A Theory For Event Processing Of Geosensor Data

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Abstract. Event processing allows to analyze huge amounts of data streams in real-time. Some environmental applications dealing with sensor data need to perform geoprocessing and respond to time-sensitive issues. The application of event processing methods to geosensor data without having into account the implicit spatiotemporal setting of the observation process may lead to inaccurate results. Spatial attributes are important to infer relationships among environmental occurrences. This paper presents a simple theory to deal with sensor observations as geospatial events.

Keywords: Geospatial Events, Complex Event Processing

1 Introduction

Traditional geographic information systems represent geospatial information using the snapshot paradigm [10], usually holding the most recent state in time for which the data was captured. However, dynamic geospatial domains deal with processes and events which require spatiotemporal processing capabilities. Nowadays, sensors are the main source of geospatial data. As part of the standardization effort, the Open Geospatial Consortium's Sensor Web Enablement (OGC SWE) group has developed standard specifications to enable sensor data encoding (Observations and Measurements - O&M), retrieval (Sensor Observation Service - SOS), streaming (Transducer Markup Language - TML), alerting (Sensor Alert Service - SAS) and notification (Web Notification Services - WNS), as well as sensor tasking (Sensor Planning Service - SPS) and encoding of sensor metadata (Sensor Model Language - SensorML) [1]. With the increasing number of sensors and sensor networks being currently deployed around the world, application domains that handle time-sensitive information demand for real-time processing of these huge amounts of data.

Event processing tools provide methods for reading, creating, transforming and abstracting events. Complex Event Processing (CEP) allows to define event patterns that are checked against continuous data flows [6]. Event Stream Processing (ESP) is a different approach to event processing, which assumes that events arrive ordered by time, i.e. in an event stream. CEP is able to perform processing in event clouds that might contain several streams of events. That is why ESP is sometimes considered a subset of CEP[1]. The use of CEP in the last years has been relegated to enterprise IT systems. Nevertheless, initiatives like the Sensor Event Service[2] (SES), successor of SAS [2], apply event processing techniques to provide a publish/subscribe service to access sensor observations.

One problem we might face dealing with sensor observations as events is the lack of a common conceptualization to define terms for event types and their properties [3]. Derived from such absence, interoperability issues may arise when the processed information is used by different applications. Moreover, CEP processes all events in the same manner, without considering spatial relations among events. To achieve geospatial processing of events with CEP, it is necessary a theory to ground observations as geospatial events.

This paper presents part of our ongoing work on the application of event processing methods to geosensor data streams. The first part of the following section introduces some work on observation ontologies. Then, a theory to categorize sensor observations as geospatial events is discussed. Last section highlights the main points of the paper and concludes with some future work.

2 From Observations To Geospatial Events

This section presents some related work on observation ontologies that serves as a basis for the following discussion. The Geospatial Event Model (GEM) [10] is used to argue the adequacy of CEP for the geoprocessing of sensor data streams.

2.1 A Few Words On Observation Ontologies

Aware of the importance of a common knowledge representation of sensing concepts and relations, one of the goals of the World Wide Web Consortium's Semantic Sensor Network Incubator Group[3] (W3C SSN-XG) was to provide ontologies to describe sensors and sensor networks to be used in Sensor Web and sensor network applications. The SSN-XG analyzed seventeen sensor-centric and observation-centric existing ontologies. At the core of the SSN ontology, we find the Stimulus-Sensor-Observation ontology design pattern, as a continuation of the work done by Stasch et al. [9] and Kuhn [5]. The purpose of this compact ontological construction is to enable reusability and flexibility in Semantic Sensor Web and Linked Data applications dealing with observations and measurements. Janowicz and Compton [4] describe the pattern and provide some hints about how to integrate it with the SSN ontology.

The SSN ontology defines the concept Observation as a social construct to connect the stimuli, the sensor, and the output of the sensor. This description differs from the one provided by Probst [8], where observations are seen as events. Despite of that, both are still compatible from a data-centric point of view [4].

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[1] http://www.complexevents.com/2006/08/01/what\%E2\%80\%99s-the-difference-between-esp-and-cep/

[2] http://52north.org/communities/sensorweb/ses/0.0.1/index.html

[3] http://www.w3.org/2005/Incubator/ssn/charter

2.2 Complex Event Geoprocessing

Environmental phenomena may lead to occurrences (events) that can be detected in sensor data streams. Certain occurrences can serve as indicators to react to specific situations. For instance, by correlating past rainfall records with flood events, similar rainfall conditions previous to a flood can be identified as patterns. When such patterns are matched by any of the data streams that sensors are continuously producing, we have an indicator of potential floods in the region, thus additional indicators can be checked and the damages can be better prevented. Monitoring environmental phenomena involves the analysis of various interrelated environmental parameters, and CEP is a valuable tool to process real-time data. The aim of applying CEP to sensor data streams is not to replace the use of environmental models. Indeed, event processing techniques can be combined with the execution of environmental models contributing to near real-time integration of sensor data, e.g. by executing a flood risk assessment model remotely when a heavy rainfall event has been detected.

Worboys [10] presented a modeling approach for dynamic geospatial domains (GEM: Geospatial Event Model) using three core elements: geospatial object, geospatial event, and geospatial setting. A spatiotemporal setting is a function that maps from a temporal setting to a spatial setting. Geospatial events are events situated in a spatiotemporal setting [10]. We categorize every individual observation as a simple geospatial event: an observation is performed at a specific time (called *Sampling Time* in O&M); and has two related indirect locations, i) the location of the physical device performing the observation, and ii) the location of the entity that inheres the physical quality that is being observed (*Entity of Interest* or in O&M, *Feature of Interest*) [8]. If the quality observed is a temporal quality inhered in a perdurant (e.g., the duration of a rainfall), the location is derived from the entities participating in the perdurant (i.e., the falling raindrops).

A simple event is the atomic unit of processing in CEP. We have grounded observations in a spatiotemporal setting to treat them as simple geospatial events, which will be our atomic unit of geoprocessing. A complex event is an abstraction composed of events [7]. Event patterns act as filters for events. When an event pattern for heavy rainfalls is modeled and checked against geosensor data streams (time-series of simple geospatial events), the compositions matching the pattern correspond to what is considered heavy rainfall occurrences in the real world (for a specific area). Therefore, the filtered group of observations that is matched by the event pattern can be abstracted as a complex geospatial event. The abstraction of event pattern matchings as complex geospatial events establishes a theoretical basis for an event-observation conceptualization.

3 Conclusion

This paper discusses the application of CEP to geosensor data streams with the purpose of performing event geoprocessing. CEP provides real-time processing capabilities, which offers huge potential for Sensor Web applications, e.g. near real-time notification of events related to environmental phenomena. Dealing with sensor observations as non-geospatial events may lead to problems identifying relations among occurrences. Spatiotemporal attributes are crucial to infer causality links in an event cloud, e.g. various flood events in a short time in the same region may have been caused by the same heavy rainfall event. We claim that time-series of observations provided by sensors can be considered as streams of geospatial events because of the spatiotemporal setting implicit in the observation process.

This work contributes to set up a theoretical framework to apply CEP to geosensor data. Applications depending on the quick analysis of observation streams to provide appropriate responses, like decision making on Environmental Monitoring, can be benefitted from this research.

Next steps will address the creation of an event-observation ontology. Previous work on the fields of observation and event ontologies will be the basis for future work. Moreover, the abstraction of complex events (aggregation) based on the spatial relationships between spatiotemporal settings [10] offers challenging research possibilities.

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