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## Real-Time IoT Stream Processing and Large-scale Data Analytics for Smart City Applications



*Collaborative Project*

### ISWC2014 Workshop on Semantics for Smarter Cities Report

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## Abstract

This report documents the program and the outcomes of 5th Workshop on "Semantics for Smarter Cities" collocated with the 13th International Semantic Web Conference.

**Conference** International Semantic Web Conference-Riva del Garda, Italy, 19 October, 2014. [www.blog.soton.ac.uk/s4sc/](http://www.blog.soton.ac.uk/s4sc/) 1998 ACM Subject Classification C.2 Computer-communication Networks, K.4 Computers and Society, B. Hardware

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## 1 Scope and Objectives

The world's population is rapidly urbanizing. By 2005, the world's population had increased to 6.5 billion, with about 50% living in cities. By 2025, UN projections show that the world population is expected to exceed 9 billion with roughly 75% expected to live in cities. This rapid urbanization is continuing to put tremendous pressure on traditional urban infrastructures, such as roads, water, and energy, and on societal institutions. This urbanization challenges require new approaches that will transform modern cities to comfortable, economically successful, and environmentally responsible habitats.

We are also seeing a rapid rise in the connection and usage of billions of low-end and affordable smart devices to the Internet, i.e. the Internet of Things, and witnessing the expansion of the Web into more areas of our personal lives. These trends make possible a new generation of smart city applications and services, with new smart city applications emerging as more data from different sources (e.g. from utility services, transport services, environmental data, and from social sensing) become available. These smart city data are large in volume, multi-modal, vary in quality, formats, and representation forms. These data need to be processed, aggregated, and higher-level abstractions need to be created from these data to make them suitable for the event processing and knowledge extraction methods that enable intelligent applications and services for smart city platforms. Semantic Web technologies and Linked Data together with data analytics solutions play a key role in providing inter-operability, association analysis, information and knowledge extractions, and reasoning about trust, privacy, provenance, and security in smart city frameworks. It is within this context that the Fifth Workshop on Semantics for Smarter Cities was held. It was held as a Workshop at the Thirteenth International Semantic Web Conference at Riva del Garda, Italy in 19th October 2014. This volume of proceedings contains the accepted posters and papers presented at the workshop.

We would like to take this opportunity to thank all the workshop authors for their contributions to the ISWC 2014 programme. We would also like to thank the members of the workshop's Program Committee for their time and work. Finally, we would like to thank the organizers of ISWC 2014 for providing the opportunity for Smart City practitioners to present current work in this fast moving area. This workshop explored the interfaces between the Web, the Web of Data, and the City Smart environment. It further explored how the Web, and the intelligences built on top of, and around the Web, can make the notion of the Smart Connected City possible and realizable.

The workshop aimed to gather researchers, city departments, service providers, application developers, entrepreneurs, and citizens to present and debate Semantic Web technologies, Linked Data and data analytics and evaluations for smart city applications as well as impact of user engagements and social networks. It also focused on related standardization activities in W3C, IEEE and ETSI.

It continued on from the successful earlier workshops on the same theme at:

- AAI 12 (<http://research.ihost.com/semanticcities12/>),
- IJCAI 13 (<http://research.ihost.com/semanticcities13/>),
- SemCity13 (<http://aida.ii.uam.es/wims13/semcity.php>) and
- AAI 14 (<http://research.ihost.com/semanticcities14/>).

## 2 Organising Committee

### Workshop Chair Committee

- Payam Barnaghi, University of Surrey, UK (CityPulse)
- Jan Holler, Ericsson, Sweden (CityPulse)
- Biplav Srivastava, IBM Research, India
- John Davies, BT, UK
- John Breslin, National University of Ireland, Galway, Ireland (DERI)
- Tope Omitola, University of Southampton, UK

**Payam Barnaghi**, University of Surrey, UK (email: p.barnaghi@surrey.ac.uk) Payam Barnaghi is a Lecturer (Assistant Professor) at the Centre for Communication Systems Research (CCSR) at the University of Surrey. He is a senior member of IEEE, an associate editor of the IEEE Internet of Things Journal, a guest editor of a special issue of the IEEE Intelligent Systems on Web of Things, and a member of the editorial board of the International Journal on Semantic Web and Information Systems. He has been involved in organising several international conferences and workshops including being program co-chair of the IEEE UIC 2013, program vice-chair of the IEEE iThings2013, program co-chair of the ISWC SSN2013 workshop, and Mobile Web, Sensors and Semantic Streams track co-chair at ESWC 2013 and ESWC2014. He has also been involved in various relevant EU research projects including IoT.est, FI-WARE, EXALTED, and SENSEI. He was a member of the W3C Incubator group on Semantic Sensor Networks as an invited expert. He is the scientific coordinator of the EU FP7 CityPulse project <sup>1</sup>. His research interests include machine learning, Internet of Things, semantic web, web services, information centric networks and information search and retrieval <sup>2</sup>

**Jan Höller**, Ericsson Research, Sweden (email: jan.holler@ericsson.com) Jan Höller is a Principal Researcher at Ericsson Research where he has a responsibility to define and drive technology and research strategies, and to contribute to the company strategies in the area of M2M and Internet of Things. He established Ericsson's research activities in the Internet of Things almost a decade ago, and has since then continued to contribute to the company strategies in the area of M2M and Internet of Things towards the Ericsson vision of "50 Billion connected devices" in the Networked Society. He has been active in a number of international research programmes on the Internet of Things, and is co-author of the book "From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence". Jan has held various positions in Strategic Product Management, Technology Management and has since he joined Ericsson Research in 1999 led different research activities and research groups. He also serves as secretary on the Board of Directors at the IPSO Alliance.

**Biplav Srivastava**, Senior Researcher and Master Inventor, IBM Research and an ACM Senior Member and Distinguished Speaker, is based out of New

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Delhi, India. His research deals with enabling people to make rational decisions despite real world complexities of poor data, changing goals and limited resources. His expertise is in Artificial Intelligence, Services and Sustainability, where he has proven track record of high-quality innovation in the global business environment. Biplav's current focus is on open APIs and data, and their real world usage in enterprise integration. As part of this, he represented IBM at W3C's working group on Government Linked Data and is active in open data and AI circles. Previously, he had explored influential web services techniques in this space <sup>3</sup>.

**John Davies** is Chief Scientist in BT's ICT Research Practice. His interests include the application of semantic, IoT and data analytics technologies to smart cities, business intelligence and information integration. He is Project Director of the Stride TSB collaborative project and has previously coordinated a number of European collaborative research projects. Currently chairman of the Web Intelligence, Mining and Semantics (WIMS-14) conference, he has served on the program committees of many conferences in related areas and was founder of the ESWC conference series.

**John Breslin** is a senior lecturer in Electronic Engineering at the College of Engineering and Informatics, NUI Galway, and a researcher with the Insight Centre for Data Analytics at NUI Galway (formerly DERI), a Semantic Web research institute. His research interests include the Social Semantic Web and sensor applications. John is leader and founder of the Social Software Unit at Insight. He is co-author of the book "The Social Semantic Web" (Springer, 2009), and has over 140 peer-reviewed academic publications. He was General Chair for the ICWSM-12 conference, and has served on over 75 committees for workshops, conferences or journals. He is also the founder of the SIOC project (Wikipedia article), which aims to interlink online communities with semantics. SIOC recently won the seven-year most influential paper award from ESWC <sup>4</sup>.

**Tope Omitola** is a senior research fellow working in the Web and Internet Science Group at the School of Electronics and Computer Science at the University of Southampton.

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#### Programme Committee

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<sup>3</sup><http://www.research.ibm.com/people/b/biplav/>

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### 3 Publication Plan and Time line

Publication plan and time line was aligned with other workshops at ISWC 2014.

- Final CFP: 15 April 2014
- Final Marketing Plan: 15 April 2014 (to coordinate the distribution of CFP)
- Final Nomination of TPC: 20 April 2014 (based on 40-50 expected submissions)
- Final Workshop Website: 30 April 2014
- Submission Deadline: 22 June 2014 (+14 days pre-planned extension)
- Decision Notification: 30 July 2014
- Final Papers: 20 August 2014

- Final Program: 1 October 2014 (including keynotes and panels)

In order to guarantee a timely notification of acceptance, we had a detailed review plan based on the experience of the organizing team with previous events. A preliminary list of TPC members can be found in the draft *ISWC2014-Workshop Proposal* which is included as an Annex to this dissemination report.

## 4 Topics of Interest

Topics of interest included but were not limited to:

1. Semantic platforms to integrate, manage and publish smart city data
  - Provenance, access control and privacy-preserving issues in open data Collaborative and evolving semantic models for cities. Challenges and lessons learned
  - Semantic data integration and organization in cities: social media feeds, sensor data, simulation models and Internet of things in city models
  - Big data and scaling out in semantic cities. Managing big data using knowledge representation models
  - Knowledge acquisition, evolution and maintenance of city data
  - Challenges with managing and integrating real-time and historical city data
2. Process and standards for defining, publishing and sharing open city data
  - Platforms and best practices for city data inter-operability
  - Foundational and applied ontologies for semantic cities
3. Robust inference models for semantic cities
  - Large-scale stream reasoning
  - Semantic event detection and classification
  - Spatio-temporal reasoning, analysis and visualization
4. City applications involving semantic models
  - Intelligent user interfaces and contextual user exploration of semantic data relating to cities
  - Use cases, including, but not limited to, transportation (traffic prediction, personal travel optimization, carpool and fleet scheduling), public safety (suspicious activity detection, disaster management), healthcare (disease diagnosis and prognosis, pandemic management), water management (flood prevention, quality monitoring, fault diagnosis), food (food traceability, carbon-footprint tracking), energy (smart grid, carbon footprint tracking, electricity consumption forecasting) and buildings (energy conservation, fault detections)
5. City as a Smart Utility

- Internet of Things
- Interaction paradigms in the Smart City
- Smart City operating systems
- Semantic Complex Event Processing
- City services discovery
- Service ranking, provenance, and data discover

## 5 Workshop Publications and Overview of Talks

In this workshop the main targeted audience were the PhD students and researchers from industry and academia with desires to have more insight on the state-of-the-art solutions and developments on data modelling, data analytics and knowledge engineering in smart city domain. We had received a total number of 12 paper submissions for this workshop from which 9 papers have been accepted for publishing. Accepted papers subjects and abstracts summarised as follows:

*Blending Building Information with Smart City Data*, Amin Anjomshoaa

**Abstract.** The increasingly urbanized world together with modernization and industrialization trends has led to the explosive growth of city information. Cities can be considered as data factories that daily produce a huge amount of data from different sources such as people, infrastructure, machines, events, sensors, and smart devices. In the context of Smart City, built environments play an important role and convey a lot of useful information that can be used to realize the Smart City goals. Currently, the Building Information Modelling (BIM) methods are used intensively to capture the building information. Conventionally, building models are used during the planning and construction phases of buildings and mainly address the static aspects of buildings. In the Smart City era however, the situation is changing. During the operation phase, buildings are now producing more data than ever before. This paper is aiming to address the data integration challenges of BIM in context of Smart City by utilizing the current research work in the Linked Data domain in order to facilitate the interoperability between and beyond BIM resources.

*Towards a Semantic City Service Ecosystem*, Irene Celino, Alessio Carenini

**Abstract.** We introduce the concept of City Service Ecosystem (CSE) as digital environment for the governance of urban services. We trace the research challenges and opportunities of adding semantics to improve the management of such ecosystems, especially in relation to description and retrieval of urban-related Web services. We explain the peculiarities and distinct characteristics of CSEs resulting from their relation to the city space and we introduce our current work to enhance with semantics an existing CSE in the city of Milano, in relation to the forthcoming World Exposition (EXPO 2015).

*A Linked Data Lifecycle for Spanish Smart Cities*, Almudena Gonzalez Guimerans, Boris Villazon-Terrazas, Jose Manuel Gomez-Perez

**Abstract.** Smart Cities combine diverse technologies to reduce their environmental impact and offer citizens a higher quality of life. In this paper we present an ongoing effort, within the context of Ciudad2020 project, for overcoming the challenge of homogenizing the citizen's access to services offered by heterogeneous, and independent entities within a Smart City scenario. We describe how

we are applying the Linked Data Life-cycle, from specification to exploitation, within the vertical domains defined in such Spanish project.

*Semantic Discovery and Integration of Urban Data Streams*, Feng Gao, Muhammad Intizar Ali, Alessandra Mileo

**Abstract.** With the growing popularity of Internet of Things (IoT) technologies and sensors deployment, more and more cities are leaning towards the initiative of smart cities. Smart city applications are mostly developed with aims to solve domain-specific problems. Hence, lacking the ability to automatically discover and integrate heterogeneous sensor data streams on the fly. To provide a domain-independent platform and take full benefits from semantic technologies, in this paper we present an Automated Complex Event Implementation System (ACEIS), which serves as a middle-ware between sensor data streams and smart city applications. ACEIS discovers and integrates IoT streams in urban infrastructures for users' requirements expressed as complex event requests, based on semantic IoT stream descriptions. It also processes complex event patterns on the fly using semantic data streams.

*A Case Study of Active, Continuous and Predictive Social Media Analytics for Smart City*, Marco Balduini, Stefano Bocconi, Alessandro Bozzon, Emanuele Della Valle, Yi Huang, Jasper Oosterman, Themis Palpanas, Mikalai Tsytsarau

**Abstract.** Imagine you are in Milano for the Design Week. You have just spent a couple of days attending few nice events in Brera district. Which of the other hundreds of events spread around in Milano shall you attend now? This paper presents a system able to recommend venues to the visitors of such a city-scale event based on the digital footprints they left on Social Media. By combining deductive and inductive stream reasoning techniques with visitor-modeling functionality, this system semantically analyses and links visitors' social network activities to produce high-quality recommendations even when information about visitors' preferences for venues and events is sparse.

*Converging on Semantics to Ensure Local Government Data Reuse*, Laurens De Vocht, Mathias Van Compernelle, Anastasia Dimou, Pieter Colpaert, Ruben Verborgh, Erik Mannens, Peter Mechant, Rik Van de Walle

**Abstract.** When building reliable data-driven applications for local governments to interact with public servants or citizens, data publishers and consumers have to be sure that the applied data structure and schema definition are accurate and lead to reusable data. To understand the characteristics of reusable local government data, we motivate how the process of developing a semantically enriched exchange standard contributes to resolving this issue. This standard is used, for example, to describe contact information for public services which supports a representative pilot for opening up a variety of local government data. After implementing the pilot, we experienced that supporting the process of converging on semantics has a catalysing effect on the re-usability of government data.

*What Is Good for One City May Not Be Good for Another One: Evaluating Generalization for Tweet Classification Based on Semantic Abstraction*, Axel Schulz, Frederik Janssen

**Abstract.** Social media is a rich source of up-to-date information about events such as incidents. The sheer amount of available information makes machine learning approaches a necessity. However, those most often are focused on regionally restricted datasets such as data from only one city. The important fact that social media data such as tweets varies considerably across different

cities is neglected. To cope with this problem, usually the data of each city needs to be labelled, which is costly and time consuming. To omit such an expensive labelling procedure, another idea is to train a general model on one city and then apply it on data of a different city. In this paper, we present semantic abstraction that relies on features derived from Linked Open Data as well as location and temporal mentions. We show that it is a valuable means for such a generalization (increase of F-measures by 8.24 respectively). Furthermore, to get a thorough understanding of the generalization problem itself, we conducted an in-depth evaluation of our approach based on considering rule-based models. By examining the learned rule sets, we can conclude that a feature selection by an expert seems to be necessary especially for the Linked Open Data features.

*Dealing with Diversity in a Smart-City Datahub*, Mathieu D'Aquin, Alessandro Adamou, Enrico Daga, Shuangyan Liu, Keerthi Thomas, Enrico Motta

**Abstract.** In this paper, we present the data curation approach taken by the MK:Smart project, creating a large data repository of datasets about all aspects of the city of Milton Keynes in the UK and its citizens. The issues faced here, which we believe will become more and more common to large, data-centric smart-cities initiatives, is the one associated with the diversity of these thousands of datasets in terms of the licenses, policies and terms they are associated with them. We describe this repository of datasets, the MK Data-hub, and its architecture to create data work-flows from original sources to applications. We focus on the approach taken to record, in a structured, ontology-based way the components of the licenses and policies of each dataset, as well as the tools we are developing to manage such representations and to reason with them.

*Trusted Tiny Things. Making Devices in Smart Cities More Transparent*, Stanislav Beran, Edoardo Pignotti, Peter Edwards

**Abstract.** In this demo we present the Trusted Tiny Things system that can be used to interrogate Internet of Things (IoT) devices and present users with information about their characteristics and capabilities. The system consists of a mobile application used to retrieve information about IoT devices supported by RESTful web services. In order to infer IoT device capabilities our services perform reasoning over the provenance of devices characterised using a number of Semantic Web technologies. In this demo we illustrate the use of the system with two distinct IoT devices: an NFC tag used at bus stops to provide a means to access real-time bus timetables, and a black box device installed into vehicles by insurance companies to track driving behaviour.

## 6 Panel Discussion

During the discussion session, the major challenges present in the domain of Smart cities had been discussed by the participants. Some of the main topics were as follows:

- Interoperability
- Big Data
- Machine Learning and Semantics
- Publishing Government Data and Open Data

- Quality Analysis of Data
- Utilisation of smart city products by society
- Real-Time Large scale Data Analysis
- Visualisation
- Impact of the applications
- Sustainability
- Discovery of data and sensors

Of these major topics, the foremost stress had been put on the interoperability of models that while everybody desires to dominate their own model in the science community, there is no consensus on a common information model for smart cities. As an exemplification, one of the participants had given an interesting example from the Smart City projects going on in Italy, stating that the cities that are even present within the same country don't employ the same information models.

Publishing government data and open data was another hot topic among the participants. The majority of the participants reported that it is extremely difficult to persuade government authorities to publish their data as open data, which suggests that there's a strong need of an awareness regarding the value of open government data. It was also pointed out that city councils usually prefer to see an applied example in other cities before making a decision to share government data.

The necessity of open data was followed by another hot subject: privacy and security. It had been stated that the subject is remained untouched by the science community since scientists usually focussed on other problems. Moreover, there was a discussion about the integration issue of diverse data sources, where it had been pointed out that license and policy restrictions are the biggest obstacles to integrate diverse sources, such as industry APIs and public data (e.g. DBPedia).

Finally, the significance of the utilisation of smart city applications had been expressed by remarking the fact that "challenges cannot be resolved unless it appears". Therefore, people should start publishing open data and use the tools, so that the problems can be visible.

The major challenges of smart cities and communities were also taken part in the keynote speech, titled "To be or to do?: The Semantics for Smart Cities and Communities" by Professor Paolo Traverso, who had also actively taken part within the discussion session. In his speech, while categorising some of the successfully going on EU smart city projects — such as CityPulse<sup>5</sup>, simpli-city<sup>6</sup>, Planet Data<sup>7</sup> — as "to be", he stressed the importance of the actuation in the smart cities as future work with a sentence: "A smart community needs "to do" things in a city, and the people need to act within their own community". Adding that: in the future, "smart cities should not be only to know where it is possible to find a parking spot, which cultural event is happening tonight, or

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<sup>5</sup><http://www.ict-citypulse.eu/page/>

<sup>6</sup><http://simpli-city.eu/>

<sup>7</sup><http://www.planet-data.eu/>

when the next bus will arrive, but it also need to actually pay for parking our car, buy a bus ticket, or reserve a seat in the theatre. All these activities (e.g. paying, booking, buying) need semantics in the same way as data does, and such a semantics should describe all the steps needed to perform such activities.”

