Design decisions of the SEU-RedSun Rescue 2011 Team on the Challenges of the Virtual Robot competition

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Abstract. This discussion paper highlights the design decisions of the SEU-RedSun Rescue Team on the challenges imposed by the 2011 competition. The SEU-RedSun Rescue Team focus on SLAM and applicability of several different robots. This paper shortly describes the main features and implementation of the SEU-RedSun rescue simulation team.

Keywords: probability-based map; SLAM; 3D map; wireless Communication

1 Introduction

The RoboCup Virtual Robot competition is a great platform for rapid prototyping in urban search and rescue scenarios with teams of robots. Generally, the problem cannot be solved by single robot, and a team of heterogeneous robots that dynamically combines individual capabilities and cooperatively solves the task is needed. Our multi-robot system will demonstrate the progress of the skills necessary for urban search and rescue, including mapping, mobility, victim finding, communication and cooperation skills. This discussion paper highlights the design decisions of the SEU-RedSun Rescue Team regarding the challenges of the 2011 competition.

2 Our Goal

The main goal of our team will not change much despite of the simplification of the rule in this year's competition. The aim of our team is to develop a system in which all of the rescue robots can make decision by themselves. The system was designed to have a hierarchical structure, with each component functioning independently. The robots all have the ability for mobility, exploring, victim finding, communication and cooperation. In addition, it is hoped that the system and underlying mathematics can be portable to the real robots with minor modifications.

Robots can make decisions on their own. However, in some special circumstances, they may also be controlled by human operators through the Wireless Communications Server. All control commands are sent via the base station.

Considering the remove of sub-problems in this year's rule, our team will focus on the searching of victims. We develop more precise simultaneous localization with multiple sensors, as well as a mapping algorithm based on probability theory which adds to the robustness in complex environment. We also use a new path finding and exploration algorithm which leads to more careful search for victims.

3 Path-Planning and Exploring

The mapping algorithm we used in the previous years is mainly based on line matching. It works well in structural environment but behaves unsatisfactorily in distinguish barriers of complex figure, and makes it quite difficult to apply the algorithm to the real robot where noise and interference are much more serious. To solve these problems, we develop an algorithm rely on probability. Since the interval of each frame is quite short, we can get a large amount of data describing the same area. In common algorithms, only the first frame of these data are used, which might be affected by noise or imprecise localization and thus leads to errors in mapping and later work. But in this probabilistic algorithm, we make full use of all those data. An obstacle is confirmed only when a certain percentage of data suggest its existence. This largely reduced the ambient noise and the effect of imprecise localization. Besides, this adds to the robustness against tough environment, and it can be proved that map created by this mapping algorithm will converge to the real map when the amount of data is enough. In addition, since the algorithm is no longer based on line matching, it can now distinguish obstacles of irregular figure, which may enhance its performance on real robots.

Similar to occupancy grids, the algorithm above provides an intuitive representation of the geometry of a robots physical environment. The greatest drawback, however, is that its space and time complexities grow exponentially with the grid resolution. Thus, we tried a special method of path-planning (we call it "follow-the-wall" or FTW), based on obstacle-recognition [Figure 1]. The advanced version of this method behaves just like a topological map [Figure 2], but is much more simplified.

Fig. 1. result of auto-exploring

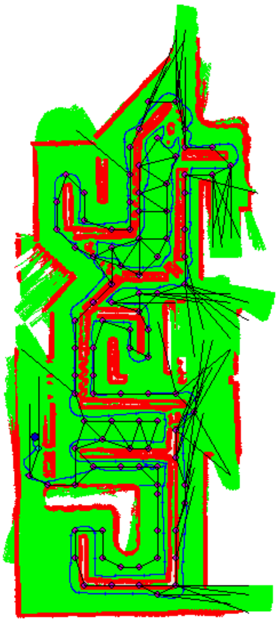

Fig.2. topological map

The process of FTW is in following steps:

1. Go straight until recognize an obstacle in a certain range.
2. Make a swerve based on comparison of free space on both sides.
3. Establish the topological map while moving.
4. When the robot get to a node already detected by itself or other robots, find the nearest undetected area using the topological map and search that area.

FTW, ensuring the robot move along obstacles, enhances the safety of exploration and expended the field that can be searched. It is much simpler than the previous algorithm so that less time is spent on route calculating and a larger map can be dealt with within acceptable time. In addition, in real disaster scenes, victims are more likely to be found in corner rather than open area, this method may also contribute to search and rescue.

As a probabilistic algorithm, the main drawback of FTW is recognizing details. Thus, we decide to improve its proformance by adding a self-localization algorithm in order to model the robot’s environment by a local map for further mission. Since previous attempt demonstrates that information offered by a single sensor may not be accurate, which may undermine further localization and navigation, we try to merge mutiple sensors for a more accurate localization. We find it may be feasible to use a combination of MCL and Kalman Filter for real-time localization [Figure 3].

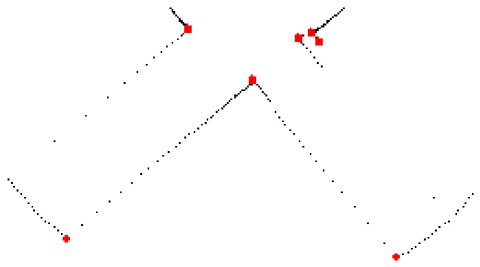

Fig. 3.. A period of laser-scan where landmarks are pointed out

We’ve already used laser-scanning information to find out landmarks (junctions and termination points) for further attempts.

4 Wireless Communication

Wireless Communication plays a very important role in transferring variety information among robots such as sharing the victim position and map information. We must create a structural level information management mechanism. Firstly, the base information is received from the connection layer, the connection layer parse the message for the first time and then send the package message to the message management. Secondly, the message management parses the message for the second time, and decides which message should be transmitted to the other robots, which message is unusable, which message should be updated to own Disaster Space and how to update the Disaster Space. The soon message management worked, the robot could decide how to work in the environment using the information stored in the Disaster Space.

Message type we used is listed below:

1. Control messages by human operator which are sent from base station to control the robots straight.
2. Disaster Space sharing information which is used to share the Disaster Space with other robots.
3. Victim message
4. Parameters of control center, the base station as the center will decide some parameters for all the robots.
5. Cooperate message

In some situation, it is too far for a robot to send information directly to the base station. However, the information could be transferred by another robot. Link State Routing algorithm is used in our system. In the Disaster Space of each robot, a routing table is stored and updated every several cycles. Using the routing table, each robot knows how to send the information to the base station.

5 3D Map Building

The information we captured in the previous years is mainly based on 2D laser range scanner. This year, our Team uses both scanners and camera to acquire environment information. And we capture the feature of the picture information from the camera. As the Robots can locate precisely and move effortless, we analyze the position changes of feature points in the different frames. In this way, we can transform the information of camera to the 3D space and connect the points to build the 3D map.

Step:

1.Analysis of the image data from the camera.

We calculate the module M of RGB vector difference of the longitudinal adjacent points. If the module M is greater than the threshold M0, then mark the point. Like that, we can convert a picture in a frame to some feature points [Figure 4].

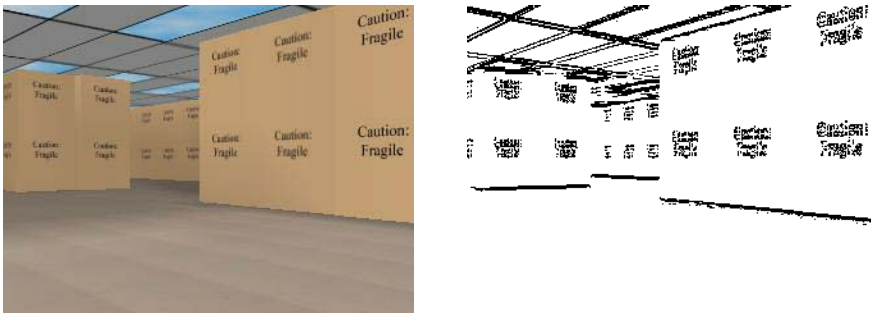

Fig. 4. Mark the feature points

2. Locate the points to 3D space

The robot captures three feature points: 1, 2, 3. At the same time, the laser scanners get the distance L in this direct.

Based on the pitch angles of every feature points, we can project these points (1, 2, 3) to a vertical plane which is at a distance of L from the robot. Then we get the other three points 1’, 2’, 3’ and record the current positions of the robot.

After some time, when the distance between the robot and the obstacles becomes L’ , the robot repeats the same step mentioned and get three points 1’’ , 2’’ , 3’’ (see map) . As we can see, the point 1’ and the 1’’ coincide, so do the point 2’ and "2’’. But the point 3’ is not. In this way, when the points we capture are in the plane, which is measured by the laser scanner, these points in the different frames will have a fixed relationship.

After a while, as the position of the robot changes and we can get enough data, we will know which plane the feature is in.

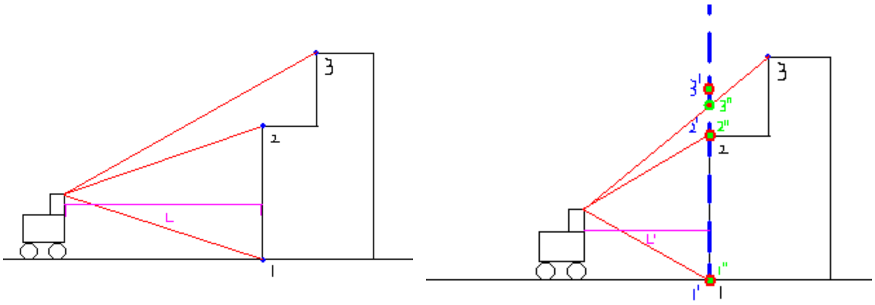

Fig. 5. Locate the points in the plane to 3D space

3.Plot a 3D map.

With this method, we can locate each feature points in the 3D space and plot a 3D map. Though not very clear, we describe the rough 3D shape of obstacles, which may help when deal with complex obstacles.

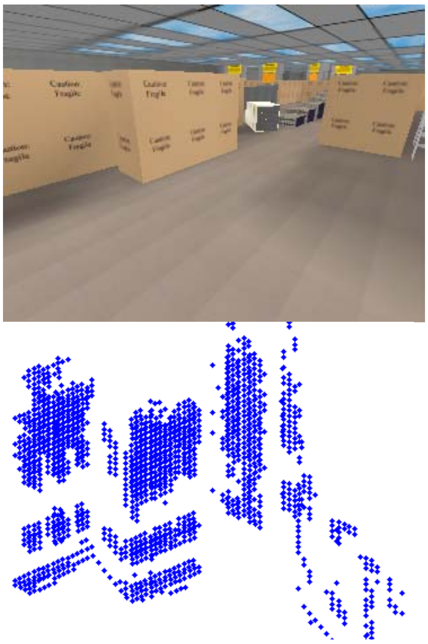

Fig.6. The original image and 3D Map

6 Application in real robots

Our school has persisted with real robot rescue research, since the end of 2008. Most algorithms, developed on the virtual platform, has been transplanted to real robot and proven to be effective after being revised. We refer the performance of our program to meet real-time demand in real robot rescue as our ultimate goal.

7 Future works

In this paper, we highlight several new improvements in our current work. The update covers 3d SLAM, information merge and path-planning. While the newly achievement provide great hope for the future, many works are left to be done. Among them, multi-robot cooperation and victim detection ought to be emphasized.

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