A Knowledge-based system for the Detection and Classification of Unplanned Human Settlements

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March 6, 2007

1 Introduction

The discovery, access and sharing of suitable geospatial information in current open and distributed Spatial Data Infrastructures (SDI) still pose a major challenge [1]. These problems usually stem from a lack of consistent semantics (i.e. different interpretations of geospatial concepts), heterogeneity of data formats and systems as well as a reluctance to share data, amongst others. However, SDI is about communication and sharing of spatial data and information [2], which has largely been addressed by recent intiatives such as the OGC Sensor Web Enablement [3]. The ability to discover and access sensor data over the Web is only part of the problem. The processing and extracting of relevant information from this data and building applications that use this information poses a further problem. The Sensor Web Agent Platform (SWAP) has been proposed for dynamically discovering and extracting information from sensor data and for building dynamic and flexible Sensor Web applications [4]. SWAP is a collaborative ongoing project, proposed by researchers from the school of Computer Science at UKZN, the Geoinformatics department at University of Muenster and the Information Communications Technology for Earth Observation (ICT4EO) unit at the Meraka Institute, CSIR, Pretoria. SWAP uses ontologies to describe data, entities and interactions in the system. Thus far there is has been one developed application, on wildfire detection, on SWAP, and this by no means proves its suitability for the development and deployment of diverse Sensor Web applications. The aims of this research are to design, develop and deploy another Sensor Web application, for detecting unplanned human settlements in South Africa, on SWAP.

2 Case Study

Unplanned settlements are dynamic landscapes that cause changes in the spatial patterns and land use associated with such areas [5]. Survey and census data are currently used to monitor unplanned settlements which in many cases are unreliable, outdated, and in some areas, non-existent. Remote sensing techniques currently used are usually based on a single source and not frequent enough to incorporate the rapid changes occurring within unplanned settlements [6]. A Sensor Web application, the Unplanned Settlement Information System (USIS), will be developed to aid planners, policy and decision makers to monitor these settlements more regularly and effectively. SWAP will facilitate accessing and integrating multiple data sources, including remote sensing, archival and attribute data, with different spatial and temporal resolutions. The increase in the frequency and amount of data received will substantially improve on the accuracy when monitoring these unplanned Settlements. Much of the processing currently manually configured by a team will now be automated within this application. This will lead to quicker analysis of the state of settlements and quicker decision-making for the deployment of the appropriate services required for such settlements.

3 The SWAP framework

SWAP is an abstract architecture used for the development and deployment of Sensor Web applications over the Internet. The current SWAP prototype is based on MASII, a multi-agent system infrastructure for the internet [7]. The USIS application will be implemented on the MASII platform within the framework of SWAP.

3.1 SWAP abstract architecture

SWAP consists of three layers namely a *Sensor layer*, a *Knowledge layer* and an *Application layer*. A Sensor Web application will have access to sensor data through the *Sensor layer*. The processing e.g. Feature extraction, data modelling and prediction of this sensor data will take place in the *Knowledge layer*. The *Application layer* presents the user interface which allows human users or other client machines to interact with the system. The user can then view the processed data (output) through a customised view via the *Application layer*.

3.2 Ontologies in SWAP

SWAP currently provides upper ontologies as well as domain ontologies. The upper ontologies contain abstract concepts and ground all other ontologies in SWAP and used as a starting point to develop domain and application ontologies. These ontologies serve as a starting point and are able to ground other domain and application ontologies that will be developed and added to it.

Agent service offerings i.e. properties of data or service that an agent provides, the spatio-temporal characterictics of this data as well as the data structures used to hold and access this data are described by ontologies. These ontologies provide a common vocabulary shared between agents permitting agents to communicate and understand the syntax and semantics of messages from other agents. This promotes interoperability between heterogeneous sensor resources. Furthermore, conversation protocols specify the sequence of messages sent between agents to allow for meaningful interactions.

4 The USIS application

The Unplanned Settlement Information System (USIS) application aims to automate many of the processes that are currently manually configured. Agents within SWAP perform different application functionality. At the *Sensor layer*, sensor agents expose their data offerings using a common representation of space, time and phenomena. This allows workflow agents in the *Knowledge layer* to fuse heterogeneous data. This sensor data is then analysed at the *Knowledge layer* using expert knowledge encoded and stored in workflow, tool and modelling agents. The interpreted data is then presented to the end user in the form of end-user applications via application agents [4].

Workflow agents in the knowledge layer coordinate the workflow to generate a sequence of messages that are sent to the appropriate agents [4], [7]. The following sequence of actions will take place at run time:

1. *step 1:* The workflow agent sends a query to a sensor agent requesting for the relevant QuickBird Sensor data. The sensor agent responds with the QuickBird image data that satisfies this query. The workflow agent then passes the image data to the next step of the workflow, step 2.

2. *step 2:* Unplanned settlements have unique spectral signatures. By calculating the NDVI value in conjunction with edge detection techniques based on Quickbird image data, the NDVI values will be analysed to get an indication on the NDVI values associated with unplanned settelements. These values will thereafter assist in the detection of the unplanned settelment.Unplanned settlements have unique spectral signatures. NDVI analysis and edge detection will be applied to the QuickBird image data in order to determine the unique NDVI and edge detection values for each unplanned settlement type. These values will thereafter assist in the detection of the unplanned settlements.

3. *step 3:* The output in from step 2 will be used together with ancillary datasets such as income levels, road networks, etc in order to classify the different unplanned settlement types.

4. *step 4:* A prediction model will be developed in order to monitor and predict the growth of the unplanned settlements

5 Conclusion and expected results

The principle deliverables from this research would be:

1. A prototype ontology for Unplanned Settlements

2. Investigating how this ontology can be used in a SWAP context

3. Exploring the feasibility of using ontologies and agent technology for building Sensor Web applications

4. Automate the application for the detection and classification of unplanned settlements

5. The additional value of using SWAP for building Sensor Web applications

6. Quantify the additional value provided by SWAP for building Sensor Web applications

The role of the ontology to support the building of the USIS application will be tested using this multi-agent environment. Many of the image processing steps that were previously manually configured will now be automated. A bottom up approach will be attempted here where each of the steps mentioned above will be implemented and thereafter concepts from each of the steps added to the ontology. This would determine the purpose and scope of the ontologies.

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