Towards Believable Crowds
A Generic Multi-Level Framework for Agent Navigation

Real-time crowd simulation in virtual environments requires many types of algorithms. In this work, we propose a generic five-level hierarchy for agent navigation. For the three center levels, we describe an efficient and flexible navigation mesh for 2D and multi-layered 3D environments. Finally, we present our modular crowd simulation software, which is easily extendable and can simulate large autonomous crowds in real-time.

Planning Hierarchy

1. High-level planning
   Convert a semantic action (e.g. “go home”) to a geometric query (e.g. “find a path from a location s to another location g”).

2. Global route planning
   Compute an indicative route from s to g. This is a global indication of the path to follow.

Environment Representation

The Explicit Corridor Map (ECM) is a navigation mesh that efficiently describes the walkable space. It has many useful properties for levels 3, 4, and 5 of the planning hierarchy. Next to the ECM, an environment can contain weighted regions for which agents have personal preferences.

3. Route following
   Compute a preferred velocity to an attraction point on the indicative route, possibly based on weighted regions. This step leads to smooth movement, but it is often overlooked.

4. Local movement
   Choose an actual velocity that avoids future collisions with other agents or obstacles, while staying close to the preferred velocity.

Implementation and Results

We have implemented our research in an ECM-based crowd simulation framework. It is used by simulation companies, e.g. for predicting the crowd flow at large-scale events, or for populating urban areas in a driving simulator. The framework is modular and easily extensible. Next to the features shown above, our software has the following advantages:

- Fast ECM computation for large 2D / multi-layered 3D environments;
- Efficient re-planning in response to dynamic events;
- Small memory footprint that allows simulation of $\geq 1,000,000$ agents;
- Simulation of $\geq 10,000$ agents in real-time using multi-threading;
- An API for integrating the system into other software, e.g. Unity3D.

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