Interactive Large-Scale Crowd Simulation

Department of Computer Science   University of North Carolina at Chapel Hill   Oct. 2010

The Challenge

The goal of crowd and multi-agent simulation is to model the movement and behavior of large numbers of people, creatures, or other characters all sharing an environment. These agents are expected to move to their goals, interact with the environment, and respond to each other. Crowd simulations have many uses, including improving architectural planning, enhancing training scenarios and virtual environments, and driving artificially-intelligent characters in games and movies. Our group has worked on many aspects of crowd simulation, including fast, guaranteed collision avoidance, real-time path and motion planning, modeling crowd flows, and emergent behaviors.

Simulation of a large trade show floor. 80,000 people are simulated at 800 ms/frame on a desktop PC.

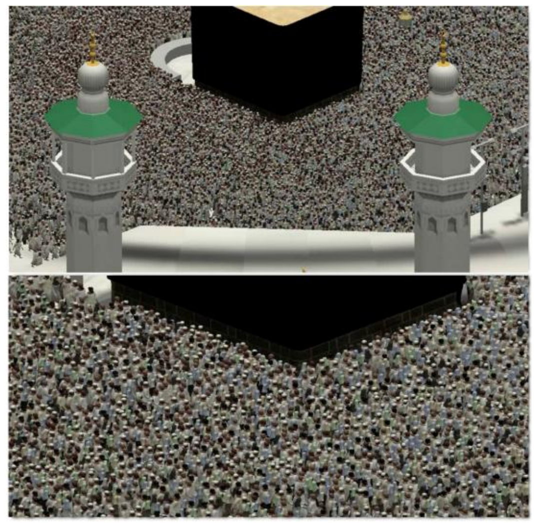
The Approach

Our simulation methods use geometric techniques to model the motion of individuals in the crowd. We ensure that each individual avoids collisions with all their neighbors in a reciprocal, anticipatory fashion and use biomechanical models to compute the trajectory for each human agent towards their goal. We have also developed parallel algorithms that can map to current multi-core CPUs and many-core GPUs to simulate the motion of very large numbers of agents on commodity platforms.

Complex real-world scenarios such as the five-way crosswalk at Shibuya metro station in Tokyo can be effectively simulated.

Highlights

- **Simulate tens of thousands of human-like agents in virtual environments.**
- **Heterogeneous Crowds: Each simulated agent has their own behavior, desires, and abilities.**
- **Our approaches can perform collision avoidance and simulate many emergent and group behaviors**



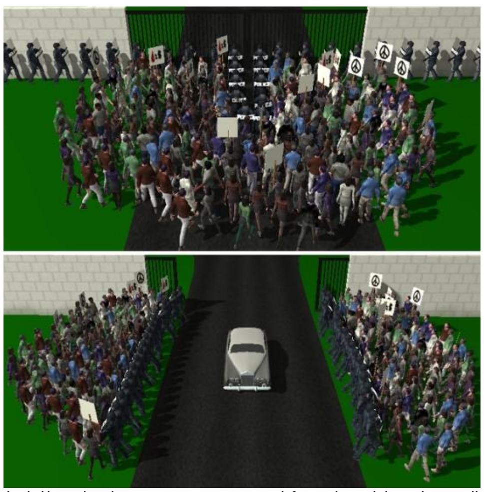
25,000 simulated individuals performing the Tawaf as part of the Hajj in Mecca (200 ms/frame).

Large-scale Simulations. Many scenarios need to simulate a very large number of agents, tens of thousands or even more. These include political or religious events, such as simulation of crowd movement during the Hajj, when almost three million pilgrims visit Mecca. Similarly, there are thousands of pedestrians in a large city. In order to simulate a large number of agents at interactive rates, we have been investigating efficient algorithms for large crowds based on flow-based models and hierarchical methods.

Modeling Social Behaviors. In order to capture a wide variety of decisions and behaviors shown by real people, we have studied systems for modeling how humans respond to each other at a social level. For example, we have used geometric techniques to model social priority, such as ensuring people on a subway train get off before others get on (next page). Likewise, similar techniques can model other behaviors such as grouping, aggression,

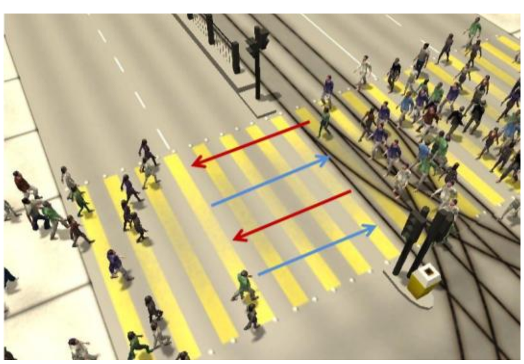
Agents departing from the train are given priority ahead of those boarding. Such protocols are frequently observed in daily life.

lane following, and civil authority (below). We have also modeled various emergent and social behaviors including lane formation, vortices, jamming, arching, edge effect, congestion avoidance, and others (right).



Simulated civil authority prevents a crowd from breaking the police line.

Directing Simulations. We are researching novel ways for event planners, animators, and others to interact with crowd simulation. We have developed sketch-based techniques for directing and interacting with crowds and have implemented them in a collaborative environment on a custom-built touch table.



An artist directs the simulated crowds as to where they should form lanes when crossing the road.

Crowd Validation and Analysis. We are developing methods for analyzing the accuracy of our simulations. For example, several behaviors commonly emerge in studies of real humans. This includes comparing the results with real-world footage or other data collected about pedestrian simulations.

Simulated group reaches a narrow passage, which causes it to slow down and form an arch around the passage.

Current Project Members

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Selected Publications

S. J. Guy, M. Lin, and D. Manocha. “Modeling Collision Avoidance Behavior for Virtual Humans”, *Conference on Autonomous Agents and Multiagent Systems (AAMAS)*, 2010.

S. J. Guy, J. Chhugani, C. Kim, N. Satish, M. Lin, D. Manocha, and P. Dubey. “ClearPath: Highly Parallel Collision Avoidance for Multi-Agent Simulation”, *Symposium on Computer Animation (SCA)*, 2009.

S. J. Guy, J. Chhugani, S. Curtis, P. Dubey, M. Lin, and D. Manocha. “PLEdestrians: A Least-Effort Approach to Crowd Simulation”, *Symposium on Computer Animation*, 2010.

S. Patil, J. van den Berg, M. Lin, and D. Manocha. “Directing Crowd Simulations Using Navigation Fields”, *IEEE Transactions on Visualization and Computer Graphics*, 2010.

R. Narain, A. Golas, S. Curtis, and M. C. Lin. “Aggregate Dynamics for Dense Crowd Simulation”, *ACM Transactions on Graphics (Proc. SIGGRAPH Asia)*, 2009.

H. Yeh, S. Curtis, S. Patil, J. van den Berg, D. Manocha, and M. C. Lin. “Composite Agents”, *Symposium on Computer Animation (SCA)*, 2008.

Keywords

crowd simulation; evacuation planning; directing crowds; disaster response; crowd psychology; motion planning; emergent phenomena; lane formation; self-organization

For More Information

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