The 2010 IEEE/RSJ International Conference on
Intelligent Robots and Systems
October 18-22, 2010, Taipei, Taiwan

Empirical Evaluation of a Practical Indoor Mobile Robot Navigation Method Using Hybrid Maps

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Abstract—**This video presents a practical navigation scheme for indoor mobile robots using hybrid maps. The method makes use of metric maps for local navigation and a topological map for global path planning. Metric maps are generated as occupancy grids by a laser range finder to represent local information about partial areas. The global topological map is used to indicate the connectivity of the 'places-of-interests' in the environment and the interconnectivity of the local maps. Visual tags on the ceiling to be detected by the robot provide valuable information and contribute to reliable localization. The navigation scheme based on the hybrid metric-topological maps saves memory space and is also scalable and adaptable since new local maps can be easily added to the global topology, and the method can be deployed with minimum amount of modification if new areas are to be explored. The video demonstrated that the method is implemented successfully on physical robot in a hospital environment, which provides a practical solution for indoor navigation.**

I. Introduction

Majority of the navigation methods developed for indoor mobile robots utilize map-based techniques. Metric [1], topological [2], sensor-level [3], appearance-based [4] and semantic maps [5] are major types of maps that has been developed and used in a number of robotic applications [6]. We propose to use hybrid maps which combine the strengths of both metric and topological maps. The metric map in the form of occupancy grid represents local environment accurately for localization and obstacle avoidance. The topological map abstracts the environmental representation with nodes and edges, which is useful for global path planning and symbolic problem solving.

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II. Method

The method consists of an offline mapping phase and actual navigation phase. The metric maps are generated by laser range finder in the form of occupancy grids to represent local knowledge of certain areas in the environment. In order to be able to build a higher-level topological map, it is assumed that any local metric map has an overlapping region with at least another local metric map. The global topological map is simply an undirected graph, which indicates the connectivity of the 'places-of-interests' in the environment and the interconnectivity of the local maps. For topological navigation, the method additionally makes use of visual tags placed at the overlapping regions of local metric maps. These visual tags require minimal installation effort, and they simply act as artificial landmarks that are highly distinguishable and easily detectable.

A. Map Generation

Mapping consists of 3 stages. The first stage is exploration, which starts with collecting datasets from the environment. A dataset consist of two different types of data: odometry correlated range measurements and image sequences. Post processing odometry correlated range measurements; which is simply a simultaneous localization and mapping process, result in a set of local occupancy grid maps.

Next stage of the mapping is annotation. This task is mainly human driven, in which a supervisor manually enters poses of 'places-of-interest' and the positions of the visual tags in the environment. The latter can be also referred as 'switching nodes'. As a result, a set of annotated metric maps, and implicitly, a set of local connectivity graphs are obtained.

Final stage of mapping is global topology creation. This stage takes place automatically, given a set of annotated local metric maps. A simple search algorithm basically looks for multiple occurrences of switching nodes in different maps and creates a data structure where the local maps are linked symbolically through common switching nodes. As a result, global connectivity of all points-of-interest in the environment is achieved through switching nodes.

B. Navigation

Assuming that the robot is initialized at one of the points-of-interests in the map, it is possible to plan a global path using the topological map to reach a destination node. The generated path is a sequence of nodes, which starts with the initial position, followed with a number of switching nodes (if destination node is not in the same local map) and a final destination.

Knowing the sequence of the nodes in the path; the local map that includes the first two nodes in the sequence is instantiated, the robot is placed at the initial node and a local path in the metric map is planned to the second node. As the robot reaches its local goal, the first node is dropped from the global path and the procedure restarts with the new pair of nodes until the robot reaches its final destination. The laser scanner is used to avoid obstacles in navigation and the visual tags are used for reliable localization.

III. Experiments

The described method is developed as a software library and tested in both simulated environments and a real hospital setting. CARMEN [7] is used as the software framework for the experiments. Gmapping [8] is used to generate metric maps and ArtoolkitPlus [9] markers are used as visual tags at the switching nodes.

Physical experiments are conducted on a Pioneer-3dx platform, which is equipped with a Sick-LMS200 laser range finder and PointGrey Firefly-MV camera and a laptop computer running Linux operating system.

Experimental tests took place in Bispebjerg Hospital, Copenhagen, Denmark, where the environment is divided into five regions: Acute Medical Attention (AMA) unit, Offices, Waiting Room, Intensive Care and Mammography. Seven points-of-interest were identified in the environment, and there are four switching nodes in the global topologic map. It was demonstrated that the robot could successfully navigate between any point-of-interest inside the region, handling the map transition effectively.

IV. Discussion and conclusion

In this video, a new navigation scheme based on the hybrid metric-topological maps is evaluated empirically in a real hospital environment. The method provides a practical solution for indoor mobile robot navigation. The salient advantages of the proposed scheme are: reliability, as visual tags provide valuable redundancy in localization; scalability; as new local maps can be easily added to the global topology; and adaptability; as the method can be deployed for indoor navigation with minimum amount of modification if new areas are to be explored.

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