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Ontology-Based Modeling of Effect-Based Knowledge in Disaster Response

Leopoldo Santos Santos, Universidad de Alcalá de Henares, Henares, Spain
Miguel-Angel Sicilia, Alcalá de Henares University, Henares, Spain
Elena Garcia-Barriocanal, Alcala de Henares University, Henares, Spain

ABSTRACT

Emergency response and management requires the coordination of agencies and different services in a complex evolving situation. This in turn, requires diverse models representing detailed knowledge about the types of adverse events, their potential impact and the means and resources that are best suited for an effective response. The basic formal infrastructure incident assessment ontology (BFiaO) is oriented towards fulfilling these needs. BFiaO is a meta-model for handling infrastructure-related situations, but it did not provide models for a catalogue of adverse events and the means necessary for an adequate response. In this article, the authors present the key ontological commitments required for developing BFiaO-based extensible typologies of adverse events that are driven by the effects rather than by other aspects such as causes, or facilities affected. The model of a concrete case study is then presented that connects adverse event types to the kind of actions and resources required for mitigation.

KEYWORDS

Adverse Events, Decision Support System, Disaster Management, Disaster Response, Emergency Management, Emergency Response Systems, Ontology, Situation Awareness

1. INTRODUCTION

Emergency management (EM) is the continuous process by which individuals, groups, and communities manage hazards to avoid or mitigate the impact of disasters resulting from them. Emergency response is triggered by the occurrence of geospatially localized adverse events or incidents of a very diverse nature and that typically chain or combine with others as the situation evolves (Fan and Zlatanova, 2010). As we have seen in recent events, a global approach is required in order to achieve as complete an awareness as possible of the situation to assess the possible courses of action for the unfolding emergency. Such a global approach calls for models of different domains in which it is possible to connect incidents with resources and means, that are able to provide support for situation awareness during the course of the incident. The links between these aspects are determined by the potential effects that some kinds of incidents are known to have in particular contexts. For example, certain kinds of fires have different behaviors depending on the infrastructure or area affected, and consequently the means to deal with them are also different.

The complexity of emergency management requires models covering different aspects that are part of the situation triggered by the incident. A survey of situation awareness ontologies can be found in Baumgartner & Retschitzegger (2006). There are different approaches to deploying an Emergency Management (EM) concept. Di Maio (2007) - based on Rex Brooks (OASIS - http://www.oasis-open.

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org/committees/emergency/) – distinguishes between Emergency Response Management Systems (ERMS) and Emergency Response System Management (ERSM). In addition to this, there are some other proposals where ontologies are used in different ways in Emergency Management Systems, for instance Malizia et al. (2010) define an ontology to manage alerts called SEMA4A. Zhong et al. (2017) focus on the use of ontologies for geospatial information. Authors like Othman and Beydoun (2010) found references in major models for the concept of adverse event or incident, identifying them as the triggers of coordinated actions.

There exist several adverse event taxonomies, but they differ significantly and the ontological criteria they build on in the breakdown into event categories is in most cases not made explicit. This is hampering their extension and reuse. Also, these taxonomies are not associated to the kinds of actions and resources that are known to be effective in handling them, which represents a critical kind of expert knowledge in unfolding situations. Some other authors like Truptil et al. (2008) and Ford et al. (2015) first proposed a mediation tool dedicated to support interoperability, but this approach does not replace the need for a shared meta-model.

Several proposed ontologies for EM have included incidents in their structures. However, the relation of incidents to particular kinds of other elements has not been subject to formalization in most of them (Fan and Zlatanova, 2010; Galton and Worboys, 2011). However, Sicilia and Santos (2009) described BFiaO, which provides a model covering the common high-level aspects of infrastructures (electrical, gas, etc.), causes of incidents (be them natural or caused by humans) and the incidents themselves as situations that in some cases evolve or are qualified as emergencies. Rules could then be used to combine the structure of events representing the evolving situation to infer potential situations of risk associated to infrastructures. The model proposed here, as an extension to BFiaO, allows for the codification of EM knowledge in a reusable way that could later be used for the planning of actions accounting for available resources and other contextual circumstances.

This paper describes an ontological framework for a unified account of effect-based EM. Our point of departure is an analysis of previous models that include effects and resources. From that, the structure of BFiaO as a meta-model is put in relation with the specific requirements of knowledge about the effects of the incidents and situations. The resulting models are then evaluated in a case study that is succinctly describes. The model presented serves as a blueprint and also a basic ontology for building knowledge-based event systems crossing domains and integrating additional models. To keep the discussion short, we have only showed some of the aspects of the model.

This paper is structured as follows. Section 2 provides a review of existing related taxonomies and terminologies related to addressing adverse event typologies. Section 3 explains the global view of our emergency model. Section 4 explains refactoring events, missions and resources, and how to use them for inference using the BFiaO approach to separate generic and concrete means. Section 5 describes a case study in which the models and techniques presented are put into practice for a concrete situation. Finally, conclusions and outlook are provided in Section 6.

2. RELATED WORK

This section surveys previous work in ontologies and models in disaster management that are relevant to the work presented here. The point of departure is the concept of effect-based modeling first proposed by Santos, Sicilia and Padrino (2011). Existing proposed ontologies and other schemas are contrasted in their support to events, actions and resources.

2.1. Emergency-Related Taxonomies

Systems dealing with emergencies are data-intensive and require a number of integrated data models, including geospatial information, inventories of available resources and of vulnerable facilities or populations. Proposed standards for the interchange of data related to EM have emerged in the last years, e.g. the Tactical Situation Object (TSO) is aimed at exchanging information during EM