Bushfire BLOCKS: A Modular Agent-based Simulation

David Scerri, Sarah Hickmott, Fabio Zambetta
Ferdinand Gouw, Isaac Yehuda, Lin Padgham

School of CS and IT
RMIT University
Melbourne, Australia
firstname.lastname@rmit.edu.au

ABSTRACT

`Bushfire BLOCKS` is a modular, distributed, agent-based simulation for exploring and informing bushfire response strategies. Separate independent modules capture the fire spread, evacuation of traffic and human behaviour such as the decision whether to remain at property. These modules have been developed largely independently, using paradigms and data models appropriate to their individual purpose. Modules are integrated into a single global simulation via central services for managing time advancement and access to shared variables. Execution is distributed, with modules running on different machines, whilst a custom interface enables viewing and control from one screen. The underlying architecture of this system facilitates extension of individual modules and addition of new modules, with limited alteration to other modules.

Categories and Subject Descriptors

I.6.3 [**Simulation and Modeling**]: Applications

General Terms

Design, Experimentation

Keywords

Agent-based simulation, modular architecture, distributed simulation, bushfire response

1. SYSTEM OVERVIEW

Faced with a changing climate, and threatened by an increased risk of major disasters ranging from bushfire to flooding, the world is looking in all directions for long-term adaptation solutions and more effective emergency response strategies. Agent-based simulation is possibly the only experimental means for exploring complex social systems, (see e.g. [2]), and can thus play an important role in the exploration of adaptation and emergency response strategies which – undoubtedly – must include consideration of human behaviour. In order to be useful however, these simulations must capture a range of aspects of the considered scenario, each possibly requiring distinct expertise. Moreover, different paradigms may be useful in modelling, ranging from those that use many lightweight reactive agents, to those that use cognitive agents, to those that focus on agent teams and organisational structures. Our work here has been driven by the desire to build up an increasingly realistic simulation by incrementally adding new modules, created by members of a large distributed community interested in the application area, without placing restrictions on the paradigms and data models to be used by each module.

`Bushfire BLOCKS`[1] is an extensible agent-based bushfire simulation currently consisting of three individual modules, developed independently and run on separate machines, integrated into a single global simulation via central coordination services and a custom interface. The aim of `Bushfire BLOCKS` is to let users experiment interactively with bushfire evacuation strategies, to appreciate how their choices unfold throughout the simulation. Residents of the coastal town of Anglesea are threatened by a bushfire which spreads through the town during the simulation. Based on various personal factors, and public information, each resident may – at some point during the simulation – decide to go to an evacuation point. The chosen route of an evacuating resident depends on information available to them both visually and via radio announcements. Besides setting the initial attributes of residents, `Bushfire BLOCKS` allows users to change the location of roads and evacuation points, sound a warning system, and make announcements on the local radio to inform people of the current location of fire, road blocks, etc. Clearly, this has the potential to help predict similar patterns and situations arising in real-life fire emergencies, concurrently teaching simulation users about complex choices, such as when to retreat to an evacuation point or shelter in place.

It should be noted how the fidelity of the simulation is achieved via real-data collections such as vegetation information retrieved by the State of Victoria in the coastal town Anglesea, and real road maps, conditions and topography. Moreover, the fire module uses Fire Behaviour SDK fire spread libraries as used in FARSITE [2], incorporating surface and crown fires thus further increasing the accuracy of the simulation offered by `Bushfire BLOCKS`.

Whilst there exists various significant frameworks for modular distributed simulation, none are entirely appro-

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[1] Building Large, Open, Complex, Knowledge-Based Simulations (BLOCKS).
[2] `http://firemodels.fire.org/content/view/112/143/`

priate for application to multi-agent simulation and the type of modularisation we are targeting. In particular, difficulties arise when multiple modules affect the same variable at the same logical time, in particular if this variable is part of an atomic action involving multiple variables. A detailed discussion of the problems can be found in [3]. The `Bushfire BLOCKS` system employs an architecture we developed specifically for the integration of multiple modules, including agent-based simulations, into a single global simulation [3]. Each module captures some specialised aspect of the scenario – human behaviour, evacuating traffic, fire spread – and multiple modules can potentially affect the same aspect of an environment at the same logical time, e.g. traffic and behaviour modules both depend on and influence human agents' levels of panic.

2. INDIVIDUAL MODULES

`Bushfire BLOCKS` currently consists of three modules, each capturing a different aspect of the bushfire response scenario: `Fire Spread`, `Traffic Evacuation` and `Human Behaviour`.

The `Human Behaviour` module captures the decision process surrounding the question to "stay or go", for individuals exposed to a bushfire threat. Each person is modeled by a single agent with attributes such as age, gender, health, energy, velocity, panic level, access to vehicle, family members, perceived distance from hazards (e.g fire, smoke), visibility, and area fire rating. An agent's decision to shelter at their property, or evacuate, is based on: the aforementioned attributes; other people leaving the area (herding behaviour); and, any external help available. Panic level greatly affects an agent's decision, and is based on factors such as distance from the fire, emergency level declared by local authority, knowledge of road blocks, family, access to a vehicle, and the time of the fire.

The `Traffic Evacuation` module adapts and extends Nick Malleson's Repast City program[3] to simulate the evacuation of all agents that have decided to leave their property. The module takes in a GIS map of roads and houses, and information regarding the location of people, smoke and fire. When an agent decides to leave, they are made to follow the shortest path to an evacuation point, along which the individual agent is not aware of any hazard (e.g. fire, road block). Whilst moving, agents continue to scan their surrounding area and listen to the radio, updating their knowledge accordingly. If they become aware of a hazard in their planned path they calculate a new route. Agents also keep some distance between each other and try to avoid collisions, and travel faster on roads.

The `Fire Spread` module utilises the widely used Fire Behaviour SDK to model the growth of a bushfire through a rural area. It incorporates topographical, vegetation and wind and weather information to realistically simulate the behaviour of the fire in a specific environment. Surface fires, crown fires and spotting are all modelled separately within the module and smoke and heat data is also produced.

Each of these modules have been developed independently, using the paradigm and data structures considered to be most appropriate for their individual purpose. For example the `Traffic Evacuation` module uses a coordinate-based map of Anglesea whereas the `Human Behaviour` simulation is cell-based. Whilst both these modules use lightweight reactive agents, implemented in Repast[4], we are currently developing a `Country Fire Authority` (CFA) module – to capture the service provided by this fire fighting organisation – which uses the Belief Desire Intention (BDI) agent paradigm. This will allow us to assign CFA agents more complex reasoning and planning abilities, and more easily include team-oriented behaviour.

[3] `http://portal.ncess.ac.uk/access/wiki/site/mass/repastcity.html`

3. INTEGRATED SIMULATION

The architecture of `Bushfire BLOCKS` provides centralised services which integrate the above modules into a common environment. Two main services are the Time Manager (TM) and the Conflict Resolver (CR). The TM ensures that all modules advance time in a consistent way despite having potentially different time scales. This is implemented in much the same way as the conservative algorithm of the High Level Architecture [1]. The CR manages module interaction with shared data to avoid the potential problems identified in [3]. For example, the `Evacuating Traffic` and `Human Behaviour` module may concurrently access agents' panic level; the CR resolves any conflicts between logically concurrent updates or value-based decisions.

The most important aspects of each module are integrated into a single custom interface, to allow viewing and control from a single screen where appropriate. However, individual modules can run their own user display. The use of multiple displays allows analysis of the simulation data from the different points of view offered to the user For instance, in the `Traffic Evacuation` module the user can choose to view the perspective of an individual agent, which can give a better understanding of the reasoning behind their movements, or the entire road network. This ability to zoom in and out of the data allows the user to concentrate on specific details of the simulation, or grasp the bigger picture.

The modularity of the `Bushfire BLOCKS` framework means that we can incrementally increase the complexity or focus of the simulation, by extending an existing module, or adding an entirely new, possibly pre-existing, module. This aids the creation of more complex global simulations. Moreover, modules can be re-used in a different scenario. For example the `Fire Spread` module may be part of a simulation which looks at longer term adaptive responses to bushfire such as town planning. Finally, the architecture of `Bushfire BLOCKS` enables us to run each module on a separate machine. In these ways, both the conceptual and computational complexity of the bushfire scenario is addressed.

4. ACKNOWLEDGMENTS

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[4] `http://repast.sourceforge.net/`