AGGREGATION OF SEMANTIC SENSOR DATA

Graduation proposal

by

Ivo de Liefde

November 13, 2015

CONTENTS

ACRONYMS

API application program interface . . . 3
JSON javascript object notation . . . 3
OGC open geospatial consortium . . . 3
O&M observations and measurements . . . 7
OSM open streetmap . . . 5
OWL web ontology language . . . 7
RDF resource description framework . . . 3
REST representational state transfer . . . 7
SensorML sensor modelling language . . . 3
SOS sensor observation service . . . 3
SSN semantic sensor network . . . 3
SSW semantic sensor web . . . 3
SWE sensor web enablement . . . 3
W3C world wide web consortium . . . 3
XML extensible markup language . . . 3

1 INTRODUCTION

This document should include:

- motivation / problem field /relevance
- position in the academic and professional debate
- problem statement, objectives, research questions
- approach, theoretical framework, methodology
- references
- preliminary project set up and results

an introduction in which the relevance of the project and its place in the context of geomatics is described, along with a clearly-defined problem statement

1.1 PROBLEM STATEMENT

How to find the sensor data you need?
How to combine sensor data from different sources?
How to make sense of the bulk of sensor data?

Wang et al. (2015b), Corcho and Garcia-Castro (2010), Ji et al. (2014), Huang and Javed (2008)
Sensor data discovery Janowicz et al. (2013)
Sensor data fusion Wang et al. (2015a)

2 RELATED WORK

a related work section in which the relevant literature is presented and linked to the project;

2.1 SENSOR WEB

open geospatial consortium (OGC) sensor web enablement (SWE) standards such as sensor observation service (SOS) and sensor modelling language (SensorML) (Botts et al., 2007), (Botts et al., 2008)

Different data formats: extensible markup language (XML) (SWE), EXI (world wide web consortium (W3C)) and javascript object notation (JSON) SensorThings application program interface (API) (Zanella et al., 2014)

Sensor data discovery (Goncalves, 2014) and visualisation (Yoo, 2014)

2.2 LINKED DATA

Linked Data (Berners-Lee et al., 2001)

OSM as Linked Data (Auer et al., 2009)

Publishing geodata as resource description framework (RDF) and mapping on-the-fly (Missier, 2015)

2.3 SEMANTIC SENSOR WEB

semantic sensor web (SSW) (Sheth et al., 2008), (de Mel et al., 2011), (Bakillah et al., 2013)

W3C semantic sensor network (SSN) ontology (Compton et al., 2012)

Three layer model

Adding semantics to SOS (Henson et al., 2009), (Pschorr, 2013)

Extending RDF with the ability to represent spatial and temporal data (Koubarakis and Kyzirakos, 2010)

Research on connecting smart devices to SSW (de Vera et al., 2014)

2.4 INTERNET OF THINGS

More and more devices connected to the internet. Also a growing amount of research on using sensors of smart devices. (Waher, 2015), (Calbimonte et al., 2011), (Žarko et al., 2015)

OpenIoT platform (Calbimonte et al., 2014)

2.5 SMART CITIES

The role of sensors in smart cities (Zanella et al., 2014)

The role of OGC standards in smart cities (Percivall, 2015)

3 RESEARCH OBJECTIVES

the research objectives and/or research questions are clearly defined, along with the scope (ie what you will not be doing);

3.1 RESEARCH QUESTION

How can the semantic sensor web improve the discovery, integration and aggregation of distributed sensor data?

3.2 OBJECTIVE

Develop a method to semantically link sensor metadata to real world objects for spatial, semantic and temporal data aggregation.

I would like to bridge the efforts by Henson et al. (2009), Pschorr (2013), of adding semantics to SOS, and the efforts by Auer et al. (2009) of adding semantics to open streetmap (OSM) data using the SSN ontology proposed by Compton et al. (2012) in order to improve the discovery, integration and aggregation of sensor data from different sources.

The thesis research should result in a prototype implementation which consists of two parts:

1. An application that takes locations (HTTP addresses) of SOS servers as input and automatically links them to the OSM data. It results in an extended mapping of the sensor web that will be used by the aggregation queries in the second part of the implementation.
2. An application that allows users to query aggregated sensor data from different sources. This takes an OSM feature and a time interval as input, optionally with other spatial/temporal parameters (like a value for a buffer operation or a time interval to aggregate on). It returns a set of aggregated sensor data.

3.3 SCOPE

focus on OGC's SWE standards / SOS and W3C's SSN ontology. Not going into evaluation of different standards. Not specifically focussing on smart devices.

4 METHODS

overview of the methodology to be used;

4.1 STANDARDS

4.1.1 Sensor Web Enablement

SOS and SensorML, or Sensorthings API?

4.1.2 Semantic Web

- Store OSM data: create RDF on-the-fly to prevent double storage.
- Store sensor metadata: create RDF from observations and measurements (O&M) which is returned by SOS getCapabilities request
- Use web ontology language (OWL) as language for semantic RDF triples

Query metadata: SPARQL, geo-SPARQL or stSPARQL, etc. and which query engine?

4.2 ONTOLOGIES

The O&M ontology is retrieved from sensors
Use SSN ontology or O&M-OWL ontology to store metadata from sensors.

4.3 MIDDLEWARE

Creating own middleware to link sensors semantically and retrieve aggregated data

representational state transfer (REST)ful service

5 PLANNING

time planning—having a Gantt chart is probably a better idea then just a list;

5.1 GANTT CHART

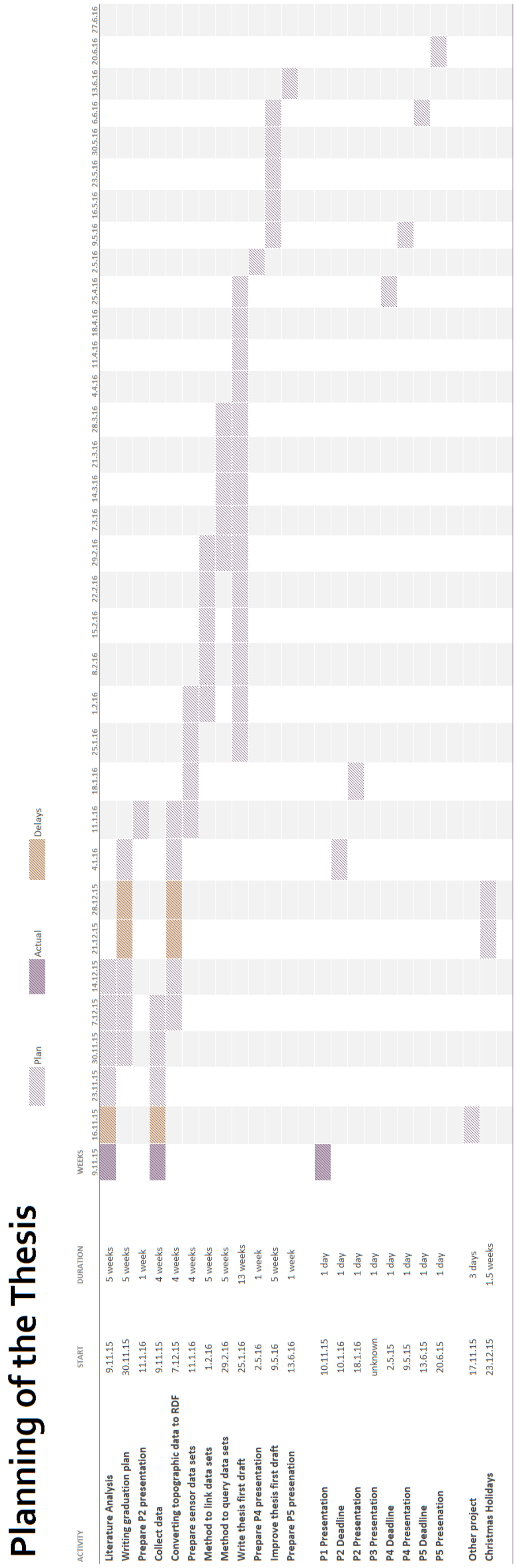

Figure 5.1: GANTT chart showing the planning of the thesis

6 TOOLS AND DATA

since specific data and tools have to be used, it's good to present these concretely, so that the mentors know that you have a grasp of all aspects of the project;

6.1 DATA

Topographic data
Sensor data (different sources)

6.2 DATABASE

Oracle?

6.3 SERVER

Or localhost?

6.4 PROTOTYPE

Use Python programming language and Flask for server sided scripts
Perhaps with Python's Request library for making POST or GET requests.

BIBLIOGRAPHY

Auer, S., Lehmann, J., and Hellmann, S. (2009). *Linkedgeodata: Adding a spatial dimension to the web of data*. Springer.

Bakillah, M., Liang, S. H., Zipf, A., and Mostafavi, M. A. (2013). A dynamic and context-aware semantic mediation service for discovering and fusion of heterogeneous sensor data. *Journal of Spatial Information Science*, 6:155–185.

Berners-Lee, T., Hendler, J., Lassila, O., et al. (2001). The semantic web. *Scientific american*, 284(5):28–37.

Botts, M., Percivall, G., Reed, C., and Davidson, J. (2007). Ogc sensor web enablement: Overview and high level architecture. OGC document 06-021r1.

Botts, M., Percivall, G., Reed, C., and Davidson, J. (2008). Ogc sensor web enablement: Overview and high level architecture. In *GeoSensor networks*, pages 175–190. Springer.

Calbimonte, J.-P., Jeung, H., Corcho, O., and Aberer, K. (2011). Semantic sensor data search in a large-scale federated sensor network.

Calbimonte, J.-P., Sarni, S., Eberle, J., and Aberer, K. (2014). Xgsn: An open-source semantic sensing middleware for the web of things. In *7th International Workshop on Semantic Sensor Networks*, number EPFL-CONF-200926.

Compton, M., Barnaghi, P., Bermudez, L., GarcíA-Castro, R., Corcho, O., Cox, S., Graybeal, J., Hauswirth, M., Henson, C., Herzog, A., et al. (2012). The ssn ontology of the w3c semantic sensor network incubator group. *Web Semantics: Science, Services and Agents on the World Wide Web*, 17:25–32.

Corcho, O. and Garcia-Castro, R. (2010). Five challenges for the semantic sensor web. *Semantic Web-Interoperability, Usability, Applicability*, 1.1(2):121–125.

de Mel, G., Pham, T., Damarla, T., Vasconcelos, W., and Norman, T. (2011). Semantically enriched data for effective sensor data fusion. In *SPIE Defense, Security, and Sensing*, pages 80470L–80470L. International Society for Optics and Photonics.

de Vera, D. D. P., Izquierdo, l. S., Vercher, J. B., and Gomez, L. A. H. (2014). A ubiquitous sensor network platform for integrating smart devices into the semantic sensor web. *Sensors*, 14(6):10725–10752.

Goncalves, P. (2014). Ogc opensearch geo and time extensions. OGC Implementation Standard.

Henson, C., Pschorr, J. K., Sheth, A. P., Thirunarayan, K., et al. (2009). Semsos: Semantic sensor observation service. In *Collaborative Technologies and Systems, 2009. CTS'09. International Symposium on*, pages 44–53. IEEE.

Huang, V. and Javed, M. K. (2008). Semantic sensor information description and processing. In *Sensor Technologies and Applications, 2008. SENSORCOMM'08. Second International Conference on*, pages 456–461. IEEE.

Janowicz, K., Broring, A., Stasch, C., Schad, S., Everding, T., and Llaves, A. (2013). A restful proxy and data model for linked sensor data. *International Journal of Digital Earth*, 6(3):233–254.

Ji, C., Liu, J., and Wang, X. (2014). A review for semantic sensor web research and applications. *Advanced Science and Technology Letters*, 48:31–36.

Koubarakis, M. and Kyzirakos, K. (2010). Modeling and querying metadata in the semantic sensor web: The model strdf and the query language stsparql. In *The semantic web: research and applications*, pages 425–439. Springer.

Missier, G. A. (2015). Towards a web application for viewing spatial linked open data of rotterdam. Master's thesis, Delft University of Technology.

Percivall, G. (2015). Ogc smart cities spatial information framework. OGC Internal reference number: 14-115.

Pschorr, J. K. (2013). Semsos: an architecture for query, insertion, and discovery for semantic sensor networks. Master's thesis, Wright State University.

Sheth, A., Henson, C., and Sahoo, S. S. (2008). Semantic sensor web. *IEEE Internet Computing*, 12(4):78–83.

Waher, P. (2015). *Learning Internet of Things*. Packt Publishing Ltd.

Wang, M., Perera, C., Jayaraman, P. P., Zhang, M., Strazdins, P., and Ranjan, R. (2015a). City data fusion: Sensor data fusion in the internet of things.

Wang, X., Zhang, X., and Li, M. (2015b). A review of studies on semantic sensor web. *Advanced Science and Technology Letters*, 83:94–97.

Yoo, B. (2014). Visualization and level-of-detail of metadata for interactive exploration of sensor web. *International Journal of Digital Earth*, 7(11):847–869.

Zanella, A., Bui, N., Castellani, A., Vangelista, L., and Zorzi, M. (2014). Internet of things for smart cities. *Internet of Things Journal, IEEE*, 1(1):22–32.

Žarko, I. P., Hromic, H., Phuoc, D. L., Serrano, M., Antonic, A., Hayes, C., and Decker, S. (2015). Real time analysis of sensor data for the internet of things by means of clustering and event processing. In *Proc. of the IEEE International Conference of Communications (ICC2015)*. Hrvatska znanstvena bibliografija i MZOS-Svibor.

COLOPHON

This document was typeset using LaTeX. The document layout was generated using the `arsclassica` package by Lorenzo Pantieri, which is an adaption of the original `classicthesis` package from André Miede.