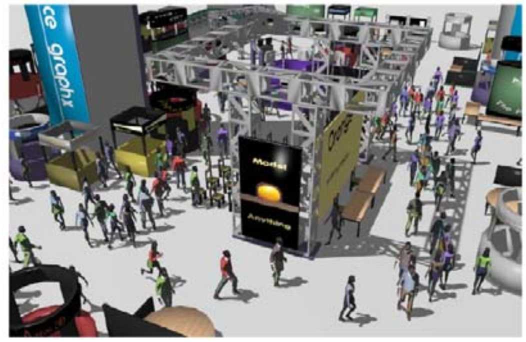
Multi-Agent Planning and Crowd Simulation

Background and Challenge

The problem of simulating and controlling large groups of agents arises in many applications, including robotics, virtual environments, computer animation and traffic engineering. There are many behavioral and computational challenges in creating a real-time system for multi-agent planning. As each agent navigates in the environment, it needs to behave as an individual that adheres to social standards while allowing itself to function as a member of a group. Additionally, the agent needs to reach any goal in a timely manner. This requires both local navigation and global path planning. These problems are further complicated when agents need to avoid moving obstacles and are moving in large and complex environments. Our goal is to develop novel algorithms and systems for interactive multi-agent simulation and crowds modeling. We are pursuing many approaches that address different sub-problems. Moreover, we plan to demonstrate their application to training environments, computer animation, games and disaster response.

Multi-Agent Navigation Graphs

We introduce a new data structure, Multi-agent Navigation Graph (MaNG) that is computed from the first- and second-order Voronoi diagrams. The MaNG is used to perform route planning and proximity computations for each agent in real time. We compute the MaNG in real-time using graphics hardware and present culling techniques to accelerate the computation.

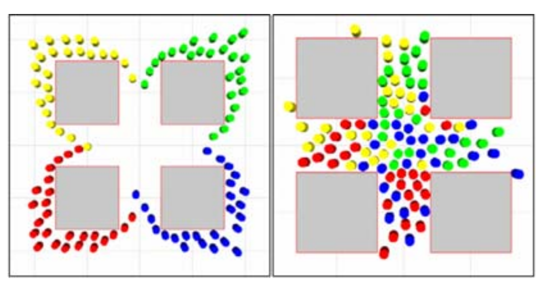


Navigation within an indoor environment. Using AERO, our system can generate collision-free paths for 1,000 agents at 22 fps.

Adaptive Elastic Roadmaps

We have developed a novel roadmap data structure to plan the motion of large number of agents in dynamic environments. The roadmap representation, called Adaptive Elastic Roadmap (AERO), replaces straight-line links with bands that deform based on Newtonian physics. This approach allows the roadmaps to locally adapt to the dynamic environment without the overhead of global recomputation. Isolated roadmap maintenance removes links which have are too deformed and adds links as new paths are revealed. Agents follow the deforming links and bands based on a social-force model to provide realistic local motions.

Reciprocal Velocity Obstacles



Narrow Passage Scene: Four groups start in opposite corners and must exchange positions.

We introduce Reciprocal Velocity Obstacles (RVO) for real-time multi-agent navigation. We consider the case in which each agent navigates independently without explicit communication with other agents. Our approach takes into account the reactive behavior of the other agents by implicitly assume that the other agents make similar collision-avoidance reasoning. RVO can generate safe and oscillation-free motions for each agent. We apply our concept to navigation of hundreds of agents in densely populated environments containing static and moving obstacles.

Applications and Results

Our approaches have been used for real-time multi-agent planning in a number of scenes, including pursuit-evasion, crowd simulation, and planning among moving obstacles. Simulations can have tens to many hundreds of agents in varying density situations. Many realistic effects such as lane formation can easily be seen in some of the results. We have also integrated some of these ideas into Second Life, a programmable massive multiplayer online metaverse.

Members

Dinesh Manocha, Phi Delta Theta/Matthew Mason Distinguished Professor
Ming C. Lin, Beverly Long Distinguished Professor
Jur van den Berg, Postdoctoral Researcher
Avneesh Sud, Postdoctoral Researcher
Russell Gayle, Graduate Student
Sean Curtis, Graduate Student

Research Sponsors

- Army Research Office
- Defense Advanced Research Projects Agency
- National Science Foundation
- Office of Naval Research
- Intel Corporation
- RDECOM
- DOE High Performance Computer Science Fellowship administered by the Krell Institute

Multiple Agents in Second Life: One human controlled and 8 autonomous avatars explore the UNC CH island in Second Life

Selected Publications

Avneesh Sud, Erik Andersen, Sean Curtis, Ming Lin, and Dinesh Manocha Real-time Path Planning for Virtual Agents in Dynamic Environments. Proc. of IEEE Virtual Reality 2007.

Russell Gayle, Avneesh Sud, Ming C. Lin, Dinesh Manocha. Reactive Deforming Roadmaps: Motion Planning of Multiple Robots in Dynamic Environments. Proc. Of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2007

Jur van den Berg, Ming Lin, Dinesh Manocha "Reciprocal Velocity Obstacles for Real-Time Multi-Agent Planning" Technical Report, Department of Computer Science, UNC, 2007.

http://gamma.cs.unc.edu/planning