Probabilistically Voxelated Occupancy Map for Path-Planning

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1 Introduction

Map-building is one half of a solution to simultaneous localization and mapping (SLAM) problem. SLAM acts as a utility to solve robotic exploration in an unknown environment. SLAM is stochastic and involves error in data reading. Stochastic information from multiple sensors are used to form information gain through filtering and data fusion.

Map building requires the same data fusion for local map registration. The registration method involves filtering technique to transform a local map into a global map. However, most of the solution for three dimensional map-building are in the form of point clouds, occupancy grid map, and a variant of occupancy grid map. Point clouds involves rich representation of geometric data for autonomous robots. Unfortunately, point clouds increases computational load (Borrmann et al., 2008; Cole and Newman, 2006; Engelhard et al., 2011; Weingarten and Siegwart, 2005). These point clouds are discrete series of metrical data. A map suiting the robotic ability to move in three dimensional space requires three dimensional map that emphasize the geometric information of an environment and the have a structure that will not hinder online computation.

In tandem to automatic motion, this map should represent the probabilistic nature of the sensor and the locomotion of the robot to be effectively used in SLAM solution. Hornung et al. (2013) introduced a three dimensional occupancy grid map, coined as Octomap, that extend the two dimensional grid map introduced by Elfes (1989).

Octomap uses grid cells seeded with binary values to represent occupancy in space. The grid cells are stacked continuosly in series of cubic primitives. Octomap thus far are used only to represent static environments. This paper will attempt to create a variant of octomap, continous-octomap, to discern its feasibility on dynamic environment representation for path-planning purposes.

2 Related Works on Evolution of Map Building

A confident map is instrumental for a correct localization. Since mid-1990's, the mobility of mobile robots have increased from three degree-of-freedoms to six degree-of-freedoms (DOFs). A manipulator such as an articulated industrial robot arm also have 6-DOF end effector. An autonomous robot with these mobilities requires confident map that represent an environment in three dimensional space. Three types of maps commonly used for autonomous robots are point clouds, graph maps, and occupancy grid maps.

Point clouds are three dimensional representation of spatial space. Point clouds are often used with iterative closest point matching (ICP) or scan matching to register local maps. These type of maps are limited by their large number of information containing metrical data that puts computational strain to an algorithm (Olson, 2009). However, with the advent of parellel computing, and the optimization of a library called OpenCL (Rusu and Cousins, 2011), the computational efficiency for point clouds manipulation may increase.

Graph maps use graph theory to represent an environment semantically. The concept of graph maps relates poses and features as nodes and abstracting raw sensor data into pose-graph (Grisetti et al., 2010). A pose of a robot contains positional information that reflects the degree of freedom of the robot. Unlike point clouds, graph maps lacks geometric structure and oftenly used for optimizing localization processes in SLAM solution.

Two dimensional occupancy grid map is a type of map that contains probability description of an environment from sensor reading. The map uses Poisson distribution to ascertain the occupancy of a two dimensional space. This map was introduced by Moravec (1989) and Elfes (1989) using sonar sensors, as an output, to map an environment for an autonomous robot. From this map, the environment is divided into planar grid cell to represent occupancy. The concept of occupancy grid cell is still used today to develop a more advance mapping and localization method particularly for SLAM solution (Member and Member, 2006; Ray et al., 2012).

Three dimensional occupancy grid map such as Octomap (Hornung et al., 2013) enables robot to move in three-dimensional space with three to six DOFs. Octomap extend the use of grid map-building into three dimensional space and embed each grid cell with a relaxed logit function to give a binary value of occupancy. In this map, occupied space is represented by a probability value of "1" and unoccupied space is represented by a probability value of "0". Octomap adopts octree data structure to allow efficient computation of the localization posterior distribution. However, currently, octomap is only being used for semi-online autonomous robot. With a semi-online design, an autonomous robot perform poorly in highly dynamic environments.

A part of SLAM solutions is on registering multiple maps from local coordinates into maps in global coordinate system. As autonomous robot moves in an unknown environment, a collection of maps in the form of scans are introduced to its vision system. One method of map registration is done post-exploration (Burgard et al., 1999). However, online registration is more desirable in the context of an autonomous robot. A semi-online map registration would bundle a collection of map before registering the map globally during exploration.

This paper extend the definition of occupancy in octomap by introducing continous probability value instead of binary in each grid cell. We will compare the perfomance of a number of path-planning algorithms in these maps. We will use octomap as the benchmark. The metric of perfomance is based on time to complete a path planning from a predefined starting position to a final position in a static environment. This approach is reapplied for environment containing moving objects and human.

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