Quantitative Evaluation of the Exploration Strategies of a Mobile Robot

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How should a mobile robot explore its environment in order to build a high-quality world model as efficiently as possible? We address this question through experimentation with a sonar-equipped mobile robot.

The robot is taken to be a delivery robot, such as could be used in an office, hospital or home. Its objective is to execute efficient collision-free paths between user-specified locations. A grid-based free-space map is generated for this purpose. This map is derived from a feature-based map, built using techniques similar to those of (Leonard & Durrant-Whyte 1992).

Before starting to evaluate an exploration strategy, it is vital to have a clear definition of map quality. Previous map-building research has typically judged map quality either by visual inspection or by measuring the robot's success in achieving its goals with a *completed* map. Neither approach provides an objective quality measure *during* map construction. There is therefore a need for a quantitative measure which can be applied during exploration. We solve this problem by defining a small number of numeric measures which together *predict* the robot's efficiency if it were to use its current world model to achieve its objectives.

The quality of the robot's map is measured by comparing its performance in a set of tasks using either the robot's map or an ideal map. The set of benchmark tasks is created by selecting pairs of locations such that there is an executable path between them, according to the ideal map. For each pair of locations, an attempt is then made to plan a path between them, using the robot's map. Counts are kept of the numbers of these paths which fall into each of three categories; "Impossible", "Collision" or "Feasible". A path is "Impossible" if the current map shows either that one of the endpoints is occupied or that the path is blocked. A path is a "Collision" if the current map shows the route to be possible, but in fact the planned route would cause a collision with an obstacle. A path is "Feasible" if the planned route is possible without collision. In this case, we compare the cost of executing the planned route with the "ideal" cost from the true map. The categorisation of the paths and the efficiency of the feasible paths measure different aspects of the map quality. The relative significance of these aspects can be assessed in the context of the robot's application.

These measures were used to fine-tune the map construction process. Parameter values were selected and design choices were made to maximise the map quality obtained from given sensor data. Objective quality measures were essential during this process.

We report the results of the evaluation and comparison of a number of exploration strategies by monitoring the quality measures as the robot explores a set of test environments. The first strategy tested was wall-following, a completely reactive navigation strategy in which all decisions are made on the basis of immediately available sensory data. The map is not used to control the exploration. In sparse environments the map quality increases rapidly at the start of the exploration but reaches a plateau when, for example, the robot is following a wall which has already been observed from elsewhere. An immediate challenge in designing an exploration strategy is to use the information gathered so far to eliminate such redundant movements.

We also report the results of a "Visit All" behaviour (Zelinsky 1992), which directs the robot systematically towards unknown regions, and a "Seed-Spreader" technique (Lumelsky, Mukhopadhyay, & Sun 1989), which is theoretically guaranteed to find all obstacles in the environment.

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References

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