DisVis 2.0: Decision Support for Rescue Missions Using Predictive Disaster Simulations with Human-centric Models

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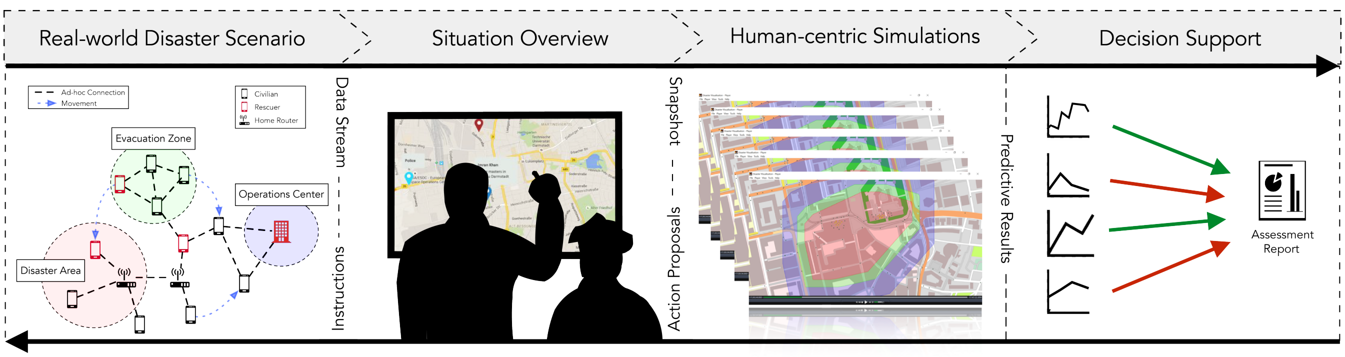

Figure 1: System design with processing flow

ABSTRACT

In disaster situations, the coordination of rescue missions is a difficult task since the person in charge makes decisions under pressure and inappropriate instructions to rescuers could cost many lives. The aim of *DisVis 2.0* approach is to release pressure from those responsible by providing decision support using predictive human-centric disaster simulations. More precisely, we enhance existing simulation frameworks only relying on ad-hoc network and mobility models by (1) human-centric models considering cognitive processes and behavior reactions, as well as (2) a novel automated decision support considering real-world sensor data.

CCS CONCEPTS

•**Computing methodologies** → **Modeling and simulation;** • **Networks** → *Mobile ad hoc networks;*

KEYWORDS

Simulation, Ad-hoc Network, Mobility & Communication Analysis

1 MOTIVATION

Well-accomplished rescue missions or relief actions coordinated by the operations center may save lives in disaster scenarios. However, the success of a mission initially depends on a few people in charge making the decisions under pressure and issuing instructions to rescuers such as first responders. To support those responsible, technical systems such as disaster simulations are used. However, providing automated decision support on real-world sensor data during emergency situations is still challenging.

In literature, disaster simulators for mobility and communication investigate the applicability of new communication technologies under dynamic conditions in reconstructed scenarios before the actual disaster [8]. To simulate realistic movements, different mobility models including random mobility [3] and behavior-based mobility [1] have been proposed. Based on the applied mobility models, different ad-hoc networks can be achieved by interconnecting mobile devices carried around by rescuers and civilians. In [8], the authors even execute mobility simulations with network simulations in parallel to enable them to influence each other.

In this paper, we enhance current disaster simulators such as *DisVis* [8] by proposing (1) novel human-centric models considering cognitive processes and behavior reactions, which influence both the communication model and the mobility model (cf. Fig. 2), as well as (2) an automated decision support system on top of predictive human-centric simulations, which can also be used on real-world sensor data during emergency situations (cf. Fig. 1).

2 SYSTEM DESIGN

We propose *DisVis 2.0*, a novel disaster simulation concept that can be traditionally used to investigate new communication technologies before an emergency situation occurs, but also during emergency situations to investigate human behaviors as well as the

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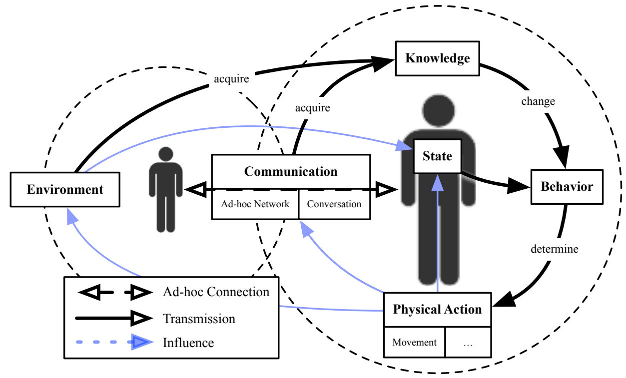

Figure 2: Human-centric simulation model

effect of newly deployed communication hardware for providing *decision support* using predictive *human-centric simulation models*.

2.1 Human-centric Simulation Model

Figure 2 shows the proposed human-centric simulation model, which is inspired by the concept of software or intelligent agents [2]. Such agents (termed *nodes*) act autonomously, i.e., they have the capabilities of knowledge understanding, goal-directed behavior, and decision-making without human intervention (*autonomy*). Initially, each node has limited local knowledge about the world. We consider cognitive processes to acquire additional knowledge through perceiving of the environmental context, communicating with other nodes via wireless ad-hoc networks or verbal conversations (*social ability*). A further distinction to current disaster simulation models is that our model uses a goal-based behavior instead of a predefined set of rules (*reactivity*), i.e., the node's physical actions such as moving are chosen among multiple possibilities to reach the goal state that is desirable (*proactivity*). This behavior decision highly depends on the constantly increasing knowledge and the current human state (*adaptivity*), e.g., an injury would limit or change the human behavior. Finally, the performed actions including mobility of a node influence the environment, the node state, and the communication within the wireless ad-hoc network [4].

2.2 Decision Support System

Using the proposed human-centric simulations, we design an automated processing pipeline with following steps (cf. Fig. 1): *first*, the operations center creates an overview of the situation based on real-world sensor data (e.g., locations of people [5] or stationary communication devices [6]) automatically collected from the ad-hoc network [4] built by interconnecting mobile devices carried around by rescuers and civilians in the field. *Second*, the person in charge can then create a snapshot of the current situation and trigger multiple human-centric simulations in parallel to investigate either the results of different instructions (e.g., evacuation) given to the people in the field, or the effect of deploying new communication hardware (e.g., range extenders) in the affected area. In addition to the ad-hoc networking mobile devices, stationary communication devices such as upgraded wireless home routers [6] can be considered within the simulations. Connecting to a network simulator (e.g., *PeerfactSim.KOM* [9]), different communication technologies and in-network processing methods over multiple nodes [7] can be simulated. *Third*, the results of these predictive simulations are evaluated with several defined performance metrics (e.g., network coverage, walking times for evacuation routes) in terms of providing an appropriate decision support for those responsible. The decision support may have various forms like an assessment report or a live integration into the situation overview. Based on these predictive scenarios, the person in charge is able to give assessed instructions via the wireless ad-hoc mesh network to rescuers (e.g., hardware deployment, rescue missions) or to civilians (e.g., evacuation).

3 SUMMARY AND OUTLOOK

While many other disaster simulators only concentrate on ad-hoc network and mobility models, *DisVis 2.0* is different: we propose a human-centered approach considering cognitive processes of acquiring knowledge over ad-hoc networking, understanding information, as well as behavior and movement reactions to these new insights. To provide a novel decision support for coordinating rescue missions, an automated system which loads real-world sensor data (e.g., location of people) and runs predictive simulations for investigating different emergency responses is introduced. All in all, our novel simulation framework design aims to copy human behaviors to investigate ad-hoc communications and mobility from a novel view, and minimize the manual effort of creating, running, and interpreting disaster simulations for the person in charge.

In future work, we focus on the implementation and the evaluation of different knowledge, behavior, and communication models of relevant involved parties such as rescuers and civilians.

Acknowledgments

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REFERENCES

[1] Aschenbruck, N., Gerhards-Padilla, E., Gerharz, M., Frank, M., and Martini, P. Modelling Mobility in Disaster Area Scenarios. In *MSWiM'07*, ACM (2007), 4–12.
[2] Balmer, M., Cetin, N., Nagel, K., and Raney, B. Towards Truly Agent-based Traffic and Mobility Simulations. In *AAMAS'04*, IEEE Computer Society (2004), 60–67.
[3] Camp, T., Boleng, J., and Davies, V. A Survey of Mobility Models for Ad Hoc Network Research. *Wireless Communications and Mobile Computing 2*, 5 (2002), 483–502.
[4] Conti, M., and Giordano, S. Mobile Ad Hoc Networking: Milestones, Challenges, and New Research Directions. *IEEE Communications Magazine 52*, 1 (2014), 85–96.
[5] Meurisch, C., Schmidt, B., Scholz, M., Schweizer, I., and Mühlhäuser, M. Labels - Quantified Self App for Human Activity Sensing. In *UbiComp'15: Adjunct*, ACM (2015), 1413–1422.
[6] Meurisch, C., Seeliger, A., Schmidt, B., Schweizer, I., Kaup, F., and Mühlhäuser, M. Upgrading Wireless Home Routers for Enabling Large-scale Deployment of Cloudlets. In *MobiCASE'15*, Springer (2015), 12–29.
[7] Nguyen, T. A. B., Meurisch, C., Niemczyk, S., Böhnstedt, D., Geihs, K., Mühlhäuser, M., and Steinmetz, R. Adaptive Task-Oriented Message Template for In-Network Processing. In *NetSys'17*, IEEE (2017).
[8] Panitzek, K., Weisenburger, P., Schweizer, I., and Mühlhäuser, M. Towards an Integrated Mobility Simulation for Communications Research. In *MOBILITY'13* (2013), 24–29.
[9] Stingl, D., Gross, C., Rückert, J., Nobach, L., Kovacevic, A., and Steinmetz, R. PeerfactSim.KOM: A Simulation Framework for Peer-to-peer Systems. In *HPCS'11*, IEEE (2011), 577–584.