BushFire, a fire-fighting game with potential applications to the training of forest-fire emergency staff

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Abstract

Forest fires are causes of damage and fatalities world-wide and require heavy counter-attacks with powerful equipment and well-trained personnel. We first present an outline of the causes and consequences of forest and wild-land fires and then describe a fire-fighting game, which might find application as a training tool. The game, called "BushFire", simulates the spreading of fire in an area covered by brushwood and scrub, and the player's task is to get the fire under control by cutting firelines with simulated bulldozers. In view of the fact that extended wildfires typically are fought with water or chemicals using fire engines or droppings from aircraft, the BushFire game presents a rather special fire-fighting scenario. However, the player of the game is faced with challenges, which are basically the same as those facing the fighters of many real forest-fire calamities, especially when hampered by the scarcity of water. He or she must be able to foresee in what direction and how fast the fire is likely to spread as well as exploit the fire-fighting resources expediently and safely in order to limit the fire and its consequences. These game features make BushFire an instructive piece of simulation software that could serve as a useful supplement to the education and training of firemen and other field personnel attached to forest-fire emergency organisations.

1. Introduction

Whereas the consequences of most emergency situations are limited to the local neighbourhood of their origin, specific types of emergency may have huge influences nationally or even internationally. Transnational types of disaster are defined by Rosenthal (1998)[1] as disasters in which 'the original source of the problem at hand may continue to be local or national, but the immediate and long term impact of disasters and crises to come will span countries and continents'. This type of disaster has been experienced in the second half of the twentieth century related to industrial emergencies like the Chernobyl accident in Ukraine and the Sandoz chemical accident in Basel, Switzerland, both in 1986[2]. In natural disasters, however - like forest fires - the transnational dimension has been experienced, e.g. in Malaysia in 1997 and 1998 where

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bordering countries like Indonesia and Brunei, respectively, were faced with thick haze. In the climax period a haze emergency was claimed for several days with an air pollutant index (API) of more than 500[3].

Nevertheless, for thousands of years fire has played an important and often beneficial role in many forest and grassland ecosystems. Fire cleans out dead and weakened vegetation, reduces disease, insect and invasive plant pest, and makes room for new plants to grow.

2. Forest Fires

In fact, forest fire situations in certain areas are normal annual occurrences and even deliberately lit by the large plantation companies as the cheapest way to clear the land; but under specific circumstances the fire escalates to such an extent that is goes completely out of control. The consequences of such fires are not only that huge amounts of shrub are destroyed, but also widespread pollution, a contribution to the global warming, and soil erosion that damages rivers and lakes. Furthermore, an extensive escalation of respiratory problems, particular among asthmatic patients, is caused, and even airplane crashes suffered by civilian airlines have been reported as a consequence of the poor visibility due to the haze. Besides this, crashes of aircraft mobilised for the fire fighting represent a major part of the fatalities caused.

The United States Forest Service and the individual American states report more than 100,000 fires every year. Possibly the largest wildfire occurred in October 1825, burning from Maine through New Brunswick, Canada. A group of loggers ignited a fire in a drought area that soon burned out of their control. The fire consumed 3 million acres of forest and killed more than 160 people. The most devastating fire in American history, in terms of human lives and property lost, happened in Peshtigo, Wisconsin in 1871. The fire killed 1,300 people in a single night. More than 1 million acres burned[4].

2.1 Fatality causes

Individuals involved in wild-land fire operations during the nineties died more often in burnovers than from any other cause. This is indicated by the National Wildfire Coordinating Group based on data collected from 1990 to 1998[5]. *Burnovers are fires that overrun you and your equipment*. Fifteen separate burnovers led to the death of 39 firefighters during these nine years. One of the larger tragedies connected with burnover is the Mann Gulch Fire back in 1949, where 16 fire fighters (smokejumbers) were overran by the fire and died[6]. This tragedy is still being analysed from the points of view:

- How did the fire, which was burning on a ridge when the crew landed, get below them at the mouth of the gulch?
- What was their position relative to the fire as it progressed?
- Why couldn't they escape?
- Did the evasion of fire ignited by the crew foreman overtake his own crew?

In comparison with this misfortune, the efficiency of new equipment was demonstrated from the Butte fire on the Salmon National Forest in 1985, where 73 fire fighters escaped injury after being trapped in a fire much more intense than the grass fire at Mann Gulch. Investigators estimated that without the protection of the safety zones and the reflective fire shelters now carried by all fire fighters, at least 60, if not all, would have died. The safety zones, which were larger that football fields, had been cleared by bulldozing before they were needed and were within easy reach.

Other causes of fatalities are aircraft accidents, heart attacks, vehicle accidents, and falling snags. The cause of death by percentage of 133 persons who died while they were involved in the fighting of wild-land fires from 1990 to 1998 is indicated below[7]:

- Burnovers - 29%
- Aircraft accidents - 23%
- Heart attacks - 21%
- Vehicle accidents - 19%
- Falling snags - 4%
- Other (drowning, electrocution, training) - 4%

The origin of wildfires are indicated in Figure 1, which shows the acres burned by wildfires in the US in the period 1984 -90[8] due to various causes of the fire accident. It is seen that the far dominating cause for the generation of a wildfire is the natural one of lightning. However, lives and property are unfortunately threatened by man-made arson in 20% of the wildfires. Figure 2 shows scenery from a bushfire[9].

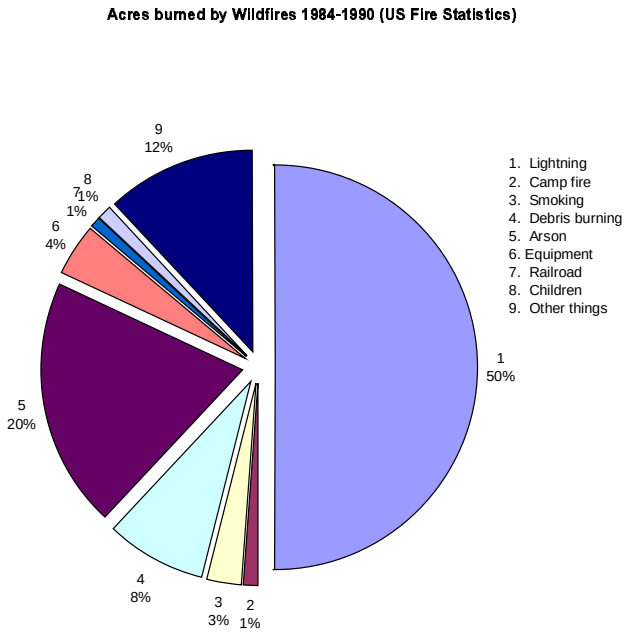

Figure 1. Acres burned by wildfires in the US in the period 1984-90

2.2 Work performed by fire fighters

Fire fighting is hard and dangerous work. In the US fire fighters are usually attached to one or the other of the following types of crew:

- *Engine crews* responsible for initial attack of fires in their immediate area. They use small trucks equipped with water, pumps, hose, and tools to slow the spread of the fire.
- *Hand crews,* which construct fuel breaks using chainsaws, shovels, and axes. They also "mop up" (put the fire out piece by piece after it has been contained).
- *Heli-rappellers* and *smokejumpers* who perform initial attack on small, remote fires. Rappellers rappel from the helicopter to the ground; smokejumpers parachute to the ground from airplanes.

Figure 2. Scenery from a bush fire

Besides the professional fire fighters, volunteers are often involved in the fire fighting, and due to their lack of training, equipment or being physically up to the task, these are often the ones most likely to perish during the fighting of a wild-land fire. The percentages of fatalities in the US by recruitment organisation has been compiled by the Forest Service and is shown below[10].

- Volunteer - 31%
- Federal - 26%
- Contractor- 21%
- State - 14%
- County/city - 5%
- Private - 2%
- Military - 1%

2.3 Fire-fighting methods

The fire fighters may use various methods for extinguishing, limiting or slowing down the fire. They can use water pumped from nearby sources if such sources are available or transported from more far distances by airplanes and dumped over the area. Likewise, airplanes or helicopters may be used to dump retarding materials over the area (see Figure 3[11]). Using their chainsaws, shovels and axes, fire fighters may construct breaks in the fuel, or "fireline". However, more efficient firelines used for fuel breaks are built using tractor plows when there is a need of going deeper to cut also the roots in order to stop the fire (Figure 4), or bulldozers are used to clean a broad belt serving as a fireline (Figure 5[12]). Furthermore, bulldozers may be used to prepare safety zones in which the fire fighters may survive in critical situations. As described later, the BushFire game exemplifies the perhaps less likely situation that no water at all can be provided for the fire fighting, so that the cutting of firelines is the only possible way of getting the fire spreading under control.

Figure 3. A Sikorsky S-64 Sky Crane dumping retardant material over a fire

Figure 4. Deep fireline produced by a tractor plow

Figure 5. More spacious firelines or safety areas may be produced using bulldozers

3. The BushFire game

3.1 Simulation system

The BushFire game simulates the spreading of fire through an area covered by brushwood and scrub. Its user interface enables the human operator or "player" to control the movements of four robots, which simulate bulldozers deployed in the area to cope with a fire emergency. The player's task is to get fires under control by commanding the bulldozers to encircle burning vegetation behind safe barriers of coherent fireline. This simulated fire fighting is performed in a window, which displays a map of the area. Gridlines on the map divide the area into a large number of square cells, which are the basic elements for the simulation of fire spreading. Undamaged cells are greenish. Such a cell becomes black when all of its fuel has been stripped by a bulldozer. If a cell catches fire, it becomes red and later turns grey after it has burnt out. The traverses made by the bulldozers proceed from cell to cell along tracks between the gridlines in accordance with commands issued by the player through mouse actions or key strokes. Each bulldozer is identified by an icon, which displays a number and a unique colour and overlays the cell that hosts the bulldozer at the present time. When a bulldozer receives a track command, the gridlines along the track are highlighted with the colour of the bulldozer icon.

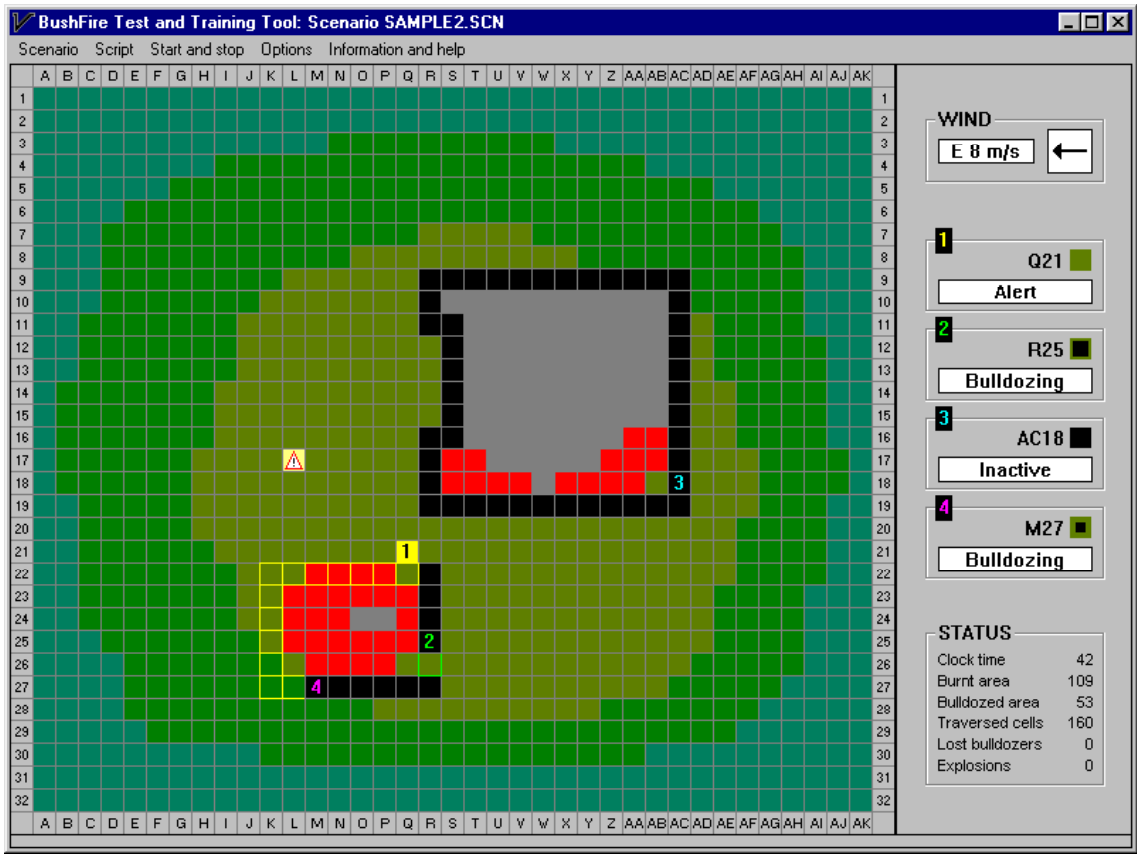

Figure 6. Screen dump showing a player's use of encirclement strategies in a fire-fighting game performed with BushFire

The natural time unit of a discrete simulation like BushFire is the interval, typically 10 seconds, between the clock ticks, which prompt the simulation system to update itself.

Figure 6 shows a screen dump saved after 42 time units in a BushFire game which started with a fire in a cell north-east of the map centre. At this particular stage of the game the player has successfully applied bulldozer #3 to enclose an extended fire created by the initial fire during the time it lasted to complete the fireline. The emergency is not over, however, because sparks and hot debris have ignited a cell to the south-west of the original fire zone, and the player is now attempting to encircle the resulting new extended fire by letting the three other bulldozers share the job of cutting a fireline around this additional fire zone. While the tracks specified for bulldozers #2 and #4 in Figure 6 appear to be reasonably safe for the time being, the player has just realised that the track specified for bulldozer #1 is inapplicable since it includes cells that have caught fire shortly after the bulldozer began its work. The player's response to this observation is to alert this bulldozer with the intention to command it into a safe track outside the fire zone.

This example demonstrates that the players of BushFire must pay great attention to the direction and speed by which fires spread, and that it is typically necessary to re-deploy the bulldozers at intervals. Feedback information from the bulldozers is displayed in text boxes in the monitoring window to the right of the map window (Figure 6). Additional feedback is obtained from an icon above each textbox. These icons are "live" copies of the current host cells for the bulldozers. They visualise the progress of the work done by the bulldozers and incite the player to command a bulldozer out of a cell that goes on fire.

The spreading of forest and wild-land fires is governed by the density and the moisture content of the fuel and by the wind in the area[13]. In BushFire the fuel density is the same in all of the cells, but their moisture content may vary, and wind shifts may occur. Heat transferred from a burning cell to its adjacent cells is simulated by radiation heat and heat transported by the wind (convection heat). The heating of a cell first evaporates moisture from the cell and then gradually raises the temperature of the cell to the point where it ignites. In the example above, the fuel moisture is small over a large central region as reflected by the olive-green cell colour in this region, while the plain green and the bluish-green cell colours farther away are indicators of an increasing fuel moisture content towards the edge of the area. The wind in BushFire blows with a speed of between 2 and 8 m/s in one or the other of the four main directions defined by the gridlines. A wind indicator is available to the player at the top of the monitoring window (Figure 6). Wind shifts and the generation of new fires by sparks and debris are simulated as events in the scenario file used to set up a game.

The map in Figure 6 displays an icon marked by a warning triangle. This icon represents an ammunition dump which may be heated by fire in the surrounding vegetation and explode. Such an explosion induces an abrupt number of new fires in cells, which are less than two grid distances apart from the detonating cell. The option to include explosive cells in a scenario is a typical game feature since organisations responsible for the disposal of ammunition waste would hardly select a dumping site, which is exposed to a fire danger. A BushFire game with one or more explosive cells presents the player to an additional challenge in his or her efforts to minimise the overall damage produced in the area by fire and bulldozing.

3.2 Program components

BushFire is written in Smalltalk, one of the first true object-oriented programming languages[14] and the platform for the application is the Smalltalk/V for Windows system

released by Digitalk Inc. in 1992. In addition to a game module, the program includes a scenario editor and a test & training tool.

The scenario editor makes it possible to design games of a varying complexity and difficulty, and to save the scenario data in a file. The map window displayed by the editor is identical to that displayed in a game. It is used to deploy the bulldozers in their initial positions, assign different moisture contents to various parts of the area, select cells for the initial fire and the possibly later occurring spot fires, and, optionally, include one or more ammunition dumps in a game. A panel next to the map displays an event-time selector, a clickable wind arrow and a wind-speed selector. These tools are used to generate a time-stamped script for the game. By ascribing a negative event time to the initial fire, the latter may be allowed to spread before the game is opened, so that the player is confronted with an extended fire to begin with.

The test & training tool is included as a facility for checking out the difficulty of game scenarios and enabling a player to acquaint him or herself with the fire simulation and the command interface for the bulldozers. The screen dump in Figure 6 was produced in a trial game with this program component, which, unlike the game module, displays a menu bar that offers the user to stop and resume a game and get on-line help. In the game module the player cannot interrupt the system timer to get a thinking pause or read a help text, and the player's success with acting as a fire commander is recorded in a log file which accumulates the data displayed at the bottom of monitoring window (Figure 6).

4. Conclusion, remarks

The development of BushFire was motivated by experience obtained with NEWFIRE, a fire-fighting simulation developed in collaboration with the Department of Psychology at Uppsala University with the purpose of getting a platform for experimental research on human decision making and control under time pressure[15]. "Micro-world" experiments with NEWFIRE, performed in the MOHAWC Esprit Basic Research Action (1989-92), produced several interesting results of relevance to the Human Factors area[16 17 18]. For example, when the subjects who acted as fire commanders were allowed to disregard cost factors, they tended to overreact to the initial fire and did not attempt to economise with their resources by trying to learn to balance the rate of fire spreading against the aptness of the simulated fire-fighters. On the other hand, displaying updated cost information to the subjects made them less willing to try out new strategies and had an adverse effect on their performance. Despite its proven value as a research tool, the NEWFIRE simulation was however too simplistic and unrealistic to deserve attention as a possible training tool in the fire-fighting profession.

This situation was remedied with the implementation of BushFire, which is based on a realistic fire spreading model and a recognised method of getting a wildfire under control by means of firelines. We believe that BushFire, in particular the test & training tool, is an instructive piece of simulation software that could serve as a useful supplement to the education and training of firemen, service personnel and volunteers attached to forest-fire emergency organisations and centres. Especially novices unfamiliar with the fighting of fire in natural environments might benefit from acting as players of the game to learn about the spreading of fire through a vegetation cover and acquire skills in using an encirclement strategy to enclose a fire behind safe borders.

BushFire is freeware from Risø National Laboratory and can be downloaded from the Internet address: http://www.risoe.dk/sys/spm/bushfire_challenging_fire.htm.

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