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Modelling and Monitoring Environmental Risks through a Semantic Framework

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ABSTRACT

The widespread availability of IoT technologies allows, among others, detailed monitoring of environmental parameters that can be used for effective prevention and forecasts of natural disasters. When such events occur, or are about to occur, the primary concern of authorities responsible for the public safety is to organise and enforce the relief in an as quick as possible and effective way. However, the huge amount of information that an IoT infrastructure is able to provide is useless if not correlated and contextualised on the territory where the hazard has occurred. In this paper the authors present the design of a semantic information model which integrates different information domains into a unified framework. In particular, some ontologies have been defined to represent, respectively, the information domain of hazards, the domain of sensors (which are responsible for measuring the phenomena that may trigger hazards), the geographic domain and the environmental risk domain, also including the potential damage and dangerousness of such events. In the proposed semantic framework, a place (be it a single building or an entire region) can be characterised from the environmental risk point of view. The resulting knowledge base can then be used to build monitoring services capable of identifying on the territory those sensing units whose sensed data are really useful for the setup of a relief plan. A prototype of such a monitoring tool was also implemented. Finally, two simple yet complete use case examples focusing on the wildfire hazard and on the flood risk respectively are discussed in the paper.

KEYWORDS

Environmental Risk Model, Geospatial Ontology, Knowledge Engineering, Semantic Technologies, Sensor Ontology

INTRODUCTION

The mission of a country's Civil Protection is to guarantee the public safety of citizens against any possible threat brought by destructive natural phenomena such as earthquakes, hurricanes and floods. The work of Civil Protection consists of constantly monitoring the areas at greatest risk, and promptly putting in force the relief whenever natural disasters have occurred or are expected to occur. The relief effort needs to be coordinated from the time the hazard is detected to when the normal situation has been restored. Throughout this time, it is of paramount importance that the coordinating team has access to both the real time data pertaining the specific area interested by the natural phenomenon and the data of other surrounding areas, which may potentially be threatened as well. Also, among

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the multiple sources of information spread out in the territory at risk, it is useful to identify those capable of producing data which may help to monitor the evolution of the specific phenomenon that has occurred. We believe that a prompt and sensible organization of the data "sensed" on the territory is crucial for the planning of the relief effort.

What emerges from these considerations is the need of integrating some different, yet intertwined, knowledge domains, in order to obtain a complete view of the potential environmental risk: the sensors, intended as sensing elements capable of providing real time data useful to measure the development of natural phenomena; the hazards to which people are subjected; the geographic areas to be put under observation in case a hazard occurs or is about to occur; the potential damage that a hazard could cause on a place and its level of dangerousness. Under a semantic perspective, each domain may be represented through an ontology populated by semantic concepts which relate to each other by means of semantic properties. Independently of the semantic representation that may be adopted to represent the domains, they are heterogeneous to each other, in a way that it is hard to find an overlapping area of semantic concepts which are shared by the different domains. The contribution of this work, which extends the one presented in (Calcaterra, Cavallo, Di Modica, & Tomarchio, 2015) is twofold: a) to define the semantic models for the characterisation of the previously cited knowledge domains; b) to specify semantic properties which build inter-domain relationships.

Final objective of the work is to provide an integrated semantic framework where the above-cited domains provide a common information ground on which to build tools and services that are useful to monitor the territory in case of a natural disaster. As mentioned earlier, primary concern of Civil Protection (CP) is the life of citizens who populate territories which are known to be historically exposed to hazards. Specifically, the CP needs to monitor all those densely or sparsely populated territories for which a concrete risk exists. Actually, looking at a specific geographic area, an event (be it natural or atmospheric) may turn into a natural disaster and thus represent a threat to the population only if that area is "sensible" to that particular event. To make an example, heavy rains that unceasingly fall over a restricted area may trigger a flooding if in that area there are lakes or rivers that may overflow, otherwise no flood will materialise. Again, a volcano eruption may represent a serious hazard only in places which are close to either the crater hole or to the lava's expected flowing path. Therefore, the tools we offer will enable CP to: a) characterise, and draw on a map, places that are known to be under an environmental risk, also evaluating the level of potential damage in case of different kinds of hazard; b) identify on the map the sensors that populate a place and their capability to measure an event which may turn into a natural disaster; c) in case of hazard, query the system to retrieve the sensors that are useful to monitor and provide useful information about the places affected by the hazard.

The remainder of the paper is organized as follows. In Section 2 related work is reviewed. In Section 3 the semantic model is discussed in technical details by describing the proposed ontologies. In Section 4 we present a web tool that grounds on the proposed model to offer a monitoring service. Two simple use cases are also discussed along. Finally, Section 5 concludes the work.

RELATED WORK

The representation of sensors through a semantic model is a recurrent and hot topic in the literature. The amount of data produced by the multitude of deployed sensors is extremely large and highly heterogeneous, making it complex to discover and use (Miorandi, Sicari, De Pellegrini, & Chlamtac, 2012). The heterogeneity of data, as well as of sensing environments, is a key obstacle for realizing smart sensing infrastructures. One of the solutions to deal with heterogeneity is annotating sensors and sensors data with semantic information (Compton, Henson, Laurent, Neuhaus, & Sheth, 2009). Semantic technologies are largely used in the IoT research as well (Barnaghi, Wang, Henson, & Taylor, 2012). Notable efforts in this field are the SSN ontology (Compton et al., 2012) for annotating sensors and sensor networks, "linked data" for sensor data publishing and discovery (Patni, Henson,