Learning Topological Maps: An alternative Approach

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Abstract

Our goal is autonomous real-time control of a mobile robot. In this paper we want to show a possibility to learn topological maps of a large-scale indoor environment autonomously. In the literature there are two paradigms how to store information on the environment of a robot: as a grid-based (geometric) or as a topological map. While grid-based maps are considerably easy to learn and maintain, topological maps are quite compact and facilitate fast motion-planning.

We integrated both kinds of maps to gain the best of both worlds. This paper describes an approach to convert grid-based maps into topological maps. It differs from previous approaches because it integrates grid-based maps. Therefore it is automatically consistent, not dependent on disambiguous landmarks and all geometric information is available. It scales better to large-scale environments. Previous approaches constructed topological maps from the scratch.

This algorithm builds on our software for building grid-based maps. For every point in these maps the probability is given wether it is occupied or not.
The algorithm could be divided into the following parts:

- Tresholding: Divides the map into "free" and "occupied" space
- Voronoi: Generates the Voronoi-diagram [Lat1] V of the grid-based map (fig. (a) black line). Let the nearest occupied point be called basis-point and the line(s) between the basis-points of $v \in V$ basis-line(s).
- Critical points: A point $v \in V$ is a critical point, if its clearance [Lat1] is a local, linear-oriented minimum. In other words: v is a critical point, if (a) it is part of the voronoi diagram and (b) on the perpendicular to its basis-line is no point v' with smaller clearance within an ε-surrounding. Each basis line of a critical point is called critical line. (fig. (b))
- Region-segmentation: The entirety of the critical lines divides the map into regions. (fig. (c)) These regions can be connected by a graph (from center to center),
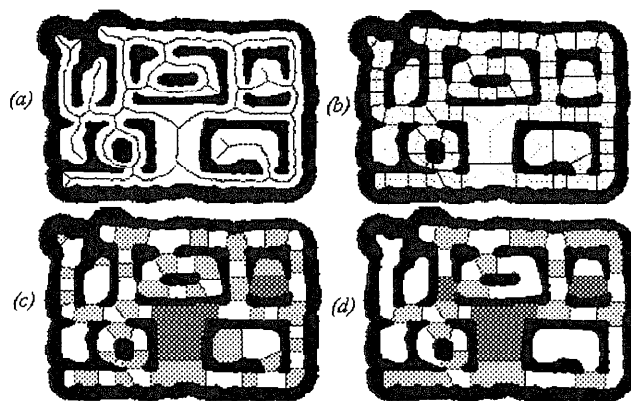
which is a topological map for the given grid-based map.

- Optionally pruning is possible: Let each region, that has a maximum of two neighbor-regions, be pruned with each neighbor-region, that has a maximum of two neighbor-regions, too. The result is a map that is close to human communication because the regions come nearly rooms or part of rooms (entry part of room x) (fig. (d)). It is possible to label the regions by room-names.

Results: The algorithm is integrated into the current RHINO software, that is already capable of building grid-based maps. It works in nearly real-time (<10 sec.) and accelerates motion-planning by 10^3 to 10^6. Tests have shown that the detour caused by topological map based planning is only about two percent (detour if it is possible to reach the destination-point faster than first driving to nearest point of the destination-region), but this is equalized by the smaller time for calculating the motion-path.
Another advantage of this representation of the environment is the possibility to count narrow passages easily (critical lines). These narrow passages are most likely to be blocked by obstacles. So an "optimal" path should be as short as possible and includes as little as possible critical lines or should cross as little as possible regions.

References:

[Lat1] J. C. Latombe: Robot Motion Planning, Kluwer