Towards a taxonomy of crisis management simulation tools

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ABSTRACT

Experimentation is an essential element to improve crisis management and to assess crisis management tools. Unfortunately, for the moment, real crisis management experimentations are episodic and generally focus on a specific geographical and/or thematic area. This is why the European DRIVER project aims to provide a test-bed platform where crisis management testing and experimentation can be carried out with a mix of live and simulated actions. To achieve this goal, simulation tools have to be identified, described and classified in order to (i) help the user to select tools and models based on the experimentation requirements and (ii) to allow the DRIVER platform to insure exchange information between simulated actions and live actions. This paper focuses on the taxonomy used to classify simulation tools relevant for crisis management. This taxonomy is divided into three main categories of characteristics: (i) business (type/topic of the simulation), (ii) legal (terms of use), (iii) technical (integration within the DRIVER platform and/or other crisis management (simulation) tools).

Keywords

Simulation, test-bed, crisis management tool, taxonomy.

INTRODUCTION

To face a more complex and wider spectrum of crisis situations, crisis management organisations are expected to deal with all types of crises (natural disasters, terroristic attacks, etc.). In the meantime, various mature and competent crisis management capabilities are available across the European crisis management community. Instead of redesigning the whole existing crisis management capabilities to face new challenges (which will be very costly and may induce loss of crisis management capability during the redesign phase), a solution could be the share and the connection of existing capabilities, at the local, regional, national and European levels and exploit the modularity, flexibility and adaptability of the combination of existing capabilities. To achieve this objective, the interoperability of these capabilities has to be supported and, first of all, assessed through experimentations and trainings.

One of the main objectives of the European DRIVER project is to support this solution by proposing a test-bed, i.e. a space for experimentation which will provide physical and organizational platforms, methodologies and tools (i.e. crisis management tools), where crisis management testing and experimentation can be carried out.

Therefore, the test-bed will propose to design and support experimentation. The design phase consists in providing scenario generation, development of metrics, etc. while the support phase consists in gathering data and executing simulations that permit the mix of live (e.g. action performed in the real world) and simulated action. Thus, considering the diversity in existing simulation tools, the main question is *how to help the user (researcher, industrial, practitioner) to select relevant software simulation tools in order to implement the chosen simulation models to test their crisis management tools or processes*?

To achieve this objective, software simulation tools have to be classified thanks to a taxonomy, which is based on relevant characteristics to help the users (local/national authorities, civil protection, industrials, citizens) or any organisation involved in crisis management in their decision making process to choose the right simulation tools to implement the targeted simulation.

Moreover, simulation tools can be regarded as sustainable if they meet two requirements: (i) they have to be at least mature prototypes, i.e. having a Technology Readiness Level (TRL) (Mankins, 1995) equal at 4 (i.e. the concept is a component and/or a breadboard validated in laboratory environment) (European Commission, 2014) or more; (ii) and they have to be freely available.

First, this paper presents the purpose of a taxonomy of crisis management simulation tools. In a second time, the structure of the first version of the taxonomy is detailed. Then, some perspectives regarding its use and governance are described before concluding.

CONTEXT

General context

In order to tackle the complexity of crisis management, in which a set of distinct actors have to be managed and coordinated (sometimes involving an international dimension), the simulation of a crisis situation (or a sub part of it) needs the use of several software simulation tools. Indeed, nowadays, there is no tool able to cover any kind of disaster situation. Thus, a combination of several simulation tools is required in order to support the simulation of any crisis situation.

One of the reasons of crisis management complexity is the multiple and tangled up interactions between three heterogeneous subsystems (Truptil, Bénaben, Couget, Lauras, Chapurlat and Pingaud, 2008): (i) the environment impacted by the crisis, (ii) the treatment system and (iii) the crisis itself. In this context, crisis management might be seen as the steering of a treatment system (including first responders and any other types of resources available to respond to the crisis) to deal with the crisis scenario on the impacted environment.

The *environment system of the crisis* is defined as the sub-part of the world affected by the crisis. It contains all the elements that can; on the one hand, be concerned by the situation, and on the other hand influence the crisis situation (physical descriptions of goods, roads and buildings, behavioral description of people, etc.), especially by providing their own intrinsic or emerging complementary risks.

The *treatment system* embeds all actors, capabilities and resources deployed to solve (or at least to reduce) the crisis. Consequently, such a treatment system contains involved actors (first responders) as well as crisis management systems (sensor networks, structure of sea walls, etc.).

The *crisis scenario* is defined as the dynamic description of the crisis. It contains the succession of events that describes the crisis progress. Most of these events concern components of the environment system (or potentially components of the treatment system if considered as new components of the environment system).

Consequently, because a specific crisis management situation information is required regarding (i) the specific environment system of the crisis, (ii) the specific treatment system available to solve the considered crisis and (iii) the specific scenario of the crisis, simulation of crisis situation and crisis management may require the same kind of inputs: one *scenario* to run over one *environment* and one *crisis management system* (*e.g.* one specific flood scenario over one specific European territory with a specific dike network and one evacuation plan). This triplet is called a *simulation model*.

How to select simulation tools to support experimentation

As explained before, DRIVER test-bed will propose to design and support crisis management experimentation. Therefore, when a user (i.e. an organization, an institution, a practitioner) wishes to test a crisis management tool, realize an experiment campaign, or even create a training session, he/she may need to simulate a subpart of (i) the crisis scenario (ii) and/or the impacted environment (iii) and/or the treatment system.

Selecting simulation tools able to feed the tested crisis management tools is not a trivial step, considering the sheer spread and diversity of existing simulation tools (in terms of covered topics and of types of simulation: virtual reality, pure simulation, etc.). Simulation tools are not always dedicated for crisis management but they can support it. For instance, SIAFU is a context simulator that allows simulating agents moving into places. These agents could be cars, pedestrians, particles or any entity the user wishes to simulate and visualize. Even if SIAFU is not specifically intended to simulate an emergency situation, it could be considered as a relevant simulation tool in the context of feeding crisis management tools.

This selection is based on user requirements that are dependent on the chosen scenario, the chosen environment and the chosen crisis management system (i.e. the chosen *simulation model).* Moreover, selected simulation tools have to interact together and also with the tested crisis management tools through the DRIVER test-bed platform. Thus, the input and output data have to be known from a functional (or business) and technical point of view to allow the integration with other simulation tools or live actions.

A taxonomy is defined to support this selection. This taxonomy aims at classifying simulation tools by business, legal and technical aspects. These three categories are presented in the remainder of this paper.

DEFINING A TAXONOMY

As such taxonomy has to help the user to select relevant simulation tools, it starts with three main entry points following user's main requirements: (i) business data (i.e. non-technical data), (ii) legal data and (iii) technical data. Whatever the chosen entry is, other entries are covered during the selection process, i.e. the user can decide to start the selection on business characteristics, then on technical characteristics and finally on legal characteristics. After investigation about taxonomies related to simulation tools to support crisis management tools, we found that if disaster taxonomies are widely discussed (Sementelli, 2007), and that research works aim at defining taxonomy for collaboration and command-and-control tools (Saarelainen and Jormakka, 2010), such a taxonomy dedicated to simulation tools does not exist to our knowledge.

Methodology

A campaign of investigation was lead among various users involved into crisis management: researchers, industrials and practitioners. A questionnaire was sent to them in order to describe the simulation tools they provide and/or use. The questionnaire covers several characteristics of the simulation tools (intended users, applicable types of crisis situation, functional and technical characteristics, successful past uses of the tool, etc.). The categories and questions are let as open as possible in order to allow the user to add other kinds of characteristics or relevant data that can improve the description of the simulation tool.

The first version of this taxonomy relies on the results gathered during the first campaign of investigation on existing simulation tools (three additional campaigns are scheduled) in order to create the most relevant taxonomy based on users' experience. For the moment, most of the categories values are set as open lists. The first investigation about simulation tools aimed at providing an overview of the common characteristics and the differences between the tools. The results of this investigation were used to define the first version of the taxonomy.

Business level characteristics

This first entry allows focusing on the most relevant tools (according user's requirements) from a non-technical point of view. Business characteristics are organized under 3 categories:

- *Domain* is the kind of disaster/emergency situation.
- *Type* is the kind of simulation tool.
- *Service* represents the service(s) offered by the tool.

Domain represents the disasters the simulation tool can handle. For this category, existing disaster taxonomies were used. The focus was set on taxonomies that distinguish natural disasters, industrial disasters and man-made disasters as higher levels of the disaster taxonomy like the ones described in (Taylor, 1987; Wirtz, Below, and Guha-Sapir, 2009). It is interesting to note that if the simulation tool can support a mix of several crisis situations occurring in a given time window in a given area (e.g. a tsunami followed a few hours after by a nuclear accident in a plant), this characteristic is also mentioned to help the selection of a simulation tool in the case of a simulation model including such a crisis situation.

The *type* of simulation tool focuses on the main purpose of the tool, e.g. the simulation of (i) a scenario (e.g. fighting wild fires), (ii) a model of crisis management actors (e.g. first responders), (iii) a model of crisis management system (e.g. a detection system) or (iv) a physical environment (e.g. a plant, a city).

Finally, the *service* category classifies the services that the simulation tool offers. These services can be related to (i) information visualization (e.g. maps, layers, diagrams), (ii) the level of immersive experience (e.g. 2D or 3D visualization, control of avatars), (iii) the available communication means (e.g. live chat, live tweets, radio, (mock) news), (iv) the generation of datasets, (v) the creation of reports, (vi) data analysis.

Legal level characteristics

The legal level gathers the characteristics related to the licensing, the terms of use, etc. In the first version of the taxonomy, legal characteristics are:

- *Licensing*. Depending on the licensing of the tool and of its produced material (open-source, proprietary), some restrictions may be applied to implement the simulation model.
- *Transborder area*. As the taxonomy is intended for a European use, the case of simulation model taking place into a transborder area has to be taken into account. Crisis management in transborder areas have an additional level of complexity due to the laws of the countries involved into the crisis. The use of the tool has to be validated by all the parties involved in the realization of the simulation model or considering the existing agreements between European countries.

Technical level characteristics

The technical level focuses on various characteristics of the simulation tools, from inputs and outputs to performance. In the first version of the taxonomy, we can find the following categories:

- *Owner*. The owner of the simulation tool. It is interesting to know the owner, as some simulation tools are part of a same tool suite. Even if they work independently, they can be more efficient if they work together.
- *Input/Output data*. The (i) format, (ii) interfaces and (iii) protocols used by the simulation tool to receive and produce data.
- *TRL*. The level of maturity of the simulation tool (according the European Commission definition (European Commission, 2014)).
- *Performance*. This category concerns (i) the time performances (real time simulation? N*real time?), (ii) the space performances (maximum size of the virtual terrain) and (iii) the scalability of the simulation tool (number of entities and events handled simultaneously).
- *Security*. The security requirements in terms of (i) communication protocol, (ii) data encryption, and (iii) data dissemination level (public, private, and confidential).

Further versions of the taxonomy will include a deeper technical description of simulation tools, according the results of the next rounds of investigation.

EXCERPT FROM THE TAXONOMY

In this section, we will present an excerpt of the first version of the taxonomy, where some of the investigated simulation tools are classified. This excerpt focuses on the Business level characteristics (one of the three entry points of the taxonomy).

	Natural disaster				Industrial disaster		Man-made disaster		…
	Fighting fires	Flood mitigation	Severe weather conditions	Pandemics	CBRN	Plant accident	Evacuation of large population	Terrorist attacks	…
AnyLogic	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
AnySim					Yes				
PROCeed		Yes		Yes		Yes			
SE-Star							Yes		
SUMO		Yes				Yes		Yes	
XVR	Yes				Yes	Yes	Yes	Yes	
Smart Water		Yes	Yes			Yes			
RIB Dispersion Air					Yes				

Table 1. Extract from the Domain category of the taxonomy

Table 1 presents a part of the *Domain* category (only few kinds of possible disasters are shown). Some of the investigated tools are frameworks that are able to support the design and/or the simulation of any kind of disaster. Thus it is also necessary to list the simulation models they actually offer. For example, AnyLogic offers a simulation model of flood mitigation in the Mediterranean area. On the contrary, some tools offer ready-to-run simulation implementations. For instance, PROCeed proposes by now three ready-to-run scenarios about flood, epidemic, and train accident (all located in West Poland).

Table 2 shows the types of tools (*Type* category of the taxonomy), i.e. if the simulation tool can simulate scenarios, models of Crisis Management (CM) actors and/or systems, physical environments.

	Scenario	Model of CM actors	Model of CM systems	Physical environment
AnyLogic	Yes	Yes		Yes
AnySim	Yes	Yes	Yes	Yes
PROCeed	Yes	Yes	Yes	Yes
SE-Star	Yes			
SUMO	Yes			Yes
XVR	Yes	Yes	Yes	Yes
Smart Water	Yes		Yes	Yes
RIB Dispersion Air			Yes	Yes

Table 2. Extract from the Type category of the taxonomy

Table 3 presents an extract from the *Service* category of the taxonomy. For the moment, the services are related to visualization, data (generation and analysis), interactions and communication. In Table 3, Y stands for Yes.

For clarity reasons, some details do not appear in the table. For example, the Data

Analysis category includes details about the used method: in the case of AnySim, the data analysis is a statistical one, based on Monte Carlo method.

	Vizualisation			Data			Interaction		Communication
	Diagrams	Maps	3D environment	Generation of datasets	Analysis	Metrics	Question & Answers	Immersion (avatar)	Textual comunication (chat)
AnyLogic	Y					Y			
AnySim	Y	Y		Y	Y				
PROCeed	Y						Y		Y
SE-Star			Y	Y					
SUMO	Y	Y		Y					
XVR			Y	Y				Y	
Smart Water		Y		Y					
RIB Dispersion Air		Y		Y					

Table 3. Extract from the Service category of the taxonomy

PERSPECTIVES

To improve the selection process and offer the user a better support, a knowledge base (such as an ontology or a graph database) can be created using the taxonomy. The addition of exploitation rules may greatly improve the selection process. Indeed, similarity between (sub) categories of the taxonomy can help the suggestion of the nearest available simulation tool in the case where no match was found regarding the user's requirements and the available simulation tools.

In addition, even if this taxonomy is designed in the context of the DRIVER project, it is intended in the end to be used by a wider community than DRIVER's one. From this perspective, a taxonomy governance policy has to be defined, in order to take in charge of the ongoing maintenance (considering the potential evolution of users' needs, their feedback, the release or improvement of simulation tools, etc.).

CONCLUSION

In this paper, we have presented a taxonomy to describe and classify crisis management simulation tools. This taxonomy aims at helping the stakeholders to choose relevant simulation tools to stimulate their own crisis management tools on the DRIVER test-bed according their simulation model. For the moment, the first version of the taxonomy focuses on general aspects such as the kind of applicable disaster, the kind of tool and the services offered by the simulation tool, and some legal and technical characteristics. Further evolutions of the taxonomy will include (i) an extended and consolidated taxonomy of existing disasters and services, and (ii) a deeper description of data exchanged among the simulation tools and the test-bed. An implementation of the taxonomy as an ontology or a graph database (using Neo4J (Neo Technology, Inc, 2015), an open-source NoSQL graph database) is also envisioned to improve the selection process of simulation tools. In the end, the taxonomy will have a sufficient structure to embed the knowledge gathered about simulation tools and help the user to implement the required simulation model.

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