# Social Coverage Maps

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**ABSTRACT**

This paper introduces Social Coverage Maps (SCM) as a visual representation of the societal impact of localized disruptions in urban areas. Incited by the recent deliberate interruption of wireless services for the purpose of crowd control in San Francisco, we focus on the use of SCMs for representing emergent effects of electronic warfare. As a prequel we discuss maps and other visualizations as representations of human behaviour and relations. The SCM concept is defined and grounded in simulation-based parameters. Using an experimental scenario based on cell phone jamming in a city we show how SCMs are generated using an agent-based population simulator. We find that Social Coverage Maps could become a useful tool for analysing emergent effects of actions and events including electronic warfare, roadblocks, smoke, teargas, chemical and radioactive contamination with applications in operational and emergency planning as well as crisis management.

**Keywords: Social simulation, Visualization, Command and control, Electronic warfare**

## INTRODUCTION

In the introduction we exemplify the wide-ranging consequences of communication disruptions in urban areas, outline the motivation for introducing Social Coverage Maps (SCM) and briefly discuss related research. The next section defines the SCM concept and how SCMs are related to population simulations. The POPSIM dynamic society simulator is introduced in the third section. The experimental section describes the simulated scenario and provides examples of the use of SCMs for operational planning.

### The San Francisco Incident

In August 2011, the San Francisco area transit authorities, Bay Area Rapid Transit – BART, cut off mobile access in a number of train stations in order to disrupt a planned protest. The intention with the wireless service interruption was to secure public safety through preventing a protest to happen (Bart, 2011). That in turn, resulted in new protests, queries and demands on free speech, democracy, and public safety in different lairs from governmental authorities, civil right movements and political organizations. (e.g. Spencer, 2012; Neill and Shruti 2012). After the incidents several issues were raised by the Federal Communications Commission, FCC: Under what circumstances, if any, is it appropriate for a public agency to interrupt wireless services? What are the risks related to interrupting wireless services? How is the work of first responders and other emergency personnel and government authorities affected by intentional interruptions of wireless services? (FCC, 2012).

There are several other examples of how mobile phones, social media and the Internet can be used to organize demonstrations, flash-mobs and attacks. Some of the most recognizable examples of such occurrences are The Arab Spring and The London Riots, 2011, showing how digital media and communications devices helped activists turn protest meetings into well-structured movements (Howard, 2011) and demonstrations into riots (Ball and Brown, 2011). Terminating wireless services is sometimes used as a component of governmental strategies for disrupting different kinds of organized activities (see e.g. Bhuiyan, 2011).

**Problem description**

How can operational or crisis management staff understand the indirect and emergent societal effects of actions such as cell phone jamming? The physical effects are readily displayed on a planning map e.g. as a jamming coverage map visualizing the immediate technical effect of the jamming. The San Francisco event illustrates that indirect impacts on human individual and collective behaviours are important elements of the situation but that planners often find it difficult to integrate such aspects in analysis and planning. Social Coverage Maps are, in this paper, suggested as a tool for describing and visualizing emergent consequences of actions such as electronic warfare in urban environments.

**Background**

This sub-section provides examples of research directions that are related to and have inspired the SCM concept.

*Maps for representing societal factors*

A map is a representation of phenomena presented in a particular relational format, and is not showing "the truth", but should be seen as a model that highlights some aspects and downplays others. Maps are representations of something but also constitute and create knowledge (Ruitenberg, 2007). They can be thought of as a language for mediating different views of the world and are never value-free since it always is a matter of choice on what should be shown and what should not be shown. Therefore, maps can be controversial and have been used for both good and evil (Harley, 2001).

Social geography, or human geography, is concerned with the ways in which social relations are created, focusing on the spatial aspects of society. Social cartography has to do with theory and methods for visualizing discourse, social positioning and social change. It is typically concerned with "the locations, relations and movement of ideas, persons, or social groups in social space" (Ruitenberg, 2007:9). Social cartography does not have to do only with geographical mapping but with any kind of plotted or mapped relations (Ruitenberg, 2007). Related scientific fields are economic, political and cultural geography.

Time-geography (or time-space geography) evolved during the 60's and 70's stressing the temporal aspect in spatial human activities. With modern technology it is possible to design time-space GIS tools that are capable of showing complex activity as spatio-temporal processes in an integrated time space environment (e. g. Kwan and Lee, 2003; Shaw and Yu, 2008).

Geospatially plotted social media communication has become a source of information to support crisis management. The Ushahidi Crisis Map is an example of a tool that presents crowd sourced information that has proved to be useful during disasters and other crises. However, analysis of such information is an issue since data can be of unknown quality (McClendon and Robinson, 2011). In the EU FP7 research project Alert4All which focuses on improving the authorities' effectiveness in alerting and communicating with the population during a crisis, one substantial part is to monitor social media to find out how people perceives crises and reacts to alert messages (Párraga, Weber, Skoutardis, Hirst, Ramírez, Rego, Gil, Engelbach, Brynielsson, Wigro, Granazzi, and Dosch, 2011). A *Screening New Media* tool is developed to first harvest the data and then analyse and visualize it in various ways, not only geographically (Johansson, Brynielsson and Narganes Quijano, 2012).

*Visualization and simulation of human behaviour*

An important objective of crisis management research is to investigate the technical as well as social implications of systems and tools for visualization of human behaviour in crisis situations. Such tools may be used for training or in a real crisis, especially related to population behaviour in relation to social media and smart phone usage (Nilsson, Brynielsson, Granåsen, Hellgren, Lindquist, Lundin, and Trnka, 2012; Kluckner, Sautter, Max, Engelbach, and Weber, 2012).

Both formal theories of social behaviour (e.g. Friedkin,1986) and simulations involving selected relevant factors can help us to improve models and better understand the complexities of social systems. We may for example be interested in how social norms emerge and evolve. A norm can be described as a prescription on how humans should act in a given situation. Norms help constitute and coordinate systems of action (Therborn, 2002). Examples of agent-based simulations of possession norm emergence are for example (Flentge, 2001), where it is shown that the concept of memes advantageously can be applied to social norm modelling. Another example is simulation of opinion dynamics where models for opinion formation are investigated showing, for example how a group of people come to consensus or disagreement and how fast opinions converge (Hegselmann 2002; Hegselmann, 2005; Deffuant, 2002).

Simulation of warning diffusion is one way of investigating the effectiveness in warning systems and warning response behaviour. In an analysis of the timing of warning system information dissemination, including alerting the public and the distribution of a warning message, a general model of the diffusion of emergency warnings is presented, where alternative warning systems are characterized in terms of the parameters of the model (Rogers and Sorensen, 1991). The results indicate that a single technical system can provide adequate warning effectiveness provided that the available warning time (after detection and decision to warn) extends to an hour. Though the study is over 20 years old and new ways of alerting and new information channels are at hand, the principle of the diffusion model can still be valid.

Micro-simulation of warning diffusion in social networks where the network structure may change over time is an interesting arena for tracing the flow of information. Hui, Goldberg, Magdon-Ismail and Wallace (2010) present a general model of diffusion in dynamic networks, examining how network structure, seeding strategy, and population inhomogeneity with respect to trust, affects the diffusion process. Results show that when trust is modeled, the diffusion is more effective, but also that network structure and seeding strategy affect the effectiveness of the diffusion (Hui, et al. 2010).

In emergency planning, people's reaction to warnings is an important factor. According to the Protective Action Decision Model, PADM (Perry and Lindell, 2007), there are four main variables that influence people's responses to disaster warnings. These are environmental cues, social context, warning components (source, channel and message) and receiver characteristics (Perry and Lindell, 2007:303). We can assume that these variables have impact on people's behaviour even in other extraordinary situations.

Demographic characteristics such as income, education, age, gender and ethnicity constrain human behaviour, but these factors cannot be used to predict human behaviour in, for instance, an evacuation. Furthermore, there seem to be few examples showing personal characteristics as a defining factor for how people react in a crisis situation, although the effect of emotional state has been investigated. Emotional state can be divided in two sub-factors: initial feeling (Zhao, Lo, Zhang and Liu 2009) and stress (Vorst, 2010). Persons with a positive initial feeling combined with a low stress level are able to think rationally in critical situations while stress appears to have a great negative effect on adaptive behaviour for example during an evacuation (Vorst, 2010; Zhao et al. 2009).

## SOCIAL COVERAGE MAPS

In this section we define the concept of a Social Coverage Map (SCM) and explain how SCMs can be computed using population simulation tools.

A SCM represents the social impact of a disruption and is displayed as colour-coded zones on a planning map. The intended use is to highlight social consequences in a command and control (C&C) or crisis management situation in a way that is easily integrated with other C&C information and that is effortlessly understood by police and military staff that are habituated to the concept of a technical coverage map. SCMs are particularly suitable for time-critical decision making since the simple visual representation is easy to comprehend and compare with other map-related information. SCM are principally useful when the disruption can be represented by a coverage map including situations where radio communication systems are jammed by EW actions. The jamming zone can in this case be displayed as a jamming coverage map indicating areas where radio communication is disrupted. The social ramifications of broken communications in an urban landscape are, however, much more widespread than the actual jamming sector. People outside the jamming coverage zone will try to call into the zone and change their mental state and behaviour because of the failure to connect. People inside the jamming coverage zone will also feel and act differently for example by trying to move outside the zone. How denizens interpret the lack of communication makes a huge difference for how the emergent effects of the physical jamming ripples through society. In some operations it is essential that such dynamic social effects of intended actions are understood by operational planners.

The archetypal disruption that will be the focus of this paper is radio jamming in the context of EW operations. Using SCMs for describing the social reverberations of a perturbation works best if the physical source of agitation is localized and reasonably can be presented as a corresponding Perturbation Coverage Map (PCM). The disruption could be a single sudden spike of perturbation such as a flash grenade but is typically extended in time. Examples of such disruptions other than our model case of radio jamming are floodings, roadblocks, smoke, teargas, chemical and radioactive contamination. Ideally planners should be used to visualizing the disruption as a coverage map.

An SCM can represent a wide range of socially relevant attributes and circumstances. A given operational or crisis management situation may utilize one or several types of SCM for the purpose of illustrating societal variables of interest in the context of the operation or crisis. Each SCM visualizes an underlying socially relevant variable that we in the following will label $Q_{SCM}$. SCM is a useful representation only if the geographical distribution of $Q_{SCM}$ significantly differs from the PCM and evolves dynamically in an intuitively unexpected and emergent manner. SCMs could alternatively represent actions, mental states and relations. It is also possible to define complex compound $Q_{SCM}$ that embodies a balanced mix of action, mind-set and relational information. Action variables could for example indicate people changing position, changing velocity and taking cover because of the disruption. Mind-set variables could measure changes in anxiety, anger, trust and opinion that are caused by the disruption. Relational variables could indicate children that have lost contact with parents because of the disruption or rioters that rally to a leader as a result of the disruption.

An SCM is based on a what-if analysis that compares how social events would unfold with and without the disruption. To compute an SCM, analysts must first define the disruption. A specific radio jamming action could for example be the disruption. Analysts must secondly express the underlying attribute $Q_{SCM}$ that is of interest in the planning context. Planners might e.g. be interested in how people move physically during an operation. The SCM attribute could in this example be defined as binary attribute that is related to each person in the operations zone so that $Q_{SCM} = 1$ if the person has moved more than 10 meters because of the disruption and $Q_{SCM} = 0$ otherwise. Simulations are required for asserting how people move with and without the disruption. Thirdly, the analyst or an automatic software function defines the spatial resolution $R_{SCM}$. In a densely populated cityscape $R_{SCM}$ could for example be set to 100 meters. The software could also dynamically define the resolution so that $Q_{SCM}$ is averaged over a target number of people. The simulator will now run simulations with and without the disruption. Initially the attribute $Q_{SCM}$ is set to zero for all simulated individuals. At each moment of simulated time the simulator computes the distance between the same person in the undisrupted world and the disrupted world. If the distance is more than the set threshold $Q_{SCM}$ is set to one. Conceptually the SCM could be computed as follows. Around each point on the map an imaginary circle with a radius corresponding to the resolution $R_{SCM}$ is drawn. The fraction of people with $Q_{SCM} = 1$ is computed for the population within the circle. This fraction is colour-coded and displayed as the colour of the pixel in the centre of the zone. The SCM is created by iterating this for all points in the map. In practice the software will employ reasonable approximations of the conceptual process by selecting a finite subset of map points, perhaps replacing the circle with some other computationally convenient area and smoothing the resulting distribution with some suitable filtering process.

## THE POPSIM DYNAMIC SOCIETY SIMULATOR

In this work we generate SCMs using an in-house developed tool targeting the modelling and simulation of human populations in urban environments (Luotsinen, 2013). The tool, from now on referred to as POPSIM, employs an Agent-Based Modelling approach (ABM) where each individual in the real-world population is intuitively represented by an autonomous agent in the simulated population. A screen-capture of POPSIM is provided in **Figure 1**. The spatial dynamics of the population is visualized using GIS-based maps. Superimposed on the map are the agents, represented by color-coded blobs, and a grid-based intensity map used here to highlight areas that are densely populated (white) and those that are not (grey). The map view is complemented by line- and bar-plots to visualize distributions of agent properties such as health, activity, emotional state, cell phone usage etc.

The work-flow illustrating the process of creating a population model using the POPSIM tool is show in **Figure 2**. A population synthesizer tool, which is embedded in POPSIM, is used to generate properties and their initial values for all agents in the population. The synthesizer tool uses as input aggregated demographic as well as geographic data and generates as output disaggregated agent properties such as age, gender, occupation, etc. as well as locations representing the agent's home, work-place, etc. The synthesizer tool also associates agents with each other to form families/households, friends and other social networks that are useful when developing scenarios focusing on, for instance, information propagation. The next step of the work-flow is the routine behaviour modelling phase. In this phase, all agents are associated with daily activities that are, similarly to the population synthesizer tool, generated using statistics provided by the modeller. Domain specific behaviours are modelled and added to the agents in the last phase of the work-flow.

In POPSIM all agents interact with each other through infrastructural services that provide the basic functions to, for instance, identify agents that are within the agent's Field of View (FoV), to navigate and to plan trips within the environment's road-network or to communicate with other agents either directly "face-to-face" or using the mobile cell phones (assuming that both the caller and receiver have cell phone coverage). The implementations of these services largely originate from previous works using the ABM approach. For instance, FoV is modelled using the approach described in (Reynolds, 1999), traffic and traffic congestion is modelled using an adaptation of the behavioural rules embedded in the agent-based transportation planning tool TRANSIMS (Nagel and Rickert, 2001) and agent communication follows the Foundation for Intelligent Physical Agents (FIPA) specification implemented in the JADE framework (Bellifemine, Poggi and Rimassa, 1999).

Furthermore, central to the tests presented in this work, POPSIM embeds a model to calculate cell phone reception in the presence of noise originating from both natural (thermal noise) and man-made sources (jammers). Reception is represented by a binary value that is set to true if the Signal to Noise Ratio (SNR) is above a predefined threshold and false otherwise. Agents in POPSIM can only communicate using cell phones when both the caller and the receiver have reception (i.e. the reception flag is set to true). The Signal (S) and Noise (N) factors are calculated assuming isotropic antennas and Free-Space Path Loss (FSPL). Although the reception model may at first seem too simplistic it is a good enough representation for the purpose of this study.

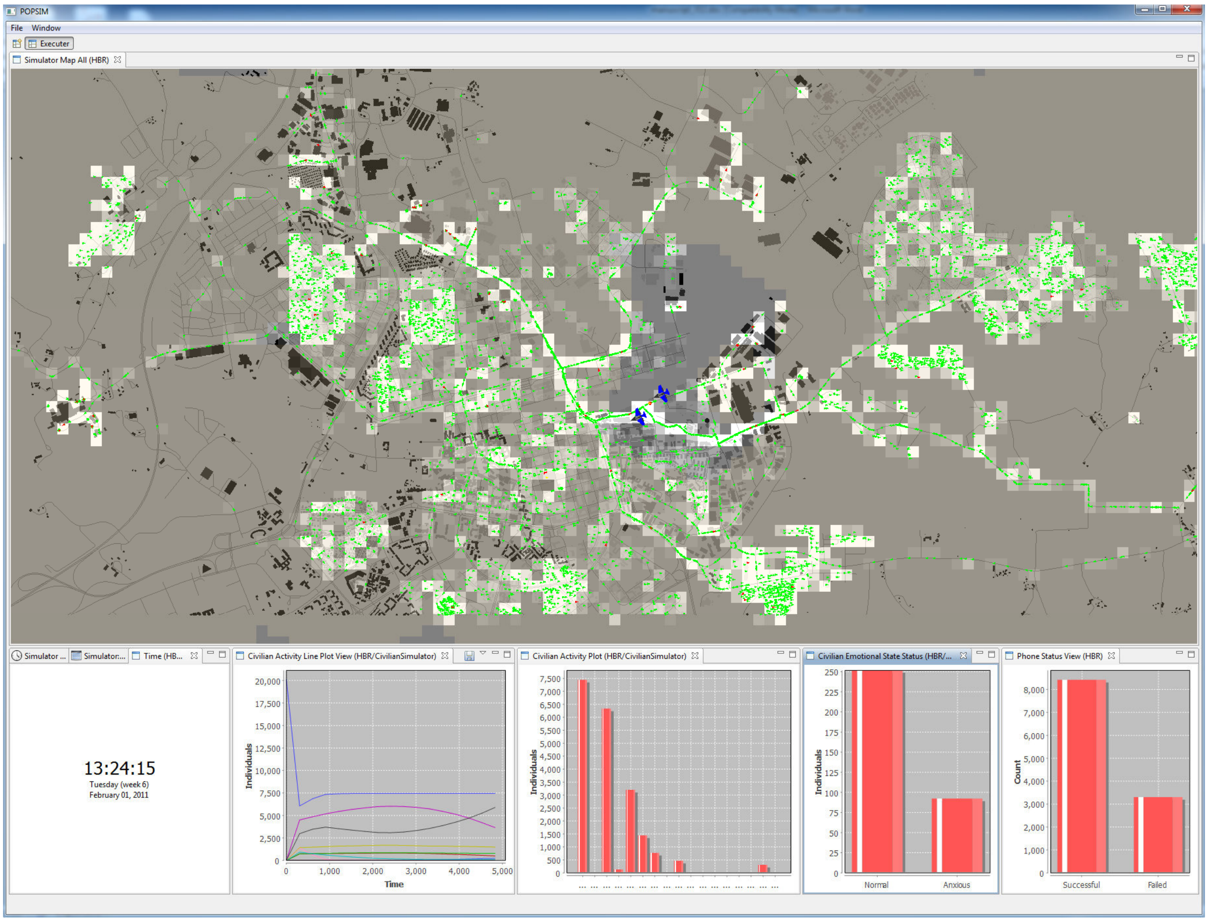


**Figure 1. Screen-shot illustrating the POPSIM tool. The spatial dynamics of the simulated population is visualized using GIS-based maps where agents are represented by superimposed blobs. Simulated calendar time, population activity over time (line-plot), current population activity (bar-plot), emotional state (bar-plot) and cell phone usage (bar-plot) are shown below the map in that order from left to right.**

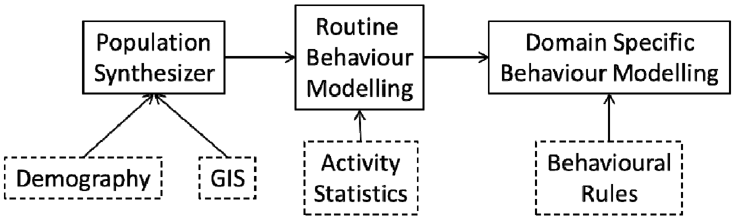


**Figure 2. The population modelling work-flow. Dashed rectangles represent input.**

## TESTS

We have performed exploratory small-scale experiments not involving end-users using a scenario that is relevant for planning urban electronic warfare in low-intensity conflicts.

The scene is a city with opposing blue and red forces. The blue forces are tasked with sending a convoy of military vehicles into the city for the purpose of picking up six political leaders and safely transport them to an important negotiation outside the city. The red force consists of peaceful but well-organized protesters that are determined to prevent the politicians from leaving the city. The vast majority of the population are law-abiding citizens that leave children at schools and day-care, commute to work, toil nine-to-five, commute back to the suburbs, pick up children and return home for well-deserved rest and recreation. Demonstrators act just like other civilians until they spot the convoy and use their cell phones for alerting fellow activists for the purpose of assembling a flash-mob. Once assembled, the flash-mob will use non-violent resistance to stop the convoy. The rules of engagement of the blue force forbids the use of violence for clearing the street from passively resisting protesters and the local police will not take sides in the conflict.

The success of the activists depends, however, on cell phone communication since any other communication channel is too slow. The blue force commander has therefore enrolled the support from an electronic warfare unit consisting of staff, operators and two unmanned aerial vehicles (UAVs) carrying powerful jammers that are able to stifle mobile communication over designated target areas. Jamming prevents obviously the formation of flash-mobs but has also unintended effects on the behaviour and mind-sets of the main population. A sizeable fraction of the population will respond to the communication black-out by getting into their automobiles and head home to make sure that relatives are safe. The resulting increase in road traffic may cause congestion and could hence slow down or stop the blue force convoy. Slowing down the convoy makes it easier for the red side to discover it and gives more time for assembling flash-mobs. Jamming will also have a negative impact on hearts and minds with increased anxiety and decreased trust.

The electronic warfare operations staff is tasked with planning jamming operations that ensures that the convoy gets through but causes minimal mental collateral damage. The staff uses a visual planning tool that displays the map of the city overlaid with pick-up points for politicians, planned convoy route, UAV trajectories, cell phone service coverage map, jamming intensity time schedule and the immediate result of jamming represented as jamming coverage maps. The emergent social effects of the jamming are presented as SCMs. The objective of the planning exercise is to design the UAV trajectories and jamming policies that will be used in the actual operation.

Our tests emulate the use of SCMs in the present scenario. We use POPSIM for simulating the city including civil population and the opposing forces. The civilian population was modelled following the process described above. Real-world GIS and demographic data originating from a mid-sized Swedish city were used to generate the initial population. Artificial activity statistics were used to generate the population's routine behaviour and domain specific behaviour rules were added to simulate the civilian population's reactions to communication black-outs as specified above.

We exemplify the use of SCMs by presenting simulation results comparing jamming policies where the jammers are turned off and turned on respectively. The jamming policies were selected because they provide lucid illustrations of the SCM concept although they are suboptimal from a blue force tactical point of view. POPSIM computes and visualizes two types of SCMs. The action SCM indicates changes in physical motion caused by the jamming. A person in the perturbed simulation that deviates more than ten meters from the corresponding path in the unperturbed simulation is permanently marked as aberrant. The action $Q_{SCM}$ measures the local fraction of aberrant people and the action SCM visualizes this fraction using colour maps that are superimposed on the geographical map representing the city. Action SCMs are illustrated in **Figure 3** and **Figure 4** at times *t+1h* and *t+2h* respectively where time *t* marks the onset of jamming. The colour map ranges from blue to red where the blue and red colours represent changes in the positioning of the population when the jammer systems are turned off and turned on respectively. Areas that are green indicate no change in position. In the first figure a vague bluish colour can be seen near the current jamming positions, represented here by striped circles, of the UAVs. The SCM indicates that individuals have moved away from these areas when the jammer systems are used. In the second figure the blue and red areas are intensified indicating that as time progresses more individuals are affected by the operation. Perhaps not too unexpected, considering the behaviour model used by the agents, the agents move away from the downtown parts of the city to the residential areas in an attempt to locate their family members.

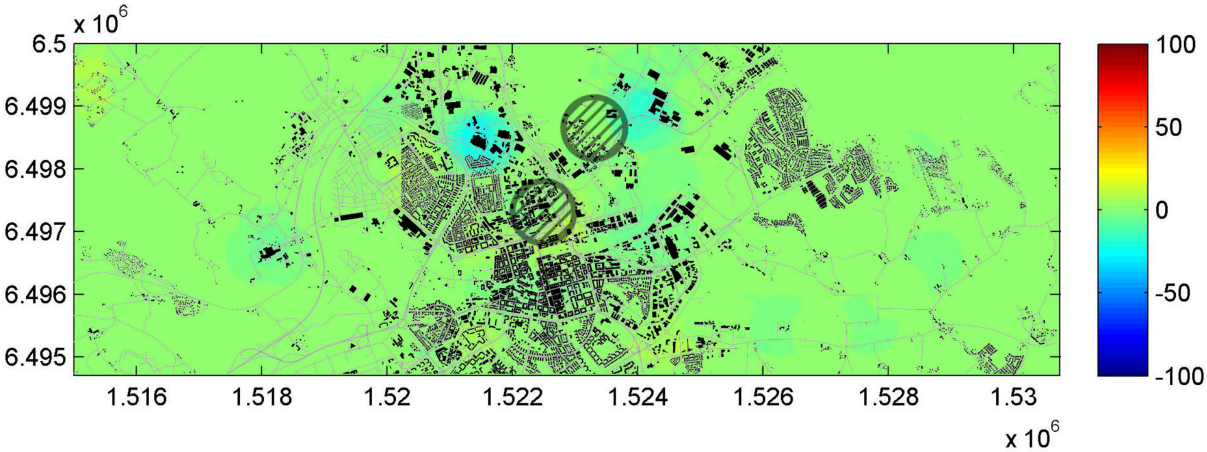


**Figure 3. Action SCM at *t*+1h.**

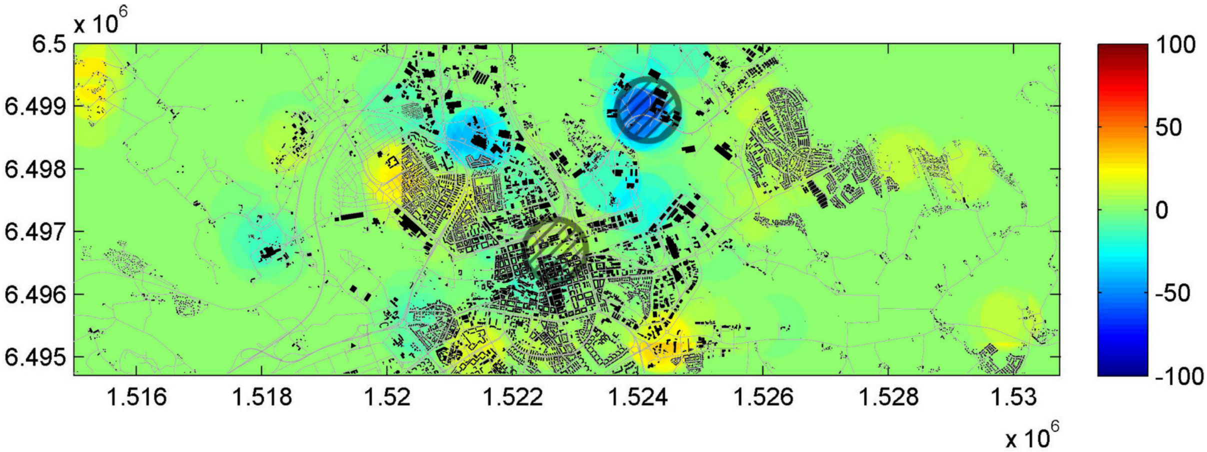


**Figure 4. Action SCM at *t*+2h.**

The mind-set SCMs in **Figure 5** and **Figure 6** represent the impact of jamming on population anxiety. Each simulated person has an anxiety level which is a binary variable. The mind-set $Q_{SCM}$ is the average local change in anxiety caused by electronic warfare actions. The $Q_{SCM}$ value in a given point consists of the average change in the group of people that are within 500 meters of the point. Similarly to the action SCM, the colour map represents changes between the simulation runs, but in this case with respect to anxiety levels. The absence of blue areas in the mind-set SCM is a natural result of using the no jamming policy where no individuals were emotionally affected.

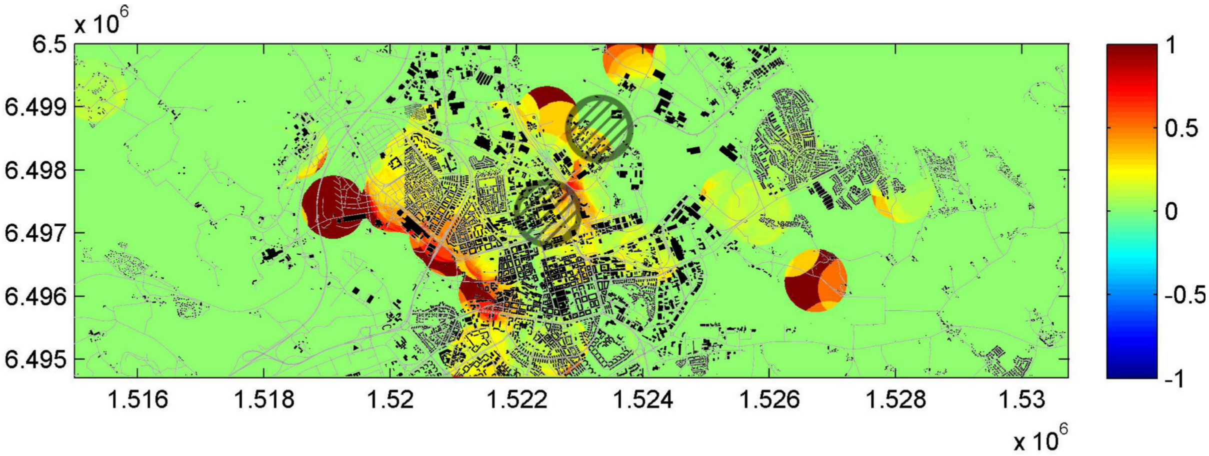


**Figure 5. Mind-set SCM at *t*+1h.**

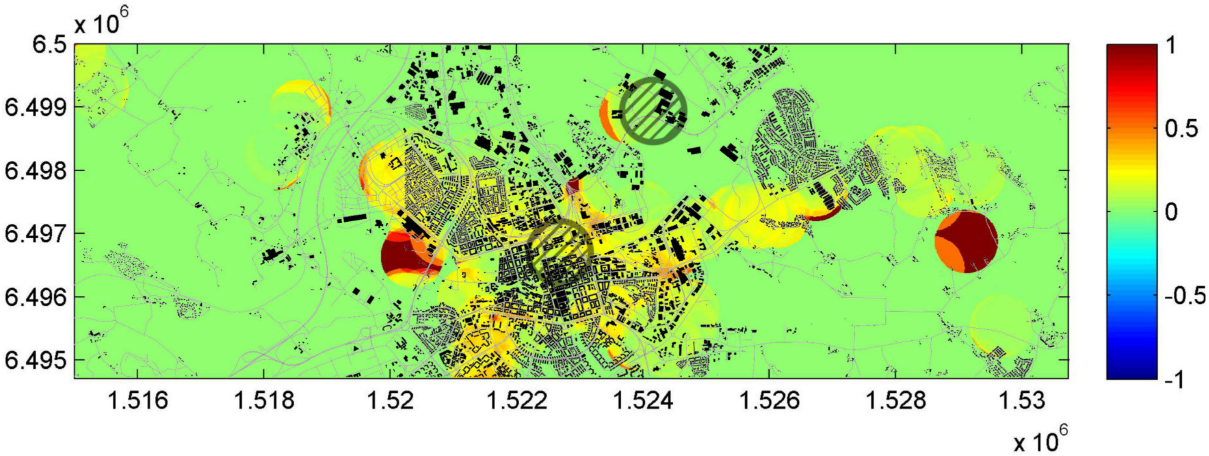


**Figure 6. Mind-set SCM at *t*+2h.**

## DISCUSSION

In conclusion, we find that even though the specific set-up of our tests is somewhat unrealistic the use of simulation-based SCMs can help planners to better understand the full complexity of social ramifications. Military planners, police operation leaders or crisis management teams could use SCMs to get direct and tangible feedback on the social impact of planned actions. SCMs are overlaid on the main planning map and would therefore be viewed as more significant and immediate than text annotation or verbal warnings. Action-oriented officers might give more attention to social factors if they are presented as coverage maps that visually share the same status and significance as physical factors that also are visualized as coverage maps. Military staff considering a communications blackout in a major city should be warned that roads might be filled with people seeking physical contact with relatives that no longer can be reached by cell phone. Police officers pondering the option of suppressing football hooligans with cloud of teargas could be reminded of the number of children that will be separated from guardians in the resulting fracas. Crisis managers assessing the option of blocking the roads to a rioting suburb should reflect on how fear and anxiety spread in the community.

It is crucial that decision makers have an appropriate degree of trust in the SCMs. The trust should be related to the accuracy of the underlying simulation with respect to the quantities that are displayed in the maps. If the simulation lacks sufficient realism, planners should be trained to appreciate that SCMs are not accurate predictions but rather qualitative reminders of that social effects often evolve in unexpected, contorted and emergent directions. If the SCMs, on the other hand, are based on realistic and thoroughly verified and validated models, decision makers should be made aware of the trustworthiness of the results and it would also make sense to graphically indicate known uncertainties. It is hence essential to train users of SCMs properly both to avoid overconfidence in the details of the SCMs and to engender trust in proven and accurate simulation results that can be put to use in detailed operational planning.

This paper is the first conceptual step in evolving a simulation tool for creating SCMs for emergency planning and crises management. Several issues, such as identifying variables that are relevant for predicting people's instant and long-term reactions and behaviour, representations of those reactions, trustworthiness in the SCM and the simulation system in relation to other sources of information and how that affect decision making, need to be discussed and further elaborated on. For future research we would like to include different and more detailed psychological and opinion dynamics models. It would be interesting to investigate the effects of warning messages before a planned disruption and further elaborate on the timing and distribution of warning messages. The concept, simulations and graphical representations should also be evaluated by stakeholders representing operations and crisis management, preferably in a design workshop or focus group seminar.

## ACKNOWLEDGMENTS

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## REFERENCES


1. Ball, James and Brown, Symeon. (2011) Why BlackBerry Messenger was rioters' communication method of choice. Series: Reading the Riots. guardian.co.uk, Wednesday 7 December 2011. Retrieved 2012-10-24.
2. Bart – Bay Area Rapid Transit (2011) Statement on temporary wireless service interruption in selected BART stations on Aug. 11. www.bart.gov. Aug. 12, 2011 1:08 pm (retrieved 2012 11 27).
3. Bellifemine, F., Poggi, A. and Rimassa, G. (1999) JADE - A FIPA-compliant agent framework, Proceedings of the Practical Applications of Intelligent Agents, 1999.
4. Bhuiyan, S. I. (2011) Social Media and Its Effectiveness in the Political Reform Movement in Egypt. *Middle East Media Educator* 1, 14-20.
5. Deffuant, G., Amblard, F., Weisbuch, W. and Faure, T. (2002) How can extremism prevail? A study based on the relative agreement interaction model, *Journal of Artificial Societies and Social Simulation*, 5.
6. FCC – Federal Communications Commission (2012) Public notice, Released: March 1, 2012. Commission seeks comment on certain wireless service interruptions, http://www.fcc.gov/ (retrieved 2012 11 27).
7. Flentge, F, Polani, D. and Uthmann, T. (2001) Modelling the Emergence of Possession Norms using Memes, *Journal of Artificial Societies and Social Simulations* 4.
8. Friedkin, N. E. (1986) A Formal Theory of Social Power , *Journal of Mathematical Sociology*, 12, 103-126.
9. Harley, J. B. and Laxton, P., ed. (2001), The New Nature of Maps: Essays in the History of Cartography, The John Hopkins University Press.
10. Hegselmann, R. and Krause, U. (2002) Opinion Dynamics and Bounded Confidence Models, Analysis, and Simulation, *Journal of Artificial Societies and Social Simulation*, 5.
11. Hegselmann, R. and Krause, U. (2005) Opinion Dynamics Driven by Various Ways of Averaging , *Computational Economics*, 25, 381-405.
12. Howard, H. N. and Hussain, M. M. (2011) The Role of Digital Media, *Journal of Democracy* 22, 35-48.
13. Hui, C., Goldberg, M., Magdon-Ismail, M., and Wallace, W. A. (2010) Agent-based Simulation of the Diffusion of Warnings. Proceedings of Agent-Directed Simulation Symposium (ADS'10), as part of the 2010 Spring-Simulation Multi-conference (SpringSim'10), Orlando, Florida.
14. Johansson, F., Brynielsson J. and Narganes Quijano, M. (2012) Estimating Citizen Alertness in Crises Using Social Media Monitoring and Analysis. *Proceedings of EISIC 2012 - 2012 European Intelligence and Security Informatics Conference,* 189-196.
15. Kluckner, S., Sautter, J., Max, M., Engelbach, W., Weber, T.. (2012) Impacting Factors on Human Reactions to Alerts. *Proceedings of the 9th International ISCRAM Conference* – Vancouver, Canada, April 2012.
16. Kwan, M., and Lee, J. (2003) Geovisualization of Human Activity Patterns Using #D GIS: A Time-Geographic Approach. In *Spacially intergrated Social Science: Examples in Best Practice* (Eds. Goodchild, M. F., and Janelle, D. G.), Oxford University Press, Oxford.
17. Landau, D. A. (2011) How Social Media is Changing Crisis Communication: a Historical Analysis, Master's thesis, Fairleigh Dickinson University, Madison, New Jersey.
18. Luotsinen, L. J. (2013) POPSIM: A Platform Targeting the Modeling and Simulation of Human

Populations in Urban Environments, Submitted to: The Twenty-Fifth Annual Conference on Innovative Applications of Artificial Intelligence (IAAI), Bellevue, Washington, USA, July 2013.

19. McClendon, S. and Robinson, A. (2012) Leveraging Geospatially-Oriented Social Media Communications in Disaster Response. *Proceedings of the 9th International ISCRAM Conference* – Vancouver, Canada, April 2012.
20. Nagel, K. and Rickert, M. (2001) Parallel implementation of the TRANSIMS micro-simulation, Parallel Computing, 27, 12, 1611-1639, 2001.
21. Neill, A. & Shruti, J. (2012). Comment of New Media Rights on the Intentional Interruption of Wireless Services. On the Matter of the Public Comment on Intentional Interruption of Wireless Services. April 30, 2012.
22. Nilsson, S., Brynielsson, J., Granåsen, M., Hellgren, C., Lindquist, S., Lundin, M., Narganes Quijano, M., Trnka, J.. (2012) Making use of New Media for pan-European Crisis Communication. *Proceedings of the 9th International ISCRAM Conference* – Vancouver, Canada, April 2012.
23. Párraga Niebla, C., Weber, T., Skoutardis, P., Hirst, P., Ramírez, J., Rego, D., Gil, G., Engelbach, W., Brynielsson, J., Wigro, H., Granazzi, S. and Dosch, C. (2011) Alert4All: An integrated concept for effective population alerting in crisis situations, *Proceedings of the Eighth ISCRAM Conference.*
24. Perry, R. W. and Lindell, M. K. (2007) Emergency Planning, John Wiley & Sons, Inc., Hoboken, New Jersey.
25. Reynolds, C. W. (1999) Steering Behaviors for Autonomous Characters, Game Developers Conference (GDC), 1999, 763-782.
26. Rogers, G. O. and Sorensen, J. H. (1991) Diffusion of Emergency Warning: Comparing Empirical and Simulation Results. *Risk Analysis.* (Ed. Zervos, C.). Plenum Press, New York.
27. Ruitenberg, C. W. (2007) Here be dragons: Exploring Cartography in Educational Theory and Research , *Comlicity: an international Journal of Complexity and Education* 4, 7-24.
28. Shaw, S., and Yu, H. (2008) A GIS-based time-geographic approach of studying individual activities and interaction in a hybrid physical-virtual space. *Journal of Transport Geography*, 17, 2, 141–149.
29. Spencer, J. (2012) No Service: Free Speech, the Communications Act, and BART's Cell Phone Network Shutdown. *Berkeley technology law journal*, 27, 767-806.
30. Therborn, G. (2002) Back to Norms! On the Scope and Dynamics of Norms and Normative Action., *Current Sociology*, 50, 863-880.
31. Vorst, H. C. M. (2010) Evacuation Models and Disaster Psychology, *Procedia Engineering,* 3, 15-21.
32. Zhao, C. M., Lo, S. M., Zhang, S. P. and Liu, M. (2009). A Post-fire Survey on the Pre-evacuation Human Behavior, *Fire Technology*, 45, 1, 71-95.