10042 Abstracts Collection
Semantic Challenges in Sensor Networks
— Dagstuhl Seminar —

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Abstract. From 24.01. to 29.01.2010, the Dagstuhl Seminar 10042 "Semantic Challenges in Sensor Networks " was held in Schloss Dagstuhl – Leibniz Center for Informatics. During the seminar, several participants presented their current research, and ongoing work and open problems were discussed. Abstracts of the presentations given during the seminar as well as abstracts of seminar results and ideas are put together in this paper. The first section describes the seminar topics and goals in general. Links to extended abstracts or full papers are provided, if available.

Keywords. Sensor networks, semantics

10042 Executive Summary – Semantic Challenges in Sensor Networks

There has been significant progress in the number and capabilities of mobile devices, wireless sensors, and sensor networks. These developments, combined with the improved ability to bridge between the physical and cyber world in a more seamless way, have fostered the broad availability of sensor data capturing the state of the physical world. Promising and already successful examples are applications in environmental monitoring, agriculture, surveillance and intrusion detection, public security, and supply chain management. Furthermore, ideas towards a Web of sensors have been proposed, which is to be understood as a (large scale) network of spatially distributed sensors. In particular, terms like "Internet of Things", "Collaborating Objects" and "Ambient Intelligence" emphasize the trend towards a tighter connection between the cyber space and the physical world.

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Keywords: Sensor networks, semantics

Joint work of: Aberer, Karl; Gal, Avigdor; Hauswirth, Manfred; Sattler, Kai-Uwe; Sheth, Amit P.

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Geospatial Semantics and Spatial Reasoning for Sensor Networks

Alia Abdelmoty (Cardiff University, GB)

It is generally agreed that the spatio-temporal data elements associated with sensor observations are important and needed for the interpretation and inference of the phenomena of interest. On one hand, sensor data can be regarded as a type of geographic data and can be represented along the three traditional dimensions of space, time and theme.

The complexity, however, stems from the challenges posed by the dynamic and uncertain nature of the data, the need to integrate data from hybrid sources and record the spatio-temoral "change" in the phenomena being monitored as well as identifying and reasoning over processes causing this change.

This domain and its applications provide, therefore, novel and interesting challenges to the research area of spatiotemporal modelling and reasoning.

On the other hand, the emerging need to serve this data on the semantic web and to possibly also integrate it with other forms of "sensed" data on the social web, raise the question of whether the current semantic web technologies can be "spatio-temporally enabled"? Some interesting open questions are: Is the Observation and Measurements (O&M) ontology proposed by the OGC enough or is there a need for a complementary spatio-temporal ontology for the sensor networks? Are the current ontology languages sufficient for representing spatio-temporal phenomena? Can the current rule languages and reasoning engines be used for expressing spatio-temporal constraints or for reasoning with spatio-temporal change? How can the issue of uncertainty be addressed on the representation and reasoning levels? What, if any, architecture components for enabling this spatio-temporal, semantic sensor web are still needed?

Keywords: Spatio-temporal ontology, spatio-temporal reasoning

See also: AI Abdelmoty, PD Smart, BA El-Geresy and CB. Jones (2009). Supporting Frameworks for the Geospatial Semantic Web, Advances in Spatial and Temporal Databases, 11th International Symposium, SSTD 2009, Aalborg, Denmark, LNCS 5644 Springer, pp. 355-372, ISBN 978-3-642-02981-3

Enabling Ontology-based Access to Streaming Data Sources

Oscar Corcho (Univ. Politec. de Madrid, ES)

The availability of streaming data sources is progressively increasing thanks to the development of ubiquitous data capturing technologies such as sensor networks. The heterogeneity of these sources introduces the requirement of providing data access in a unified and coherent manner. In this talk we describe an ontology-based streaming data access service, based on extensions to the R2O mapping language and its query processor ODEMapster, and to the C-SPARQL RDF stream query language. A preliminary implementation of the approach is also presented. With this proposal we expect to set the basis for future efforts in ontology-based streaming data integration.

Keywords: C-SPARQL SNEE ODEMapster

Joint work of: Corcho, Oscar; Calbimonte, Jean Paul; Gray, Alasdair J

Manage Uncertainty with Multimodal Representation of Events

Ernesto Damiani (Università degli Studi di Milano - Crema, IT)

Pervasive Computing aims to provide users with computer-supported capabilities anywhere, anytime and in the most appropriate form for the user's current context. The research in pervasive computing has focused on facilitating the heterogeneous nature of the infrastructure. But the connection of these techniques and standards with monitoring process is still an open issue. This basically implies the aggregation of multimodal representations from different sources of information (elaborated data) into a coherent mathematical framework. In this context the issues related to Uncertainty Management and Representations are very relevant. In particular it is not clear how combinations of uncertainty models are to be applied on a single knowledge base.

We argue that metadata annotations could be used to map data to corresponding reasoning and representation strategies. This mapping allows the system to analyse the information on the basis of the right uncertainty model, running the inference process according to the respective model.

Keywords: Uncertainty Ontology Pervasive Environments

Multimodality in Pervasive Environment

Ernesto Damiani (Università degli Studi di Milano - Crema, IT)

Future pervasive environments are expected to immerse users in a consistent world of probes, sensors and actuators.

Multimodal interfaces combined with social computing interactions and high-performance networking can foster a new generation of pervasive environments. However, much work is still needed to harness the full potential of multimodal interaction. In this paper we discuss some short-term research goals, including advanced techniques for joining and correlating multiple data flows, each with its own approximations and uncertainty models.

Also, we discuss some longer term objectives, like providing users with a mental model of their own multimodal "aura", enabling them to collaborate with the network infrastructure toward inter-modal correlation of multimodal inputs, much in the same way as the human brain extracts a single self-conscious experience from multiple sensorial data flows.

Joint work of: Anisetti, Marco; Bellandi, Valerio; Ceravolo, Paolo; Damiani, Ernesto

SemsorGridForEnv Introduction

David De Roure (University of Southampton, GB)

Many parts of the SemsorGrid4Env project are presented in separate talks in the Seminar. This talk provides an overview from an applications perspective in order to motivate the architectural discussions.

SNEE: A Sensor Network Query Processing Engine

Alvaro A. A. Fernandes (University of Manchester, GB)

This talk describes the SNEE query processing engine designed and implemented at the Information Management Group, School of Computer Science, University of Manchester. Currently SNEE optimizes continuous queries in the SNEEql query language for execution inside wireless sensor networks (WSNs). SNEEql is inspired by and extends CQL (a language for push streams used in the Stanford STREAM system). SNEEql queries can range over pull (i.e., acquisitional) streams, such as emitted by WSNs. SNEEql is very expressive (e.g., there is support for time- and count-based windows are allowed over the past and the future and can be mixed, the execution semantics is uniform over pull- and push-based streams as well as stored extents). SNEE is distinctive is viewing a WSN as distributed computing platforms (and hence, a wireless sensor node as a computer with sensing capabilities) albeit a very constrained one. Thus, SNEE uses the classical two-phase approach to distributed query optimization, i.e., a query is first compiled as if it were to execute in a single site, then the implications of multi-site execution are taken into account. One contribution of SNEE is to demonstrate an approach as to how these implications should be taken into account in detail. The solution embodied in SNEE is to decompose this process into four steps, viz., defining a routing tree in the physical network

onto which the dataflow computation represented as an operator tree can be mapped; breaking up the single-site plan into fragments that can be distributed; allocating each such fragment to an execution site; determining the duty cycles for each site in order to establish precisely when nodes will be active and when they will be snoozing. The talk is driven by an example query that is used to explain these step-by-step transformations. Finally, the talk briefly describe the state of SNEE in January 2010, and what can be expected in January 2011, and in January 2012 by way of extensions. The most important among these are flexible, expressive specification of per-query optimization objectives; and the incorporation of model-building capabilities (e.g., building statistical models that underpin outlier detection).

Keywords: In-network processing, wireless sensor networks, query processing, query optimization

Full Paper:
http://code.google.com/p/snee/

Modelling Pull-Based Data Gathering with Execution Intervals

Avigdor Gal (Technion - Haifa, IL)

We propose a model for pull-based data gathering from sensors that can be applied to flash memory aided sensors. At the heart of the model is the execution interval abstraction. An execution interval associates a period of time with some resource to be probed, with the possible semantics of "monitor this resource within this time period." In this talk we present the abstraction, show challenges in semantics of sensor networks that can be modeled using execution intervals and suggest algorithmic solutions to tackle these challenges.

Keywords: Modeling and representation

Distributed Query Processing over Streaming and Stored Data

Alasdair J G Gray (University of Manchester, GB)

Users of sensor data often need to combine multiple sources with widely different capabilities: streams of data from sensors with extremely limited resources, combined with historic archives and stored data where resources seem unlimited. We assume that the user has identified a set of live data sources that can contribute the required data, and used some sort of semantic integrator to eliminate semantic heterogeneity. In this talk we characterise the issues for performing distributed query processing over a variety of streaming and stored data sources.

One key challenge is that there is no standardised query language for incorporating data from pull-stream, push-stream, and stored sources. We present SNEEql as a declarative query language, which has a well defined evaluation semantics, for expressing data needs in a unified way over such data sources. We then show how the execution of a SNEEql query is divided into parts that are evaluated over the relevant data sources.

Keywords: Distributed query processing, stream query processing, wireless sensor networks, SNEEql

SNEE In-WSN Query Processing Demonstration

Alasdair J G Gray (University of Manchester, GB)

In this demonstration we show the execution of a join query being processed within the sensor network.

Keywords: In-network query processing, WSN

Joint work of: Galpin, Ixent; Gray, Alasdair J G; Fernandes, Alvaro A A; Paton, Norman W

Virtual Presence + Real Presence = Semantic Presence

Manfred Hauswirth (National University of Ireland - Galway, IE)

To understand the availability of humans or things based on their presence is a key problem in many areas, for example, in corporate environments. Correctly determining presence raises new scientific challenges and requires the integration and aggregation of arbitrary physical, virtual, and social sources of presence into a reconciled view, governed by flexible policies to control the disclosure and delivery of presence based on the context of the watcher and the presentity, thereby supporting fine-grained control of privacy for users and organisations. This talk discusses the problems and requirements of semantic presence and proposes an initial conceptual model along with initial experiments and infrastructural building blocks for an overall solution.

Keywords: Presence management, proximity

Joint work of: Hauswirth, Manfred; Le Phuoc, Danh; Osterloh, Martin; Polleres, Axel; Reynolds, Vinny; Zuniga, Marco

Telehealth Demo

Manfred Hauswirth (National University of Ireland - Galway, IE)

This demo showcases an experiment in which we integrated live mobile sensor feeds into an off-the-shelf patient management system to enable remote patient monitoring.

The sensors where connected to a mobile phone via Bluetooth and where streaming readings via this mobile connection.

Keywords: Telehealth monitoring

Joint work of: Hauswirth, Manfred; Aguilar, Tony; Reynolds, Vinny

Telehealth Demo (Video)

Manfred Hauswirth (National University of Ireland - Galway, IE)

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Keywords: Telehealth monitoring

Joint work of: Hauswirth, Manfred; Aguilar, Tony; Reynolds, Vinny

Sensor Data and Perception

Cory Henson (Wright State University - Dayton, US)

Currently, there are many sensors collecting information about our environment, leading to an overwhelming number of observations that must be analyzed and explained in order to achieve situation awareness. As perceptual beings, we are also constantly inundated with sensory data, yet we are able to make sense of our environment with relative ease. Why is the task of perception so easy for us, and so hard for machines; and could this have anything to do with how we play the game 20 Questions?

Keywords: Sensor Data, Perception

Modeling and Querying Metadata in the Semantic Sensor Web: the Model stRDF and the Query Language stSPARQL

Manolis Koubarakis (National and Capodistrian University of Athens, GR)

RDF will often be the metadata model of choice in the Semantic Sensor Web. However, RDF can only represent thematic metadata and needs to be extended if we want to model spatial and temporal information. For this purpose, we develop the data model stRDF and the query language stSPARQL.

stRDF is a constraint data model that extends RDF with the ability to represent spatial and temporal data. stSPARQL extends SPARQL for querying stRDF data. In our extension to RDF, we follow the main ideas of constraint databases and represent spatial and temporal objects as quantifier-free formulas in a first-order logic of linear constraints. Thus an important contribution of stRDF is to bring to the RDF world the benefits of constraint databases and constraint-based reasoning so that spatial and temporal data can be represented in RDF using constraints.

stRDF and stSPARQL have been developed in the context of European project SemsorGrid4Env (http://www.semsorgrid4env.eu/). In this project, we are developing a query processing engine for stRDF and stSPARQL, called Strabon, by extending the Sesame RDF store. Strabon is the basis for the implementation of the registry in the SemsorGrid4Env service-oriented architecture.

Keywords: RDF SPARQL spatial temporal

Joint work of: Koubarakis, Manolis; Kyzirakos, Kostis

On the Semantics of Observations

Werner Kuhn (Universität Münster, DE)

Sensor networks remain largely disconnected from the general web, sensor services cannot be assessed for semantic interoperability, and core notions of sensor technology standards are ambiguous. I present a sensor observation ontology addressing these issues. It treats observation as an informational rather than technological process, relates observations to real world phenomena, separates symbolization from signal processing, includes human observations, and supports sensor fusion. An outlook will be given on how to deal with resolution and uncertainty, location and time, trust and reputation, as well as actuators and observation-action cycles.

Keywords: Sensor observation measurement semantics ontology interoperability

Full Paper:
http://ifgi.uni-muenster.de/~kuhn/research/publications/pdfs/refereed%20conferences/GeoS%202009.pdf

See also: Kuhn, W., 2009. A Functional Ontology of Observation and Measurement. K. Janowicz, M. Raubal, and S. Levashkin (Eds.): Third Workshop on Geosemantics (GeoS 2009), Mexico City, 3-4 December 2009. Springer-Verlag Lecture Notes in Computer Science 5892: 26-43

GeoS3Web, Cyber-Physical System and Environmental Observatories: Semantically-enhanced Virtual Sensor Web

Yong Liu (Univ. of Illinois - Urbana-Champaign, US)

The convergence of GeoWeb, Social Web, Sensor Web and Semantic Web (GeoS3Web) provides tremendous opportunity to revolutionize how environmental observatories will be used for research and decision making. One key barrier to the sensor network-driven revolution is the difficulty faced by individual researchers when attempting to use sensor data from multiple sources (including participatory citizen sensing) for purposes beyond the scope of the original sensor design and deployment . This type of use requires that the data be transformed, interpolated, fused, or otherwise processed, sometimes with machine-learning based algorithms, before can be used for domain-specific analysis, modeling and visualization. It is necessary to consider virtualization of sensors and sensor networks so that existing deployments of sensor networks and their measurements can be easily repurposed and shared in new ways. We have developed a virtual sensor system(Liu et al., 2009) that can create virtual sensors that are derived from one or multiple sensor data through spatial, temporal and thematic transformations and can then be republished as live new virtual sensor data streams for internet-scale data sharing. Another emergent need is the capability to provide feedback control based on the sensing data and coupled with physics-based models to do dynamic calibration and adaptive change of sensor behaviors, which is also called Cyber-physical system. Semantics plays increasing roles as the scale of the sense network exponentially grows (e.g., Imagining everyone on the planet carries a mobile phone which has several environmental sensors attached). This leads to on-demand semantically annotated data streams to be discovered and integrated and newly derived provenance-aware virtual sensor streams to be re-used for the task-specific analysis and decision making. We share our experiences and lessons learned in this seminar talk.

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2. Liu, Y., Hill, D., Rodriguez, A., Marini, L., Kooper, R., Myers, J., Xiaowen Wu, and Minsker, B. 2009. "A new framework for on-demand virtualization, repurposing and fusion of heterogeneous sensors". In Proceedings of the 2009 international Symposium on Collaborative Technologies and Systems - Volume 00 (May 18 - 22, 2009). CTS. IEEE Computer Society, Washington, DC, 54-63. DOI= http://dx.doi.org/10.1109/CTS.2009.5067462
3. Rodriguez,A., R. E. McGrath, Yong Liu and J. D. Myers, (2009) "Semantic Management of Streaming Data", 2nd International Workshop on Semantic Sensor Networks at the International Semantic Web Conference, Washington, DC, October 25-29, 2009.

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Keywords: Virtual sensor, sensor web, reuse, re-purpose, semantic meta-data, provenance, sensor network as a service

Analysis of Sensor Data Streams with AnduIN

Kai-Uwe Sattler (TU Ilmenau, DE)

Sensor networks have evolved to a powerful infrastructure component for event monitoring in many application scenarios. In addition to simple filter and aggregation operations, an important task in processing sensor data is data mining – the identification of relevant information and patterns. Limited capabilities of sensor nodes in terms of storage and processing capacity, battery lifetime, and communication demand a power-efficient, preferably sensor-local processing. In this demo, we present a system for developing, deploying, and running in-network data mining tasks. The system consists of a data stream processing engine, a library of operators for sensor-local processing, and a box-and-arrow editor for specifying data mining tasks.

Semantics enhanced Data, Social and Sensor Webs

Amit P. Sheth (Wright State University - Dayton, US)

40 billion mobile sensors and many more stationary sensors are periodically or regularly recording and reporting what they are observing. Increasing number of 4 billion people with mobile devices are sharing what they see, mediated by human knowledge and intellect. This citizen sensing (also called participator sensing) have been the dominant mechanism for information gathering and reporting to organizing and activism - as we saw for 26/11 Mumbai attack, 2009 Iran Election and 2010 Haiti Earthquake. [4] Very often machine sensing and citizen sensing are complementing each other [3]-for more comprehensive situational awareness, increasing trust the information, and many other purposes. However, the heterogeneity at all levels - system, syntax, representational and semantic-of these machine and citizen sensor data is bewildering. Semantics, especially with the ability to dynamically modeling the domain of interest, complemented by use of SOA and Semantic Web standards and technologies, as well as use of community knowledge and linked data are key to integrating these data, further enabling sophisticated analysis leading to insights, collaborative activities and decision making.

Kno.e.sis Center researchers are working on a number of relevant topics of semantics-enabled services, semantic-enhanced sensor and semantics-empowered social computing:

- semantic sensor web (by Cory Henson) [1][SSW]
- aggregation, integration and spatio-temporal-thematic analysis of social data (Karthik Gomadam, Meena Nagarajn, Hemant Purohit, see: Twitris) [6][Twitris]
- analysis of user-generated content (by Meena Nagarajan) [2,5]
- extraction/creation of a domain model from Wikipedia or similar community authored content (by Christopher Thomas)
- use of schema, abstractions and specialized reasoning for better use of Linked Data [8]

We are also collaborating researchers in social science for studying phenomena such as emergent social order. All these are steps towards a strategic vision I describe as Computing for Human Experience. [7]

For the Dagstuhl seminar, I will in will initiate discussions with the help of a series of informal demos where semantics have been used over machine sensor data, citizen sensor data (primarily Twitter) and Linked object Data cloud. [SDLoD]

References/More Details/Demos:

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5. Meena Nagarajan, User-Generated Content on Social Media, Keynote talk at Social Data on the Web (SDOW09) workshop collocated with ISWC, October 2009. Also http://knoesis.wright.edu/research/semweb/projects/socialmedia/
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8. Prateek Jain, Pascal Hitzler, Peter Z. Yeh, Kunal Verma and Amit P. Sheth, Linked Data is Merely More Data, AAAI Spring Symposium Linked Data Meets Artificial Intelligence, Stanford, CA, USA, March 22-24, 2010.

On-line Demos:

[SSW] Semantic Sensor Web - Spatio-teporal-thematic and role-based queries over Mesowest Data

[SDLoD] Sensor Discovery on Linked Data: 1+ billion triple of US storms data on LOD cloud, with Sensor Discovery Mashup

[Twitris] Twitris: Twitter through Theme, Space, and Time. ISWC Semantic Web Challenge, October 2009.

Keywords: Semantic Sensor Web, Semantic Social Web, Semantic Data Web

Towards Expressive Stream Reasoning

Heiner Stuckenschmidt (Universität Mannheim, DE)

Stream Data processing has become a popular topic in database research addressing the challenge of efficiently answering queries over continuous data streams. Meanwhile data streams have become more and more important as a basis for higher level decision processes that require complex reasoning over data streams and rich background knowledge. In previous work the foundation for complex reasoning over streams and background knowledge was laid by introducing technologies for wrapping and querying streams in the RDF data format and by supporting simple forms of reasoning in terms of incremental view maintenance. In this paper, we discuss how this existing technologies should be extended toward richer forms of reasoning using Sensor Networks as a motivating example.

Keywords: Streaming Data, Reasoning, C-SPARQL, Sensor Networks

Joint work of: Stuckenschmidt, Heiner; Ceri, Stefano; Della Valle, Emanuele; van Harmelen, Frank

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2010/2555

Semantic Challenges in (Mobile) Sensor Networks

Demetris Zeinalipour (University of Cyprus, CY)

The widespread deployment of mobile phones along with the massive production of sensors for every aspect of modern life provides evidence that Computer Science research and education will evolve dramatically over the next few years. The boundaries of Mobile Devices and Sensor Devices are nowadays blurring as the former devices are already equipped with a multitude of sensing capabilities, including GPS (which enables the derivation of geospatial coordinates), accelerometers (which enable the derivation of orientation, vibration and shock) and an exciting set of other sensors (e.g., proximity sensors, ambient light sensors, while more traditional sensors such as temperature, acoustic, magnetometers and others will be integrated in these devices very soon). That creates the

notion of Mobile Sensor Devices that will become even more ubiquitous than their predecessor "smart-phone" devices.

In this talk, I will provide an overview and definitions of Mobile-Sensor-Network (MSN) related platforms and applications. In particular, I will show how applications in environmental monitoring, body sensor networks, vehicular sensor networks and intelligent transportation systems have brought a dramatic shift on how spatio-temporal data is nowadays generated. I will then outline some semantic challenges that arise in this context including: vastness, uncertainty, data integration, query processing and privacy. I will also address some more general challenges that currently hinder the evolution and uptake of semantic MSNs.

Keywords: Mobile Sensor Networks, Semantic Challenges, Applications

Full Paper:
http://www.cs.ucy.ac.cy/~dzeina