

Mapping Contoured Terrain: A Comparison of SLAM Algorithms for Radio-Controlled Helicopters

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1 Introduction

In the context of a natural disaster, or when a military pilot has to eject in enemy territory, Search and Rescue teams often have to find people in unknown or hazardous areas. For safety reasons, Search and Rescue teams of the future will probably make use of unmanned aerial vehicles. For such a rescue vehicle, the ability to localize itself, both to avoid dangers (mountains/enemy bases) and to scan the entire area until survivors are found, is essential. However, this area may be unknown (enemy territory), or not mapped precisely (mountain summits). Moreover, global positioning systems (GPS) may not be usable in the area, or they may be not accurate enough, as is often the case in areas with dense foliage.

In such a situation, a helicopter capable of mapping its surroundings while localizing itself on this map would be of special interest. In this project, we have investigated such a platform. We have implemented a SLAM algorithm for a helicopter moving in an area with uneven terrain and using 3-D rangefinder sensors. Our goal was for this helicopter to be able to create a 2-D map of the ground surrounding it, while localizing itself on that map.

2 Goals of the Project

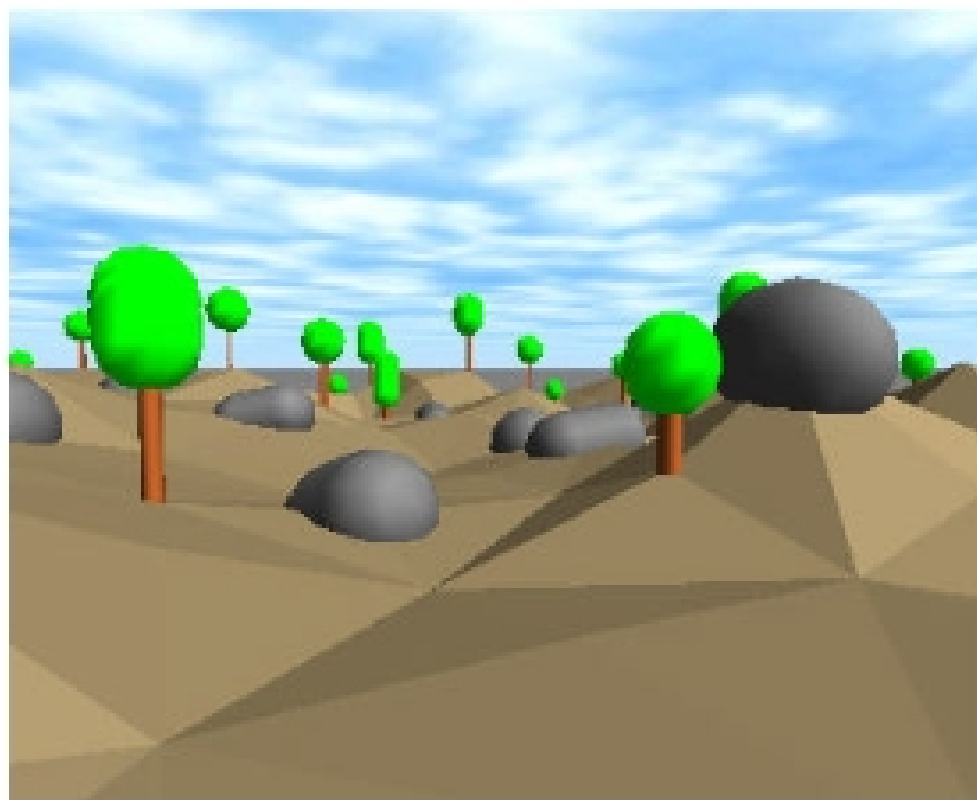


Figure 2.1: Problematic Terrain

The first goal of this project is to be able to do 2-D SLAM in a simulated, forested outdoor environment where the ground is not flat. Our platform of choice is a small, radio-controlled helicopter. In such a situation, traditional 2-D SLAM is problematic because the horizontal plane of the laser rangefinder can hit contoured ground, causing spurious landmarks to be placed on the map. The laser rangefinder can also miss low-lying landmarks if the helicopter is hovering too high. For instance, in the contoured scene in Figure 2.1, no horizontal plane of laser rangefinder casts can hit all the landmarks (rocks and tree trunks) at once, and the raised ground could be seen as a spurious landmark. Thus, we will use full 3-D laser rangefinder scans so that we can see all the landmarks in the scene. We will then process the 3-D scans to yield 2-D, leveled

range scans. Once we have 2-D, leveled range scans, we can use traditional 2-D SLAM algorithms to generate a 2-D map.

The second goal of this project is to compare two common SLAM algorithms and their abilities to perform 2-D SLAM in our environment. The two algorithms are FastSLAM, which uses landmarks as its map representation, and DP-SLAM, which uses occupancy maps. Both algorithms use particle filters to perform Bayesian updates. Each has advantages and disadvantages in terms of processing time, memory storage, and pre-processing requirements, and so our goal is to find out what the benefits and pitfalls of each method are, and to evaluate their performance and requirements.

The third goal of the project is to evaluate the ability of each 2-D SLAM algorithm to be extended to 3-D, by which we mean tracking the helicopter's pose as (x,y,z,θ) rather than simply (x,y,θ) . In general, we assume the helicopter is controlled to avoid significant pitch and roll, and so only yaw is considered. If we could track the helicopter's elevation using either the relative elevation of the landmarks or the elevation of the points on the occupancy map, we would have the full 3-D pose of the helicopter. With the full 3-D pose, we could create either 2-D terrain maps (by appending just the ground points to the determined path of the helicopter), or even full 3-D maps (by appending the full 3-D scans to the determined path of the helicopter).

Thus, the objectives of this project are:

- 1) To simulate an appropriate forested outdoor environment and the motion/perception of a small, radio-controlled helicopter
- 2) To segment and process the 3-D rangefinder data to create leveled range scans, rejecting spurious landmarks
- 3) To perform 2-D SLAM using the leveled range scan data with both landmarks and occupancy maps, and to compare these two algorithms
- 4) To evaluate the ability of 2-D landmark and occupancy map SLAM algorithms to be extended to 3-D

3 Previous Work

In terms of mapping of non-flat terrain from a helicopter, (Thrun, 2003) creates a 3-D map using 2-D rangefinder data. A small helicopter is equipped with rangefinders whose measurements lie in a plane perpendicular to the direction of motion. Using scan-alignment techniques, the noisy data is combined into a smooth 3-D picture of the world. However, they are not using SLAM, and the helicopter cannot image the same location twice with their algorithm.

(Montemerlo, 2003) creates a 3-D map of a non-flat underground mine from a cart platform. The robot uses a forward-pointing vertical rangefinder (whose plane is parallel to the direction of motion and the up-direction) to reject spurious 'wall' detections made by a horizontal rangefinder pointed at non-level ground. The resulting data is used to create a 2-D map with a normal 2-D SLAM algorithm. The 3-D map is then created using a plane of rangefinder measurements perpendicular to the direction of motion, combined using the helicopter's estimate of its location on the 2-D map generated using SLAM and smoothed using scan-alignment. This work is similar to what we are attempting to do, in that it performs 2-D SLAM with disambiguation of spurious