Modelling and Simulating Emergency-Response Operations

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Motivation

- ➢ Disastrous incidents over the past decade (e.g., Hurricane Katrina) have exposed serious weaknesses in the emergency-response capabilities of modern countries.
- ➢ We are investigating a subset of the factors negatively impacting emergency response; specifically, we are interested in minimizing the effect of inter-organizational conflict to improve response effectiveness.
- ➢ At present, we are exploring the normative (i.e., policies) and structural dimensions of the various organizations involved to investigate how conflicts can be minimized.

Scenario

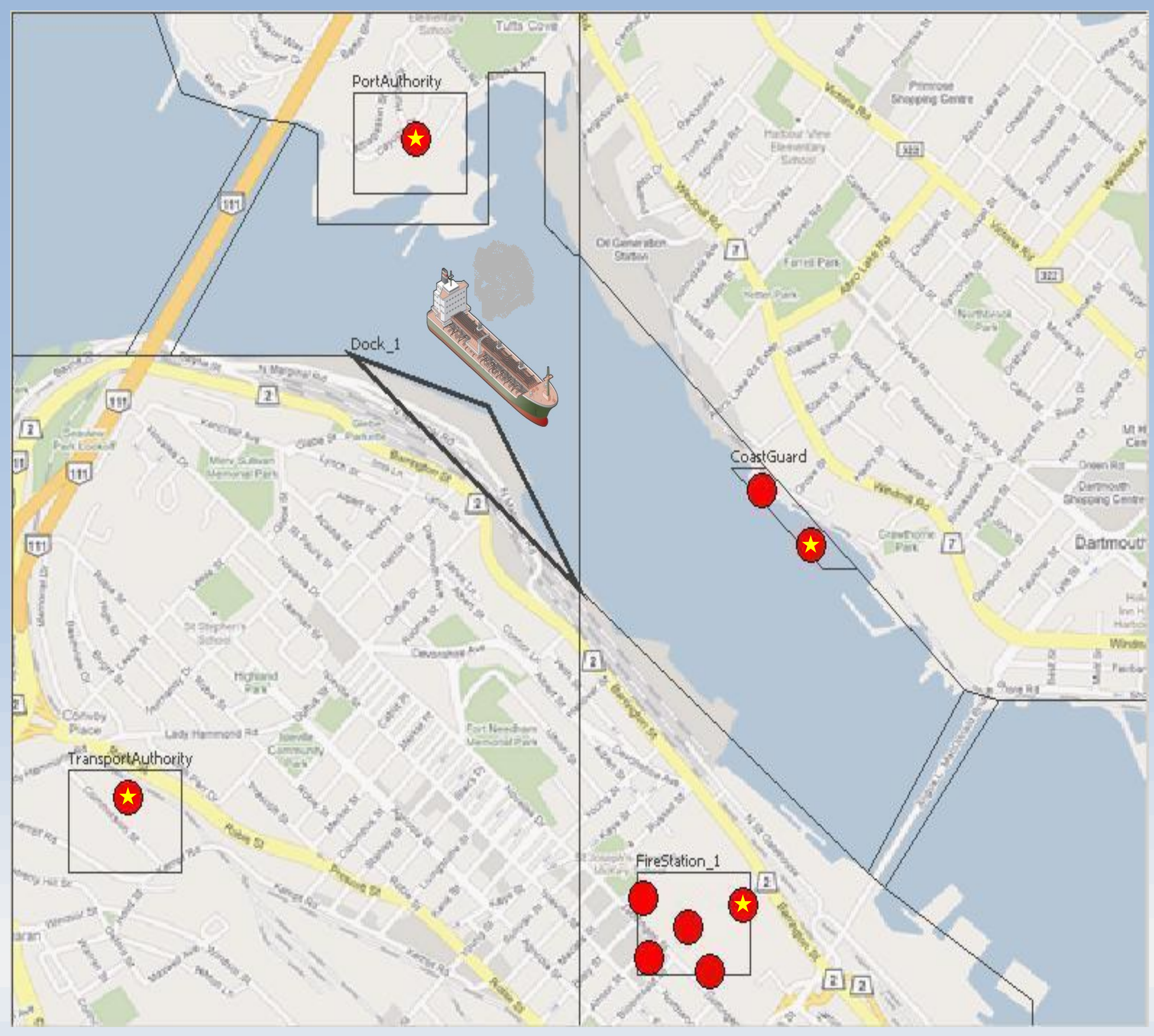

Figure 1. A view of the simulated world, including the burning ship and the four simulated organizations: Port Authority, Firefighters, Coast Guard, and Transport Authority (leaders are denoted by stars). In this world, there are three possible outcomes: (i) the fire may be stopped early, while it is still small; (ii) the fire may escalate to engulf a larger portion of the ship, but still be stopped before the fire spreads further; and (iii) the fire may cause an explosion onboard the ship, causing fire to spill out onto the dock. The effectiveness of the response—based on the ability to contain the incident—is a function of the interaction among the involved organizations (i.e., the effect of their combined policies).

Methodology

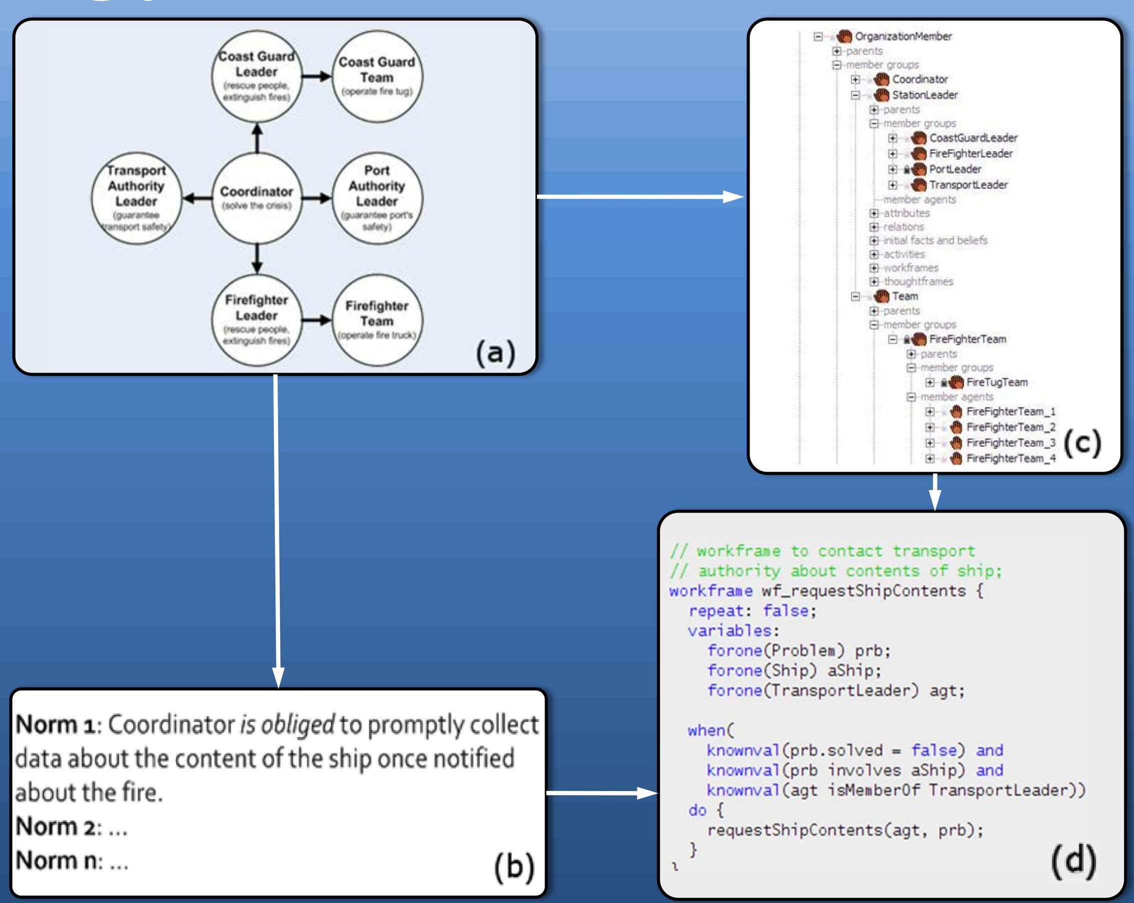

Figure 2. Our general methodology for building accurate representations of our organizations involves capturing their structure, as well as their policies (or norms). We begin by modelling these dimensions in OperA, a language used to model agent organizations. We then take these models (the structural model (a) and normative script (b)) and implement them in Brahms, an agent-simulation language. The structural model is converted into Brahms groups (c), while the normative script is translated into Brahms workframes (d). These workframes specify the condition (in the "when" clause) in which group members may follow the indicated policy.

Experiment

Table 1. The four rule sets used to test the three variables of interest in our experiment.

Variable	Rule Set 1	Rule Set 2	Rule Set 3	Rule Set 4
1. Coordinator promptly collects data from Transport Authority (Normative Dimension)	¬Obligated	Obligated	¬Obligated	¬Obligated
2. Fire tug team enters exclusion zone (Normative Dimension)	Prohibited	Prohibited	¬Prohibited	Prohibited
3. Fire tug team owned by (Structural Dimension)	Coast Guard	Coast Guard	Coast Guard	Firefighters

Table 2. Aspects in the simulation which are randomized to account for environmental uncertainties.

Aspect	Reason
1. Communication time	Some messages take longer to convey than others; people are not always immediately available
2. Team effectiveness	Teams have different levels of fatigue and experience
3. Travel times	The time of day, traffic levels, and condition of roads/water impact travelling time
4. Explosion threshold	The explosion is not a strict function of the response: it may take longer (or shorter) for the explosion to occur even when the response is identical
5. Weather conditions	Temperature, wind direction, and wind strength affect the fire

Results

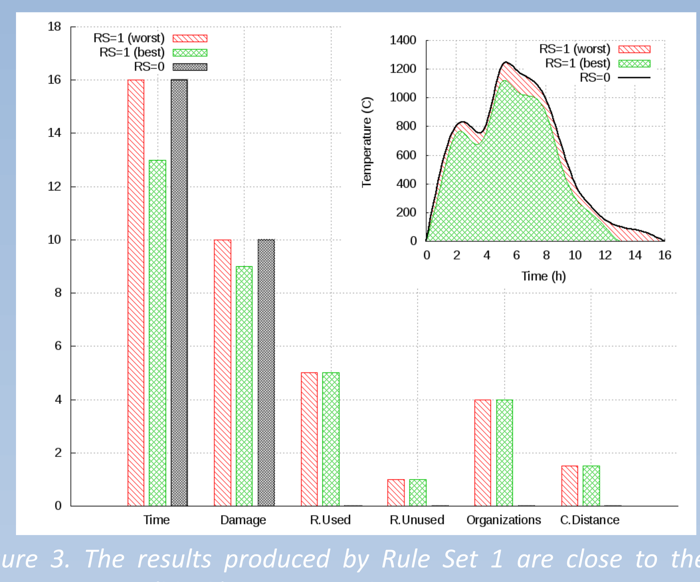

Figure 3. The results produced by Rule Set 1 are close to the no-response case (black). Because the coordinator does not quickly collect data about the ship, the fire grows more rapidly than expected, an exclusion zone is established as a result, and the fire tug team is unable to assist at the scene when requested (policy conflict).

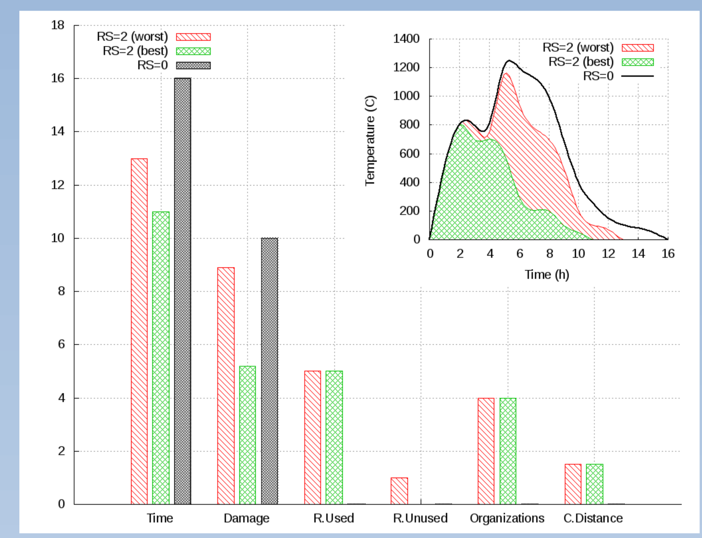

Figure 4. The results produced by Rule Set 2 show a large difference between the best and worst cases (i.e., low reliability). This is because the fire tug team sometimes arrives at the scene before (and sometimes after) the exclusion zone is established due to the randomized aspects presented in Table 2.

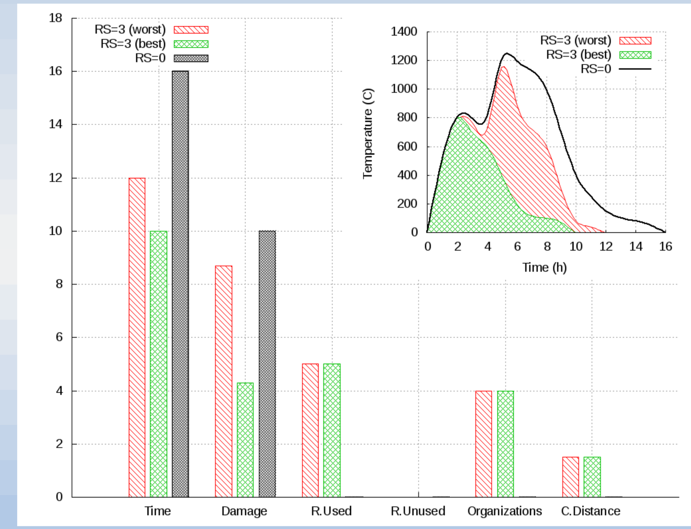

Figure 5. The results produced by Rule Set 3 again show a large difference between the best and worst cases. Because the coordinator lacks important data, sometimes the fire tug team is requested before the explosion, and sometimes after the explosion.

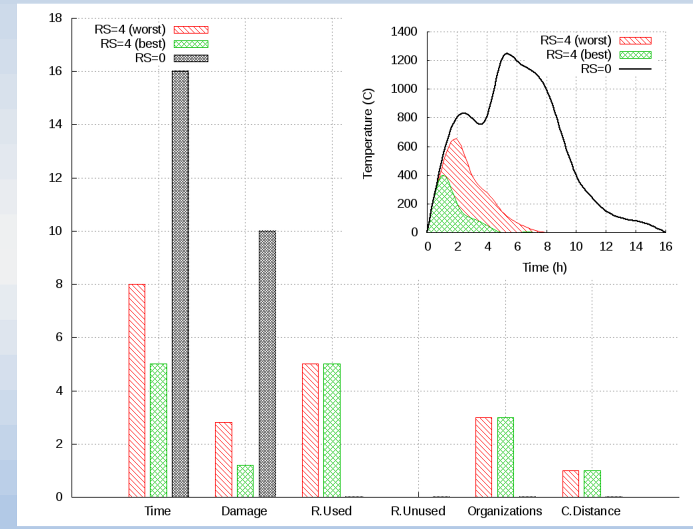

Figure 6. The results produced by Rule Set 4 show that in all runs of the simulation the explosion of the ship is prevented. Having one less organization saves valuable communication time. In our experiment, this rule set produced the most effective response.

Conclusion

- ➢ We constructed organizational representations for the four organizations involved in our scenario.
- ➢ We then examined the impact of two normative dimensions and one structural dimension on the simulated response.
- ➢ Finally, using a set of original metrics capable of showing the effectiveness (i.e., the best case) and reliability (i.e., the difference between the best and worst cases) of the response under various configurations, we determined that Rule Set 4 produced the best response in our experiment.

NOTE: Our experimentation approach can be used to test other variables and variable combinations in our simulation.

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