M-CREAM: A Tool for Creative Modeling of Emergency Scenarios in Smart Cities

Antonio De Nicola[1][0000−0002−1045−0510],
Michele Melchiori[2][0000−0001−8649−4192],
Maria Luisa Villani[1][0000−0002−7582−806X]

[1] Computing and Technological Infrastructure Lab, ENEA
Rome, Italy
{antonio.denicola|marialuisa.villani}@enea.it
[2] University of Brescia,
Dip. di Ingegneria per l'Informazione, via Branze, 38
25123 Brescia - Italy
michele.melchiori@unibs.it

Abstract. We present M-CREAM (eMergency-CREAtivity Machine), a novel tool for model-based elicitation of emergency management scenarios by the city planners. M-CREAM suggests creative insights on new emergency situations to users, in the form of ontology-based conceptual models named mini-stories. Search and ranking techniques allow users to explore the mini-stories' space, by leveraging semantic and computational creativity methods. A demonstration scenario focused on an Italian city illustrates the main features of the tool.

Keywords: emergency management, domain ontology, contextual rules, design pattern, computational creativity.

1 Introduction

A smart city aims at providing high quality of life to people living and visiting it. However, smart city ecosystems are threatened by several types of hazards, possibly hard to foresee, as natural disasters, terrorism, cyber attacks and cascading failures, due to the complexity of infrastructure interconnections. Thus, preparation to manage emergencies in this context is a relevant issue.[3]

We present M-CREAM[4], a new tool for emergency preparedness through scenarios elicitation and information sharing among different institutional operators who have a role in emergency management processes. Based on the architecture described in [3], the tool aims at easing human imagination and creativity to foresight emergency scenarios, by means of automatic creation of (parts of) emergency management (EM) scenario models, named *mini-stories*, by relying on formalized knowledge of the problem domain. In addition to [3],

[3] https://www.smartresilient.com/emergency-preparedness
[4] Demo video at https://youtu.be/HVuHxCttnss

mini-stories are the basis for more detailed user descriptions of EM situations realizing scenario analysis models by means of a storytelling approach.

The distinguishing features of the tool are: a domain ontology to describe the smart city ecosystem, the roles operating in it, and the types of hazards, which is used both to represent known emergency situations and search for new possible ones by means of semantic reasoning and computational creativity [2] techniques; a library of design patterns for EM scenario models; an engine for automatic generation of mini-stories based on design patterns and rules; intelligent search functions for exploring the mini-stories repository; automatic building the textual description of the full EM scenario from a pre-defined structure following a storytelling-type approach.

As far as we know, this tool is original in both aim and semantics-based EM scenarios modelling method. Previous works by some of the authors, e.g., [1], present a CREAM application to risk analysis of critical infrastructures, whereas a different creativity support to safety assessment in industry is proposed in [4].

Section 2 of the paper presents the M-CREAM architecture and modelling functions. The users and functioning of M-CREAM are described in Section 3 by means of a demonstration scenario.

2 M-CREAM for scenario modelling

The M-CREAM architecture, shown in Fig. 1, consists of a knowledge base and a set of modules to support creative scenario modelling through a web interface. Our approach, enhancing [3], requires some configuration activities on the knowledge base to adapt it to a specific city. These are performed by knowledge engineers through general purpose tools, like Protégé[5] and XML editors. The knowledge base components are the following.

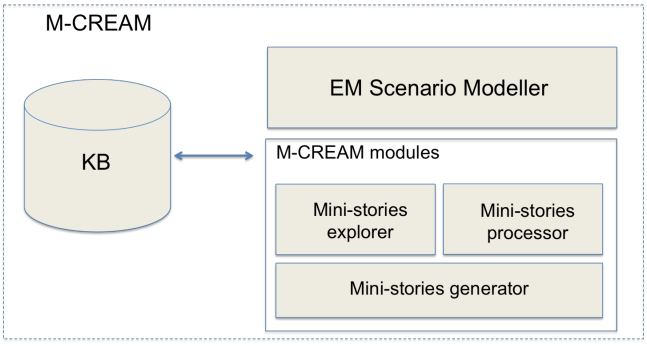

Fig. 1. M-CREAM architecture

EM smart city ontology and design patterns. The ontology integrates knowledge on hazards, critical infrastructures, (smart) services for companies and citizens, emergency services, and users. These categories are linked by means of an upper level ontology based on the CEML metamodel, a SysML profile to

[5] https://protege.stanford.edu

model emergency management in socio-technical systems. CEML concepts include: *External Event*, *Service*, *Human Service*, *(Human) Resource*, and *User* [6]. Mini-stories are generated by means of CEML-based design patterns.

Scenario structure, representing a trace for user scenarios at run-time. A scenario is a composition of mini-stories. Similarly to games, it has a target state (e.g., recovery of people or extinguishing a fire), and an initial state, i.e., available resources and involved actors. Following this view, a scenario is associated with three stages: *opening*, *exploring* and *closing*. The first stage defines the initial role of actors involved in the scenario and the initial events. The second stage is when the actors explore the scenario and new situations could arise. In the third stage actors move towards the target state through actions and decisions.

Scenario context and relevance metrics. The scenario context refers to the actual city, with geographical and political characteristics. Space-time contextual rules, such as presence of infrastructure services (e.g., Rome does not have wind power plants) and current regulations on emergency management (e.g., the army does not intervene in case of clashes), are defined. These rules complete the formal requirements for the mini-stories generation by M-CREAM. Metrics such as on the economic impact of a damage, and their evaluation over the concepts of the ontology, allow to estimate the overall relevance of generated mini-stories.

The EM scenario modelling activities are performed by city planners through the web GUI of the *Scenario Modeller* component, shown in Fig. 2. A user selects a design pattern from a pre-defined list at the left-hand side of the GUI. Thus, the *Mini-stories generator* component produces a set of mini-stories based on that pattern, shown in the lower part of the GUI. The central part of the GUI shows a CEML diagram of a mini-story automatically generated from a design pattern. This represents the following situation. *The* ***Salt water intrusion*** *external event impacts on the* ***Water distribution network*** *service providing* ***drinking water*** *to users. The* ***Police*** *human service sends* ***policemen*** *to help in the emergency.* A textual description of the design pattern is reported over the diagram. The mini-stories generation process works as follows. Once a pattern is selected from the list, a SPARQL query is constructed by accounting for the CEML concepts and relationships used in that pattern to retrieve all of their specializations from the domain ontology. Structural and contextual rules provide filter statements for that query, which is implemented through the Apache Jena framework[7]. The *Mini-stories explorer* implements search methods to help users in the identification of scenario contents. These follow those computational creativity techniques [2] according to which a new design can result from *transformation* of aspects of some known design and/or by *analogy* thinking. In particular, search functions use mini-stories ranking by relevance and semantic similarity elaborated by the *Mini-stories processor*. The toolbar of the central panel of the GUI provides two means to automatically suggest a mini-story: a *Hint!* button shows a randomly chosen mini-story; a *Change* button modifies all

[6] The OWL version of the ontology can be visualized by the WebProtégé tool at the address `https://tinyurl.com/crisismng3-0`

[7] https://jena.apache.org

or parts of a given mini-story A with concepts that are either semantically very distant or very similar to their correspondent in A. The toolbar of the lower panel provides mini-story filter functions and ranking by relevance (last column). User described mini-stories, as shown in the editing window of Fig. 2, associated with the three stages of scenario definition, can be selected from the list at the right panel, and combined to provide the full EM scenario description.

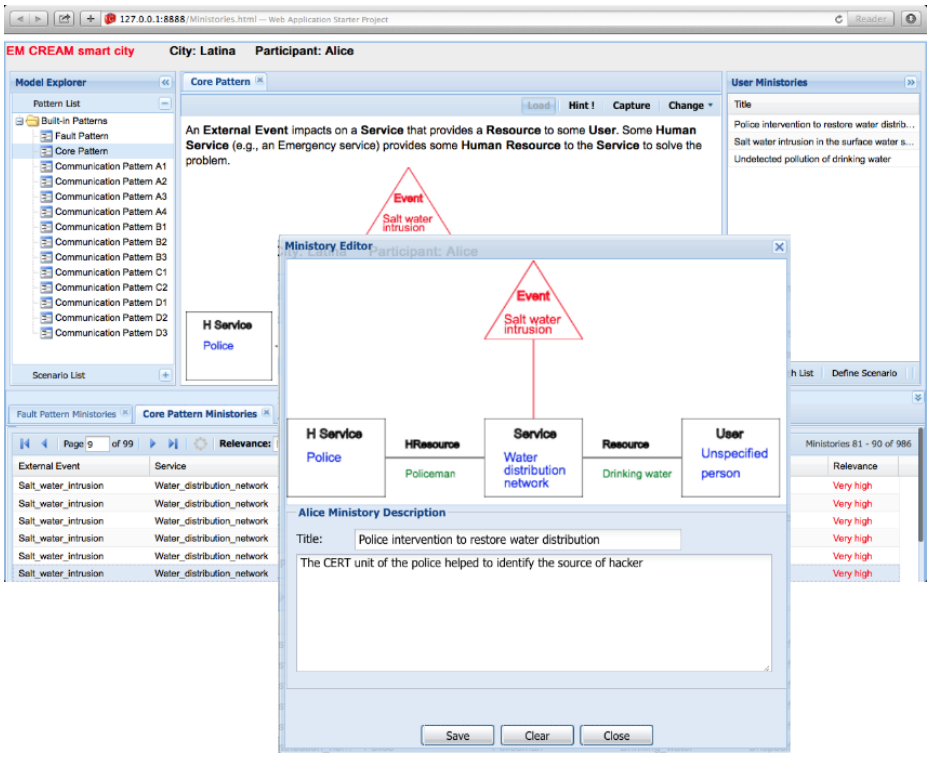

Fig. 2. M-CREAM interface: patterns, mini-stories and user mini-story editing

3 Demonstration on a case study

M-CREAM has been positively evaluated at some Italian public institutions having an official role in emergency management. We report a narrative on how the tool was used during one experiment and the resulting relevant scenario[8].

The Civil Protection intends to prepare facing emergencies from increasing seasonal temperatures in Italy in the last years. Various governmental institutions contribute to the activity of EM scenarios foresight from their own perspective, so employers of an environmental agency located in Latina use M-CREAM, which had been previously configured as follows.

A EM scenario will consist of one or two *start* mini-stories based on the *Fault Pattern* (see the patterns list on the left side of Fig. 2), referring to services

[8] Details are shown in the video at https://youtu.be/HVuHxCttnss

impacted by some events. Then a couple of subsequent mini-stories, based on *Communication Patterns*, represent how the information about the emergency is propagated. Finally, an *end* mini-story, based on the *Core Pattern*, describes intervention from emergency services.

The scenarios are located in Latina, a seaside city, and the environmental agency is mainly interested in water related hazards impacting on infrastructure services. Filter rules on events and infrastructures, such as absence of metro, are defined accordingly to restrict the scope of mini-stories generation.

Silvana, an employee of the agency, first focuses on the *highest relevant* mini-stories to describe the emergency of her scenario. While doing so, she considers a risk following a drought, based on two proposed mini-stories: one representing *salt water intrusion* interfering with *drinking water* from a *water distribution network*, and the second showing the same event impacting on the *drought monitoring* service, which sends *information about critical situation* to an *enterprise*. So, she edits the following piece of scenario by describing those mini-stories. *A drought at Latina leading to an increased groundwater abstraction, caused salt water intrusion from the nearby sea. This event, once captured by the drought monitoring unit, is communicated to the water distribution company.* For the development of the scenario with unusual situations, Silvana decides to use the *Hint!* function on the Communication Patterns. After some tries, and usage of the *Change* function on the proposed mini-stories, she describes and connects three other mini-stories suggesting an interesting sequel that is so synthesized: *An hacker-type vandalism at the water company had caused the water quality alarm being undetected internally. An employee informs the city mayor of the possible water contamination and of the service interruption. The intervention of the police cybercrime unit at the water network allows to restore the service.*

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