An Ontological Approach to Integrating Task Representations in Sensor Networks

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ABSTRACT

The sensor tasking problem in sensor networks involves the representation of users' tasks (user-level tasking) in a form which a sensor network needs to perform required operations (sensor-level tasking) leading to satisfaction of the tasks. We analysed four approaches to task representation (TR) in sensor networks: the Open Geospatial Consortium's Sensor Web Enablement, Goal Lattices, Semantic Streams, and Sensor Assignment to Missions. Each approach considers distinct aspect of the sensor tasking problem. We used the Web Ontology Language, OWL, to define the features of each TR, which enabled us then to identify mappings between them. These mappings allow us to combine the TRs into one hybrid task representation (HTR) that addresses both user-level and sensor-level tasking, thus providing a more complete, integrated approach to the sensor tasking problem. In this paper (presented as both poster and demonstration) we introduce our HTR integrated into a system working on a sensor network. It shows how a rich semantic representation of task, such as the HTR, can be used to automatically control system operations on the network, thus making it more adaptable to changes within the state of the network resources (e.g. sensor malfunction) or tasks (e.g. change of a task's requirements).

1. INTRODUCTION

Sensor networks are becoming increasingly important in many domains, for example, environmental monitoring, emergency response, and military operations. There is considerable and growing interest in developing approaches that allow sensors to be treated as information-providing resources, and integrated within Web and Semantic Web information architectures (for example, [1, 4, 5]). A key issue in this is making these networks more flexible, so they can more easily be deployed to meet the needs of new tasks. We identify two aspects of the sensor tasking problem: *user-level tasking* involves the representation of a user's tasks in a form that determines the operations a sensor network needs to perform; *sensor-level tasking* involves the specification of those required operations, leading to satisfaction of the tasks. For example, user-level tasking is concerned with tasks such as the detection of vehicles or identification of people, whereas sensor-level tasking is concerned with operations such as collecting video or audio data of a particular quality. Another way of looking at this is to say that user-level tasking focuses on issues of "what" whereas sensor-level tasking focuses on issues of "how". In practice, a complete task specification needs to include both aspects, because users will be concerned with both what they want to know, and how they get the supporting sensor data [4, 2]. Therefore, we see a need for a task representation (TR) that captures user-level tasking requests and links these to sensor-level tasking requests. Such a TR would provide all the necessary input to a system that would operationalise a user's request in terms of necessary "what" and "how" requirements.

2. TASK REPRESENTATIONS

After a literature review we have identified four existing representations addressing aspects of user-level and/or sensor-level tasking, for which there were reasonably detailed descriptions of the TR formalism: **Open Geospatial Consortium Sensor Web Enablement (SWE)** enables tasking on a sensor-level, allowing for discovery, access and setting of sensor parameters through Web service standards [1]. **Goal Lattices (GL)** assist in user-level tasking, during task planning, by defining a lattice of goals and weights, where sub-goals contribute to the satisfaction of super-goals in terms of their relative weight, allowing for goal prioritisation [3]. **Semantic Streams (SS)** are useful for both user- and sensor-level tasking, as they enable the creation of streams representing the flow of sensor-generated information and processing required in order to satisfy a task's information requirements [4]. **Sensor Assignment to Missions (SAM)** connects user- and sensor-level tasking, as it enables matching between tasks and sensor types, by mapping of a task's information requirements to a set of sensor capabilities satisfying them [2].

For each TR we have created in Web Ontology Language (OWL[1]) ontology. The model of hybrid task representation (HTR) was created through alignment of the ontologies integrating the aforementioned capabilities of the four TRs. Fig. 1 shows the mappings which create the HTR ontology. Here we use the following notation: classes are depicted as ovals; subclass relations are shown as unlabelled solid arcs; the OWL sameAs property is represented by a solid bidirec-

[1] http://www.w3.org/TR/owl-ref/

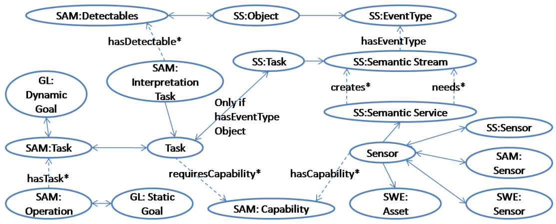

Figure 1: Mappings of ontologies creating the HTR.

tional arcs; all other properties are shown as labelled dashed arcs; we use namespace notation to indicate which TR ontology the concepts are from. The ontologies are available online[2]. The role of a task representation in a system is to capture "what" and "how" requirements of a user's task in a machine processable form which lets the system figure out how to satisfy the tasks needs. Thanks to the combination of user- and sensor-level TRs and creation of mappings between their concepts using Semantic Web technologies we have obtained an HTR able to express a user's task in human readable terms (e.g. detect a vehicle) that is visible to the sensor-level task representations dealing with setting, collection and processing of sensor information (e.g. camera, radar or acoustic sensor).

3. THE APPLICATION

Fig.2 shows the interface of a system using the HTR. The top right tree exposes the SAM TR functionality, where the user can select from currently defined National Imagery Interpretability Rating Scale[3]Tasks (e.g. detect vehicle) and specify Required Sensing Capabilities in terms of intelligence types (e.g. acoustic, imagery or radar). The bottom tree presents bundles that satisfy a task i.e. platforms with sensors mounted on them, where their combined capabilities are satisfying the requirements of a task. The map serves three purposes: to allow a user to specify the area of a task, to present the location of assets providing some of the capabilities required by a task, and to deliver processed sensor information where appropriate (the jeep icon, representing detected vehicle). The top tab uses the GL TR's capabilities to express relation between tasks, thus prioritising assignment of resources accordingly. The SS & SWE TRs capabilities since they have more to do with the sensor- then user-level tasking are not exposed to the user.The role of SS TR is processing of incoming data from sensors, e.g. from the acoustic array mounted on the PackBot platform, P2, thus pinpointing a detected vehicle (the jeep icon) on the map. Where the exploited functionality of SWE TR is discovery, configuration and use of a network's resources. Other elements of the interface are the mission tab used to switch between missions, and options tab with the application's settings.

This interface is presented for a vehicle detection task. It tells the story of what was happening during the execution of this task. The small visible window shows interrupted output that was coming from the camera mounted on the Reaper Unmanned Aerial Vehicle, P1 from the first listed bundle. In the moment when the signal was interrupted the system automatically switched to an alternative solution, re-

[2]http://users.cs.cf.ac.uk/K.Borowiecki/Ontologies.zip
[3]http://www.fas.org/irp/imint/niirs.htm

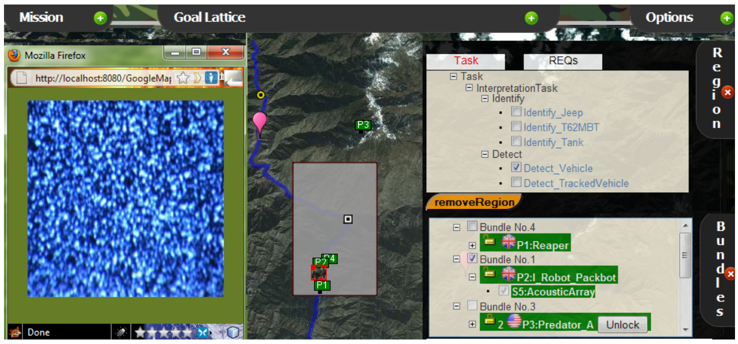

Figure 2: Interface of a system utilizing the HTR.

assigning the resources, by taking the next available bundle with platform P2 containing an acoustic array.

4. SUMMARY

The demo shows that through use of a rich semantic representation of a user's task, which allows a user to state his needs while capturing all information required to operate for the underlying technologies, it is possible to automatically control a system working on a sensor network. In result we obtain a system that is responsive, adaptive and useful in situations or sensor networks where change of sensor and/or tasks state is expected.

Demo Requirements The demo runs on a self-contained laptop but requires an Internet connection.

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