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A Multi-Scale Crowd Behavior Modeling Framework: Emergency Evacuation and Normal Scenarios

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The goal of this talk is to present a multi-scale crowd behavior modeling framework, which has been applied to various emergency evacuation as well as normal scenarios. In particular, four particular scenarios will be considered including 1) evacuation behaviors under a terrorist bomb attack, 2) evacuation behaviors under fire in a factory, 3) pedestrian behaviors in the Chicago Loop area, and 4) pedestrian behaviors in a shopping mall.

The proposed modeling framework allows us to represent both the decision-making processes (tactical behavior) of an individual (e.g. choice of an evacuation path/direction) as well as physical interactions (e.g. congestions) among pedestrians and immediate environment. The model at the tactical level is based on an extended Belief-Desire-Intention (BDI) framework, where its submodules are based on a Bayesian Belief Network (BBN), Decision-Field-Theory (DFT), and a Probabilistic Depth-First Search (PDFS) technique. At the operational level, physical interactions and congestions among the people and the environment are represented using a hybrid version of Social Force model (continuous model) and Cellular Automata model (discrete model), where pedestrians are allowed biased random-walking without back step towards their destination that has been given by the tactical level model. In this work, the original Social Force model is enhanced with the vision of each individual, and both individual behaviors as well as group behaviors are considered.

To mimic realistic human behaviors, attributes of the extended BDI framework and the operational model (e.g. Social Force Model or Cellular Automata model) are either reverse-engineered from human-in-the-loop experiments conducted in the CAVE or literature surveys. Then, the simulated environment and agents conforming to the proposed BDI framework and operational model has been implemented. The constructed simulation has been used to test the impact of various factors (e.g., demographics, number of police officers, information sharing via speakers for the case of emergency evacuation) on system performance.

While the proposed framework allows us to develop a detailed crowd simulation, its execution is computationally demanding especially for scenarios involving a large area. To resolve this issue, an aggregation methodology is proposed, where each crosswalk instead of each individual is represented as an agent. Here, pedestrian counts collected near crosswalks are utilized to derive a binary choice probability from a utility maximization model. The derived probability function is utilized to estimate average pedestrian delay with corresponding traffic flow rate and traffic light control at each crosswalk.