Proceedings of the 51st Hawaii International Conference on System Sciences | 2018

Agent-based analysis of the spread of awareness in the population in the prodromal phase of bushfires

Carole Adam
Grenoble-Alps University, France
Grenoble Informatics Laboratory
Email: carole.adam@imag.fr

Julie Dugdale
Grenoble-Alps University, France
Grenoble Informatics Laboratory
University of Agder, Norway
Email: julie.dugdale@imag.fr

Abstract*—Efficient communication is essential in disasters in order to coordinate a response and assure effective evacuation. This paper focuses on the case study of the Melbourne bushfires in 2009. We first analysed some interviews of the population to know who the population communicates with (neighbours, family, authorities, etc), and using what channel (radio, phone, internet, etc). We then developed and implemented communicative actions in a Belief-Desire-Intention model of the population's behaviour. Finally, we ran experiments in order to compare the speed at which the population becomes aware of the fires in different scenarios with different types of communication (more or less organised). Our first results show that more organised modes of communication would provide significant benefits in terms of propagation of awareness in the population.

Keywords: crisis communication, agent-based modelling and simulation, bushfires, human behaviour modelling, BDI architecture, phone tree.

I. Introduction

In order to provide an effective and unified response to crisis situations it is crucial that emergency managers and responders communicate efficiently both at the intra- and inter-organisational level [1], [2]. However, a successful crisis response also requires communication with citizens and citizen groups to ensure safe evacuation or management of the situation [3]. At the ground level, citizens need to interact and share opinions with other citizens in order to inform each other and prepare for a response [4], [5]. Indeed one of the first actions immediately following a disaster is for people to search for information in order to understand and make sense of the situation. This information may come: from news agencies, broadcasted by radio, TV or Internet; from emergency response organisations, such as the Red Cross or FEMA, communicated via social media or given to the news agencies; or more immediately from fellow citizens, through direct communication, telephone calls, and SMS. In cases where there is warning of an impending crisis, such as with bushfires or hurricanes, citizens will monitor local news sources, contact each other to find more information, warn others, or simply try to be close to family or friends.

There are several types of communication that are relevant: from the authorities to the population (usually unidirectional broadcast on TV, radio or Internet); from the population to the authorities (requesting information or help, and increasingly also providing field information via social medias); between and inside the different disaster management agencies; and within the population (exchanging information, reassuring one's family, etc).

In previous work we modelled various communication strategies that the authorities could use to influence the population's decision to evacuate the population during a bushfire. In this paper we focus on the interactions of the population with various interlocutors (their family and friends, their neighbours, and the authorities). We intend to show that these interactions could and should be more organised to improve effectiveness in spreading awareness in the population. A significant proportion of the population of Victoria live in small communities in bushfire prone areas, some of which are quite remote. Unlike in other parts of the world where the responsibility for rescue and defence of property lies with the fire services, in Australia it is often the case that the local population is responible for defending their own property or evacuating themselves to safe areas. Many people died needlessly in bushfires because they were isolated from others and became aware of the danger too late to safely react. On the contrary, other less isolated people might be warned several times. We implemented and tested several ways of organising intra-population interactions to avoid such situations, and compared how fast awareness of the danger spreads in the population with each organisation mode.

This paper is structured as follows: Section II first discusses related works in crisis communication. Section III then introduces the data available along with our methodology and the results of our analysis. Section IV then presents our model and simulation of the population's behaviour based on this analysis. Section V describes the experiments and discusses results obtained from our simulations. Section VI concludes the paper.

II. Literature about crisis communication

During an incident, information is as critically important to people as food or water. Not only can accurate information mean the difference between life and death, it can provide reassurance that response and recovery are truly underway [6].

Yet, unfortunately there are very few works that use simulation to test the effect of communication strategies on a realistic simulated population, taking into account the psychological

URI: http://hdl.handle.net/10125/49897
ISBN: 978-0-9981331-1-9

aspects of message acceptance and impact on behaviour change. One exception is the simulation we cited earlier [7], but it focuses on the interactions from the authorities to the population, and not on how the information then spreads inside the population.

Information spread was addressed at a theoretical level in [8] by combining a multi-agent system and social network analysis to study communication within groups of people. They found that the emergence of mutual knowledge may be explained as a percolation phenomenon originating from the physics domain.

Nevertheless these simulation works are often focused on small groups of people. For instance [9] provided an agent-based model and simulation of different modes of communication in an emergency control room, showing that telephonic communications are often more efficient than other forms of communication even when people are closely co-located.

A notable exception in the simulation domain that looks at communications in disasters for a wider group of people is [10], who used a GIS to analyse different modes of communication during a tsnumani. They found that a correlation exists between the time that information was received and the number of casualties.

Outside of the simulation domain, other works are interested in crisis communication. For example, [11] compared the timeliness and relevance of 4 different sources of official online information during crises. Their results provide an insight about how official sources can better manage their online communication, and how the public can find timely and relevant information online (websites and social media).

In this paper we have purposely ignored social media, as they are not mentioned in our data source. However, Twitter has indeed been used during the bushfires, and some works have already exploited Twitter. For instance, Power *et al.* [12] propose the Emergency Situation Awareness (ESA) system, that monitors Twitter to provide emergency managers with relevant information, generating alerts when detecting an unusual increase in the frequency of certain words.

The use of social medias has also been investigated by [13], who studied the engagement of risk communicators with social media in the prodromal phase of hurricane Sandy. The focus on the prodromal phase is a shared originality with our work here. Of course this prodromal phase, before the disaster actually starts but when it is already expected, is only relevant for slow-onset, predictable disasters such as bushfires or storms. Such work is not applicable to earthquakes or terrorist attacks for instance.

Finally, another originality of our approach is to design our model based on citizens' interviews where they describe their behaviour, rather than using quantitative data such as statistics. Such qualitative data is harder to analyse but provides valuable insight into the psychological determinants of behaviour, that cannot be quantified.

III. Data analysis

This section introduces our case study of the Melbourne "Black Saturday" bushfires in 2009, the data available concerning that disaster, and how it was analysed.

A. Context and data

In February 2009, severe bushfires hit the state of Victoria in South-East Australia, killing 173 people and injuring another 414. A research commission was formed and produced a report [14] that showed that communication to the population must be improved in order to avoid such high fatality and injury rates in the future.

In particular the report contains the interviews of 100 people that were involved in the bushfires: residents of the fire-affected areas, firemen who fought the fires, or relatives of deceased people. In these interviews, people recount in detail what they did before, during and after the bushfires. These interviews are quite heterogeneous in terms of their author and length. Since the interviews are in narrative form they are hard to analyse automatically.

Nevertheless, these interviews provide very rich information about the population's behaviour in the bushfires. Consequently, they have been used to extract different stereotypical behaviour profiles [15]: can-do defenders, livelihood defenders, considered defenders, threat monitors, threat avoiders, and unaware reactors. They have also been used to develop a model of the population's behaviour in the bushfires [16], [17]. This model uses a finite-state-machine architecture that provides a rather simplistic and rigid description of behaviour. In addition, it completely ignores communication between the individuals.

B. Methodology and results

In this paper, interviews have been exploited to show the importance of communication in the population's reactions to the bushfires, and to subsequently update a model to include communicative behaviour. In the absence of existing tools or methodologies for extracting a human behaviour model from narratives, we adopted the following methodology.

After reading the interviews, we empirically selected various relevant communication keywords, that we sorted into different categories of communication channels (TV, radio, Internet, social media, etc) and different categories of interlocutors (family, police, fire agencies, neighbours). We implemented a parsing tool to count occurrences of these keywords in each interview and generated statistics.

C. Results

The results are shown in Figure 2 for the communication channels, and Figure 1 for the interlocutors. As we can see, most people mention communicating, all of them used the phone, and most of them also used the radio. All of them also mention their family, and most of them mention their neighbours, showing the importance of social links inside these communities. Communication is important and happens between all types of actors involved in the crisis, with also many mention of the police and fire agencies.

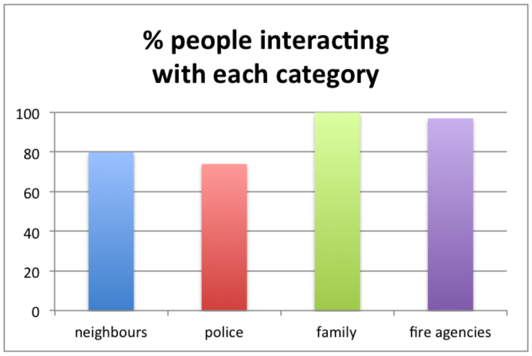

Fig. 1. Percentage of interviews mentioning each type of interlocutor

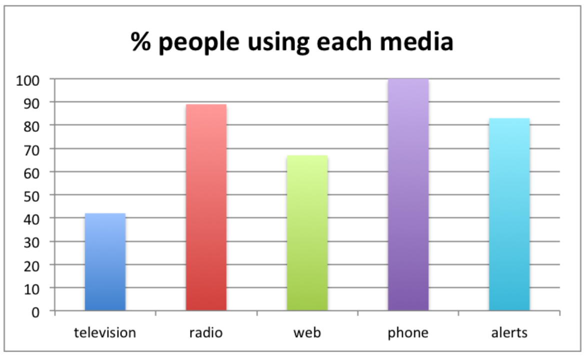

Fig. 2. Percentage of interviews mentioning each channel

D. Discussion

A more detailed semi-automated analysis of the interviews is still ongoing, trying to exhaustively list all the interactions described, with the people involved; the channel used (phone, Internet, face to face, etc); the type and content of the interaction (information, recommendation); its timing (before, during or after the fires); its trigger (why did the person decide to communicate at that time); and its effect on behaviour (did the receiver change their behaviour as a result). In the future we also intend to compare these results with communication in other types of crises (various natural disasters, terrorist attacks, etc.) and in other countries and cultures.

However this first analysis already provided interesting insights. Two points in particular are worth discussing further. First, we can see that surprisingly, there was no mention of social medias (Facebook, Twitter) in any of the interviews. It may be likely that these communication media were used more by people outside of the area. Another explanation is that social media was not as frequently used in 2009 as it is today. As a result we decided to ignore social media in the model presented here.

Second, several people mentioned in their interview that they wished that a phone tree had been organised. A phone tree [18] is a list of phone numbers where each person is asked to contact the next person in the list, etc. in order to efficiently share information in a community. There are different types of phone trees: simple (an unordered list of numbers); linear (a sequence of numbers with a defined start and end); circular (a sequence that can start anywhere in the circle); tree (the starter rings two people to trigger parallel branches of the list); or combinations. The choice of the appropriate organisation usually depends on the size of the group. In our model we decided to implement various organisations of communication in order to compare their efficiency.

IV. Model of communicative behaviour

Based on this analysis, we intend to develop a model of the communicative behaviour of the population before and during the bushfires. We focus on the communication inside the population, ignoring the other levels of communication (population with the authorities, response agencies with each other). Messages from the authorities to the population have been investigated elsewhere, for example [7].

A. Modelling choices

1) Selected human agent architecture: In agent-based modelling and simulation, there are various levels of complexity for the underlying agent model. A well-known agent architecture in artificial intelligence is the BDI model [19], which describes behaviour in terms of mental attitudes: Beliefs, Desires and Intentions. Beliefs describe how the agent sees the world, and can be incomplete or incorrect; Desires describe how the agent wants the world to be, and can be inconsistent or unrealistic; Intentions finally describe what the agent commits to do, and must be consistent and persistent.

Other works have discussed the interest of BDI models in social simulations in general [20], and shown the interest of using a BDI model (over more simplistic reactive models) specifically to simulate the population in bushfires [21]. In particular BDI models are easier to develop and extend, and the code and results are easier to understand. This is very important in crisis management, where models are likely to be used by field experts who are not computer scientists. The level of abstraction of a BDI model also matches the vocabulary used by people to describe their behaviour, making it easier to abstract a model from the interviews, and to explain it to field experts. This is essential for models aimed at raising awareness or supporting decision making, which are much more likely to reach their goal if they are well understood. Finally, BDI offers more flexibility and realism for modelling human behaviour.

The BDI model is also more adapted to describe communication. The semantics of messages can be expressed in terms of mental attitudes, explaining why a message is sent (*e.g.* because the sender **wanted** to let someone know about something, because they **believed** it was important, etc). Also, adding a new state in a Finite-State Machine architecture as the one proposed by [17] would have required specifying the transitions between that new state and all the other states in the FSM. Adding communication is much more straightforward in the BDI architecture, where one just needs to write new plans that can be selected by the agent when they want to communicate. As a result, we chose to use a BDI architecture for the human agents in our model.

2) Selected simulation platform: GAMA [22] is an open-source platform for agent-based modelling and simulation, offering an integrated programming language and development framework to develop elaborated models with up to several million agents. GAMA is supported by an active and growing community and offers many benefits for our simulation:

- The GAMA Modelling Language (GAML) is a high level agent-based language based on Java, specifically designed to be easy to use even for non-computer scientists, allowing domain experts to create and maintain their own models.
- GAMA also provides native management of GIS (Geographical Information Systems) data allowing the integration of geographical data files into simulations.
- GAMA offers interactive functions (user commands) enabling the use of participatory dynamics and the involvement of the user in interactive simulations, which is useful when aiming at raising awareness.
- GAMA has both a GUI and a batch simulation mode: the GUI mode allows visualising one simulation as it unfolds, while the batch mode allows the repetition of several simulations with various parameter values and drawing statistics and graphs.
- GAMA now provides a BDI plugin [23] to implement human agents with a BDI architecture.

We therefore chose to implement our model and simulation in the GAMA platform.

B. Our general model

There are different types of agents in our model: elements of the environment (land, rivers, roads, buildings, shelters); humans (civilians and fire-fighters); and exchanged messages.

1) Environment: The environment is built from OpenStreetMap[1] (OSM) data for the town of Marysville, which greatly suffered from the 2009 bushfires. GAMA provides native functions to handle GIS data, that we used to implement a tool to create the agents in our environment (land, rivers, roads, buildings) from an OSM file. This provides us with a more realistic environment.

2) Firemen: This environment is populated with humans agents with two possible roles: civilians and fire-fighters. We are not yet interested here in the decision process of the fire-fighters nor their interactions together and with the population. In order to optimise the simulation, we therefore modelled them with a very simple reflex architecture: their only available behaviour is to head towards and fight fires. In particular, they cannot yet inform the population or give them recommendations, but this is to be added in future work.

3) Communication model: Messages exchanged by the human agents are represented by agents with the following attributes, based on communication theory [24]: sender, list of receivers, content (a predicate), channel. For now the possible messages are only informative, and although the possible channels include phone, radio and TV, our model only uses phone. In future work we intend to add face-to-face communication between neighbours and with local fire-fighters and policemen, as well as recommendation messages in addition to information.

[1] https://www.openstreetmap.org/

C. Civilian model

In this paragraph, we detail the BDI model of civilians, which is the main focus of this paper.

1) Attributes and initialisation: Civilian agents have the following attributes:

- Physical attributes: ability, perception radius, speed, health, location, home address, work address, known shelters, known fires
- Psychological attributes: minimum home resistance required, sociability (size of social network), risk aversion, home attachment, altruism, obedience, inaction threshold (minimal motivation necessary to stop being passive)
- Communication attributes: focus on the different channels, list of neighbours, list of friends, list of calls made.

These attributes are initialised randomly for each agent at the start of the simulation, creating a heterogeneous population in terms of ability, willingness to communicate, etc. Initially the agents have no beliefs or desires.

2) Perception and reasoning: Civilians then observe their environment and can perceive other humans, fires, buildings, and messages sent to them. Their beliefs are updated following various rules, in particular:

- When the resistance of their home exceeds their required minimum, they adopt the belief that their house is ready (which is a necessary condition to defend it).
- When they detect or are informed about a fire, they adopt the belief that there are fires (they become aware).
- When they detect or are informed about a fire closer than 20m to their house, they adopt the belief that the fires are close (this is the trigger for some behaviours).

These beliefs in turn activate new desires. For instance becoming aware of the fires triggers the following desires:

- Desire to prepare themselves and their home.
- Desire to inform others about these fires, with a priority influenced by their level of altruism.
- If they are part of an organised phone tree: desire to inform others in the phone tree about the fires, with a priority influenced by their level of obedience to norms.
- If ready: desire to stay safe, with a priority based on risk aversion.
- If ready and home ready: desire to protect their home, with a priority influenced by home attachment.

When the fires get very close to their home, they change their desires again, dropping the desire to get ready (since there is no time left) and immediately adopting the two contradictory desires of escaping to safety (depending on risk aversion) and of protecting their home (depending on home attachment).

The reasoning engine then prioritises the desires depending on their respective intensity and on the context (distance to the fires, etc), in order to select an appropriate intention to pursue. For instance if home attachment is greater than risk aversion, the civilian will adopt the intention to protect their home. If no desire has a priority above the inaction threshold, the civilian does not adopt any intention and stays passive.

3) Plans and action: Civilians have the following plans to try to achieve their intentions:

- Prepare themselves: improve their resistance (this simulates wearing appropriate gear, etc), and make phone calls if needed;
- Prepare their home: improve the resistance of the building (this simulates turning on sprinklers, etc);
- Escape to a shelter: follow the roads towards the closest known shelter;
- Fight the fires: decrease the intensity of fires at a 20m distance around them, depending on their physical ability;
- Communicate with their family (not currently used)
- Propagate information about the fires: choose a receiver, try to call them (which can fail if the line is busy or the receiver is not sufficiently focused on the phone), and if they answer the phone, inform them about the fires.

4) Psychology and communication: The civilian agents therefore have several psychological attributes that influence the communication:

- Level of altruism: influences their willingness to share fire information with others (friends and neighbours), *i.e.* the priority of their desire to propagate fire information with the social and geographical strategies.
- Level of obedience to norms: influences their willingness to follow the phone tree, and to keep trying if calls fail, *i.e.* the priority of their desire to propagate fire information with the phone tree strategy.
- Focus on the phone channel: influences the probability that they answer the phone when someone calls them.

D. Communication modes

We have implemented four modes of organising communication in this simulated population: no communication at all, communication based on social relations (call one's friends), communication based on geographical proximity (call one's neighbours), and communication organised along a phone tree. The communication mode can be set by the user in the parameters of the simulation.

Concretely, the communication mode modifies the selection of receivers in the communication plan of the civilian agents:

- No communication: delete receivers, no message is sent.
- Social communication: potential receivers are the agent's friends (the number of friends depends on the sociability attribute) who were not yet contacted. If an attempt fails, the agent might retry later but new calls have priority over re-calls.
- Geographical communication: potential receivers are the agent's neighbours at a distance of 200m. In future work this distance will be made a parameter to study the influence of the size of a neighbourhood.
- Phone tree: the potential receivers are the residents of the next home to call in the list. If the call fails several times, there is a backup strategy to skip that home and call the next one in the list. We implemented a circular phone tree where the agent will loop through the entire list if needed.

V. Experiments and results

Our simulation aims at comparing the modes of organising the communication within the population described above. The simulator is intended as a tool to raise awareness by providing interesting visualisations of information propagation, as well as a tool to investigate new communication modes.

A. Indicators

In order to evaluate each communication mode, we defined the following indicators:

- Number of communication failures: an agent tried to call but failed to reach the intended receiver (line busy, receiver not focused);
- Number of messages successfully sent: the phone call reached the receiver;
- Number of useful messages: the receiver did not already know the information received;
- Percentage of agents aware of the fires after 200 cycles, and/or number of simulation cycles before all agents are aware of the fires.

B. Experiment modes

We have implemented two different experiments described below: GUI mode (visualisation of information propagation in a population using one particular communication mode); batch mode (comparison of average results with four communication modes).

1) GUI mode: In GUI mode, the user interface has the following elements:

- Parameters: global level of altruism, strength of the fire, communication mode
- User commands: send official warning to one agent, start fires
- Map with civilian agents to observe behaviour (see Figure 3)
- Other dislpays: phone network, messages exchanged
- Graphs (see Figure 4)

Figure 3 shows the user interface with the parameter selection window, the console, and the city map display. The agents change colour when they become aware of the fires, and an arrow is shown between the sender of a message and the receiver. This allows the user to visualise the propagation of information live. The user can interact with the simulation by sending the official warning (which will make one random initial agent aware of the fires) and/or starting fires (which can be perceived directly by some agents, who will then propagate their awareness).

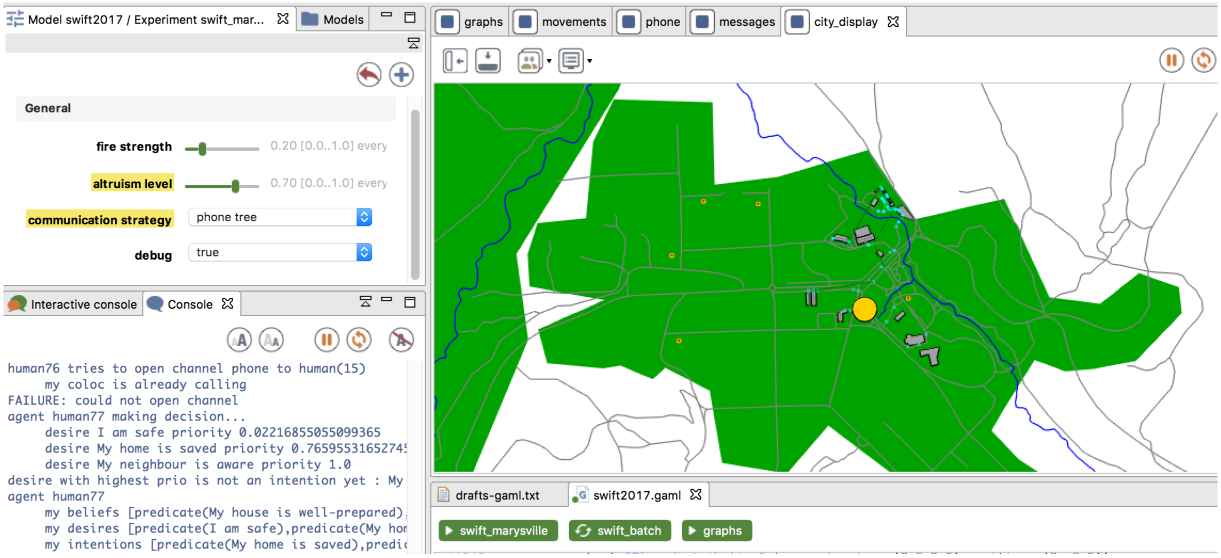

Fig. 3. Interface of the simulator: parameters (top left), console (bottom left), city map (right)

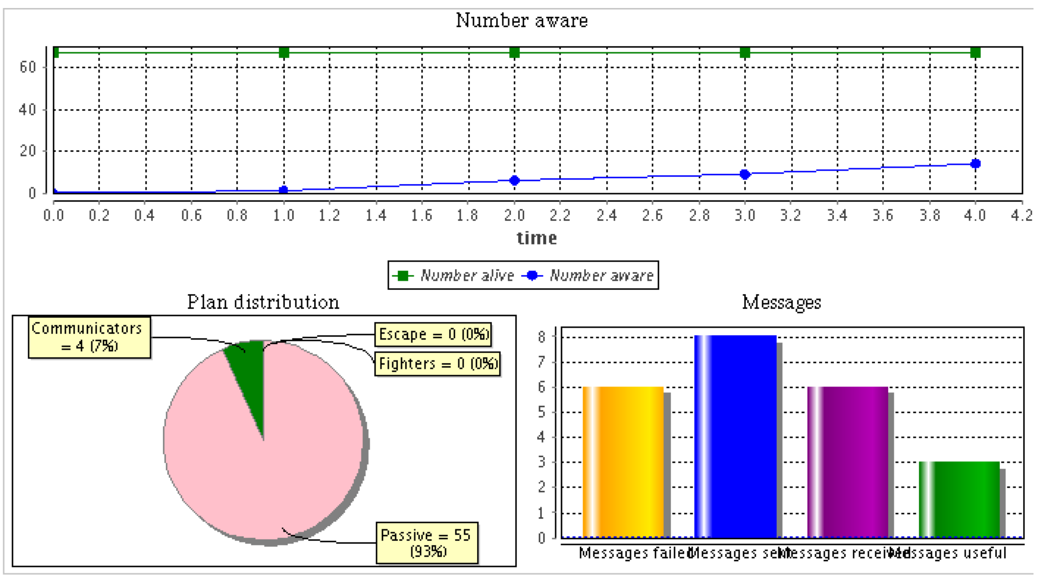

Fig. 4. Graphs obtained with geographical communication

The interface also offers some graphs to summarise interesting information. Figure 4 illustrates this display. At the top, a time series graph shows the evolution over time of the number of agents that are alive (green line) and aware (blue line). At the bottom left, a pie chart shows the percentage of agents that are communicating at a particular moment. At the bottom right, a histogram counts the number of failed interactions, successful interactions (phone call reached recipient), and useful interactions (information not already known).

2) GAMA batch experiments: In batch mode, we run 50 repeats of the simulation with each of the four communication modes, and compute average values of our indicators. The 50 repeats allow smoothing out the randomness of each simulation and obtaining more statistically significant values. Figure 5 illustrates the results.

These results show some interesting insights about the different modes of communication:

- No communication: only the agent receiving the official warning is aware, since the fires have not started yet to allow direct perception.
- Social communication is quick and motivated by people's altruism rather than obedience to norms. There is however a high redundancy (few useful messages) as the same people might be called several times by different friends. On the other hand some people might never be called if they are socially isolated, and the percentage of people

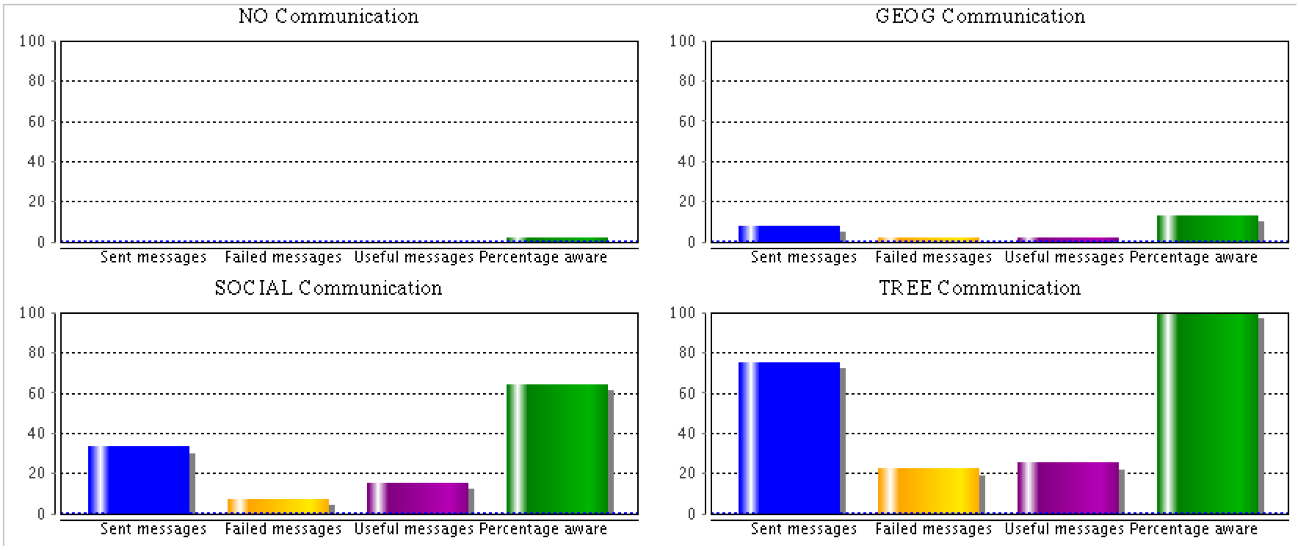

Fig. 5. Results of the comparison between 4 modes of organising communication in the population

aware reaches a maximum at about two thirds of the total population.

- Geographical communication is also influenced by altruism and solidarity. The information is local and therefore more relevant and useful. However the information does not spread out of the local neighbourhood, requiring warnings to be issued to each community. It is not the case in our model, so only a small percentage of the population is aware at the end of the simulation.
- Communication along a phone tree is the most efficient strategy because of the backup (if a call fails, the agent will call the next number, until someone is reached). However this backup means that an agent might call a number of an agent that was already informed before, reducing the percentage of useful messages. Without this backup, the tree might quickly stop when one agent does not answer, leaving the sequel of the list uninformed. This needs to balance precision (percentage of useful calls, to avoid loss of time and loss of interest or cognitive overload) with recall (percentage of aware agents, to avoid leaving anyone uninformed) is well-known in the field of Information Retrieval.

C. Discussion and limitations

These first results are interesting but we would like to discuss some limitations. First, we have limited ourselves to interactions via phone, while in the interviews many residents mention having had direct interactions with their neighbours or with firemen or policemen going door-to-door to inform the population. Second, we have limited the content of our messages to information about fires, while other contents were mentioned: information about shelters, about safety status, about the fire plan; recommendations from the authorities about what to do; negotiation about what to do inside a family, etc.

Finally, for the sake of experimentation, we have only explored very "artificial" situations: official warning sent to a single agent, no direct perception of fires (focus on the prodromal phase when initially there is no fire), use of one single strategy (no combination). In fact, the residents can receive information about fires through both direct observation and indirect communication, and strategies can be combined: using a phone tree does not prevent calling one's friends or neighbours as well.

Many things also remain to explore in future work. In the short-term, we will investigate other types of phone trees (with or without backup, circular vs linear, etc). We will also investigate less artificial situations, and observe how communication evolves when the fire starts. We will also experiment with using more parameters: size of neighbourhood, best strategy depending on various levels of alruism vs obedience, etc.

In the medium-term, we will also enrich our communication model in several ways: add face-to-face interactions; endow the fire-fighter agents with more complex behaviour, in particular interactions with the population and with each other; implement different types and contents of messages; and link communication with more psychological parameters such as trust and emotions.

VI. Conclusion

In this paper we have provided an agent-based model and simulation of the propagation of information in the population in the prodromal phase of a bushfire. The advantages of our approach is to use a BDI model of the population, providing a high-level description of their behaviour. The implemented simulator offers a visualisation of the propagation of awareness in the population before the fires actually starts, as well as measuring some interesting indicators. Despite the limitations discussed above, this work already provides interesting results about the benefits of a more organised communication, which was not in place during the 2009 bushfires.

This work opens many future avenues of work: Natural Language Processing techniques could be used to perform a deeper analysis of the interviews; more complex interactions should be investigated (not only information about the fires, but also about safety status, and about the decision to stay or evacuate within a family); and the influence of more parameters could also be studied, such as trust in the different sources of information, or the influence of emotions. In the longer-term we would also like to compare communication in different types of crises in order to generalise our model.

References

[1] D. Wenger, E. Quarantelli, and R. Dynes, "Disaster analysis: emergency management offices and arrangements," Disaster Research Center, University of Delaware, Newark, final project report 34, 1986. [Online]. Available: http://udspace.udel.edu/bitstream/handle/19716/1138/FPR34.pdf

[2] M. Lindell, R. Perry, and C. Prater, "Organizing response to disasters with the incident command system/incident management system (ics/ims)," in *Int. Workshop Emergency Response and Rescue*, 2005.

[3] A. Laajalahti, J. Hyvärinen, and M. Vos, "Crisis communication competence in co-producing safety with citizen groups," *Social Sciences*, vol. 5, no. 1, p. 13, 2016.

[4] J. Sutton, L. Palen, and I. Shklovski, "Backchannels on the front lines: Emergent uses of social media in the 2007 southern california wildfires." in *International conference on Information Systems for Crisis Response and Management (ISCRAM)*, F. Fiedrich and B. Van de Walle, Eds., Washington, DC, USA, 2008, pp. 624–631.

[5] M. Haataja, "Citizens' communication habits and use of icts during crises and emergencies," *Human Technology*, no. 10, pp. 138–152, November 2014.

[6] Emergency Management Institute, "Effective communication (student manual) - lesson 3: communicating in an emergency," Federal Emergency Management Agency, Tech. Rep. IS-242.b, February 2014. [Online]. Available: https://training.fema.gov/emiweb/is/is242b/student\%20manual/sm_03.pdf

[7] C. Bailly and C. Adam, "An interactive simulation for testing communication strategies in bushfires," in *ISCRAM*, Albi, May 2017.

[8] J. Dugdale, N. Bellamine Ben Saoud, F. Zouai, and B. Pavard, "Coupling agent based simulation with dynamic networks analysis to study the emergence of mutual knowledge as a percolation phenomenon," *Journal of Systems Science and Complexity (JSSC)*, vol. 29, no. 5, pp. 1358–1381, 2016, dOI: 10.1007/s11424-016-4298-y.

[9] J. Dugdale, B. Pavard, and J. L. Soubie, "A pragmatic development of a computer simulation of an emergency call centre," in *Designing Co-operative Systems. Frontiers in Artificial Intelligence and Applications*, R. D. et al., Ed. IOS Press, 2000.

[10] V. Clerveaux, T. Katada, and K. Hosoi, "Information simulation model: Effective risk communication and disaster management in a mixed cultural society," *Journal of Natural Disaster Science*, vol. 30, no. 1, pp. 1–11, 2009.

[11] A. Chauhan and A. L. Hughes, "Providing online crisis information: An analysis of official sources during the 2014 carlton complex wildfire," in *Computer-Human Interaction (CHI)*, 2017.

[12] R. Power, B. Robinson, J. Colton, and M. Cameron, "Emergency situation awareness: Twitter case studies." in *Information Systems for Crisis Response and Management in Mediterranean Countries (ISCRAM-med)*, ser. Lecture Notes in Business Information Processing, C. Hanachi, F. Bénaben, and F. Charoy, Eds., vol. 196. Cham: Springer, 2014.

[13] K. A. Moore, "The tweet before the storm: Assessing risk communicator social media engagement during the prodromal phase - a work in progress," in *ISCRAM*, Albi, France, 2017.

[14] B. Teague, R. McLeod, and S. Pascoe, "Final report," 2009 Victorian Bushfires Royal Commission, Tech. Rep., 2009. [Online]. Available: http://www.royalcommission.vic.gov.au/Commission-Reports/Final-Report.html

[15] Fire Services Commissioner, "Review of the community response in recent bushfires," NOUS group, Tech. Rep., 12 September 2013, http://goo.gl/wJcGn3.

[16] C. Adam and B. Gaudou, "Modelling human behaviours in disasters from interviews: application to melbourne bushfires," in *Social Simulation Conference (SSC)*, 2016.

[17] ——, "Modelling human behaviours in disasters from interviews: application to melbourne bushfires," *Journal of Artificial Societies and Social Simulation (JASSS)*, 2017, to appear.

[18] S. A. C. F. Service, accessed 2017, June 9. [Online]. Available: http://www.cfs.sa.gov.au/site/prepare_for_bushfire/know_your_community/telephone_trees.jsp

[19] A. S. Rao and M. P. Georgeff, "Modeling rational agents within a BDI-architecture," in *2nd International Conference on Principles of Knowledge Representation and Reasoning (KR)*, J. A. Allen, R. Fikes, and E. Sandewall, Eds. Morgan Kaufmann, 1991, pp. 473–484.

[20] C. Adam and B. Gaudou, "BDI Agents in social simulations: a survey," *The Knowledge Engineering Review*, vol. 31, pp. 207–238, 2016.

[21] C. Adam, P. Taillandier, and J. Dugdale, "Comparing agent architectures in social simulation: Bdi agents versus finite-state machines," in *Hawaii International Conference on System Sciences (HICSS-50)*, 2017.

[22] A. Grignard, P. Taillandier, B. Gaudou, D. A. Vo, N. Q. Huynh, and A. Drogoul, "Gama 1.6: Advancing the art of complex agent-based modeling and simulation," in *Principles and Practice of Multi-Agent Systems (PRIMA)*, ser. Lecture Notes in Computer Science (LNCS), B. T. R. S. F. D. M. K. P. G. Boella, E. Elkind, Ed. Dunedin, New Zealand: Springer, 2013, vol. 8291, pp. 117–131.

[23] P. Taillandier, M. Bourgais, P. Caillou, C. Adam, and B. Gaudou, "A situated bdi agent architecture for the gama modelling and simulation platform," in *Multi-Agent Based Simulation (MABS) workshop @ AA-MAS*. MABS, 2016.

[24] C. E. Shannon, "A mathematical theory of communication," *Bell System Technical Journal*, vol. 27, pp. 379–423 and 623–656, 1948.