Exploration of a Mobile Robot in a Boundary Environment with Unknown Obstacles Using Reaction-Diffusion Equation on a Graph

A new exploration re-planning framework for a mobile robot is proposed integrating with Reaction-Diffusion on a Graph (RDEG) for exploration in a boundary environment with unknown obstacles. The robot must plan a path that can completely coverage all unknown area, this is done by utilizing the boundary information in order to create more efficient exploration plan, however, there are chances encountering unexpected obstacles and when this occurs the predefined path cannot handle this situation and it is necessary an efficient path re-planning as shown in Fig.1.

Using an exploration algorithm that arranges observation points by the reaction-diffusion equation on a graph the boundary area is covered with a minimal number of circles (hard computation problem). After the observation points are arranged, the effective exploration path is generated by connecting all these points, for this research Lin-kernighan heuristic (LKH) is used, the distances between 2 observation points are calculated by using A* Algorithm.

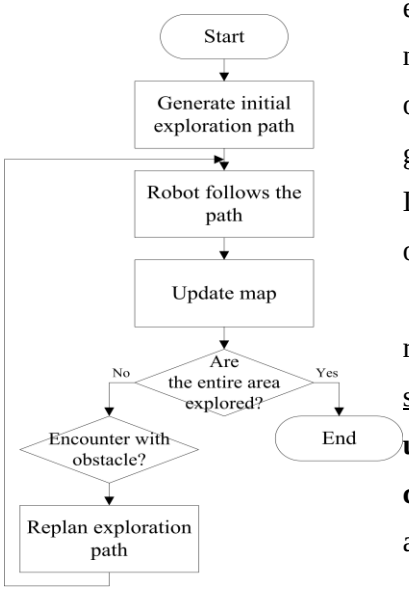

Fig.1. Overview exploration plan flowchart

In the proposed framework a grill is used as our spatial representation, each grill cell is represented with one of three states: **occupied cell** (could be obstacle area or boundary area), **unexplored cell** (the cell that has not yet been explored) and **free cell** (area already sensed by robot and it did not found obstacles) as shown in Fig. 2.

From this spatial representation, a detection process analogous to region extraction in computer vision is used to find the obstacle region. This information is used in the rearrangement of the observation points in the case that the robot encounters an unknown obstacle during its movement along the created path while updating the exploration map. In this case the robot must decide whether it cans recognize the complete shape of the obstacle or not by calculating the connected-component labeling. If shape and area can be decided this changes the state of the occupied cell. Otherwise, we made consideration that the movement of observation points follows the Reaction-Diffusion Equation, the further the distance from the place where change has occurred, the smaller the magnitude of the movement. After the observation points are rearranged the new path is generated as mentioned previously as show in Fig. 3.

Reference

[1] Theeraphol Wattanavekin and Jun OTA, "Exploration in a Boundary Environment with Unknown Obstacles Using Reaction-Diffusion Equation on a Graph", Proc. IEEE International Conference on Robotics and Biomimetics, 1332/1337 (2011).

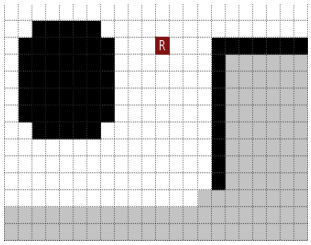

Fig.2. Occupied cell (Black), Unexplored cell

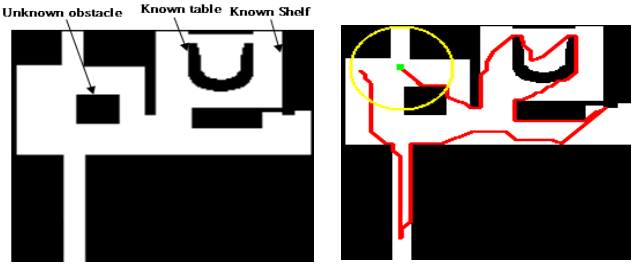

Fig.3. Simulation's practical experiment map and RDEG (proposed)