two systems of structural health monitoring and vibration control for Cable-stayed bridges are running separately, thus the joint operation of monitoring diagnosis and control decision can not been achieved. The monitoring and control integration systems based on distributed control may finish fusion of damage detection, repair strategies and control algorithm, which can protect the safe operation of cable-stayed bridge more efficiently and in real time. Therefore, it has important theoretical and practical value to study the integration. In this project, the mechanism and operation mode of multi-level wireless monitoring and control network systems are studied, an innovative wireless structural vibration control system based on WiFi is proposed and implemented, the distributed adaptive control algorithms with delay compensation are designed, the results of numerical simulations and practical experiments demonstrate that considerable improvement can be obtained by employing the proposed compensation method. This project, belonging to interdisciplinary research, can also be expanded to other civil engineering structures and thus has great application prospects.

Yan Yu received his B. S. in industrial automation, his M. S. in architecture technique science and PhD in Disaster Prevention and Reduction Engineering from Harbin Institute of Technology in1999, 2001 and 2006, respectively. Now He is an associate professor, PHD. Supervisor, Director of DUT-MEMSIC Wireless Sensor Networks Joint Lab, director of Institute of circuits and systems, Dalian University of Technology, China.

His research interests include wireless sensor network, wireless control, structural health monitoring and intelligent building. He is the author of 2 book chapters, 15 patents and more than 80 published papers including 30 SCI papers (with the highest impact factor of 6.5). He is in charge of for about tens of projects supported by the National Natural Science Foundation of China, the National Hi_tech Research and Development 863 program of China, the Key Project in the National Science & Technology Pillar Program during the 12th Five-Year Plan, and some engineering projects, and so on. He has been also awarded “Science and Technology Advancement Award, First-Class, in Ministry of Transport. China, 2012”, “Natural Science Academic Achievements, First-Class Award in Liaoning Province, China,2011”.

Wireless monitoring to assess civil infrastructure assets: a challenging undertaking

Neil A Hoult, Queen's University

This talk will examine some of the challenges involved with using wireless sensor networks to monitor civil infrastructure assets through a series of case studies. The three case studies will highlight issues associated with network deployment, sensor selection, and sensor robustness. The talk will conclude with examples of how WSNs can be used as useful tools to evaluate other sensor technologies in the field.

Neil Hoult is an Assistant Professor in the Department of Civil Engineering at Queen's University in Kingston, Canada. He received his bachelor's and master's degrees in Applied Science from the University of Toronto and his PhD from the University of Cambridge. His research interests include the behaviour of reinforced concrete and deteriorated infrastructure as well as monitoring of complex structural systems.

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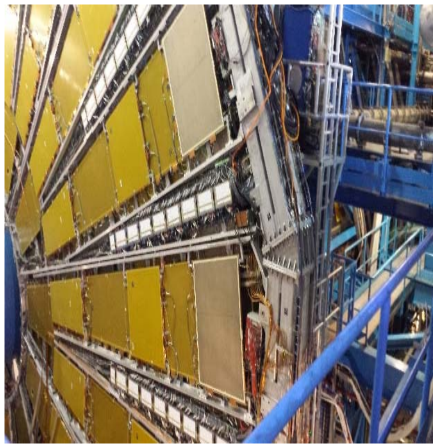

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