From Geosimulation of Urban Fires to Firefighters Serious Games

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Abstract

Multiple ignitions (MIS) are a typical secondary consequence of urban disasters – earthquakes, peripheral forest fires, or rocket strikes. When they happen, firefighters are always outnumbered and the firefighting strategy and tactic they were trained for, do not apply. Computer simulation of multi-fire scenarios is the only possible approach in this case, but to be realistic they demand sufficient knowledge of the firelighters' behaviour and decision-making rules. To reveal these rules and, simultaneously, establish the strategy and tactics for managing post-disaster multiple fires, we extend our spatialy-explicit model of urban fire spread to a Serious Firefight Game in which firefighters fight with the multiple fires. We aim at exploiting the Firefight Game for identifying MIS firefighting strategies and assessing their effectiveness.

Keywords: Serious Games, Firefighting, Earthquakes, Agent-based models, Geosimulation

1. Serious Games as a future tool for decision-making

Multiple ignition scenarios (MIS) are frequent secondary-disasters in urban spaces. MIS may occur following earthquakes, wars or severe wild-land fires (Hashemi & Alesheikh, 2013) (Lee & Davidson, 2010) (Levi, et al., 2012) (NFPA, 2015) (Zhao, 2010). Despite recent progress in city-scale modelling of urban fires (Li & Davidson, 2013) (Zhao, 2010), existing studies of fire departments' response to MIS are based on unrealistic assumptions. Their major drawback is the oversimplified representation of firefighters' decision making: the assumption that firefighters possess full information about the fires and make fully rational decisions. Serious Games are computer games developed for training or research, and are particularly useful for emergency training and research (van Ruijven, 2011). We use a serious game as a tool for understanding fire departments' decision making, accounting for firefighters' bounded rationality, limited ability of information processing and habits and rules accumulated during years of experience. Our study is focused on Mediterranean and Middle Eastern (MME) cities, which are prone to MIS.

2. Urban fires and Firefighters

Recent advances in Geosimulation of fire spread at the city scale (Himoto & Tanaka, 2008) (Lee & Davidson, 2010) (Zhao, 2010) (Shaham & Benenson, 2016) consider fires following earthquakes as the hallmark case of MIS. Two recent studies that include simulation of fire department response to MIS (Li & Davidson, 2013) (Zhao, 2010) differ with respect to firefighters' decision making.

Zhao (2010) assumes a simple FIFO queue strategy: all reported fires are pushed into a service queue in accordance with the time of the first report and firefighters suppress them by order (Zhao, 2010). In Zhao's (2010) study, firefighters' decisions do not depend on the severity of the fire. Li and Davidson explore a concentrated strategy in which fire tracks (which we call below, using professional language, "engines") are allocated to fires from highest to lowest priority, fully satisfying the demands of each fire before allocating any engines to the next lower priority one. They contrast this with a distributed strategy in which the model loops through fires from highest to lowest priority and in each loop, a single fire engine is allocated to each fire so long as there are idle engines. Some fires may thus remain unattended (Li & Davidson, 2013).

Li and Davidson (2013) assume that firefighters know about buildings involved in the fire, occupancy type and floor area of each fire and buildings exposed to fire spread.

We contend that Zhao's (2010) and Li and Davidson's (2013) assumptions are unrealistic, since firefighters cannot asses the severity of a fire before the team arrives at the scene. The general population that reports about a fire (usually, by phone) lacks the skills to provide firefighters with sufficient information. Only firefighters are able to enter a burning building, where full assessment of the fire is possible.

Firefighters overcome this information deficiency in routine by dispatching excessive force to the fire site. For example, Israeli fire departments will dispatch two engines and one ladder to any residential fire, even though one engine is sufficient in most cases. However, firefighters cannot follow this strategy during MIS, and, under extreme uncertainty have to take critical decisions regarding which fires to attend to and how to distribute the forces between them.

3. The Model of Urban Fire

Our study is based on a city-scale model of urban fire spread (Shaham & Benenson, 2016). Starting from one or more initial ignitions, the model simulates the development of each indoor fire, in all its phases: fire growth, fully-developed fire, and fire decay at high temporal resolution of a minute and less. The fire in each room of a building is simulated explicitly, based on the dimensions of the room, its openings and the room's fuel load. During the fully-developed phase fire can spread to adjacent rooms through doors and to upper floors by direct contact with window flames. Fire can also spread to adjacent buildings and vegetation by direct contact or by radiation or by fire brands. The model was validated in a residential neighbourhood in Haifa, Israel, with 452 buildings with and 7,418 apartments of a total floor area of 316,204 m2 (Figure 1) and demonstrated likely fire dynamics (Shaham & Benenson, 2016).

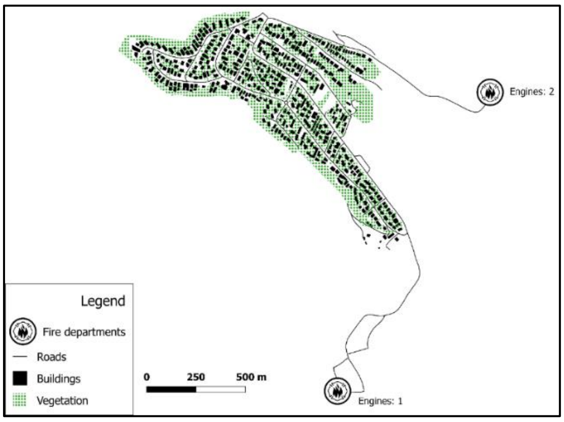

Figure 1: Study area

With the model, we have investigated fire dynamics in several scenarios which differ in the number of ignitions and in the available firefighting forces: Routine fire (one ignition), earthquake with four ignitions, and war with ten ignitions due to rocket hits. These scenarios consider fighting forces of a standard size – two or three engines that receive the fire report in up to five minutes after the ignition. We also assume that it takes the engines three minutes to complete pre-suppression procedure in the fire station and on-site, and that fire engine drives to a fire at 50 km/h using the fastest path. Each engine is a standard Israeli fire engine of “new-SAAR” model, which can deploy two nozzles, each of 20 mm diameter and pumps water at a rate of 2,400 L/minute when connected to a functional standard hydrant (National Fire and Rescue Authority, 2013). We used (Zhao, 2010) model to estimate the effect of fire suppression on fire spread.

Israeli firefighters’ decision protocol exists in a form of written procedures that one of the authors (YS) became aware of serving as a senior consultant to the Israeli Fire and Rescue Authority during the years 2011-2014. The basic rule, which was mentioned above, calls for dispatching two engines per each new fire, hereafter “routine strategy”. However, there is no protocol or procedure for MIS. We compared routine strategy to a “reduced strategy” of sending one engine instead of two for each new fire, so long as there are idle engines. In both cases, after the initial dispatch, additional engines are dispatched according to the severity of the fire, as reported by firefighters at the scene. If there are more fires than engines, engines are dispatched to the closest fires. At this point we do not consider a third strategy that ignores fires which are estimated as less dangerous and to let them burn to the end.

Table 1 shows the results of comparison between the “routine” and the “reduced” strategies. Tor the routine scenario both strategies achieve the same number of un-extinguished fires, while for the MIS scenarios the reduced strategy performs better, especially when two engines only are available.

Strategy	Number of engines	Routine Scenario	Earthquake Scenario	War Scenario
Routine	3	0 (--)	0.2 (0.1)	3.1 (0.6)
Routine	2	0 (--)	1.4 (0.5)	4.8 (0.4)
Reduced	3	0 (--)	0.2 (0.1)	2.4 (0.5)
Reduced	2	0 (--)	0.6 (0.3)	3.0 (0.7)

Table 1: Average (STD) number of un-extinguished fires for different firefighting strategies and station with 3 and 2 engines

5. From the Fire Spread Model to Serious Firefighting Game

Fire-department dispatchers are trained intensively with respect to routine circumstances. As a result, a heavy load of conservative reaction may strongly restrict their behaviour in MIS. We thus have to be sure that theoretically possible strategies, such as the “reduced one” above, would be acceptable by them. Additionally we need to let the firefighters develop their own strategies. Simultaneously the effectiveness of each strategy should be estimated. Serious game (Figure 2) is the tool for assessing the existing strategies and

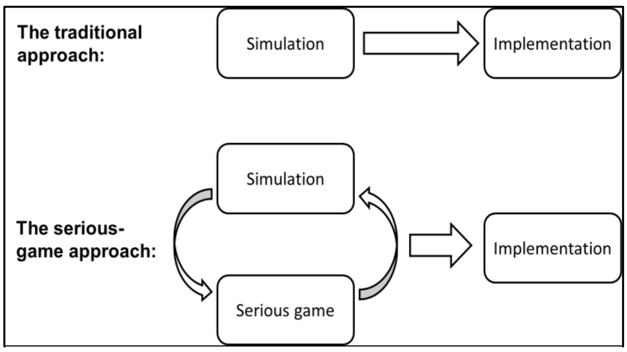

Figure 2: Game-simulation cycle

identifying the new ones.

We are now establishing a serious game environment of a fire dispatcher control room. A dispatcher has to extinguish one or several simultaneous fires. The environment includes a model-generated map with locations of fires and engines and a registry of teams dispatch status. As new fires are reported or as engines become available, the dispatcher decides how to allocate idle engines (Figure 3). The dispatcher actions are recorded and then analysed.

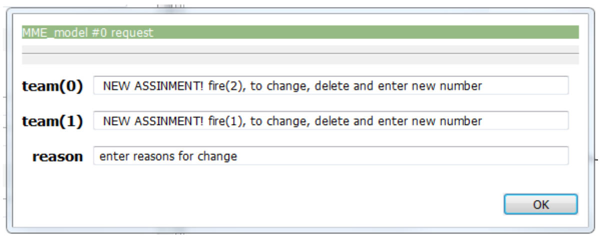

Figure 3: Engines dispatching dialog-box

Currently, in experiments with students, we establish a user's interface that is close to the one that is currently exploited in a control room of Israeli Fire and Risk Authority and that is easily understandable for making decision once in half a minute. During the development we present the system and the interface to the group of professional firefighters who have volunteered to participate in the firefighting games, and implement their recommendations. The volunteer firefighters will play firefighting game, in different scenarios, during the next three months. The results of this experiment will be presented at the conference.

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