A Comparative Study of Navigation Meshes

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In simulations and games, AI-controlled agents need to plan paths through 2D or 3D environments. A navigation mesh is a data structure that enables this. Many navigation meshes exist, but there is no standardized way of evaluating them. In this work, we conduct the first comparative study of navigation meshes, aiming to steer future research. We introduce generic definitions and quality metrics, and we use them to compare six state-of-the-art navigation meshes in a range of environments.

Definitions

3D environment (3DE): A raw 3D model of a virtual environment, including walls, ceilings, et cetera.

Walkable environment (WE): A set of polygons on which agents can stand or walk.

Multi-layered environment (MLE): A subdivision of a WE into 2D layers connected by line segments.

Navigation mesh: A set of regions and a graph, describing the WE for navigation purposes.

Quality Metrics

Given a navigation mesh M for a particular WE, we present metrics that can objectively measure the quality of M. Our metrics come in four categories:

1. Coverage
   - How well do the regions of M match the geometry of the WE?
   - How much of M is (in)correct?

2. Connectivity
   - How well does the graph of M capture the connectivity of the WE?
   - Does M capture all possible paths?

3. Complexity
   - How efficiently does M represent the WE? How large is the graph, and how complex are the regions?

4. Performance
   - How efficiently has M been computed? How much time and memory did this take?

Experiments and Results

We compare six navigation mesh implementations: two exact methods (LCT⁴, ECM⁵) and four voxel-based ones (CDG⁶, Recast, NEOGEN⁷, and a grid). We compute meshes for many environments, including these:

The images below show the navigation meshes for one environment. Regions are shown in different colors. For clarity, the graphs are not shown.

Overall, our results suggest that:
- our metrics accurately reflect the quality of a navigation mesh;
- the influence of parameter settings can be investigated further;
- voxel-based methods do not scale very well to large environments, which highlights the need for exact ways to convert a 3DE to a WE.