Community Evacuation Planning for Bushfires Using Agent-Based Simulation

(Demonstration)

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ABSTRACT

We present a proof-of-concept agent-based simulation tool, for use in training by emergency services in Australia, for planning community evacuations in the event of a severe bushfire threat. The tool allows Incident Controller personnel to interactively schedule the evacuation of a town area, by sub-region, and then evaluate the effectiveness of their plan in terms of traffic flow and overall evacuation time. A bird's eye view gives immediate visual feedback as the evacuation unfolds, while a non-interactive mode allows the scenario to be re-run hundreds to times, and results aggregated, to build further confidence in the chosen schedule.

Categories and Subject Descriptors: I.6.8 [Simulation and Modeling]: Types of simulation – *Combined, Distributed, Traffic simulation*

Keywords: Bushfire Simulation, Traffic simulation, BDI Agents, Simulation Integration, Agent-Based Simulation

1. INTRODUCTION

Bushfire threat is a reality for a large part of Australia. As evidenced by the Black Saturday fires [12], the situation can change quickly with devastating consequences, so preparedness on the part of the emergency services as well as the community is vital. Simulation is a valuable tool for emergency planning and capability building, as it allows a range of scenarios to be systematically studied and understood. For instance, in Australia, the Country Fire Authority (CFA) uses Phoenix RapidFire [13] to simulate fire fronts under a range of weather conditions, given local terrain and surrounding vegetation.

Our ongoing work with the emergency services has looked at capturing the complexity of threat response behaviours in a demographic, during emergencies such as bushfires [11] and floods [8], and using those to build an agent-based simulation to more accurately model traffic flows in such situations [9]. Agent-based simulation is valuable for accessing community response, as it allows modelling of behaviours at the level of each resident or household (data for which is more readily available), and is able to capture the key interactions that occur in this context [4].

We have found the Belief-Desire-Intention (BDI) model [10] of rational decision making to be a reasonable fit for modelling resident behaviours. It is able to capture fairly complex behaviours, using a hierarchy of goals and plan options for achieving those. Representing behaviours in terms of residents' beliefs, goals, and plans, is also intuitive to non-programmers, including emergency services, local government, and residents. This makes extraction of such behaviours from the population into a computational model feasible, using social science methods of enquiry and survey.

In this work, we build a proof-of-concept support tool, to help the emergency services plan for community evacuations in the case of a bushfire threat. We model a regional town, Halls Gap VIC, with its road network (using OpenStreetMap [2]), houses (using dataset [6]), and residents (using census data [1]). Halls Gap was chosen since an actual evacuation was carried out in January 2014, and emergency services had access to real data for this event [7]. The bushfire is modelled in Phoenix RapidFire based on conditions similar to Black Saturday. Residents are modelled as BDI agents (using JACK [5]), and their behaviours capture known behaviours of residents in bushfires, such as driving to pick up children from school, and/or loved ones who live nearby, before driving to the designated relief centre.[1] Traffic flow simulation is done in MATSim [9].

The integrated simulation tool allows incident controllers (who decide how to evacuate a region) to setup a bushfire evacuation simulation for a local area, and interactively make decisions during the simulation run, such as which region to evacuate to which relief centre, and the order in which this should be done. The impact of such decisions, such as on traffic congestion, can be seen in a bird's eye view of the terrain (using our custom build Unity [3] based visualiser), as cars start leaving homes to go to designated evacuation centres. The simulation also produces statistics on the evacuation exercise, so variations in choices can be compared. A non-interactive GUI-less mode allows a scenario to be run hundreds of times, to understand variations, giving further confidence in a chosen evacuation schedule.

2. EVACUATION PLANNING SYSTEM

Setup and Initialisation A configuration file allows the user to adjust the Halls Gap simulation parameters. Evacuation Controller is a BDI program that can non-interactively make evacuation decisions in the simulation, based on programmed defaults. The user can set breakpoints and intervene at the various decision points in the Goal-Plan hierarchy shown in Figure 1. The three goals of the Evacua-

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[1]Behaviours can be refined to fit Halls Gap data; not available to us at present.

Figure 1: Planning community evacuation for Halls Gap VIC, Australia: A fire front is progressing from the south west (currently off screen). The simulation has stopped for user input at goal `EstablishSchedule`. The large overlapping rectangles to the right of screen are the regions being scheduled for evacuation. The tiny coloured rectangles within regions are cars stationed at homes. Residents in regions ordered to evacuate, will drive from their homes along roads to designated relief centres following control points (way points) set up by the emergency services. Some residents will pick up loved ones first. Overall, poor scheduling of the regions can have significant impact on the evacuation time, due to congestion and traffic jams.

tion Controller agent, for which breakpoints can be set up in the configuration file, are `AssignReliefCentres`, `EstablishRoutes` and `EstablishSchedules`. The user can also configure the evacuation routes and the control points for those routes, the designated relief centres, the evacuation regions within the town, and the number of agents to simulate. At initialisation, all agents are randomly placed at residential addresses in the town.

Running At run time, the simulation pauses at configured breakpoints, and asks the user to select from the available plan options. This can involve choosing per region, the designated relief centre to evacuate to (e.g., evacuate the northern region to a centre to the north), the route to take (e.g., safest, fastest, etc.), and the schedule for evacuating (e.g., based on vulnerability, proximity to relief centre, etc.). Once all the choices are made, the evacuation commences, and residents start driving from their homes to the designated relief centres, when ordered to evacuate based on the schedule. Variability in residents' behaviour comes from the fact that there can be a lag between them receiving an evacuation order and acting on it, and that some residents will first drive to collect loved ones from school and/or nearby locations. The simulation stops after a configured number of simulated hours.

Analysis The user performs an initial evaluation of the impact of different evacuation decisions by visually assessing traffic flow for each run, and comparing simulation clock time for key events such as when the entire town has been evacuated. Each simulation run also produces an output log file with key information about the evacuation, such as the evacuation times for the regions and the entire town, and the distribution of each behaviour in the population over time. Results from multiple runs (in non-interactive mode) of an evacuation schedule can be aggregated to build statistical confidence in its effectiveness.

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