Simulating Spontaneous Volunteers – A Conceptual Model

Sebastian Lindner
Martin Luther University, Halle, Germany
sebastian.lindner@wiwi.uni-halle.de

Stephan Kuehnel
Martin Luther University, Halle, Germany
stephan.kuehnel@wiwi.uni-halle.de

Hans Betke
Martin Luther University, Halle, Germany
hans.betke@wiwi.uni-halle.de

Stefan Sackmann
Martin Luther University, Halle, Germany
stefan.sackmann@wiwi.uni-halle.de

ABSTRACT

Recent disasters have revealed growing numbers of citizens who participate in responses to disasters. These so-called spontaneous unaffiliated on-site volunteers (SUVs) have become valuable resources for mitigating disaster scales. However, their self-coordination has also led to harm or putting themselves in danger. The necessity to coordinate SUVs has encouraged researchers to develop coordination approaches, yet testing, evaluating, and validating these approaches has been challenging, as doing so requires either real disasters or field tests. In practice, this is usually expensive, elaborate, and/or impossible, in part, to conduct. Simulating SUVs' behaviors using agent-based simulations seems promising to address this challenge. Therefore, this contribution presents a conceptual model that provides the basis for implementing SUV agents in simulation software to perform suitable simulations and to forecast citizens' behaviors under a given set of circumstances. To achieve adequate simulations, the conceptual model is based on the identification of 25 behavior-affecting attributes.

Keywords

spontaneous volunteers, disaster management, agent-based simulation, conceptual model, citizen behavior

INTRODUCTION

Disasters during the last decade have revealed a growing number of untrained citizens participating in disaster responses. Along with the increasing number of natural and man-made disasters worldwide, the relevance of these so-called spontaneous unaffiliated on-site volunteers (SUVs) has increased dramatically. Disaster managers and practitioners have reported that several disasters would have been far more lethal and on a more dramatic scale without the help of SUVs (Detjen et al., 2015; Geißler, 2014). Beyond these undoubtedly positive aspects of their help, however, SUVs have also caused unintentional harm or put themselves in dangerous situations.

Utilizing SUVs as a valuable resource in disaster response requires proper coordination by disaster managers (Betke, 2018; Betke et al., 2017; Rauchecker and Schryen, 2018) and has led to a growing field of research for IT-supported disaster management. In Germany, e.g., the government has focused on this issue specifically by funding several projects such as KUBAS and REBEKA in order to effectively assign SUVs in disaster management (BMBF, 2017). This contribution is part of the research project KUBAS that aims at (a) an IT-based solution for coordinating SUVs, (b) a general evaluation method to measure the effectiveness/efficiency of approaches/methods/tools and drills aiming at the integration and coordination of SUVs during disaster response and (c) predicting volunteer participation in various disaster scenarios.

The main challenge of all these research efforts lies in testing, validating, and evaluating new approaches as well as proofing the concept, e.g., in practitioners' drills. New approaches are usually evaluated through field experiments, yet field experiments with many SUVs require massive numbers of participants, may have durations of many days, and can take place at several locations simultaneously. Such experiments are often expensive, elaborate, and, in part, even impossible to conduct (Balasubramanian et al., 2006; Sautter et al., 2015; Takahashi, 2007). Research approaches may also be evaluated and validated in real disasters, even though testing using human beings seems to be too dangerous, and disasters cannot be controlled to occur when testing is the objective.

Another common approach for evaluating and optimizing real-world scenarios with minimal effort is the use of computer simulation (Arai and Sang, 2012). Furthermore, a proper simulation of SUVs enables disaster managers to forecast citizen participations under given circumstances to better manage disaster situations and, beyond that, to visually track potential operating-site utilizations.

Nevertheless, the simulation of SUV's has not yet been intensively researched (Lindner et al., 2017). In our prior work (Lindner et al., 2017), we, in particular, have identified agent-based simulation as a sound approach for simulating SUVs' behaviors in disasters since it has already been proven to be appropriate for simulating human and social behavior as well as many entities (Mas et al., 2012; Pan et al., 2007; Takahashi, 2007; Wagner and Agrawal, 2014). Simulating SUVs' behaviors requires the development of software agents, and therefore, it first requires the analysis of their real-world behaviors and all behavior-affecting attributes (Macal and North, 2007). Secondly, the behaviors of SUVs have to be conceptualized in order to be implemented and run in simulation software.

Based on the attributes for representing and influencing SUVs' behaviors identified in our prior work (Lindner et al., 2017) this paper aims to develop a conceptual model that represents the behaviors of SUVs in disaster situations and represents the foundation for a later implementation in simulation software.

To achieve this aim, in the first section, related literature is discussed and a summarizing overview of SUV attributes is given. A common representation of behaviors in agent-based simulations is the statechart notation (see, e.g., Emrich et al., 2007; Fujisawa et al., 2014; Garifullin et al., 2007). To ensure broad applicability for implementing the model in simulation software, we provide the conceptual model following the statechart notation based on the Unified Modeling Language (UML) standard, which, as well as the method, will be described briefly in the second section of this work. In the third section, behavioral attributes according to our prior work will serve as the foundation for deriving behavior-affecting states, events, and transitions and, thereby, for developing a conceptual model to represent SUVs' behaviors. To prove its applicability and ability to be implemented in simulation software, in the following section, the proposed model will exemplarily be implemented in a simulation software. A conclusion with an outlook for further research is offered in the final section.

This contribution is part of a research project following the well-established methodology for Design Science Research proposed by (Peffers et al., 2006). According to this methodology, this research paper refers to the third phase of the Design Science Research Process (DSRP), i.e. the "Design and Development" phase. The results of this paper provide an indispensable foundation for the implementation and thereby the next DSRP phase "Demonstration".

RELATED WORK: ATTRIBUTES FOR SIMULATING SPONTANEOUS ON-SITE VOLUNTEERS

In our paper "Attributes for Simulating Spontaneous On-Site Volunteers," we described the enormous potential of spontaneous unaffiliated on-site volunteers (SUV) for disaster mitigation and confirmed the requirements for the proper coordination of these SUVs in order to avoid nonproductive and even counterproductive help.

Comprehensive research support for developing coordination approaches and, accordingly, the necessity to test, evaluate, and validate these approaches triggered our research efforts. Since the current practice in testing, evaluating, and validating research efforts in regard to the topic of disasters requires either real disasters or field experiments and is thus expensive, elaborate, and/or partially impossible to conduct, new opportunities to address these issues need to be explored. In (Lindner et al., 2017) we therefore, suggested developing a multi-agent-based simulation framework to simulate SUVs' behaviors.

Our literature review based on a keyword search in scientific databases resulted in a large number of research papers and practice reports. It revealed that agent-based simulation is a major topic in disaster related research, whereas many research efforts focus on evacuation scenarios: e.g. evacuation impacts on traffic flows from disaster areas (Chen and Zhan, 2008), evacuation scenarios for concert venues (Wagner and Agrawal, 2014), evacuation behavior of pedestrians and car drivers in a tsunami scenario (Mas et al., 2012). It further revealed a massive amount of research efforts on SUVs: e.g. research on their interaction, cooperation, and communication especially via social networks (e.g. Peary et al., 2012; Starbird and Palen, 2011), the role of digital volunteers during the Haiti earthquake in 2010 (Starbird and Palen, 2011) or research approaches and applications to improve communication or coordination (e.g. Reuter et al., 2015; Hofmann et al., 2014). Nevertheless, none of the related works applied simulation for SUVs in the disaster context and, hence, fostered our effort in developing a multi-agent simulation framework for simulating SUVs' behaviors.

The evaluation of the search results further led to the identification of 25 attributes (Table 1), which were then briefly described. In the process of analyzing behavior-affecting attributes, we further identified numerous dependencies and interrelations among these attributes that were initially described yet need to be analyzed in greater detail in future research. In accordance with the definition of software agents by Lind (2001), we grouped the attributes into individual, social, and environmental attributes as an indispensable step for understanding the behaviors.

Consequently, the groundwork is an adequate source for developing a conceptual model to represent SUVs' behaviors, as we have already identified and described all the attributes that affect SUVs' behavior. Furthermore, the state-of-the-art literature review has led to many literature sources that may confirm the assumptions we make within our model.

Table 1. SUV Attributes

Number	Attribute	Description
A1	Age	age of the SUV
A2	Group Affiliation	e.g. clubs, religious groups
A3	Motivation	trigger to participate in disasters
A4	Concern	emotional reactions to disasters
A5	Information Channel	e.g. social media
A6	Personal Connections	e.g. friends, family
A7	Social Networks	characteristics of the individual social network
A8	Perception	how SUVs perceive the situation
A9	Kind of Disaster	size, scale and type
A10	Weather	temperature, rainfall
A11	Experience	in prior disasters (positive, negative, non)
A12	Time of Day	e.g. day, night
A13	Supporting Tasks	e.g. filling sandbags
A14	Task Preference	preferences on what to do
A15	Capabilities	physical capabilities/ability to be led by officials
A16	Resources	provided resources (e.g. shovels)
A17	Working Time	time (in h) per day
A18	Time Preference	e.g. to work on day/night
A19	Working Duration	days somebody wants/can help
A20	Operating Site	locations where SUVs are needed
A21	Kind of Information	e.g. number of needed/current SUVs at operating site
A22	Location	current location

A23	Operating Site Preference	where an SUV is willing to help
A24	Travelling	e.g. car, walk
A25	Randomness	something unexpected happens

METHOD: CONCEPTUAL DESIGN

We constructed the proposed conceptual model for the SUVs' behaviors in consideration of the methodological notes on models of (March and Smith, 1995). Conceptual models can be constructed based on domain knowledge and can be used to represent new theories or phenomena through domain-specific elements and their associations (March and Smith, 1995). Accordingly, the concern of such models is utility, not truth (March and Smith, 1995). The model is based on our attribute identification, derives behavioral characteristics of it and was constructed under use of the Unified Modelling Language (UML). Since this conceptual model is descriptive and part of the early design phase, the evaluation is part of the subsequent iterative implementation (Gleasure, 2014).

Our recent research revealed that there is no universally valid modeling convention for developing software agents. However, based on other research outcomes in the field of agent-based simulation (see, e.g., Dawson et al., 2014; Ozik et al., 2015; Uhrmacher and Kullick, 2000; Verma, A. and Singh, Y., 2017), the UML statechart modeling notation by the Object Management Group seems to be a common conceptualization of behaviors. Furthermore, UML statechart modeling is used in early-bird representations before functional assignments in the implementation phase are made (Borshchev and Filippov, 2004) and is, by far, the most often used formalism for modeling the behavior of object systems (Fortino et al., 2004). Since our research effort is currently in the pre-implementation phase, statechart modelling is an appropriate method for descriptive purposes.

The general purpose of statecharts is to specify, visualize, construct, and document the artifacts of a software system (Latella et al., 1999). The artifact in the present research will be the software agent that represents the behaviors of SUVs. Additionally, statecharts represent a sequence of states through which an object passes during its life cycle (Khriss et al., 1999). As our aim here is to represent the behaviors of SUVs in disaster situations, the life cycle comprises all the supporting activities undertaken during a disaster.

In general, UML statecharts consist of the following (Murray, 2004):

- states that are considered as a period in the life of a system or agent during which a certain condition holds or an activity is performed;
- events that trigger state changes; and
- transitions that connect states and change states based on external events and conditions.

UML as specification and modeling language is already widely accepted (Murray, 2004) and is thus a good foundation for a broad acceptance of the model and its implementation.

The next section discusses the actual development of the conceptual model and, as a consequence, the derivation and identification of all required states, events, and transitions featuring SUVs in disaster situations based on the proposed attributes and their descriptions. The reference to the original attributes will further be given as "<*name of the attribute*> (A *##*)."

DEVELOPING THE CONCEPTUAL MODEL: SUV AGENT BEHAVIOR MODEL

UML statechart diagrams require an initial state to trigger the behavioral process (Object Management Group, 2015). Perceiving a situation as emergency or disaster has been identified as a precondition for spontaneous volunteering (Geißler, 2014; Reuter et al., 2013). The perception (A 8) can, therefore, be seen as the trigger to participate in a disaster as a spontaneous volunteer and is thereby the trigger and initial state for behaving as an SUV (***attention***). It is clear that one has to recognize a disaster; otherwise, there would be no need to volunteer. In (Lindner et al., 2017), we identified several additional attributes that may influence perception, e.g., social networks (A 7), information channels (A 5), or personal connections (A 6). As perception may be further triggered by other attributes, we summarize this first state as *"**has attention.**"*

To summarize, *"**has attention**"* means that, first, a disaster must strike as a precondition for participating in disaster relief, and, secondly, the agent must perceive this situation as an emergency. Starting here, the behavioral process of an SUV begins. Based on the attribute of location (A 22), we assume that the SUV agent is initially located at a distance from the disaster, most likely at his or her home. Furthermore, the location has a behavior-affecting influence, especially in the upcoming operating-site (A 20) search process.

After triggering the behavioral process, the first state is *“**has attention.**”* As previously described, this state requires the perception of the disaster and may be triggered/influenced by (social) media coverage or by friends or associates, more precisely other agents, who communicate with the SUV. It is crucial to be aware that broad media coverage and personal communications from friends motivate citizens to volunteer in disasters. We assume that the agent is then informed about the situation and a decision-making process about whether to participate in the disaster or not must be initiated. The transition to the next state will be triggered by a time-out event consisting of the motivation and the respective decision-making process of the volunteer agent.

We identified motivation (A 3) as the trigger to participate in a disaster response and revealed that motivation could either be increased or decreased by dependent attributes. The assumption of being highly motivated to offer support in disaster situations further leads to the assumption that people with a “high” degree of motivation are more willing to help than people with a “low” degree of motivation. We also revealed that motivation is not deterministic and, as yet, cannot be completely simulated. The motivating process has to take into consideration other attributes that affect motivation. Based on this knowledge, we assume two conditions, ***“[motivated]”*** or ***“[not motivated],”*** that determine the following state of being either *“**ready to help**”* or *“**not ready to help.**”* However, the actual logic of deciding is not part of the statechart representation and thus must be considered in the implemented model.

Since the time-out event includes the motivating process, we assume that people won’t respond to help instantly after a disaster has struck. Furthermore, the time-out event simulates the recovery phase at home, or particularly at the initial location, that SUVs need to process, perhaps, before continuing to help on another day. This assumption is underpinned by the attribute of working time (A 17), which describes that SUVs usually work between 4 and 8 hours a day (ARC, 2010). Thus, as we attempt to model the behavior of participating in disaster situations, spare-time activities are of no interest to us, and so we assume a time-out.

Some disasters have durations of several days whereby a volunteer who decided not to help initially and thus was in the *“**not ready to help**”* state may decide to help on another day. Given the complexity of the motivation and its interdependencies and relationships, e.g., environmental attributes like weather that may affect motivation and may change over time, we assume that an SUV agent can be *“**temporarily not motivated**”* and, thus, more likely to help on another day. Accordingly, entering the *“**not ready to help**”* state will first cause the agent to enter the *“**temporarily not ready to help**”* state until deciding whether the SUV is conclusively not motivated. A conclusively not motivated state could be caused by very low overall motivation ***([motivation very low])*** due, e.g., to prior negative experiences (A 11) related to helping as well as by the SUV having exceeded his or her working duration (A 19). Depending on other attributes such as age, working duration varies from several hours to several weeks or even months. Deciding to discontinue all supportive tasks will result in the agent’s final state and thereby end the SUV’s behavioral process. Otherwise (***[else]***), he or she is probably going to help again on another day, will enter the starting state *“**has attention,**”* and, given a time-out, may become motivated again.

If the SUV is motivated, his or her state will then be *“**ready to help**”* and, based on the kind of information received (A 21), will either choose a preferred operating site or move around to search for places to help. SUVs do have operating-site preferences (A 23). Individually, they will consistently show a preference for an operating site where they know help is needed over sites that are described as overcrowded. However, the operating-site preference as well as the final operating-site selection process is part of the implementation phase.

In regard to being *“**ready to help,**”* we identified randomness (A 25) as an important attribute that affects SUV behavior. Randomness is described thusly: even if the *“SUV may have [..] high motivation to help, there is still a probability that something unexpected happens preventing him or her from actual helping”* (Lindner et al., 2017). This randomness is depicted by the decision related to whether *“**[something unexpected]**”* happened or not. If *“**[something unexpected]**”* turns out to be true, the agent is still motivated but will enter the starting state *“**has attention**”* to perhaps provide help on another day. Otherwise (***[else]***), the SUV is going to move to the operating site ***(moving to operating site)***. This assumption is made by the attribute travelling (A 24), which describes how SUVs move to operating sites. Travelling will be integrated in the implementation phase and will then probably affect the time a volunteer needs to move from his or her initial location to the preferred operating site.

Recent disasters have shown that SUVs, after ***[arriving at the operating site]***, could possibly be ***[rejected]*** by operating sites by official forces, especially if the limits for required on-site volunteers are about to be exceeded (Teixeira, 2012). However, rejection leads to frustration and negative experiences that can potentially affect motivation to help on another day or in future disasters (Geißler, 2014; Kircher, 2014). In the past, not all volunteers who have been rejected have immediately lost their motivation and thus discontinued their help. Some SUVs start searching again (***[else]***) and move to other operating sites. As we described in (Lindner et al., 2017), the probability of being rejected is most closely related to the kind of information SUVs have about operating sites. It is clear that those who have a lot of information about operating sites choose sites where help is desperately needed instead of choosing overcrowded operating sites, and therefore, they are not likely to be rejected by official forces.

At any rate, if SUVs are rejected too often (***[too many rejections]***), their ambition to help on a particular day may decrease drastically, and they may discontinue their supporting activities. If this is true, the SUVs may then return home or at least go somewhere else but without helping (***[moving back home]***). However, rejected volunteers do continue to pay attention to the disaster and will therefore enter the state *"**has attention**"* when they arrive home (***[arriving at home]***). These negative experiences may then affect motivation the next day following the defined time-out event.

Not being rejected (***[else]***) results in helping at the arrived-at operating site and will thereby result in entering the state *"**helping at operating site.**"* As we revealed in (Lindner et al., 2017), the working time (A 17) depends on several other attributes and may vary from agent to agent. Exceeding the individual time preference (A 18) by helping at the operating site is an event that will cause a transition to the next state, namely, the *"**moving back home**"* state. Arriving at home will then lead to the *"**has attention**"* state again, which may lead to another round of participation.

The proposed statechart model is depicted in Figure 1. Based on our prior work, the states in the model were derived from all behavior affecting or featuring attributes and their descriptions. It is clear that spontaneous volunteering in disasters requires disaster situations, and therefore the behavior ends if the disaster situation no longer requires the help of volunteers, if the volunteer is no longer motivated, or if his or her working duration (A 19) preference has been exceeded. The end of the disaster is not modeled as a final state in the model, as the simulation will terminate when the disaster ends.

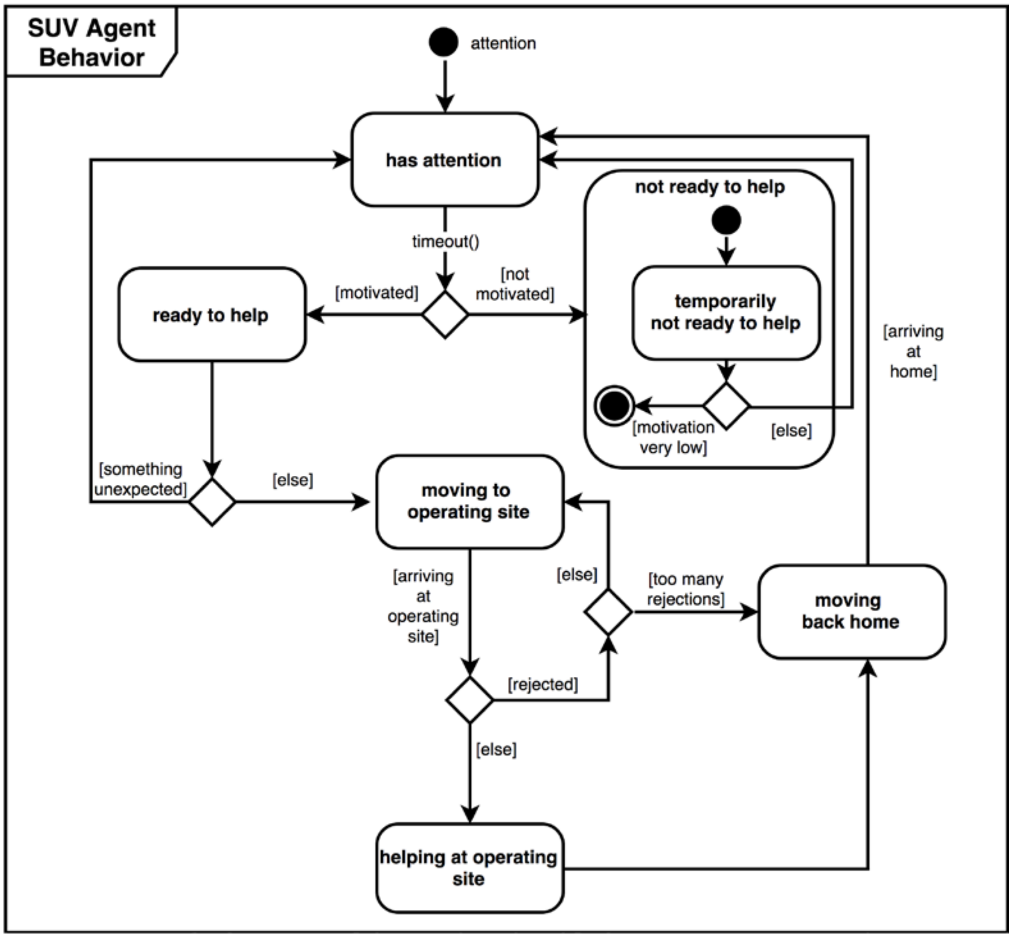

Figure 1. SUV Agent Behavior – A Conceptual Model

EXEMPLARY IMPLEMENTATION OF THE CONCEPTUAL MODEL

As the proposed conceptual model is the basis for implementing an SUV's behavior in simulation software, we exemplarily implemented the model in AnyLogic to show its applicability. Accordingly, the realistic simulation of SUVs requires further research and is not being aimed at by this implementation. AnyLogic is already being used to perform disaster-related simulations in other research projects (see, e.g., Barthe-Delanoë et al., 2015, and Barahona et al., 2013) and appears to be the proper software to test.

We implemented a population of 100 agents representing SUVs. The individual behavior of each agent originates with the behavior-affecting attributes as well as the behavioral model proposed in this contribution. Thus, we implemented the SUV's behavior exactly as the derived conceptual model in the AnyLogic simulation software (see Figure 2).

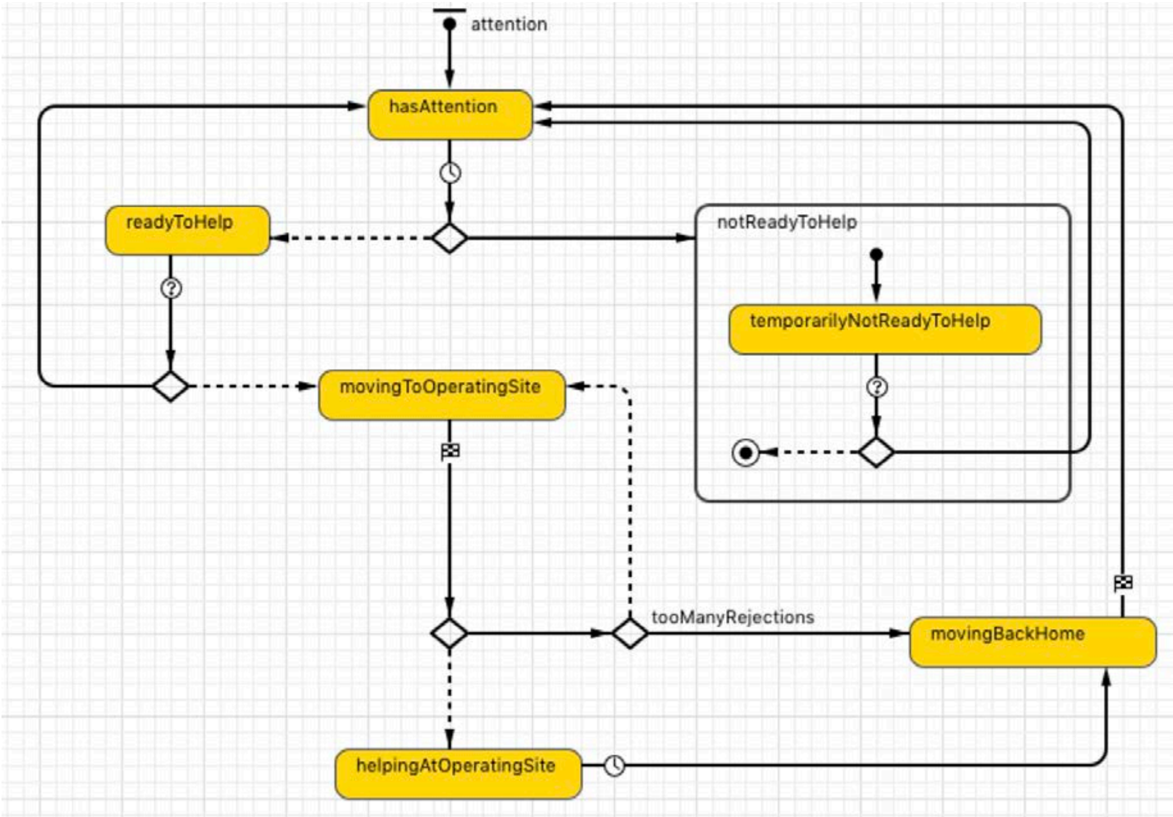

Figure 2. SUV Behavior in AnyLogic

To perform a basic simulation, we proposed the agents initial position to be randomly distributed in the area of "Halle (Saale), Germany" The city was massively affected by flooding in 2013 and where spontaneous volunteering made an enormous contribution to mitigate the scale of the disaster. AnyLogic allows the integration of GIS maps to visualize the agents in their current locations. Furthermore, we need to implement operating sites that simulate places where SUVs may help and can thereby be either empty or overcrowded. Even though operating site agents are not part of this contribution and will not be described in more detail, they are required to run realistic simulations. To show the applicability of the proposed model, the implemented logic is kept very simple, which means that the proposed decisions rely on random distributions. For example, being *"ready to help"* turns out to be true by an equally distributed probability of 50 percent.

By starting the simulation, the initial state pointer *"attention"* will be triggered, and the agent enters the state *"has attention."* The proposed time-out function in this implementation pauses the agent's actions for 8 hours before the decision of *either "ready to help"* or *"not ready to help"* is made. As previously mentioned, the decision relies on random distributions. Performing realistic simulation in the future necessitates the implementation of the decision logic as well as the attributes and their interdependencies proposed in (Lindner et al., 2017).

If the SUV agent is *"ready to help,"* the probability that something unexpected happens is 20 percent; otherwise, the agent is *"moving to operating site."* Regarding the "kind of information", we assume that the agent knows about all operating sites and randomly chooses one (Lindner et al., 2017). In this very basic example, we represent three operating sites, each with a requirement of 20 SUVs. Arriving at the operating site either leads to being rejected or to *"helping at operating site."* Being rejected will be the result if more than 20 SUVs are already helping at this particular operating site. If the agent has been rejected more than twice, he or she will return home; otherwise, he or she will move on to another of the operating sites. We assume that an agent provides help for 5 hours before returning home.

Running this simulation will lead to defined behaviors that can be proven visually by the simulation representation (see Figure 3). Although this sample implementation is very basic, it can still simulate the SUV's behavior and thereby offers a sound foundation for improving the implementation iteratively.

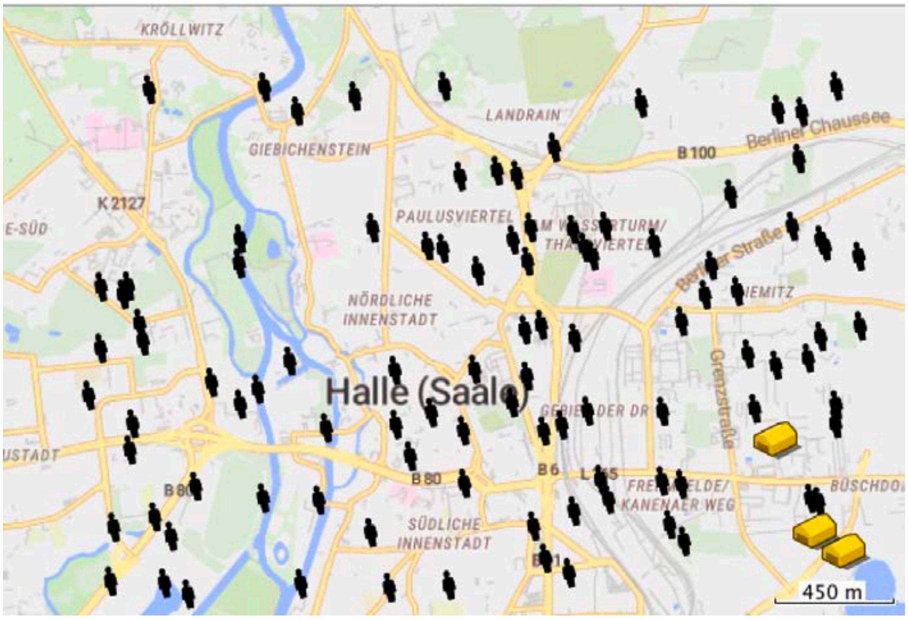

Figure 3. SUV Simulation in AnyLogic

CONCLUSION AND FUTURE RESEARCH

The numerous research efforts that have focused on spontaneous unaffiliated on-site volunteers (SUV) as well as recent disasters have revealed the enormous potential of SUVs for mitigating the scales of disasters. However, there are limitations in regard to evaluating, testing, validating, and also in comparing research approaches concerning the necessity of real disasters or field tests that are expensive, elaborate, or impossible, in part, to conduct. Simulations, in general, and multi-agent simulations, in particular, seem to be a promising attempt to complement existing approaches. Multi-agent simulations require the analysis of the behaviors of SUVs, and therefore we identified, analyzed, and classified all behavior-affecting attributes of SUVs to provide a sound foundation for developing software agents in our prior work.

The next step in simulating software agents is, therefore, conceptualizing the representation of the SUV's behavior for providing a model that can finally be implemented in simulation software. The implementation of a conceptual model in simulation software serves for improving the evaluation and validation of novel research methods and tools aiming at effective and efficient coordination of SUVs in disaster response. Furthermore, it's the foundation to develop tools that enable practitioners such as disaster managers to predict SUVs' behaviors.

Thus, the aim of this contribution was to develop a conceptual model representing the SUV's behaviors. Toward that aim, we recapitulated the attributes of the paper "Attributes for Simulating Spontaneous On-Site Volunteers" in order to identify events, states, and transitions to subsequently be modeled. Accordingly, this contribution provides: (i) a first and sound insight into the behaviors of SUVs and their corresponding states and (ii) a proof for the applicability of the conceptual model to be implemented in simulation software. The identified conceptual model is further expected to be useful for researchers/practitioners who either want greater insights into the behavior of SUVs or to implement the model in their simulations. In addition, this paper is part of a research project that necessitates a proper investigation of the volunteer's behavior as well as the foundations for the upcoming iterative implementation phase.

However, this research paper also has several limitations. Although the proposed conceptual model of this contribution is based on the latest research outcomes of (Lindner et al., 2017) it may be revised if and when there is an update on the underlying attributes. Furthermore, an implementation requires greater details on how the transitions may be triggered. For example, motivation level is assumed to be high or low, and there is not yet a specific operationalization for implementing it in simulation software. Moreover, a very low level of motivation may lead to an SUV discontinuing to help in a disaster situation and will thereby have a relevant impact on the SUV's behavior. To summarize, the decisions especially are on a high level of abstraction and consequently require further investigations before being implemented. Additionally, performing these simulations requires further agent types such as operating sites. These agents can also be derived by the attributes and, hence, will be addressed in future research.

Since the development of the artifact, i.e., the SUV agent, is based on an iterative process, the quality of the model and the level of detail can be expected to improve. However, the development cycle requires an implementation foundation to further improve the outcomes. In addition, the iterative cycle will involve interviewing a large number of SUVs and disaster experts in order to evaluate the model and to develop and survey a structured equation model for operationalizing motivation and a willingness to help.

Our entire research project follows the DSRP methodology proposed by (Peffers et al., 2006). Accordingly, this research paper is in the third phase, "Design and Development," of the artifact, and its results provide necessary fundaments for the iterative implementation and, thus, the next phase, "Demonstration."

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REFERENCES

ARC (2010) Research report - A survey of spontaneous volunteers, *Australian Red Cross*.

Arai, K. and Sang, T. X. (2012) Multi Agent-based Rescue Simulation for Disable Persons with the Help from Volunteers in Emergency Situations, *International Journal of Research and Reviews in Computer Science,* 3, 2, 1543-1547.

Balasubramanian, V., Massaguer, D., Mehrotra, S. and Venkatasubramanian, N. (2006) DrillSim: A Simulation Framework for Emergency Response Drills, *IEEE International Conference on Intelligence and Security Informatics*, 3975, 237-248.

Barahona, F., Ettl, M., Petrik, M. and Rimshnick, P. M. (2013) AGILE LOGISTICS SIMULATION AND OPTIMIZATION FOR MANAGING DISASTER RESPONSES, *Proceedings of the 2013 Winter Simulation Conference*, 3340 – 3351.

Barthe-Delanoë, A.-M., Truptil, S. and Bénaben, F. (2015) Towards a taxonomy of crisis management simulation tools, *Proceedings of the ISCRAM 2015 Conference*.

Betke, H. (2018) A Volunteer Coordination System Approach for Crisis Committees, *Proceedings of the 15th International Conference on Information Systems for Crisis Response and Management*.

Betke, H., Lindner, S., Sackmann and S., Gerstmann, S. (2017) "Informationssysteme im Katastrophenmanagement – Entwurf eines Koordinationssystems für ungebundene Helfer", *INFORMATIK 2017*.

BMBF (2017) Bewilligte Projekte aus der Bekanntmachung "Erhöhung der Resilienz im Krisen- und Katastrophenfall", Bundesministerium für Bildung und Forschung, *https://www.sifo.de/de/bewilligte-projekte-aus-der-bekanntmachung-erhoehung-der-resilienz-im-krisen-und-1936.html* (05.12.2017).

Borshchev, A. and Filippov, A. (2004) From System Dynamics and Discrete Event to Practical Agent Based Modeling: Reasons, Techniques, Tools, *The 22nd International Conference of the System Dynamics Society*, Oxford, England.

Chen, X. and Zhan, F. B. (2008) Agent-based modelling and simulation of urban evacuation: relative effectiveness of simultaneous and staged evacuation strategies, *Journal of the Operational Research Society*, 59, 25-33.

Dawson, D., Siebers, P.-O., and Vu, T. M. (2014) Opening Pandora's Box: Some Insight into the Inner

Workings of an Agent-Based Simulation Environment, *Preprints of the Federated Conference on Computer Science and Information Systems*, 1491-1498.

Detjen, H., Geisler, S. and Bumiller, G. (2015) Nutzeranforderungen eines Systems zur automatischen Helferbereitstellung, *Mensch und Computer 2015*, 11-18.

Emrich, S., Suslov, S. and Judex, F. (2007) Fully Agent Based. Modellings of Epidemic Spread Using Anylogic, *Proceedings of the EUROSIM* 2007.

Fortino, G., Russo, W. and Zimeo, E. (2004) A statecharts-based software development process for mobile agents, *Information and Software Technology, 46*, 907–921.

Fujisawa, R., Dobata, S., Sugawara, K. and Matsuno, F. (2014) Designing pheromone communication in swarm robotics: Group foraging behavior mediated by chemical substance, *Swarm Intelligence*, 8, 3, 227-246.

Garifullin, M., Borshchev, A. and Popkov, T. (2007) Using AnyLogic and agent-based approach to model consumer market, *Proceedings of the 6th EUROSIM Congress on Modelling and Simulation*, 1-5.

Geißler, S. (2014) Motivationen „spontaner“ Hilfeleistungen im Krisen- und Katastrophenfall am Beispiel der Flutereignisse in Magdeburg 2013, *Master thesis Hochschule für Wirtschaft und Recht Berlin* 2013.

Gleasure, R. (2014) Conceptual Design Science Research? How and Why Untested Meta-Artifacts Have a Place in IS, *International Conference on Design Science Research in Information Systems*, 99-114.

Hofmann, M., Betke, H. and Sackmann, S. (2014) Hands2Help - Ein App-basiertes Konzept zur Koordination Freiwilliger Helfer, *i-com Zeitschrift für interaktive und kooperative Medien*, 13, 1, 37-45.

Khriss I., Elkoutbi M. and Keller R.K. (1999) Automating the Synthesis of UML StateChart Diagrams from Multiple Collaboration Diagrams, Bézivin J., Muller PA. (eds) The Unified Modeling Language. «UML»'98: Beyond the Notation. UML 1998. *Lecture Notes in Computer Science*, 1618, Springer, Berlin, Heidelberg.

Kircher, F. (2014) Ungebundene Helfer im Katastrophenschutz Die Sicht der Behörden und Organisationen mit Sicherheitsaufgaben. *Deutsche Feuerwehr-Zeitung Brandschutz*, 593-597.

Latella, D., Majzik, I. and Massink, M. (1999) Towards a formal operational semantics of UML statechart diagrams, *Formal Methods for Open Object-Based Distributed Systems*, 331-347.

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

Lind, J. (2001) Iterative Software Engineering for Multiagent Systems: The MASSIVE Method, *Springer*, Berlin.

Macal, C. M. and North, M. J. (2007) AGENT-BASED MODELING AND SIMULATION: DESKTOP ABMS, *Proceedings of the 2007 Winter Simulation Conference*, 95-106.

March, S. T. and Smith, G. F. (1995) Design and natural science research on information technology, *Decision support systems*, 15, 4, 251-266.

Mas, E., Suppasri, A., Imamura, F. and Koshimura, S. (2012) Agent-based Simulation of the 2011 Great East Japan Earthquake/Tsunami Evacuation: An Integrated Model of Tsunami Inundation and Evacuation, *Journal of Natural Disaster Science*, 34, 1, 41-57.

Murray J. (2004) Specifying Agent Behaviors with UML Statecharts and StatEdit, *Lecture Notes in Computer Science*, 3020, Springer, Berlin, Heidelberg.

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

Reuter, C., Heger, O. and Pipek, V. (2013) Combining Real and Virtual Volunteers through Social Media, *Proceedings of the 10th International ISCRAM Conference*, 780-790.

Reuter, C., Ludwig, T., Kaufhold, M.-A. and Pipe, V. (2015) XHELP: Design of a Cross-Platform Social-Media Application to Support Volunteer Moderators in Disasters, *Proceedings of the 33rd Annual ACM*

Conference on Human Factors in Computing Systems, 4093-4102.

Object Management Group (2015) Unified Modelling Language 2.5.

Ozik, J., Collier, N., Combs, T., Macal, C. M. and North, M. (2015) Repast Simphony Statecharts, *Journal of Artificial Societies and Social Simulation*, 18, 3, 11, 1722–1729.

Pan, X., Han, C. S., Dauber, K. and Law, K. H. (2007) A multi-agent based framework for the simulation of human and social behaviors during emergency evacuations, *AI & Society*, 22, 2, 113-132.

Peary, B. D. M., Shaw, R. and Takeuchi, Y. (2012) Utilization of Social Media in the East Japan Earthquake and Tsunami and its Effectiveness, *Journal of Natural Disaster Science*, 34, 1, 3-18.

Peffers, K., Tuunanen, T., Gengler, C. E., Rossi, M., Hui, W., Virtanen, V. and Bragge, J. (2006) The design science research process: a model for producing and presenting information systems research, *Proceedings of the first international DESRIST*, 83-106.

Sautter, J., Böspflug, L. and Schneider, F. (2015) Ein Interaktionskonzept zur Simulation und Analyse von MANV- Einsätzen, *Mensch und Computer 2015 – Workshop-Band*, 51-59.

Starbird, K. and Palen, L. (2011) "Voluntweeters": Self-Organizing by Digital Volunteers in Times of Crisis, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1071-180.

Takahashi, T. (2007) Agent-Based Disaster Simulation Evaluation and its Probability Model Interpretation, *Proceedings of the 4th International Conference on Information Systems for Crisis Response and Management*, 369-376.

Teixeira, E. C. A. (2012) Hudumia: A platform to support spontaneous volunteers' situational awareness, coordination and safety under emergency scenarios, *Master Thesis University of Madeira*.

Uhrmacher, A. M., and Kullick, B. G. (2000) "Plug and test" – software agents in virtual environments, *Proceedings of the 2000 Winter Simulation Conference*, 1722–1729.

Verma, A. and Singh, Y. (2017) Software Agent Modelling Of Web Application, *International Journal of Advance Research, Ideas and Innovations in Technology*, 3, 3, 898–903.

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.