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A Comparative Study of Navigation Meshes

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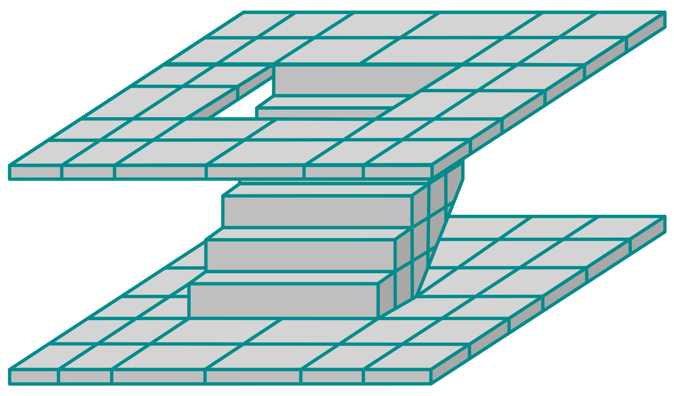
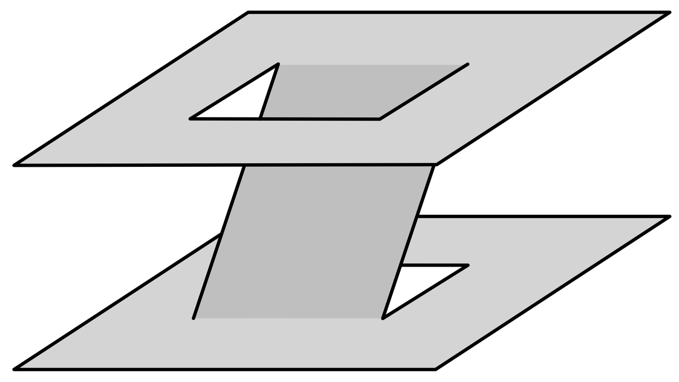
In **simulations and games**, AI-controlled agents need to plan paths through 2D or 3D environments. A **navigation mesh** is a data structure that enables this. Many navigation meshes exist, but there is no standardized way of evaluating them. In this work, we conduct the first **comparative study** 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.

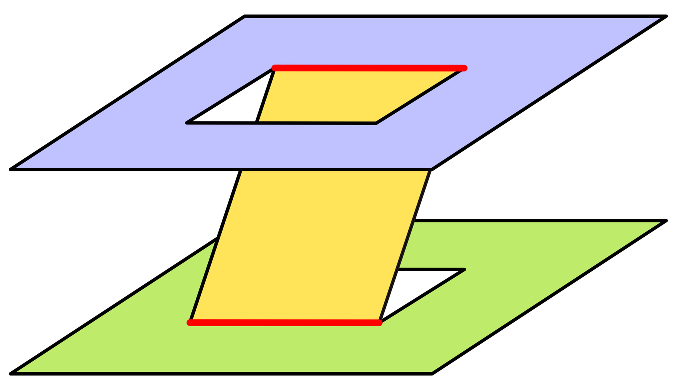
Definitions



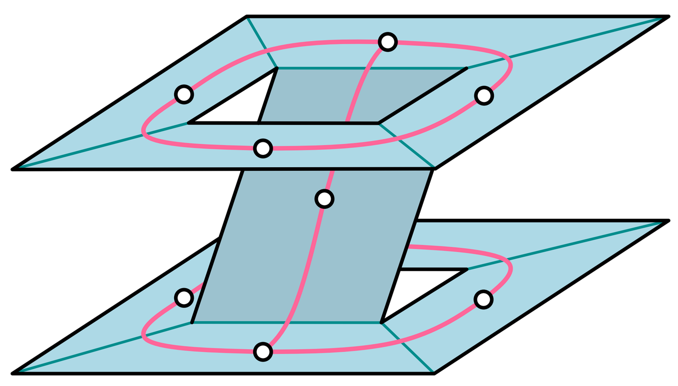
3D environment (3DE): A raw 3D model of a virtual environment, including walls, ceilings, et cetera.



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.

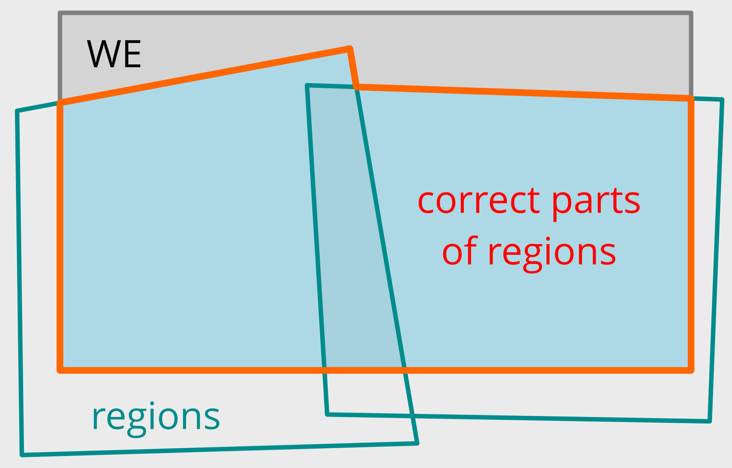
There are two ways to construct a navigation mesh:

- **Exact**: given a WE/MLE, compute a geometrically perfect navigation mesh with provable complexity.
- **Voxel-based**: given a 3DE, first approximate the WE/MLE and then compute the navigation mesh.

Quality Metrics

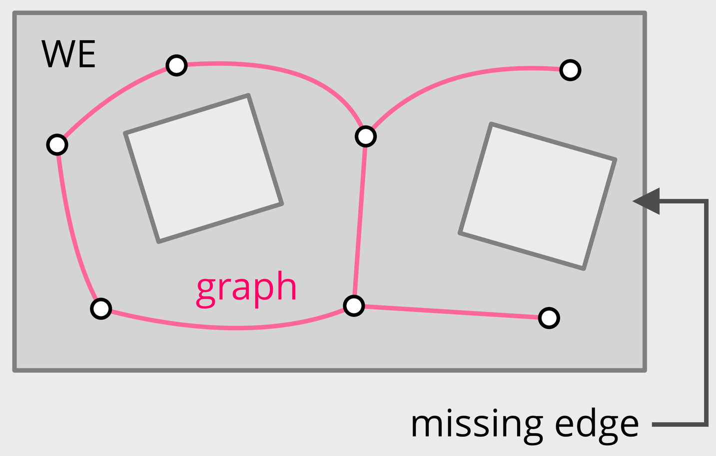
Given a navigation mesh M for a particular WE, we present metrics that can objectively **measure the quality** of M. Our metrics come in four categories:

1. Coverage



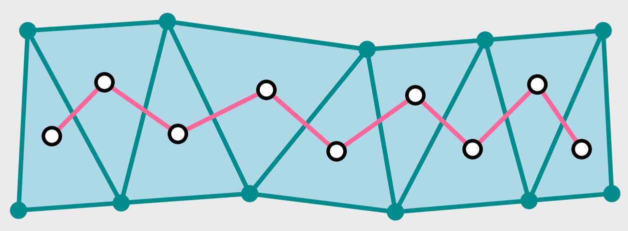
How well do the regions of M match the geometry of the WE? How much of M is (in)correct?

2. Connectivity



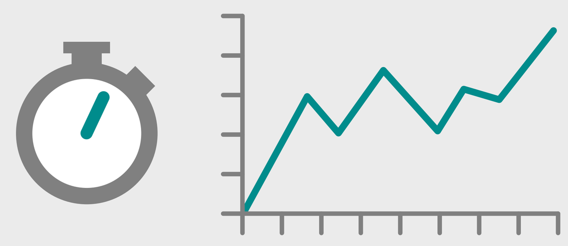
How well does the graph of M match the connectivity of the WE? Does M capture all possible paths?

3. Complexity



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

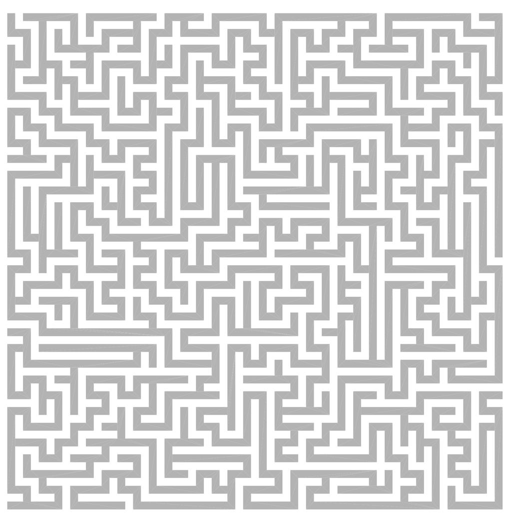
4. Performance

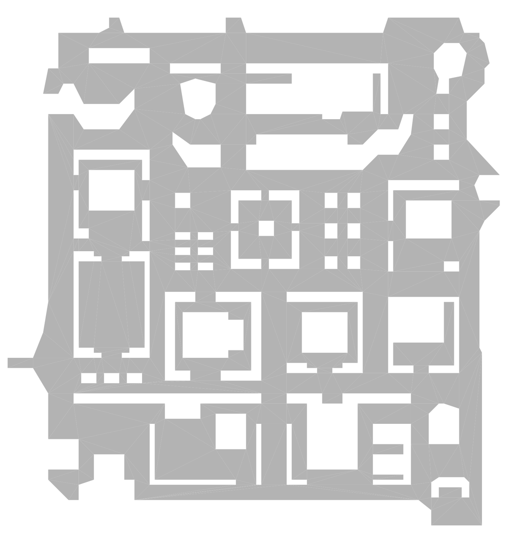


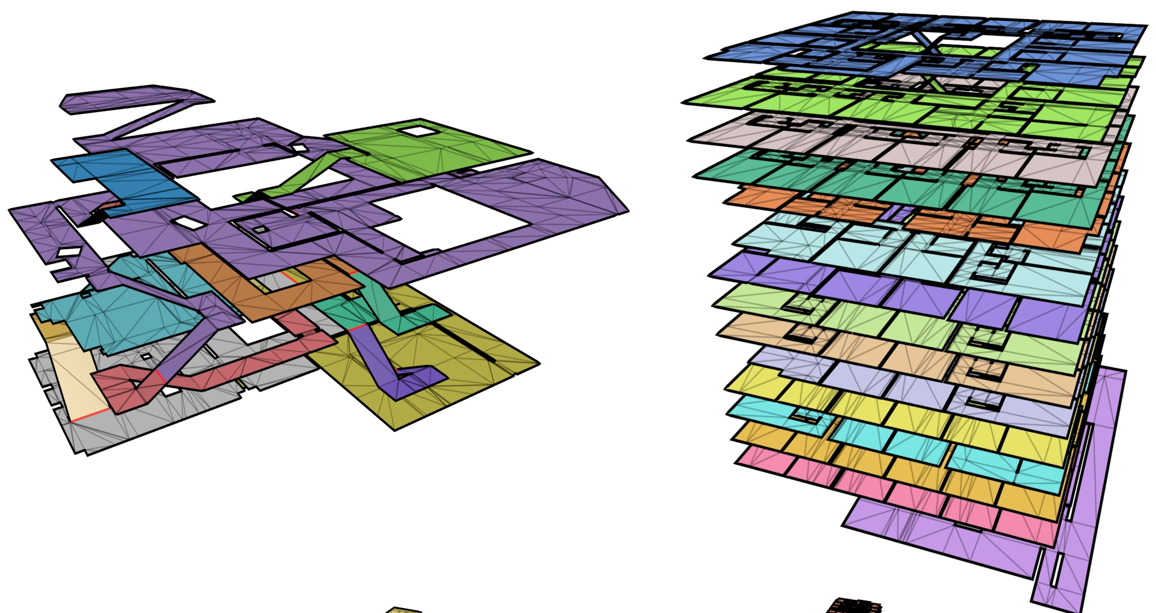
How efficiently has M been computed? How much time and memory did this take?

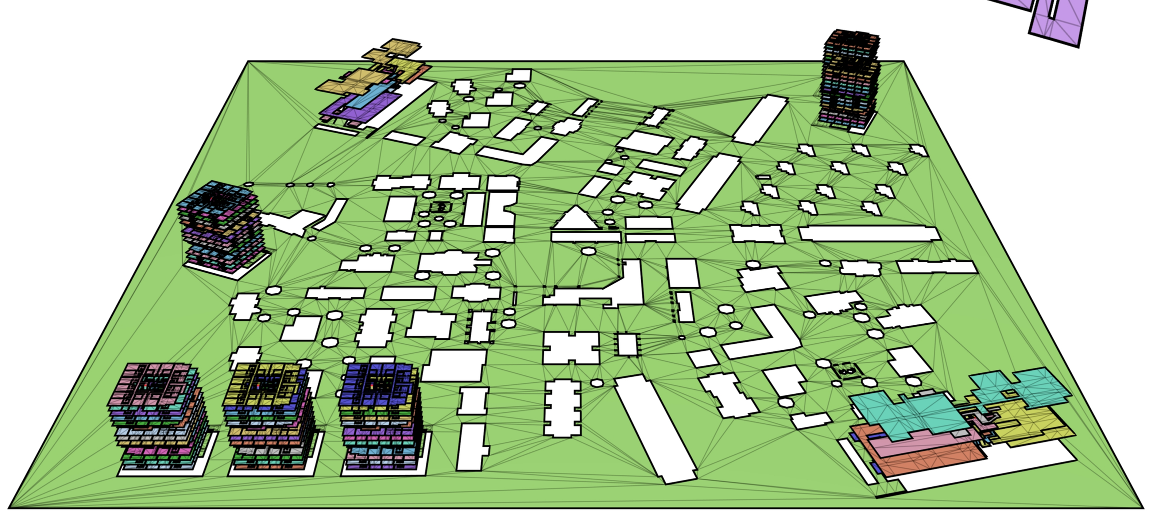
Experiments and Results

We compare six navigation mesh implementations: two exact methods (LCT [2], ECM [1]) and four voxel-based ones (CDG [4], Recast, NEOGEN [3], and a grid). We compute meshes for **many environments**, including these:

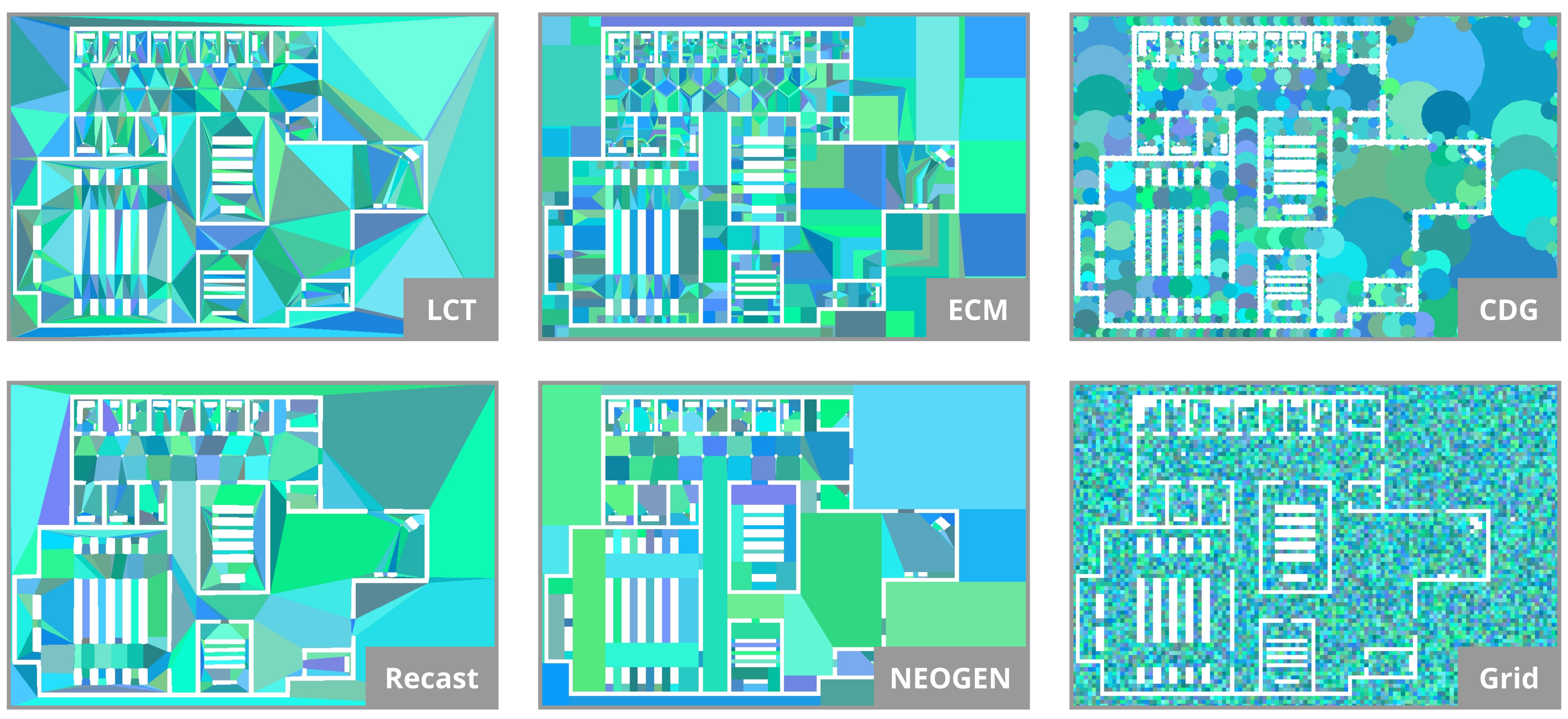








The images below show the navigation meshes for one environment. Regions are shown in different colors. For clarity, the graphs are not shown.



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.