Sensor Web and Geoprocessing Services for Pervasive Advertising

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Abstract: Pervasive advertising attracts attention in research and industry. Sensor information in this context is considered to improve the content communication of Pervasive Environments. This paper describes an architecture for integrating sensor information into Pervasive Environments. The sensor information is accessible through an abstraction layer, the Sensor Web, which is based on Web Service technology. The Sensor Web provides access to any deployed sensor for any compliant infrastructure, such as a Pervasive Environment. It thereby does not only access sensors that are deployed specifically for this system, but any sensor in the world that is available through the Sensor Web. In order to extract specific sensor information from the available sensor data, Geoprocessing Services are deployed as an intermediate component in the proposed architecture.

1 Introduction

Advertising currently introduces novel pervasive technologies installed in urban spaces (e.g. digital signage, mobile phones). These new media enable a) to show live data about the environment collected by sensors (e.g. weather forecast) and b) to adapt information presentation to the context, as determined by sensors (e.g. ads for ice cream, when the sun is shining). Currently, local and individual sensors are deployed at the devices that show the adverts. For example, cameras are installed on digital signs and GPS devices are installed in cell phones.

At the same time sensor information and geoprocesses become available on the web through Web Service technology. This trend is summarized by the term of the Geospatial Web [LA07]. The Geospatial Web evolves due to the advancements in processing and network capabilities as well as in standardization. The Sensor Web provides an abstraction layer on top of the individual sensor hardware and allows applications (e.g. advertising services) to access whole sensor networks independently of individual, often proprietary sensor hardware interfaces. Such sensor environments are already deployed in public spaces and provide measurements of real world phenomena (such as temperature or air pollution). To finally provide sensor information customized for individual applications, geoprocesses are a valid means to transform data (as for instance provided by the Sensor Web) into information. To enable the vision of such web-based sensor information Geoprocessing Services evolve currently.

Integrating Sensor Web and Geoprocessing technologies for pervasive advertising has not been achieved yet. However, this is promising to release the potentials of sensor networks for pervasive advertising and to open up the Sensor Web for a promising new type of application. Such enhanced pervasive advertising applications will provide more adequate and up-to-date information to the individual user and thereby increase the impact of the displayed content.

This paper proposes an architecture based on current standards of the Geospatial Webby integrating sensor information a) to represent it on the display and b) to adapt content presented on the display by measuring the impact of the displayed content through a feedback loop. Section 2 introduces the related concepts of pervasive advertising, Sensor Web and geoprocessing. Based on the introduced concepts Section 3 describes an architecture integrating Sensor Web and geoprocessing for pervasive advertisement applications. Section 4 discusses the architecture and provides an outlook.

2 Related Concepts & Literature

This section reviews the current activities in the context of pervasive advertising and the Geospatial Web. The Geospatial Web in a nutshell describes distributed services providing data and information. Two aspects of the Geospatial Web are the Sensor Web and Geoprocessing Services. In the Geospatial Web, the communication between the services is ensured through standardized data formats and service interfaces. In this context the Open Geospatial Consortium (OGC) plays a major role in setting standards and best practice approaches.

2.1 Pervasive Advertising

Recent advances in computing technology lead to vastly increased numbers of computers embedded into everyday items and environments, a paradigm called pervasive computing or ubiquitous computing [WE91]. For example, in the year 2007, 78,4 % of German citizens owned a mobile phone [AL07], and advances in display technology like LED, LCD, OLED and e-paper displays lead to increasing numbers of digital displays installed in public spaces. These new media are creating a pervasive information environment, where every citizen in urban spaces can be reached at almost every time via a variety of different channels. Advertising is expected to be an important business model in these pervasive information environments [MU09, RA02, KU06]. Because these media are dynamic, they present new challenges for sensor technology, both to deliver content to be presented in the media, and to determine the context of the user in order to adapt content presentation to this context [MU09a]. Because the users are often mobile, location is one of the most important context factors, such that it makes sense to use space and time as a main framework in which to interpret sensor data.

2.2 Sensor Web

Several elements of the architecture presented in this paper rely on standards published by the OGC and especially the OGC Sensor Web Enablement (SWE) suite of standards.

The OGC is an international body for standardization comprising more than 380 members from industry, research, education and governmental agencies. Its activities are centered on realizing the vision of the so called Geospatial Web. This term refers to the aim of integrating all kinds of geospatial data sources as well as processing functionalities into a common framework so that these resources become accessible through the Web. Among the different topics addressed by the OGC for the system presented in this paper, the integration of sensors and sensor data into the Geospatial Web is of special interest. This aspect is the core focus of the OGC Sensor Web Enablement Working Group [BO07].

The work performed within the SWE Working Group has lead in the last years to the creation of a set of standards that aim at fulfilling the following objectives of the Sensor Web:

- Access to sensor data (real time and historic observations)
- Controlling sensors (i.e. setting sensor parameters)
- Alerting based on user-defined alert conditions and sensor measurements (e.g. if a certain threshold is exceeded)
- Accessing sensor parameters (e.g. information about the sensor configuration)
- Provision of sensor descriptions (sensor metadata)

- Discovery of sensors and sensor data.

As a result an architecture formed by a framework of standards has been developed. This framework can be divided into two parts that address the two main aspects which have to be standardized: the SWE Information Model comprising data formats for sensor data as well as sensor metadata and the SWE Service Model consisting of (web service) interface standards offering different types of sensor related functionality.

In Figure 1 the different standards forming the two sub models of the SWE framework are shown. In the next paragraphs these standards will be introduced in more detail in order to allow a better understanding of the system architecture presented in this paper.

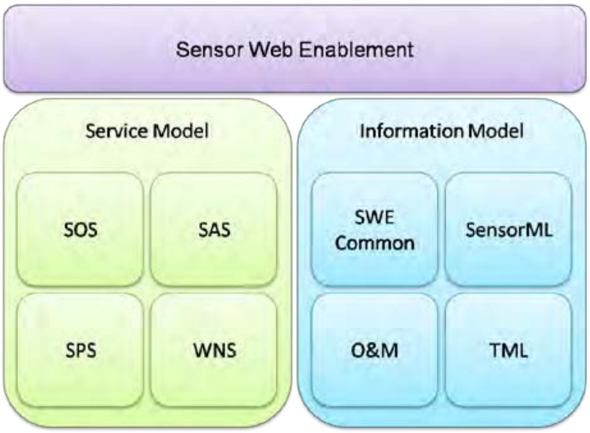

Figure 1: Overview of the SWE framework.

As outlined before the standards for encoding sensor data and metadata are contained in the SWE Information model. Thus, these standards ensure a common data model for exchanging sensor related data between SWE services and client components. There are four different standards which form the SWE Information model:

- SWE Common [BO07a]: In order to avoid overlap between the different SWE standards (i.e. the re-definition of certain simple data types within each standard), SWE Common provides several basic building blocks that are common to all SWE standards.

- Observations and Measurements (O&M) [CO07, CO08]: O&M offers a common encoding for data captured by sensors.

- Sensor Model Language (SensorML) [BO07a]: In order to correctly interpret sensor data or for allowing discovery of sensors, there is a need for describing sensor metadata. This issue is solved by SensorML which offers a standardized encoding for sensor metadata.

- Transducer Markup Language (TML) [HA07]: TML is a data format which allows the encoding of sensor data as well as sensor metadata. However compared to O&M and SensorML, TML has been optimized for supporting data streaming.

Complementary to the SWE Information Model, the SWE Service Model is formed by four different standards that define interfaces for accessing sensor related functionality. In detail, the following four standards are contained in the SWE Service Model:

- Sensor Observation Service (SOS) [NA06]: The SOS is intended for accessing sensor data and metadata. Its operations allow requesting sensor data based on spatial, temporal and thematic filter criteria as well as retrieving metadata for sensors. Furthermore the SOS offers operations for inserting observations and sensors. Typically, the sensor data is returned as O&M, metadata are usually returned as SensorML documents.

- Sensor Alert Service (SAS) [SI06]: The SAS offers a complementary approach for accessing sensor data. Whereas the SOS follows a pull-based communication model, the SAS is capable of pushing sensor data to subscribers. These subscribers usually define (i.e. through alert conditions) in which data they are interested. As a consequence the SAS is especially optimized for generating alerts if user defined conditions occur.

- Sensor Planning Service (SPS) [SI07]: The SPS can be used for controlling and tasking sensors. The most common use case is setting sensor parameters like the sampling rate. Furthermore the SPS offers a broad range of operations for managing sensor tasks (e.g. deleting, updating and cancelling tasks).

- Web Notification Service (WNS) [SI06a]: The WNS does not offer directly sensor related functionality. Instead it has to be understood as a kind of helper service enabling asynchronous communication within the SWE architecture. One important use case is the transmission of alerts generated by the SAS to users via communication means like SMS or email.

2.3 Geoprocessing Services

A geoprocess is considered to transform geodata into geoinformation. An example of a geoprocess can be a simple buffer calculation on specific objects or more complex calculations of climate change models. Complex geoprocesses are modeled as workflows, which consist of multiple processing steps.

As mentioned before, Geoprocessing Services gain currently attention from research and industry, as they enable the shift from web-based geodata to web-based geoinformation. They are an integral part of the vision of the Geospatial Web. Brauner et al. [BR09] describe the current challenges in the context of web-based geoprocessing: improving performance, enhancing service orchestration and semantic process descriptions.

One of the major attempts to standardize geoprocesses on the web is the OGC Web Processing Service interface specification (WPS) [OG07]. It describes a standardized set of operations to publish and execute any type of geoprocess on the web. According to the WPS interface specification, a process is defined as an algorithm, calculation or model that operates on spatially referenced data.

In detail, the WPS specification describes three operations, which are all handled in a stateless manner: *GetCapabilities*, *DescribeProcess* and *Execute*. GetCapabilities is common to any type of OGC Web Service and returns service metadata. In case of a WPS it also returns a brief description of the processes offered by the specific WPS instance. To get further information about the hosted processes, the WPS is able to return the process metadata through the *DescribeProcess* operation. This operation provides the description of all parameters, which are required to run the process. Based on this information the client can perform the *Execute* operation upon the designated process. As any OGC Web Service, the WPS communicates through HTTP-GET and HTTP-POST based on an OGC-specific XML-encoding.

WPS implementations have already been successfully applied in several projects ranging from groundwater vulnerability analysis [KI06] and map generalization [FO06]. WPS is also used for workflow modeling [SC08] and integration into Google Earth™ [FO09]. Additionally, an extensive discussion about the applicability of the WPS and its current drawbacks can be found in [FR07].

3 A Geospatial Web Architecture for Pervasive Advertising

The architecture applies Geospatial Web technologies to pervasive advertising. The pervasive advertising application accesses the Geospatial Web to provide relevant information to the user and to sense the context of the user. To provide the sensor data as information to the user, specific processing is required. This processing is performed by single or chained Geoprocessing Services.

The conceptual architecture is depicted in Figure 2. The pervasive environment retrieves all the information through Geo Processing and Sensor Web facilities. In particular, the Sensor Web measures the user context and the global context. The user context is provided for instance by cameras or profile settings of mobile phones. The global context is measured by for instance weather stations and satellites. We foresee that the distinction between user context and global context will disappear in the future technology-wise, as technology will advance and provide information about global and user context using any sensor. Though, the Sensor Web provides a coherent infrastructure and a common interface to all this information. Geo Processing facilities extract the relevant information. Based on this information the pervasive environment can decide what to display and measure the reaction of the user as a feedback loop.

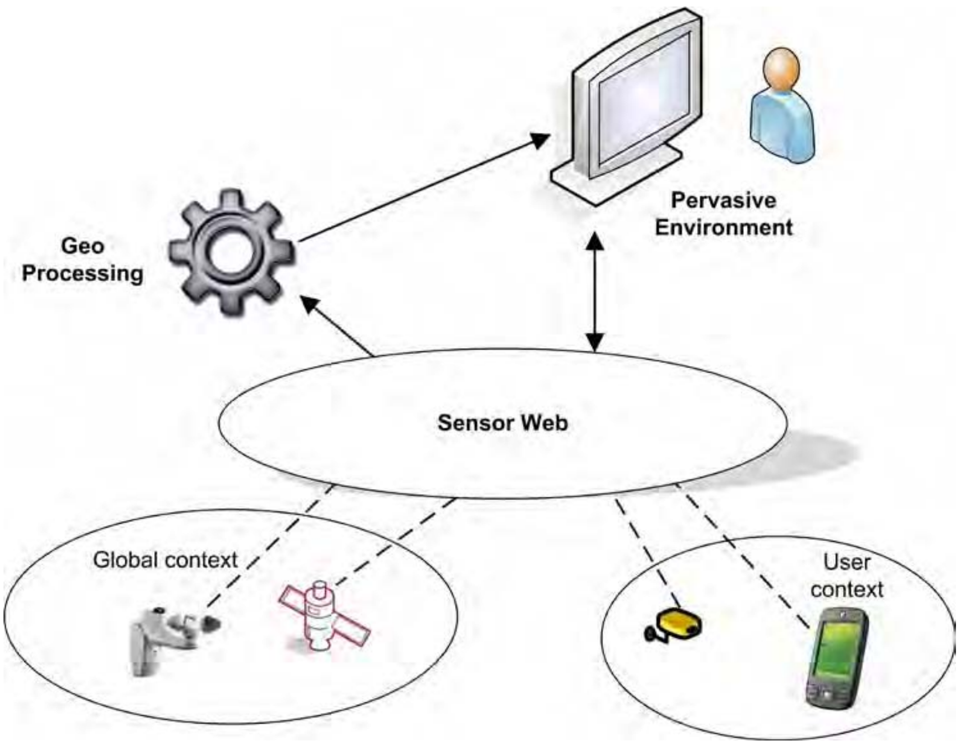

Figure 2: Conceptual architecture.

Figure 3 depicts the mapping of the conceptual architecture to the different service interfaces defined by the Geospatial Web.

In particular, three modes of interaction can be defined in the architecture, as explained in the following.

1. Pervasive Environment displays sensor data.

Sensors can be made available on the Sensor Web by registering them at one of the web services such as the SOS. To be able to do that a metadata description of the sensor in form of a schema-valid SensorML document has to be supplied. Sensors currently accessible on the Sensor Web range from simple thermometers attached to weather stations up to standard web cameras or even satellites. The data gathered by those sensors is ingested and subsequently provided by SOS instances. To access and use this sensor data the Pervasive Environment can on the one hand directly invoke the SOS to request the data in the O&M format. Since applications from the Pervasive Environment domain are often not capable of handling this format, we are proposing to pass the data firstly to a particular WPS instance to transform the O&M data to a more common format (e.g. KML, JPEG or MPEG). The data returned by the WPS is then easily displayable on the user interface.

2. Pervasive Environment reacts on events/alerts occurring in the Sensor Web

Besides a simple querying and subsequent visualization of sensor data the Sensor Web technology can also be used to react on events triggered by sensors or sensor networks. Therefore a sensor has to be registered as a data publisher at an SAS instance. This service is constantly listening for incoming data and forwards it to interested parties (this can be other web services such as an SOS) and computes alerts if for instance certain thresholds are exceeded. If such an alert occurs the SAS notifies applications and users by means of a WNS. An application, for example of the Pervasive Environment, can register at the WNS to receive notification messages via a previously specified delivery method such as SMS, FAX, e-mail or even phone calls. Once the application is notified about the occurrence of an alert or event it can adjust its display by querying a new data visualization from the WPS or can react in other ways.

3. Pervasive Environment influences sensors.

Also, it is possible for the Pervasive Environment to directly influence the behavior and state of the Sensor Web. Sensors which are registered at a SPS can be tasked. The service offers a standardized way to control sensors of arbitrary type. For instance an application of the Pervasive Environment could change the zoom level or angle of a web camera or modify the sampling rate of thermometer.

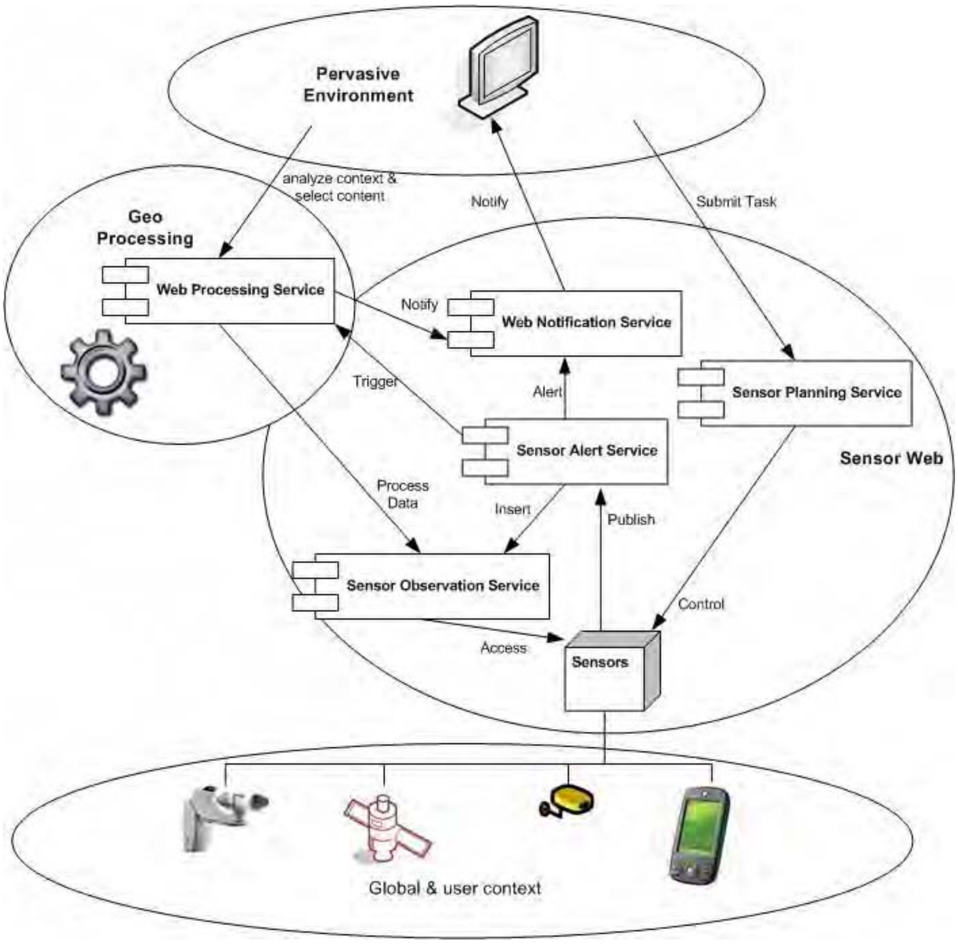

Figure 3: Implementation architecture accessing the Geospatial Web for pervasive applications.

A conjunction of the Geospatial Web and the Pervasive Environment, as outlined in the architecture above, allows the display to portray live data from global and user context as well as to adapt information presentation to these contexts. Data from the Sensor Web can be retrieved via standardized web service interfaces. The ability to send notifications in case of occurring events allows a live display of relevant information. The Sensor Web technology can be used to adapt the Pervasive Environment and the presented information on-the-fly to the context, as determined by sensors. An application, e.g. a public display showing advertisements, can adjust itself once it receives notifications or alerts from the Sensor Web. If for instance a thermometer registered on the Sensor Web starts to measure high temperatures the public display application could adjust itself by switching to an ice cream advertisement.

4 Outlook and Conclusion

Our work presents an architecture based on the Geospatial Web to improve the content communication of pervasive advertising applications. The pervasive environment such as a pervasive advertising application accesses the sensors which observe the global and user context. Based on the gathered information from sensors and processed through Geoprocessing Services the pervasive environment can adapt the displayed information. Due to the standardized interfaces defined by the Sensor Web, pervasive advertising systems can use any kind of available sensor such as weather stations or web cameras. Geoprocessing Services provide a standardized way to derive higher-level knowledge from the retrieved sensor data. The components relating to the Geospatial Web, which are part of the presented architecture, are already implemented and available as open source software solutions (see http//www.52north.org). However, a future challenge will be to create a proof-of-concept prototype for a pervasive advertisement application and to show the feasibility and utility of the proposed approach.

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