Simulating Spontaneous Volunteers: A System Entity Structure for Defining Disaster Scenarios

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ABSTRACT

Fast and easy communication, e.g. via Twitter or Facebook, encourages self-coordination between spontaneous volunteers in disasters. Unfortunately, this is more and more challenging official disaster management. The need for the directed coordination of spontaneous volunteers triggered researchers to develop effective coordination approaches. However, evaluating and comparing such approaches as well as their exercising are lacking a standardized way to describe repeatable disaster scenarios, e.g. for simulations. Therefore, we present a novel System Entity Structure (SES) for describing disaster scenarios considering the disaster environment, communication infrastructure, disaster management, and population of spontaneous volunteers. The SES is discussed as a promising scheme for including spontaneous volunteers in disaster scenarios on a general level. Its applicability is demonstrated by a Pruned Entity Structure derived from a real disaster scenario. Based on the results, we give an outlook on our subsequent research, the XML-based Spontaneous Volunteer Coordination Scenario Definition Language (SVCSDL).

Keywords

Agent-based Simulation, Spontaneous Volunteers, Spontaneous Volunteer Coordination Scenario Definition Language (SVCSDL), System Entity Structure (SES), Disaster Scenario.

INTRODUCTION

Spontaneous volunteers, i.e. people who spontaneously help in urgent disaster situations and who are not affiliated to official civil protection organizations (Barraket *et al.*, 2013; Ludwig *et al.*, 2017; Zettl *et al.*, 2017), play an important and active role in disaster response (Fernandez, Barbera and Dorp, 2006; Sauer *et al.*, 2014; Lindner, Betke and Sackmann, 2017; Ludwig *et al.*, 2017). For years, the phenomenon of spontaneous volunteers in major disaster events has moved both the media and research. Modern communication technologies, such as social media, have raised the phenomenon of spontaneous volunteers to a new level (Meissen *et al.*, 2017; Reuter and Kaufhold, 2018) that makes an examination of the topic in disaster management indispensable. During the disastrous floods 2013 in Germany, the continuous presence of the disaster in social media led to massive participation of the population to cope with the disaster. While this spontaneous support of the official disaster relief forces was crucial for overcoming the disaster, it also led to various problems: due to incorrect and subjectively designed information some operating sites were overcrowded by volunteers whereas others were dramatically understaffed, and several volunteers exposed themselves to danger through unauthorized actions (Fernandez, 2007; Hofmann, Betke and Sackmann, 2014).

The enormous cooperativeness of spontaneous volunteers, as well as the lack of approaches for their coordination, have triggered a large number of new research projects (German Federal Ministry of Education and Research, 2018b). Several projects, e.g. KUBAS (Rauchecker and Schryen, 2016), AHA (German Federal Ministry of Education and Research, 2018a), REBEKA (Johanniter-Unfall-Hilfe e.V., 2018), ENSURE (Fraunhofer-Institut für Offene Kommunikationssysteme FOKUS, 2018), KOKOS (Project KOKOS, 2018) or K3 (German Federal Ministry of Education and Research, 2018c), explore the improvement of the coordination of spontaneous volunteers by using modern information and communication technologies. Recently developed concepts, demonstrators, and prototypes are confronted with the challenge of scientific evaluation to demonstrate and compare their usability and added value. This may be done in real disasters or field tests, that, however, are usually too expensive, elaborate, and partly impossible to conduct. Since field experiments are not sufficiently realistic, real disasters are too dangerous and both are hardly reproducible, computer simulation is an appropriate approach to test, evaluate, and optimize real-world scenarios and approaches with a minimal effort. Furthermore, simulations enable the disaster staff to perform exercises in using such systems at regular intervals due to the possibility to describe and define reproducible disaster scenarios. Simulating spontaneous volunteers can also facilitate the possibility of forecasting their behaviors in real disaster situations.

Regardless of how such evaluations or exercises are carried out methodically (e.g. field trials, simulations), a reusable, standardized, and ideally formalized description of disaster situations is required. Since such suitable methods do not yet exist, our research goal is to develop a model for the specification of disaster scenarios including spontaneous volunteers as an artifact that is further the basis for the subsequent development of an XML-based Spontaneous Volunteer Coordination Scenario Definition Language (SVCDSL). On the one hand, the model enables an understanding of disaster scenarios with spontaneous volunteers on a conceptual level, e.g. to develop scenarios for field trials. On the other hand, it provides the basis for developing an executable disaster scenario definition language for simulations.

The artifact development is part of a research project following the well-established Design Science Research Process methodology proposed by Peffers et al. (Peffers *et al.*, 2007) and covers the third phase – "Design and Development". The whole project aims at the development of a universal spontaneous volunteer simulation application in disaster situations to evaluate and compare spontaneous volunteer coordination approaches as well as to predict the volunteers' behaviors in acute disaster situations. Agent-based simulation has therefore been identified as a proper method to simulate the behavior of spontaneous volunteers in a disaster context. Results of the first two DSRP-phases of this project are described in (Lindner *et al.*, 2018; Lindner, Betke and Sackmann, 2017) where a structured literature analysis has been performed and a conceptual model of spontaneous volunteer behavior has been developed. To further enable the comparison and evaluation of spontaneous volunteer coordination approaches using agent-based simulations, it is required to identify all relevant entities as well as to establish reproducible and machine-processable scenarios. Since the development of the language artifact in this paper requires a constant exchange with experts, specialists and end-users and the results have to continuously be evaluated and improved, Action Design Research (ADR) according to Sein et al. (Sein *et al.*, 2011) is utilized as a concrete method.

Based on other studies, as a first step, so-called System Entity Structures (SES) are identified and discussed as an adequate approach for our research (Section 2). Accordingly, in Section 3, relevant elements for describing disaster scenarios are identified from the literature. Following the corresponding IEEE guideline for scenario development, in Section 4 the identified elements are categorized and used for developing the aspired artifact. The applicability of the developed SES is demonstrated in Section 5 by using a concrete example of the 2013 flood disaster and transferring the SES into a so-called Pruned Entity Structure (PES). As a final step, the developed SES is discussed and an outlook for defining an open and extensible XML-based language called Spontaneous Volunteer Coordination Scenario Definition Language (SVSDL) is given.

DEVELOPING SCENARIOS WITH SYSTEM ENTITY STRUCTURES

Reproducible, reusable, and executable scenarios provide a sound foundation to evaluate coordination approaches and systems as well as to compare different ones since these scenarios enable the measurement of differences under identical circumstances. The IEEE defines scenarios on the one hand as a description of an exercise that "is part of the session database that configures the units and platforms and places them in specific locations with specific missions" (IEEE, 2011). On the other hand, scenarios are described as "[an] initial set of conditions and timeline of significant events imposed on trainees or systems" (IEEE, 2011). Although the definition and development of scenarios are defined by the IEEE on a general level, a particular method to perform scenario creation is not proposed. Instead, the selection of a proper tool or technique is seen as one explicit step of the scenario development (IEEE, 2011). To determine a suitable method for developing the aspired scenario, a literature review has been performed to identify publications that either have developed simulation scenarios in general or that have defined scenarios for the coordination of spontaneous volunteers in particular.

For the literature review, the keywords *simulation*, *scenario*, *reproducible*, *spontaneous volunteer, coordination, scenario language*, *scenario development, agent-based simulation, disaster* and some of their combinations have been searched in various scientific databases, such as WileyOnline, ScienceDirect, SpringerLink etc. as well as in Google Scholar. We have limited our search to publications after 2000 to maintain a certain topicality. In addition, forward and backward searches have been carried out to identify further relevant publications.

The literature review revealed that the development of models for standardization and description of scenarios is addressed in various areas. For example, the Military Scenario Definition Language (MSDL) published by the Simulation Interoperability Standards Organization (SISO) has been established in the military sector (Blais, 2008; Wittman Jr., 2009). Other models exist in the transportation sector where road traffic, particularly driver behavior, was described, e.g. (Adler *et al.*, 2005; Fuchs *et al.*, 2008). Standardized scenarios are also used in health management to train nurses for emergencies (Waxman, 2010; Alinier, 2011). Furthermore, Jafer et al. have developed a language that describes standard scenarios in aviation (Jafer *et al.*, 2016). In addition, there are many contributions dealing with the development of scenarios for multi-agent systems on a general level (Murakami *et al.*, 2003; Nakajima *et al.*, 2006).

The literature review also revealed that several authors research on the question of how scenarios can be developed to better manage disasters and predict their progressions (e.g. (Sun *et al.*, 2015)). However, the proposed models are either very specific (e.g. (Su, Wang and Zhang, 2016; Simões *et al.*, 2011)) and not suitable for standardization or the scenarios rather focus on decision support for emergency forces and aid organizations (e.g. (Drury *et al.*, 2009)) and do not take spontaneous volunteers as valuable resources into consideration. In summary, our literature review revealed that there is no description of disaster scenarios especially focusing on the coordination of spontaneous volunteers yet. This fosters our effort to develop a corresponding Scenario Definition Language for describing and executing such scenarios.

However, the identified work revealed successfully applied tools and techniques for developing scenarios. In particular, the Simulation Scenario Development (SSD) as a method proposed by the IEEE has already been approved, e.g. (Jafer and Durak, 2017). Following the SSD approach, the foundation of any scenario documentation is the identification of entities, their behaviors, and events that need to be represented in the scenario(s) (IEEE, 2011). Since the behavior inevitably results from the simulation environment, we focus on the identification of events and entities. The SSD approach described by the IEEE merely provides steps that are necessary for a successful scenario definition, but, unfortunately, it does not discuss its actual application. For applying the SSD, several researchers in different domains have already successfully used so-called System Entity Structures (SES) as a methodological framework (see, e.g. (Ntaimo *et al.*, 2004; Lee and Zeigler, 2010; You, Chi and Kim, 2013; Schmidt, Durak and Pawletta, 2016; Durak *et al.*, 2017)). SES is using a data model that reflects system-engineering concepts of hierarchical decomposition and specialization (Cheon, Kim and Zeigler, 2008). SES is also based on a limited set of elements (entity, aspect, specialization, and multi-aspect) and axioms that can be introduced as a directed labeled tree (Durak *et al.*, 2017). Since this characteristics allow an automatic creation of XML schemata (Cheon, Kim and Zeigler, 2008), SES is seen as suitable to close the gap between structured scenario definitions proposed by IEEE and a machine-processable language and, thus, it is seen as an appropriate method leading to the aim of our research, namely the desired SVCSDL.

Simulation scenarios can be categorized into three types that need to be developed in the scenario development process, namely operational scenario, conceptual scenario, and executable scenario (Siegfried *et al.*, 2012; Simulation Interoperability Standards Organization, 2015). Accordingly, the operational scenario usually describes the targeted real-world scenario in a textual form providing a broad description of the desired events and elements. For our research, descriptive reports on coordinating spontaneous volunteers have been analyzed to provide basic information on how volunteers were coordinated in real disaster situations. The results of this analysis as well as the required deeper investigation on element details and interrelations are presented in Section 3 leading to the identification of entities and, consequently, to the conceptual scenario, that usually is a formal metamodel representation. As the basis for a formal description of an executable scenario in an XML-Schema that can be processed by simulation applications, all scenario-specific information is subsequently represented as a System Entity Structure (see Section 4).

ELEMENTS FOR DESCRIBING DISASTER SCENARIOS WITH SPONTANEOUS VOLUNTEERS

To develop scenarios, it is important to understand what distinguishes them. According to the IEEE guideline, scenario(s) include “types and numbers of major entities/objects that must be represented within the simulation environment“ (IEEE, 2011). Consequently, the IEEE describes scenarios to have various entities being represented within the aimed at environment. As SES has already been applied to define scenarios, we adopt this method to develop the spontaneous volunteer coordination scenario. In “Modeling & Simulation-Based Data Engineering: Introducing Pragmatics into Ontologies for Net-Centric Information Exchange“ Zeigler and Hammonds explain the development of SES and all related elements. In general, SES consists of Entities, Aspects and Specializations. According to Zeigler and Hammonds “Entities represent things that exist in the real world or sometimes in an imagined world. Aspects represent ways of decomposing things into more fine-grained ones. Multi-aspects are aspects for which the components are all of one kind. Specializations represent categories or families of specific forms that a thing can assume“ (Zeigler and Hammonds, 2007).

The required authoritative domain information for the scenario development (IEEE, 2011) have been identified and analyzed by literature reviews, preliminary work and expert discussions. In this section, according to the SES development by Zeigler and Hammonds, we will discuss the relevant entities for describing disaster situations and decompose them into specializations and multi-aspects and, if necessary, attach variables to the identified entities.

As basic entities that are discussed in the following in more detail, we identified **Disaster Management** and **Spontaneous Volunteers** inevitably resulting from the targeted domain and research goal. According to the IEEE guideline, the **Environment** must be taken into consideration and, thus, is a basic entity that represents a superset of the scenario components. As experiences show, communication has a significant influence on the self-coordination of spontaneous volunteers as well as on the possibilities for official disaster management to coordinate them according to the official needs. Sackmann et al. even see communication as a central design object for the coordination of supporting activities (Sackmann *et al.*, 2018). Thus, as forth entity, **Communication Infrastructure** is defined as a basic entity for our scenario description as well. Furthermore, the IEEE guideline suggests modeling scenario triggers and stop conditions. As a starting point, these are defined according to the typical phases of disaster scenarios (Thieken *et al.*, 2007): the scenario gets triggered by the disaster event and the beginning of the disaster response phase or its simulation. The stop of the scenario is given over to the scenario modeler since it depends on the particular goal.

Environment (Basis Entity #1)

According to the IEEE guideline, the environment is a superset of the scenario components comprising aspects, e.g. geographical regions, natural environment conditions, initial and termination conditions. This entity with its aspects defines the general behavior of entities and, consequently, the simulation of their behavior.

Inherently important for any disaster scenario and its simulation is the definition of **geographical areas**. There exist several concepts for defining areas, e.g. center point and radius (Nelson, Iii and Kravets, 2007) or polygonal pathways (Wagner and Agrawal, 2014). There might be good reasons for describing geographical regions in a very detailed manner. However, as a starting point for our scenario description, we decided to use a simple concept of overlapping circles that are defined by their center (longitude/latitude) and radius. Extending or replacing this simple concept is easy to realize without changing the general result of our research. These geographical areas are represented in our SES as a Multi-aspect as there can be several areas or locations within the environment and accordingly within the scenario. The definition of the geographical areas at the beginning of the scenarios enables the re-utilization of these regions in other entities within the SES.

Our literature review revealed **weather** to be one main aspect in the disaster context (e.g. (Geißler, 2014; Kircher, 2014)). It is not only relevant to the disaster itself but also for the willingness of volunteers to help (Geißler, 2014; Kircher, 2014). Thus, the weather was chosen to be represented within the SES. Reports and publications on past disasters proposing the weather as an influencing factor usually describe weather with attributes like "nice", "warm", "bad", "rainy" etc. (Geißler, 2014; Rauchecker and Schryen, 2018) However, since such terms are rather subjective and vague, we propose a more general type of description in terms like precipitation, rain intensity, temperature, humidity, etc. as variables in our SES. These variables can subsequently be interpreted and used to simulate the influence of weather on, e.g. the motivation of spontaneous volunteers to help. In the SES, we represent the weather as a Multi-aspect as, in combination with the geographical areas, weather can be defined locally and may be different within one scenario.

Communication Infrastructure (Basis Entity #2)

Recent disasters have shown that communication (between spontaneous volunteers themselves as well as between volunteers and official disaster management) and limited accessibility has played a crucial role in the (self-)coordination of spontaneous volunteers (Reuter and Kaufhold, 2018). Communication infrastructure and their availability in a disaster situation determine how information be disseminated and, thus, have to be described within the scenario definitions. Literature and experiences show that communication is at least determined by its technical as well as its organizational realization (see, e.g. (Asplund, Nadjm-Tehrani and Sigholm, 2009; Reuter and Kaufhold, 2018)). Thus, we defined these two dimensions as relevant aspects of our scenario description.

From a technical perspective (**technologies**), communication infrastructure can differ with respect to communication channels and, thus, with respect to communication content. For example, SMS are limited to text-only content and require at least a GSM network, whereas mobile applications or social networks are not necessarily limited to a number of characters or text/media but require different infrastructures such as the Internet via WIFI, LTE, or HSDPA. Since the availability or access to communication technology is usually confined (e.g. not all people use all communication channels in parallel, limited capacity on the side of network provider, blackout), the description of a disaster scenario should necessarily enable the definition of capacities for specific areas. Thus, we defined communication technologies as a Multi-aspect of communication infrastructure as one scenario can have several technologies in different areas with different capacities.

From an organizational perspective (**communication types**), a first relevant characteristic of communication is the type of communication **participants**. Since self-coordination between volunteers as well as directed coordination of volunteers by official disaster management is in the focus of our research, communication participants include at least the official disaster management (**DM**) and the spontaneous volunteers (**SV**). Since both parties can be sender as well as the receiver of information, this is seen as one main aspect for describing communication infrastructure. A second main aspect is whether the **relationship** between sender and receiver is a one-to-one (**one2one**) or a one-to-many (**one2many**) relation. The possibility to describe these relations allows, together with the categorization of the communication participants, to define general possibilities for uni- or bidirectional communication. Scenarios can, thus, be limited to, e.g. the communication between spontaneous volunteers among themselves in a broadcasting manner (one2many) and, thus, influence their behavior and the kind of information that may be disseminated. However, also the technological perspective may play a role in how and which information can be disseminated, why we see technologies as a third influencing and limiting aspect in the communication type. As we assume that technologies indispensably be linked with the relationship and participants, we represent both, relationship and participants as Specializations that necessitate a selection of each. E.g. one kind of participant (e.g. SV2SV), can have one relationship (e.g. one2many), that can be realized upon a selection of technologies. This general description allows remaining open for current (and also future) communication technologies.

Disaster Management (Basis Entity #3)

Disaster management is responsible for organizing response activities during a disaster in order to minimize its impact. Disasters are tackled at so-called **operating sites** by disaster management, where official disaster relief forces work—sometimes supported by spontaneous volunteers—to mitigate disaster scales. Typically, disaster response and mitigation are conducted based on a command and control structure of different levels whereas the disaster management is on a strategical level, e.g. in the form of crisis committees. Operating sites are on a tactical or operational level. Since disaster management is usually organized from an official site (e.g., government) and usually not supported by spontaneous volunteers, the disaster management entity in our approach is focused on the description of operating sites. Operating sites are commonly the only physical contact points between spontaneous volunteers and official disaster relief forces. However, a subsequent extension of the model may include the integration of other crisis units and/or on-site emergency personnel in the future.

Following literature and official organization rules, operating sites are mainly characterized by its location resp. area (**geographicArea**), its required tasks and durations, and required resp. available resources. Depending on the scenario, there can be different operating sites, while each operating site can require different **tasks** to be fulfilled for completion (Rauchecker and Schryen, 2018). For example, common tasks in a flooding scenario may be sandbag filling, carrying sandbags, and so on at different locations along a river. However, the tasks that may be required on operating sites can differ and, thus, have to be considered within the scenario. Since our research is focused on the use of spontaneous volunteers as a valuable resource on operating sites, the coordination of operating sites is restricted to tasks that could be supported or executed by spontaneous volunteers. Therefore, we modeled the operating sites consisting of tasks and its locations as well as by defining the required number of volunteers working at a specific task for completing it effectively. Also, we identified the estimated duration of the specific task as an important variable as it influences the number of required volunteers per time unit and further has an effect on volunteers' decision to help if it is known.

Spontaneous Volunteers (Basis Entity #4)

For describing a disaster scenario, it would not be helpful to define each spontaneous volunteer and his/her decisions and behaviors individually. This would lead to a deterministic scenario and would not fulfill the requirements for using the described scenario for the evaluation of coordination systems or performing disaster exercises. Consequently, spontaneous volunteers are described in the form of populations with probability distributions of relevant variables and entities.

To describe characteristics of individual spontaneous volunteers and their motivation to help during a disaster, the state-of-the-art is extensively discussed in (Lindner, Betke and Sackmann, 2017) providing a solid basis for describing spontaneous volunteers in disaster scenarios. Accordingly, the age, experience, concernment, etc. were exemplarily adopted into the SES as variables to describing the **general** characteristics of the population. A comprehensive list of all relevant variables is given in (Lindner, Betke and Sackmann, 2017). To assign these attributes, the required distributions can either be chosen at will or they can be derived from (demographic) data of the respective location. Since the related literature still is in an early research phase and its behavior impacting attributes have not yet fully been proven, we propose these variables to be extended in future versions. Also, the population size of potential volunteers might differ between different areas, like there are usually massive differences between rural and urban areas. To describe these location-dependent differences in disaster scenarios, we propose **geographic areas** to be an aspect of each population, particularly being an aspect of the general entity. The location-dependent modeling of populations may lead to the representation of many populations within the scenario.

In addition to these general characteristics, the description of spontaneous volunteers should be extended by their communication abilities. As mentioned, when discussing the communication infrastructure, the use of communication devices and, thus, **technologies** vary from person to person. Consequently, the availability of communication technologies is defined as an additional aspect for spontaneous volunteer populations that should be represented in disaster scenarios. For instance, the distribution of smartphone users, users of social media, etc. would be reasonable, if these infrastructures are modeled within the scenario in the communication infrastructures. Therefore, the distribution per each technology used in the scenario must be specified to affect the volunteer's behavior.

We have further identified variables and entities that are related to the **operations** spontaneous volunteers can have. One main characteristic of volunteers is their willingness and ability to perform specific tasks. Since not everybody is able to carry heavy sandbags or to take care of shocked people, this restriction has to be part of any scenario definition. The description of scenario-specific **tasks** has already been discussed in the context of disaster management, thus, to represent these tasks within the volunteer populations, we propose a distribution of all tasks within a scenario. Another behavior-impacting aspect of volunteers is external restrictions like country-specific legal requirements or regulations. Such regulations may limit the working time of spontaneous volunteers to a few hours per day. E.g., German law restricts the working time to 8 hours per day.[1] Also, physical abilities and other commitments may affect the working time. Furthermore, individual working duration preferences, i.e. for how many days a volunteer will help, have to be modeled. Thus, for describing the operation within the SES, we propose the variables “workTimeDistribution”, “workDurationDistribution” as well as the aspect “tasks”.

MODELING SCENARIO ELEMENTS WITH SYSTEM ENTITY STRUCTURE

The entities, (multi-)aspects, specifications, and variables defined and described in the previous section represent the static dimension of the aspired scenario description. To complete the SES according to the IEEE specification, a dynamic dimension is required, namely the time-dependent progression of simulation scenarios (IEEE, 2011). To describe the dynamics of a disaster scenario, the scenario itself, as well as the variables of the entities, have to be changeable during the scenario. The IEEE proposes time-related events that trigger a change in the parameters at the respective point in time and are accordingly interpreted by the simulation software. Since events can affect all identified SES elements, they are defined as a common characteristic at the top of the SES hierarchy. Depending on the dynamics and level of detail, a simulation scenario can consist of any number of events. We suggest the use of the actual time (time and date) for executing a disaster scenario, since time might also influence the behavior of the spontaneous volunteers (see (Lindner, Betke and Sackmann, 2017)). Consequently, we propose datetime as a variable of the event. Nevertheless, faster processing of the events in the scenarios can be facilitated by the acceleration of simulation experiments. As result, the identified and discussed mandatory elements for describing and executing disaster scenarios with taking spontaneous volunteers into consideration are depicted as an SES in Figure 1.

[1] section 3 German Hours of Work Act (ArbZG)

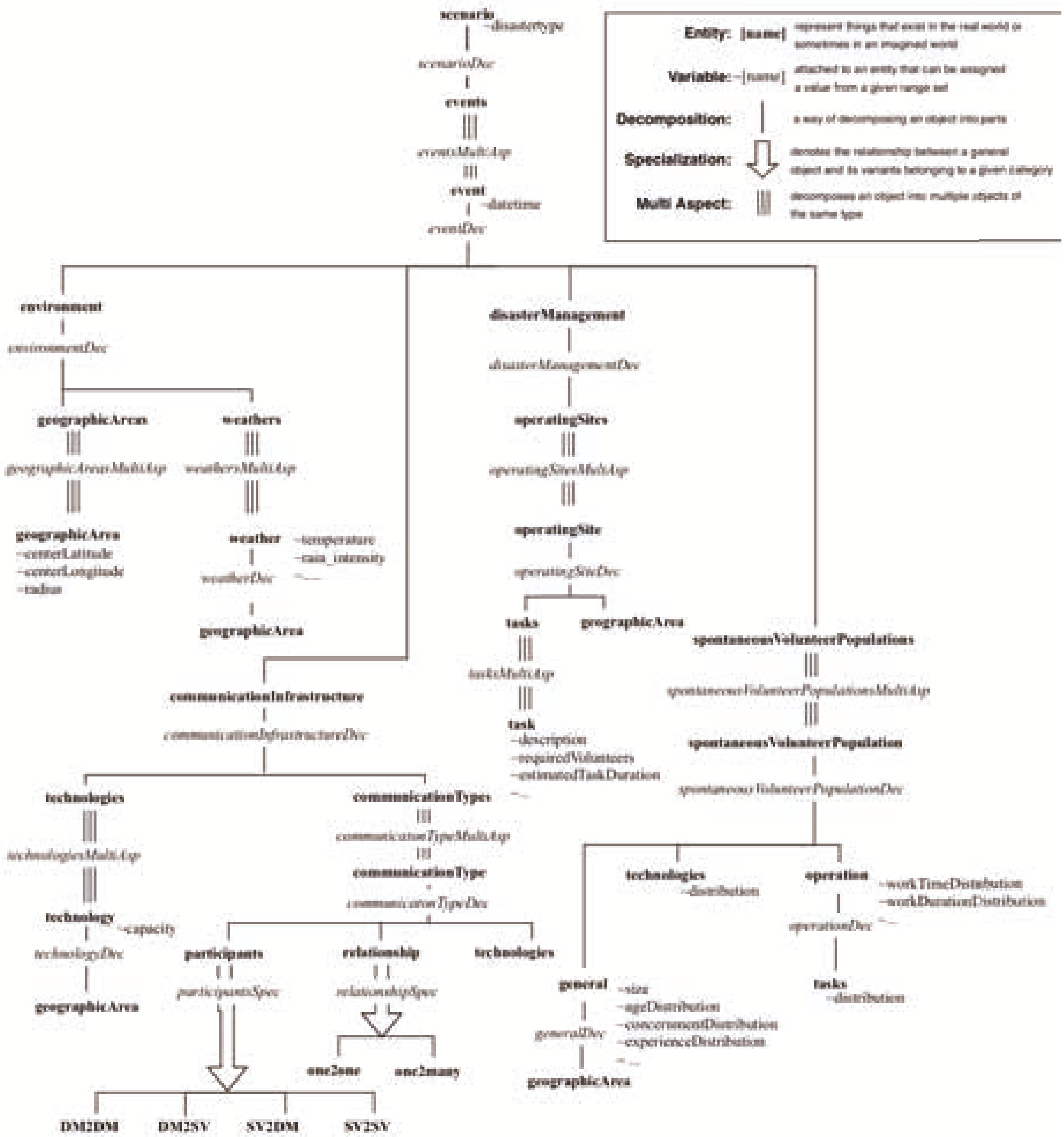

Figure 1. System Entity Structure for Disaster Scenarios

EXEMPLARY PRUNED ENTITY STRUCTURE ON 2013 FLOOD SCENARIO

To demonstrate the applicability of the proposed SES for disaster scenarios, an exemplary and simplified real-world scenario is described. Subsequently, this scenario is transformed into a so-called Pruned Entity Structure (PES) by resolving the elements of the scenario to the aspects, multi-aspects, specializations and by assigning values to the variables resulting in a selection-free tree (Durak *et al.*, 2017).

The scenario has been developed in cooperation with the responsible leader of the local disaster management authority and represents an excerpt of the flood that took place in 2013 in Halle (Saale), Saxony-Anhalt, Germany. Firstly, the scenario is described in a textual form (translated from German) and secondly, it is used to derive the PES model. All scenario-relevant elements, i.e. elements that are represented in the SES, are marked bold to better understand the development of the PES.

“The **flooding** in **Halle (Saale),** became worse on the **4th of June**. Due to the impending flooding of downtown, further sand deliveries were transported to the **sandbag filling station** on the **market place** at around **2 pm**. Due to the **midsummer weather**, there were more volunteers on site than the **100 helpers actually needed**, which challenged our personnel with additional organizational effort. Probably the central location and the proximity to the university played a role in the overcrowding market place but also the dissemination of subjective information by the local citizens via **social media** such as Facebook. In contrast, the crisis management team focused on the dissemination of information via traditional media, such as **radio**. Nevertheless, we were thankful for the numerous volunteers who helped by **filling the sandbags** at the marketplace for **more than 18 hours**."

This scenario is just a very short and basic example for pruning the SES for the disaster type: **flooding** and the datetime: **06/04/13 02:00 pm**. Since the textual scenario description is free in its structure and not complete at all, some variable assignments have to be interpreted resp. assumed. The **city** and the **market place** have been defined as geographical areas according to their center coordinates and an adequate radius. Furthermore, **midsummer-weather** has been assumed for the whole city and resolved in a temperature of 29°C and rain intensity of 0 mm/h.

As available (or relevant) communication technologies, **social media** and **radio** have been defined for the whole city. The technical capacity for both technologies is set to 100% since there haven't been reports of lacking communication availabilities during the disaster event. Since **social media** has only been used by the volunteers among themselves to communicate one-to-many, it has been interpreted as communicationType. Since official disaster management has only used **radio** for informing the volunteers, it has been defined in the same manner.

The **sandbag filling station** on the **market place** has been defined as one operating site with only one task, namely **sandbag filling**. The variables have been set to 100 volunteers needed and 18 hours estimated duration.

To define the population of volunteers, some information were not given in the textual description. E.g., we have assumed one population representing the number of inhabitants of **Halle** in 2013 according to the official statistics. The technology distributions have been chosen in line with official statistics for the percentage of people who daily use radio or social networks in Europe (European Commission, 2017).

Since we have no information on how long and how many days people have worked, we have assumed triangular distributions for workingTime (min: 2 hours, peak: 4 hours, max: 8 hours) and workingDuration (min: 1 day, peak: 3 days, max: 7 days) that seem logical to us.

Furthermore, we have assumed that only half of the population is able or willing to do heavy work. Consequently, the distribution for the task **sandbag filling** has been set to 50%. The resulting PES for the representation of the textual scenario description including all identified and interpreted information is depicted in Figure 2.

Figure 2. Pruned Entity Structure for Example Scenario

DISCUSSION AND OUTLOOK

The increasing relevance of spontaneous volunteers has led to the development of numerous research approaches aiming at their improved coordination. However, these approaches require on the one hand evaluations to test their added value and, on the other hand, a comparison to choose the approach that matches the requirements of official disaster management to transfer these approaches into practice. Computer simulations, particularly agent-based simulations, seem promising to simulate human behaviors in a disaster context and, thus, to enable evaluations and comparisons of coordination approaches. Nevertheless, agent-based simulations require reproducible disaster scenarios to compare the effects of different coordination approaches. To perform reproducible simulations in the context of spontaneous volunteer coordination, as a first step, scenarios and their related entities have to be analyzed. A second step is to provide these scenario insights as a machine-processable format to be used within the simulation.

The SES model proposed in this paper is a fundamental step for developing a Standard Scenario Definition Language for the coordination of spontaneous volunteers that can be processed within a simulation. In the presented initial version, the focus is restricted to coordination scenarios particularly for simulation experiments and, thus, only contains elements for this purpose. Following an Action Design Research approach (Sein *et al.*, 2011), the SES will be further developed and supplemented in several iteration steps in the future resulting in the SVCSDL. This is necessary, since depending on the purpose, the model may still lack information or higher level of details that may be required by other researchers. Although the SES model contains all basic entities that have been identified in our literature search and interviews addressing the coordination of spontaneous volunteers, an extensive and structured literature review (e.g. following the methodology proposed in (vom Brocke *et al.*, 2009)) is expected to bring further results. Thus, a structured literature review may supplement the proposed model and is part of our future research.

Although the SES was mainly developed for simulations, it might also be valuable for field trials in the spontaneous volunteer coordination context or even as a basis for digital volunteering scenarios as it gives insights and an understanding of what impacts and influences spontaneous volunteer scenarios. Consequently, the proposed SES model contributes to disaster research as it conceptualizes information that relate to scenarios with spontaneous volunteers.

Even though the general goal is to enable the evaluation and comparison of spontaneous volunteer coordination approaches promoted by the scenarios, we have not yet proposed and evaluated adequate measures for evaluating or comparing different coordination approaches. Since this is required for the evaluation of coordination approaches and systems, simulations, exercises, and experiments, it is one focus of our generic research project and an open research topic for the future.

Last but not least, the proposed SES model is the basis to develop an XML-based scenario language that may lead to the implementation and exchangeability of scenarios in simulation software. By defining an extensive standard language based on the SES, research on spontaneous volunteers in disaster situations, as well as the evaluation and comparison of different coordination approaches, will be supported and promoted. Thus, after completing the SES, the next step will be the language definition as a practical research question.

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REFERENCES

Adler, J. L., Satapathy, G., Manikonda, V., Bowles, B., and Blue, V. J. (2005) A multi-agent approach to cooperative traffic management and route guidance, *Transportation Research Part B: Methodological*, 39, 4, 297–318.

Alinier, G. (2011) Developing high-fidelity health care simulation scenarios: A guide for educators and professionals, *Simulation and Gaming*, 42,1, 9–26.

Asplund, M., Nadjm-Tehrani, S. and Sigholm, J. (2009) Emerging information infrastructures: Cooperation in disasters, *Lecture Notes in Computer Science*, 5508 LNCS, 2, 258–270.

Barraket, J., Keast, R., Newton, C. J., Walters, K., and James, E. (2013) Spontaneous Volunteering During Natural Disasters, *The Australian Centre for Philanthropy and Nonprofit Studies*, ACPNS61, 1–58.

Blais, C. (2008) Military Scenario Definition Language (MSDL): How Broadly Can It Be Applied?, *Proceedings of the Spring 2008 Simulation Interoperability Workshop*, Providence, Rhode Island, USA.

Vom Brocke, J., Simons, A., Niehaves, B., Riemer, K., Plattfaut, R., and Cleven, A. (2009) Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process, *17th European Conference on Information Systems*, 2206–2217, Verona, Italy.

Cheon, S., Kim, D. and Zeigler, B. P. (2008) System Entity Structure for XML meta data modeling; Application to the US climate normals, *SEDE,* 216–221, Los Angeles, California, USA.

Drury, J. L., Pfaff, M., More, L., and Klein, G. L. (2009) A principled method of scenario design for testing emergency response decision-making, *Proceedings of the 6th ISCRAM Conference,* Göteborg, Sweden.

Durak, U., Pruter, I., Gerlach, T., Jafer, S., Pawletta, T., and Hartmann, S. (2017) Using System Entity Structures to Model the Elements of a Scenario in a Research Flight Simulator, *AIAA Modeling and Simulation Technologies Conference,* p. 1076, Grapevine, Texas, USA.

European Commission (2017) Media use in the European Union. *Standard Eurobarometer* 88, Report.

Fernandez, L. S. (2007) Volunteer Management System Design and Analysis for Disaster Response and Recovery, *The George Washington University,* Dissertation.

Fernandez, L. S., Barbera, J. a and Dorp, J. R. Van (2006) Strategies for Managing Volunteers during Incident Response : A Systems Approach, *Institutional Archive of the Naval Postgraduate School*, 10, 3, 1–15.

Fraunhofer-Institut für Offene Kommunikationssysteme FOKUS (2018) ENSURE Projekt, *https://www.ensure-project.de/, [Accessed 11 Nov. 2018].*

Fuchs, S., Rass, S., Lamprecht, B., and Kyamakya, K.. (2008) A model for ontology-based scene description for context-aware driver assistance systems, *Proceedings of the 1st international conference on Ambient media and systems,* p. 5, Grapevine, Texas, USA.

Geißler, S. (2014) Motivations of "spontaneous" assistance in the event of a crisis or disaster using the flood events in Magdeburg 2013 as an example (in German: Motivationen „ spontaner " Hilfeleistungen im Krisen- und Katastrophenfall am Beispiel der Flutereignisse in Magdeburg 2013), *Hochschule für Wirtschaft und Recht Berlin,* Master Thesis.

German Federal Ministry of Education and Research (2018a) AHA: Automated volunteer offering for major incidents (in German: AHA: Automatisiertes Helferangebot bei Großschadensereignissen), *https://www.sifo.de/de/aha-automatisiertes-helferangebot-bei-grossschadensereignissen-2139.html, [Accessed 11 Nov. 2018].*

German Federal Ministry of Education and Research (2018b) Projects approved under the 'Increasing resilience in crisis and disaster situations' call for proposals (in German: Bewilligte Projekte aus der Bekanntmachung 'Erhöhung der Resilienz im Krisen- und Katastrophenfall'), *https://www.sifo.de/de/bewilligte-projekte-aus-der-bekanntmachung-erhoehung-der-resilienz-im-krisen-und-1936.html, [Accessed 11 Nov. 2018].*

German Federal Ministry of Education and Research (2018c) Information and communication concepts for crisis and disaster situations (K3) (in German: Informations- und Kommunikationskonzepte für den Krisen- und Katastrophenfall (K3)), *https://www.sifo.de/files/Projektumriss_K3.pdf, [Accessed 11 Nov. 2018].*

Hofmann, M., Betke, H. and Sackmann, S. (2014) Hands2Help – An App-based Concept for Coordination of Disaster Response Volunteers, *I-Com*, 13, 1, 36–45.

IEEE (2011) IEEE Recommended Practice for Distributed Simulation Engineering and Execution Process (DSEEP), *IEEE Std 1730-2010*, 1–79.

Jafer, S., Chhaya, B., Durak, U., and Gerlach, T. (2016) Formal scenario definition language for aviation: Aircraft landing case study, *AIAA Modeling and Simulation Technologies Conference,* p. 3521, Washington, DC, USA.

Jafer, S. and Durak, U. (2017) Tackling the complexity of simulation scenario development in aviation, *Proceedings of the Symposium on Modeling and Simulation of Complexity in Intelligent, Adaptive and Autonomous Systems,* p. 4, Virginia Beach, VA, USA.

Johanniter-Unfall-Hilfe e.V. (2018) REBEKA, *http://www.rebeka-projekt.de/, [Accessed 11 Nov. 2018].*

Kircher, F. (2014) Spontaneous volunteers in disaster management - the view of authorities and organisations with security tasks (in German: Ungebundene Helfer im Katastrophenschutz - Die Sicht der Behörden und Organisationen mit Sicherheitsaufgaben), *BRANDSchutz – Deutsche Feuerwehr-Zeitung,* 593–597.

Lee, H. and Zeigler, B. P. (2010) System Entity Structure Ontological Data Fusion Process Integrated with C2 Systems, *The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology*, 7, 4, 206–225.

Lindner, S., Betke, H. and Sackmann, S. (2017) Attributes for Simulating Spontaneous On-Site Volunteers, *Proceedings of the 14th ISCRAM Conference,* 846–856, Albi, France.

Lindner, S., Kuehnel, S., Betke, H., & Sackmann, S. (2018) Simulating Spontaneous Volunteers-A Conceptual Model. *Proceedings of the 15th ISCRAM Conference*, 159-169, Rochester, New York, USA.

Ludwig, T., Kotthaus, C., Reuter, C., van Dongen, S., and Pipek, V. (2017) Situated crowdsourcing during disasters: Managing the tasks of spontaneous volunteers through public displays, *International Journal of Human Computer Studies*, 102, 103–121.

Meissen, U., Fuchs-Kittowski, F., Jendreck, M., Pfennigschmidt, S., Hardt, M., and Voisard, A. (2017) A general system architecture and design for the coordination of volunteers for agile disaster response, *Proceedings of the 14th ISCRAM Conference,* 890–900, Albi, France.

Murakami, Y., Ishida, T., Kawasoe, T., and Hishiyama, R. (2003) Scenario description for multi-agent simulation, *Proceedings of the second international joint conference on Autonomous agents and multiagent systems,* 369-376, New York, New York, USA.

Nakajima, Y., Shiina, H., Yamane, S., Yamaki, H., and Ishida, T. (2006) Caribbean/Q: A massively multi-agent platform with scenario description language, *2nd International Conference on Semantics Knowledge and Grid*, p. 26, Guilin, China.

Nelson, S. C., Iii, A. F. H. and Kravets, R. (2007) Event–driven , Role–based Mobility in Disaster Recovery Networks, *Proceedings of the second ACM workshop on Challenged networks,* 27-34, New York, New York, USA.

Ntaimo, L., Zeigler, B. P., Vasconcelos, M. J., and Khargharia, B. (2004) Forest Fire Spread and Suppression in DEVS, *Simulation,* 80, 1, 479–500.

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007) A Design Science Research Methodology for Information Systems Research, *Journal of Management Information Systems,* 24, 3, 45–77.

Project KOKOS (2018) KOKOS - Supporting cooperation with volunteers in complex emergency situations (in German: KOKOS - Unterstützung der Kooperation mit freiwilligen Helfern in komplexen Einsatzlagen), *https://kokos.wineme.fb5.uni-siegen.de/projekt/, [Accessed 11 Nov. 2018].*

Rauchecker, G. and Schryen, G. (2016) Project KUBAS: Coordination of unbound on-site volunteers (in German: Projekt KUBAS: Koordination ungebundener Vor-Ort-Helfer), *Im Einsatz*, 23, 252–254.

Rauchecker, G. and Schryen, G. (2018) Decision Support for the Optimal Coordination of Spontaneous Volunteers in Disaster Relief, *Proceedings of the 15th ISCRAM Conference,* Rochester, New York, USA.

Reuter, C. and Kaufhold, M. A. (2018) Fifteen years of social media in emergencies: A retrospective review and future directions for crisis Informatics, *Journal of Contingencies and Crisis Management,* 26, 1, 41–57.

Sackmann, S., Lindner, S., Gerstmann, S., and Betke, H. (2018) Involvement of unbound helpers in the management of loss events (in German: Einbindung ungebundener Helfer in die Bewältigung von Schadensereignissen), in: Reuter C. (eds) *Sicherheitskritische Mensch-Computer-Interaktion*, 529–549, Springer Vieweg, Wiesbaden.

Sauer, L. M., Catlett, C., Tosatto, R., and Kirsch, T. D. (2014) The utility of and risks associated with the use of spontaneous volunteers in disaster response: A survey, *Disaster Medicine and Public Health Preparedness,* 8, 1, 65–69.

Schmidt, A., Durak, U. and Pawletta, T. (2016) Model-based testing methodology using system entity structures for MATLAB/Simulink models, *Simulation*, 92, 8, 729–746.

Sein, M. K., Henfridsson, O., Purao, S., Rossi, M., and Lindgren, R. (2011) Action Design Research, *MIS Quarterly*, 35, 1, 37-56.

Siegfried, R., Laux, A., Rother, M., Steinkamp, D., Herrmann, G., Lüthi, J., and Hahn, M. (2012) Scenarios in military (distributed) simulation environments, *SISO 2012 Spring Simulation Interoperability Workshop,* Orlando, Florida, USA.

Simões, André & Rodrigues, Armanda & Pires, Patrícia and Sá, Luís. (2011) Evaluating Emergency Scenarios using Historic Data: Flood Management, *Proceedings of the 8th ISCRAM Conference,* Lisbon, Portugal.

Simulation Interoperability Standards Organization (2015) Standard for Guidance, Rationale, and Interoperability Modalities for the Real-time Platform Reference Federation Object Model, 2.

Su, B., Wang, Z. and Zhang, N. (2016) Urban pluvial flood risk assessment based on scenario simulation, *Proceedings of the 13th ISCRAM Conference,* Rio de Janeiro, Brazil.

Sun, C., Zhang, F., Zhong, S., and Huang, Q. (2015) Expression and Deduction of emergency scenario based on scenario element model, *Proceedings of the 12th ISCRAM Conference,* Kristiansand, Norway.

Thieken, A. H., Kreibich, H., Müller, M., and Merz, B. (2007) Coping with floods: Preparedness, response and recovery of flood-affected residents in Germany in 2002, *Hydrological Sciences Journal*, 52, 5, 1016–1037.

Wagner, N. and Agrawal, V. (2014) An agent-based simulation system for concert venue crowd evacuation modeling in the presence of a fire disaster, *Expert Systems with Applications*, 41, 6, 2807–2815.

Waxman, K. T. (2010) The Development of Evidence-Based Clinical Simulation Scenarios: Guidelines for Nurse Educators, *Journal of Nursing Education*, 49, 1, 29–35.

Wittman Jr., R. L. (2009) Defining a standard: the Military Scenario Definition Language version 1.0 standard, *Proceedings of the 2009 Spring Simulation Multiconference, San Diego, California, USA*.

You, Y. J., Chi, S. Do and Kim, J. I. (2013) HEAP-based defense modeling and simulation methodology, *IEICE Transactions on Information and Systems*, 3, 655–662.

Zeigler, B. P. and Hammonds, P. E. (2007) Modeling & Simulation-Based Data Engineering: Introducing Pragmatics into Ontologies for Net-Centric Information Exchange, Academic Press, Inc. Orlando, FL, US.

Zettl, V., Ludwig, T., Kotthaus, C., & Skudelny, S. (2017) Embedding unaffiliated volunteers in crisis management systems: Deploying and supporting the concept of intermediary organizations. *Proceedings of the 14th ISCRAM Conference*, 421–431, Albi, France.