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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.

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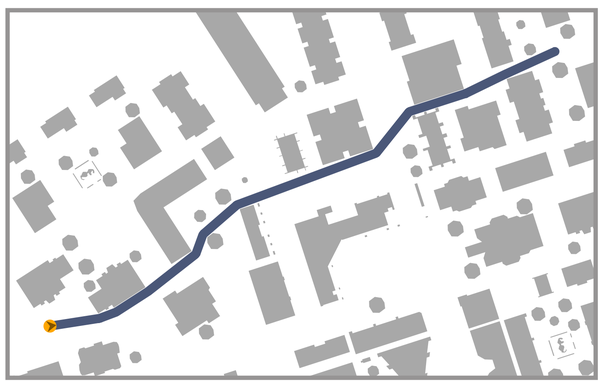
Planning Hierarchy

1. High-level planning

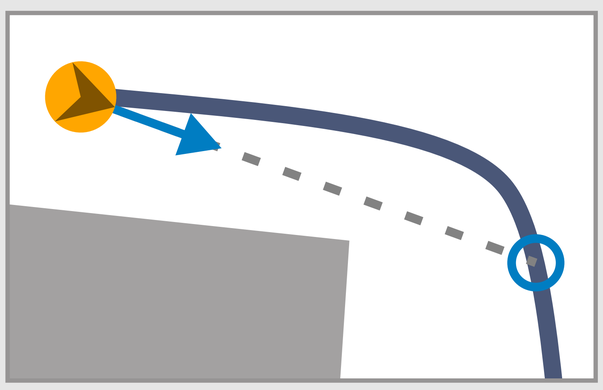
Convert a semantic action (e.g. "go home") to a **geometric query** (e.g. "find a path from a location *s* to another location *g*").



2. Global route planning

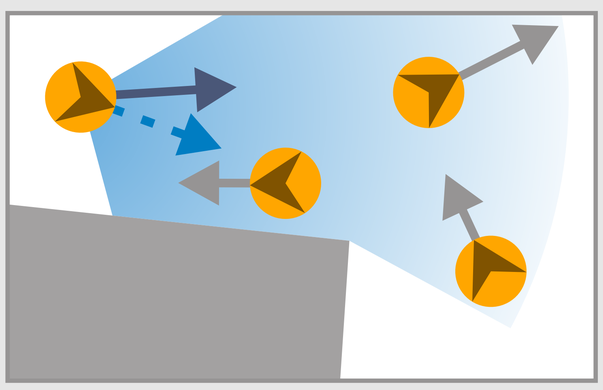
Compute an **indicative route** from *s* to *g*. This is a global indication of the path to follow.

Simulation loop: Performed using a fixed frame rate, e.g. 10 FPS



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.

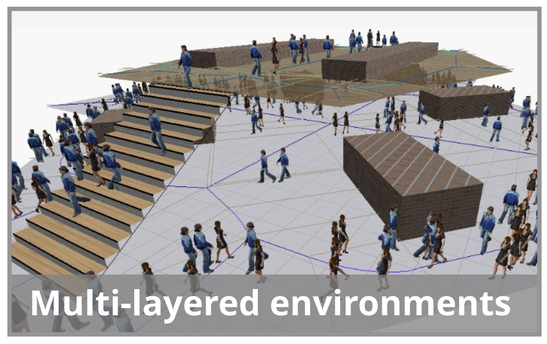
Rendering loop: Application-dependent

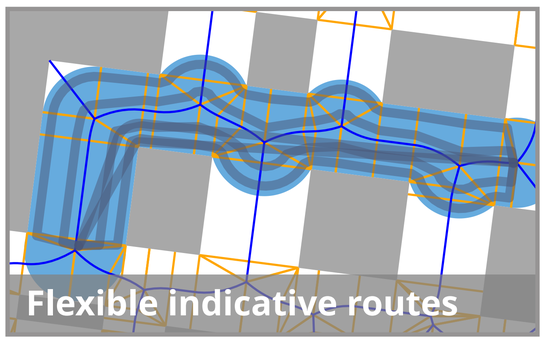
5. Animation

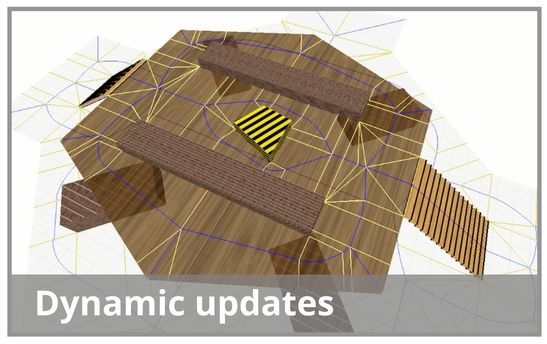
Smoothly **move** the agent's (3D) model to its next position in the simulation. The visualization frame rate can be much higher than the simulation frame rate.

Environment Representation

The **Explicit Corridor Map (ECM)** is a navigation mesh that efficiently describes the walkable space. It has many useful properties for levels 2, 3, and 4 of the planning hierarchy. Next to the ECM, an environment can contain **weighted regions** for which agents have personal preferences.







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 **>1,000,000** agents;

Simulation of **>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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