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Towards Semantic Generation of Geolocalized Models of Risk

We present the architecture of a tool suite that aims to generate geolocalized conceptual models of risk to be used for the risk assessment of a geographical area, such as a city, a district or a country. This suite consists of three main components: CREAM, a tool for the automatic generation of conceptual models of risks, leveraging semantic and computational creativity techniques; TERMINUS, a domain ontology that gathers knowledge concerning environment, critical infrastructures and related risks; and CIPCast, a GIS-based tool for critical infrastructures protection, enhanced with forecasting and decision support functionalities. Then, we describe the interoperability issues we considered to design this suite of tools. Finally, we discuss usage scenarios for the risk assessment of an urban area.

51.1. Introduction

Different geographical areas are characterized by their specific Critical Infrastructures (CI), and services targeted at populations individual needs. Given a specific area, natural hazards (e.g. flash floods, earthquakes), anthropic hazards (e.g. terrorist attacks, cyber attacks), and threats related systems, and vulnerabilities and stakeholders define a potential risk of given severity [1]. Hence, each zone could be subject to different risks. An open research problem is to conceive the possible risks of a given geographical area and quantify them. Associating risks with geographical areas could support the work of risk analysts. These risks can be used before a crisis event to assess the potential impact on a specific area (i.e. a prevention phase) or during a crisis event to assess its possible consequences

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(i.e. a response phase). To this purpose we propose a phased approach supported by a suite of tools. In the first phase, possible risks of a given geographical area are automatically generated as fragments of conceptual models. In the second phase, such risks are quantitatively assessed by the means of mathematical functions of risk. In this chapter, we face the first phase of the problem and, in particular, we aim at geolocalizing fragments of automatically generated conceptual models of risks and showing them on a map.

We propose a suite of tools consisting of three main components: CREAM (CREAtivity Machine), a software application able to automatically generate conceptual models of risks by leveraging semantic and computational creativity techniques [2]; TERMINUS (TERritorial Management and INfrastructures ontology for institutional and industrial USage) [3], a domain ontology that gathers territorial knowledge concerning environment, critical infrastructures and related risks; and CIPCast [4], a GIS (Geographical Information System)-based tool for CI protection, enhanced with forecasting and decision support functionalities. We discuss how such geolocalized fragments of risks, termed risk mini-models [2], are generated and the interoperability issues we faced to design the architecture of the tool suite.

Localizing vulnerabilities and hazards is a fundamental aspect of risk assessment [7]. However, existing approaches mainly focus on information systems for quantitative estimates and only a few approaches address the conceptual problem of supporting the identification of new risks [6]. To the best of our knowledge, our solution, which integrates quantitative and conceptual risk assessment by leveraging semantic and computational creativity techniques and a GIS interface, is novel and unprecedented.

The rest of the chapter is organized as follows. Section 51.2 presents the system architecture for geolocalized risk assessment. Section 51.3 describes the interoperability issues. Section 51.4 presents a usage scenario of geolocalized risk assessment. Finally, section 51.5 provides some conclusions.

51.2. System architecture for geolocalized risk assessment based on semantics

Traditional systems for risk assessment consider a limited number of predefined vulnerabilities of systems and compute the level of related risk based on some mathematical risk functions. Even if the accuracy of these systems is increasing, a limitation is that the corresponding mathematical models do not consider the overall complexity of the problem but address only some of the aspects of a potentially harmful situation. To overcome this limit, we consider risk assessment from a wider perspective where traditional quantitative risk assessment methods are enriched by semantic reasoning mechanisms that generate likely and unlikely risks. To this purpose we propose a suite of tools that is configurable according to location.

Figure 51.1 illustrates the architecture of the tool suite and the related process flow. Accordingly, institutional operators (e.g. civil protection) interact with the suite through a WebGIS interface to select an area of interest and other contextual information as systems, services or possible hazards. This information is used by CREAM to generate possible risk situations for the area and by CIPCast to compute the level of risks for the area. Reasoning performed by CREAM is based on the TERMINUS domain ontology. In what follows, we briefly describe the overall architecture.

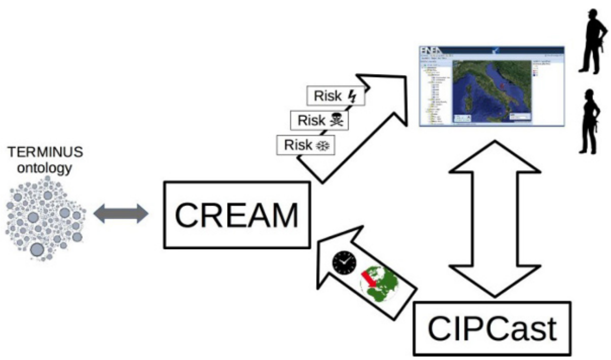

Figure 51.1. *Architecture of the tool suite for the semantic generation of geolocalized models of risk. For a color version of this figure, see www.iste.co.uk/zelm/enterprise.zip*

The TERritorial Management and Infrastructures ontology for institutional and industrial USage includes knowledge representing environment, CI and related hazards, risks and threats. At the current stage, TERMINUS is built deriving concepts from the vulnerability upper model (VUM) and from the system aspect design pattern presented in [3]. It also includes knowledge related to interdependencies between critical infrastructures [5].

The CREAtivity Machine is a software application that automatically generates models of risks; more specifically, it creates conceptual representations of risk situations by means of a combination of semantic and computational creativity techniques. Conceiving new risks requires involving operators with interdisciplinary technical expertise that are not always available or accessible. CREAM overcomes the problem by autonomously suggesting new risks to institutional operators. Such risks are extracted as risk mini-models from the TERMINUS domain ontology by means of SPARQL queries based on some predefined system design patterns and logic rules.

CIPCast is a novel Decision Support System (DSS) [4] able to produce a real-time operational risk forecast of CI in a given area due to natural hazards. The main functionalities of CIPCast are: (1) real-time monitoring of natural phenomena; (2) *prediction of natural events (if predictable);* (3) *prediction of damage scenario* on critical infrastructure components; (4) *prediction of impacts of critical infrastructure services and impacts on citizens*; and (5) *definition of efficient strategies* to support decision-making operator processes.

51.3. Interoperability issues

In this section we briefly discuss the interoperability levels concerning the interoperation of the CREAM software with the CIPCast DSS. We identified four levels: *risk assessment*, *process*, *model*, and *data*. These are represented in Figure 51.2.

The *risk assessment level* concerns the system risk. In our case, CREAM deals with identifying some of the types of risks whereas CIPCast deals with the quantitative assessment of risk by associating a severity value to a predefined type of risk. Ensuring interoperability at this level means to define how these two approaches for risk assessment can be used together. The *process level* deals with the interoperability of the processes implemented by two systems. In our case, for instance, it is dedicated to the interoperability of the process that CREAM uses to generate risk mini-models with CIPCast processes to make simulations and forecasting and vice versa. The *model level* concerns semantics. For instance, here, the challenge is to specify how to map the CIPCast data model to TERMINUS by identifying the possible clashes between software applications. The *data level* deals with identifying the technical aspects concerning the information exchange between the two systems. In our case, for instance, the problem is to define which data should be passed from CIPCast to CREAM and how these data should be managed (e.g. syntactic format of data).

51.4. Usage scenarios

Usage scenarios of the combined CREAM-CIPCast systems serve to demonstrate the enhancement of the risk assessment functions and to validate the CREAM ability to identify risks relevant to a given spatiotemporal context.

Generally, we envisage two phases for systems' interoperation to support risks analysts: (1) *prevention phase* from potential crisis events that pose risks to a specific area; and (2) *early response phase* during some crisis event to foresee and assess its direct and indirect consequences on the given area for the purpose of decision-making. An example of the latter usage is water distribution management after an earthquake in a nearby area. Such analysis requires the availability of dynamic data updates on environmental conditions, infrastructure failures and so on. In such a setting, CREAM can be set to select risk situations possibly appropriate for the new context.

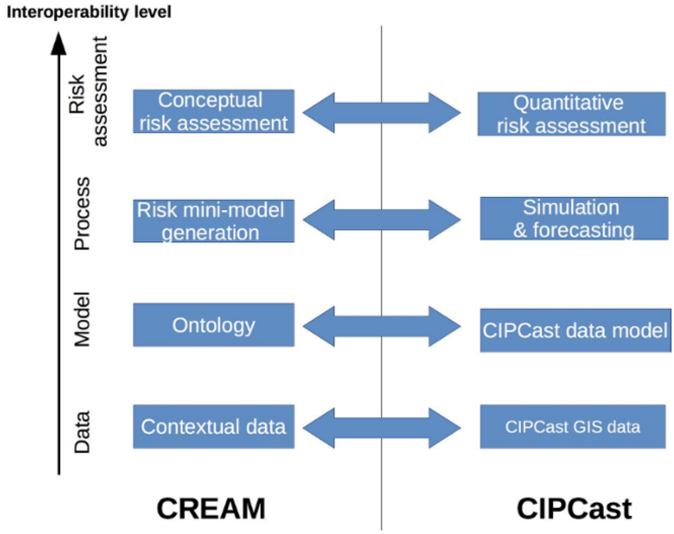

Figure 51.2. *Interoperability levels concerning the tool suite*

The following scenario illustrates the usage of CREAM-CIPCast in the prevention phase:

> A risk analyst wants to assess the consequences of an earthquake for a zone of an urban area. The analyst specifies the hazard and selects the city area by interacting with a map by means of the WebGIS interface of the CIPCast system. Relevant geographic information for the area include: points of interest such as schools, hospitals and public places; and CI components such as water pipes, road characteristics, the position of electric substations, etc. These entities can be automatically identified using CIPCast and this information will be exploited by CREAM to generate semantic descriptions of possible damage scenarios for the selected area. Results include both direct damages (e.g. on the buildings) and cascading effects (e.g. a broken water pipe interfering with a school evacuation). Damage scenarios can be quantified through CIPCast functions, and the results are supplied to the risk analyst on the WebGIS interface. The analyst is also supported by the system in the identification and browsing of all relevant risk situations, with the final aim to improve completeness, and hence reliability, of the risk assessment.

51.5. Conclusion

Risks identification in socio-technological systems is a complex activity due to uncertainties of hazards, to an increased interdependence of CI, and to the limited ability to foresee cascading failures. To this aim, CREAM is a novel software system to support risk analysts by projecting relevant risk situations with semantic reasoning and computational creativity techniques [2] based on a formal description of the scenario. On the other hand, risk assessment requires data on the geographical areas and on the societal and infrastructures' characteristics of the specific system under analysis. This problem is addressed by CIPCast [4], which is a GIS-based tool for CI protection, enhanced with forecasting and decision support functionalities. In this work, we proposed an architecture that enables these two systems to interoperate and complement the newly developed CREAM risk assessment system with location specific risk descriptions and analysis capabilities.

51.6. References

[1] COLETTI A., DE NICOLA A., VILLANI M. L., "Building climate change into risk assessments", *Natural Hazards*, vol. 84, no. 2, pp. 1307–1325, 2017.

[2] COLETTI A., DE NICOLA A., VILLANI M. L., "Enhancing creativity in risk assessment of complex sociotechnical systems", *Computational Science and its Applications – ICCSA 2017. LNCS*, vol. 10405, Springer, Cham, pp. 294–309, 2017.

[3] COLETTI A., DE NICOLA A., VICOLI G. *et al.*, "Semantic modelling of cascading risks in interoperable sociotechnical systems", *Proc I-ESA*, 2018.

[4] GIOVINAZZI S., POLLINO M., KONGAR I. *et al.*, "Towards a decision support tool for assessing, managing and mitigating seismic risk of electric power networks", *Computational Science and its Applications – ICCSA 2017 LNCS*, vol. 10405, Springer, Cham, 2017.

[5] RINALDI S. M., PEERENBOOM J. P., KELLY T. K., "Identifying, understanding, and analyzing critical infrastructure interdependencies", *IEEE Control Systems*, vol. 21, no. 6, pp. 11–25, 2001.

[6] MAIDEN N., ZACHOS K., LOCKERBIE J. *et al.*, "Establishing digital creativity support in non-creative work environments", *Proceedings of the 11th ACM Creativity and Cognition Conference*, ACM, 2017.

[7] VAN WESTEN C. J., CASTELLANOS E., SEKHAR K. L., "Spatial data for landslide susceptibility, hazard, and vulnerability assessment: An overview", *Engineering Geology*, vol. 102, nos 3–4, pp. 112–131, 1st December 2008.