AGENT-BASED DISCRETE-EVENT SIMULATION AND OPTIMIZATION OF REGIONAL TRANSPORTATION EVACUATION

by

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ABSTRACT

This dissertation develops a flexible and efficient simulation framework and a simulation optimization procedure for regional transportation evacuation. Computer simulation is a powerful approach to analyzing real-world complex systems. Agent-based simulation (ABS) and discrete-event simulation (DES) are two main simulation paradigms in current simulation research. The agent-based simulation approach simulates real systems by modeling underlying objects as intelligent and autonomous agents and studying the interactions between them. On the other hand, discrete-event simulation models systems by representing underlying system operations as a sequence of events. This dissertation proposes an integrated simulation framework that combines advantages of agent-based simulation and discrete-event simulation and implements and tests it as an application of regional transportation evacuation.

In order to model the individual behavior and decision-making process of evacuees during an evacuation, a pure ABS model is developed first. This pure ABS model captures real-time driver behavior and dynamic traffic interactions, and supports different evacuation routing strategies. It applies a time-step based scheduling method to synchronize states of agents. A list-based algorithm is proposed to facilitate agent-and-agent interactions and agent-and-environment interactions. Different from other simulation models in which evacuation maps are predefined and hard-coded inside the models, this simulation model can take different networks as input and is more flexible in real-time animation by allowing dynamic resolution of the simulation space.

Pure ABS models suffer from low efficiency and could require a large computational power because of its time-step-based update mechanism. To mitigate this limitation, we introduce an integrated agent-based discrete-event modeling approach based on a hybrid space environment. Having a hybrid space environment in an ABS evacuation model allows flexibilities in evaluating evacuation scenarios and overcomes the limitation of cellular space in cell-based models. We construct an ABS evacuation model by using the Parallel DEVS formalism and develop algorithms for the corresponding DEVS simulators. Our hybrid agent-based discrete-event modeling approach achieves efficient event-based scheduling by executing necessary agent

interactions. Compared with traditional approaches, this approach has a low computational cost and a high degree of scalability.

To make effective planning decisions for regional transportation evacuation, we develop an adaptive routing and guidance algorithm (ANS) and integrate it with our simulation model. This simulation-based approach relaxes several unrealistic assumptions made in conventional evacuation routing methods and considers traffic interaction and variable link travel times as well as their dependence. ANS only requires local traffic information for routing and guidance, making ANS feasible and easy to implement in practice. Experimental results show that ANS can disperse highly concentrated traffic flows and significantly reduce network clearance time. In congested networks, ANS can achieve even better performance than the well-known user-equilibrium condition.

We investigate the effectiveness of five different evacuation routing strategies in various road network layouts. These routing strategies differ from each other as they require different amount of network information, from zero online information to perfect online information. Intuitively, online information can help travelers avoid congestions and evacuate faster. However, experimental results show that it is not always better to provide travelers with more information. The reason is that more information gives a larger degree of freedom for selfish travelers to compete network resources, leading to worse overall evacuation result.