YILDIZ Team Description Paper for Virtual Robots Competition 2014

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Abstract. This paper is a short review of technologies developed by YILDIZ team for participating in RoboCup 2014 Virtual Robot Competitions. This year our focus is on improving our SLAM abilities, foggy image enhancement, multi robot exploration, and obstacle avoidance for the autonomous exploration.

1 Introduction

Probabilistic Robotics Group of Yıldız Technical University, which consists of a team of students and academicians, has been working on autonomous robots since its establishment in 2007. Autonomous robots can perform desired tasks without continuous human guidance which is necessary for Urban Search and Rescue area [1, 2]. Last year's world championship was the third experience of our team on RoboCup. We took second place at Mexico RoboCup and Netherlands RoboCup competitions. We have learned a lot of lessons over three years as following:

- Our user interface is very useful.
- Our message routing protocol is very useful.
- We should develop our SLAM algorithm.
- We should improve our air-robot localization algorithm.
- We should improve our autonomous navigation algorithm by obstacle avoidance.
- We should improve our image enhancement algorithm.
- We should improve our automatic victim detection algorithm.

This year, several developments over some of these systems and they are presented at this report.

The system is designed to have a hierarchical structure, containing different modules responsible of different jobs. Every fundamental part of the main problem divided into modules which can function independently. Normally, each of our virtual robots is intelligent enough to explore the area, find the victims and construct a map. Using multiple robots made the system more accurate and robust.

The team members and their contributions are as follows:

Control and monitor interface	: Gürkan Şahin
SLAM algorithm	: Muhammet Balcılar, Gürkan Şahin, Furkan Çakmak, Erkan Uslu, Sırma Yavuz
Obstacle avoidance	: Muhammet Balcılar, Gürkan Şahin
Multi robot exploration	: Gürkan Şahin, Muhammet Balcılar, M. Fatih Amasyalı
Foggy Image Enhancement	: Muhammet Balcılar, Nihal Altuntaş
Supervising, system design	: Sırma Yavuz, M. Fatih Amasyalı

2 System Overview

The main software modules are user interface, localization, mapping, navigation, communication and victim detection. Robots on their own have all those modules equipped and ready-to-use, there is also a multi-robot coordination module covering them all. As the ground robots we use the Pioneer 3AT and Kenaf models. The sensors to be used are determined as Hokuyo URG04L model laser scanner, camera, ultrasonic, encoder, touch, and odometry sensors. We also use Air Robots with only two camera sensors.

3 User Interface

The user interface is developed to control 16 robots at the same time and consists of two forms as shown in Fig. 1(a) and Fig. 1(b).
At the Form 1 of the user interface (Fig. 1(a)), the thumbnail of all robots' camera views, the camera view and the orientation of the selected robot can be seen.
At the Form 2 of the user interface (Fig. 1(b)), the map of the disaster area, the coordinates and directions of the robots, the scanned areas and obstacles can be seen. The robot to be controlled is selected from the map. The robots can be controlled by the user keyboard or the direction arrows on the Form 1. The speed of the robots can be adjusted by the controller next to the direction arrows.

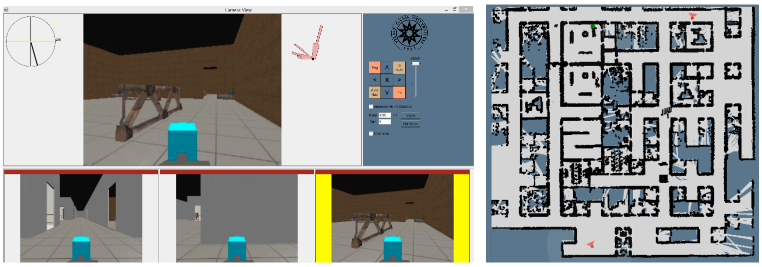

Fig.1 User Interface (a) Form 1, (b) Form 2

4 SLAM Algorithm

Structural indoor environments have large amount of perpendicular walls. The algorithm called “ymapping” which is developed by our group, is a SLAM method that uses this a priori information. Introduction of ymapping is our major innovation for Robocup 2014. According to ymapping extracted lines with predetermined angles and with a particular minimum length are considered as landmarks. When a new landmark is sensed, firstly the algorithm investigates if this landmark is really a new one or previously seen according to similarity measures. New landmarks are included in the set of previously seen landmark. On the other hand, previously seen landmarks are used for update process according to Extended Kalman Filter (EKF) [3]. Through the update process SLAM can be performed both for the position of robot and the position of ~~the~~ previously seen landmarks.

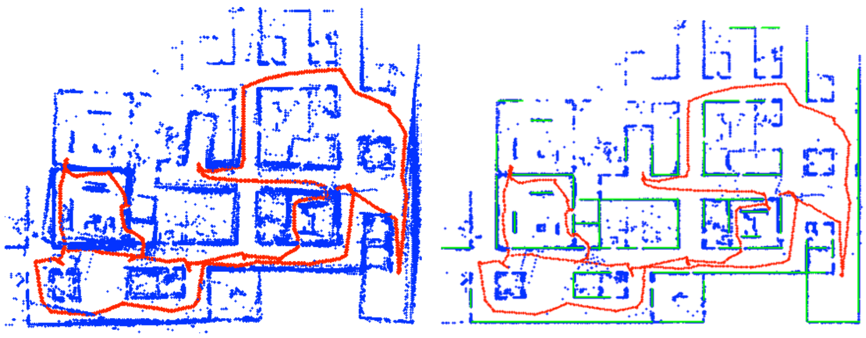

Fig. 2 Mapping with odometry (a) and mapping with proposed method (b)

When creating visual map, instead of keeping the absolute coordinate of the obstacle points, the algorithm keeps relative coordinates according to closest landmarks. By this way, when landmark coordinates are updated, the obstacle points in the map are updated too.

Proposed EKF method uses INS sensor (as odometer) to estimate prior probability of the robot pose. State vector consists of robot pose (x, y, angle) and all landmarks (angle, distance). In the UsarSim's structured environment, the landmark (walls) angles can have only two values (0, pi/2). Using this assumption, only distance values of the landmarks are updated in proposed EKF. The angle value of the robot pose is updated to closer the found landmark's angles to perpendicular. To demonstrate the efficiency of our proposed algorithm, a robot is run during 15 minutes and laser data and INS data are collected. In Fig.2, the maps derived from raw data (a) and proposed EKF (b) are shown. The landmarks found by our algorithm are shown with green lines in Fig.2 (a). The robot trajectories are shown with red lines.

5 Foggy Image Enhancement

At disaster areas, the images coming from robot cameras can be very problematic because of dust, the darkness and the smoke. To solve this problem, we applied Retinex algorithm which is an image enhancement algorithm that is used to improve the contrast, brightness and sharpness of an image primarily through dynamic range compression [4]. The algorithm also simultaneously provides color constant output and thus it removes the effects caused by different illuminants on a scene. It synthesizes contrast enhancement and color constancy by performing a non-linear spatial/spectral transform. The original algorithm is based on a model of human vision's lightness and color constancy developed by Edward Land. Jobson et al. Single Scale (SSR) [5] and Multi Scale (MSR) [6] version of Retinex are defined in literature.

We use gray level image and SSR method because of computational costs. The SSR is defined in Eq(1).

$$R = log (I) - log [F \circ I] \qquad [1]$$

Where R is the Retinex output and I is the input image, the symbol $\circ$ denotes the convolution operation and F is the Gaussian low pass filter mask which parameters are σ=20 and window size is 20.

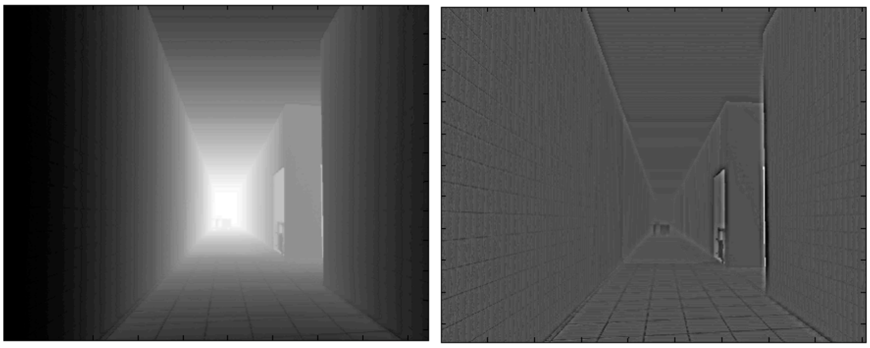

Fig. 3 Results of SSR Algorithm

In Fig.3, it can be seen that the processed images are more understandable than the original ones.

6 Obstacle Avoidance

Controlling multiple robots is not effective by using turn right, turn left etc. level commands. Another and more useful approach is waypoint control which depends on only indicating points where the robot should go. Last year, we have implemented the waypoint control approach with the theory of Proportional Control [7]. The disadvantage of our implementation was the need of clear way between the current and target coordinates. If there is an obstacle along the path, an obstacle avoidance method must be used. We applied Vector Field Histogram (VFH) proposed by Borenstein and Koren [8] for this purpose. The method searches a middle target to go to the real target. The middle target is selected along possible targets. Possible targets can be defined as empty areas within 2 meters and 20˚ range. In VFH method, all possible targets are evaluated according to Eq(2).

$$G = a*p1 + b*p2 + c*p3 \quad [2]$$

Eq(2) has 3 parameters (p1, p2, p3) and 3coefficients (a, b, c). The parameters are shown in Fig 4. The coefficient reflects the importance of the parameters. According to our experiments, each parameter has the equal importance. So we set coefficients equal.

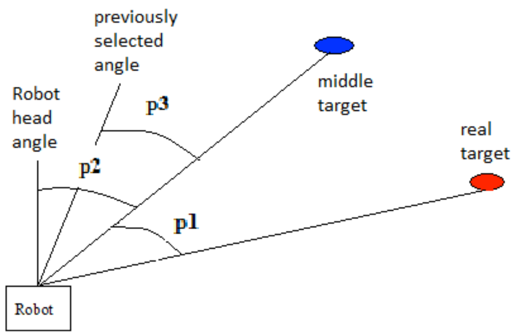

Fig. 4 The parameters of VFH Algorithm

The target (angle) having the least value according to the Eq(2) is selected as the middle target. To demonstrate the efficiency of using obstacle avoidance, we run a robot having autonomous exploration capability (see Section 7) in 4 different maps, 3 times. In Table 1, the numbers of visited points are given for each map.

Table. 1 The effect of obstacle avoidance

Map ID	# of visited points1,2,3 without obstacle avoidance	# of visited points1,2,3 with obstacle avoidance (VFH)
1	54, 75, 72	165, 233, 198
2	47, 46, 41	167, 212, 212
3	131, 142, 139	211, 145, 142
4	147, 148, 130	213, 211, 207

The benefit of usage of obstacle avoidance easily can be seen In Table 1. When we use VHF algorithm, the robot does not attached to the obstacles, so the number of visited points increases.

7 Multi Robot Exploration

Our autonomous exploration strategy is based on finding the frontiers having the most potential. A frontier is defined as an area consists of connected grids having unexplored neighbor grids. The potential of a frontier is calculated according to Eq(3).

$$p(F,R)=A(F) / distA(F,R) \qquad [3]$$

In Eq(3), F is the frontier, R is the robot, A(F) is the area of the F, distA(F,R) is the length of the minimum path between F and R. distA(F,R) is calculated with A* algorithm. A frontier having the biggest p(F,R) value is selected as the goal.

When we have multi robot, a robot-frontier matching method should be applied. We decided to use the method proposed in [9]. The computational load of distA(F,R) is very high in multiple robot scenarios. In [9], distE (Euclidean distance) was proposed instead of distA in the early steps of matching algorithm. It [Vis] also proposes a matching algorithm without searching all possible matches.

8 Conclusion

In this paper, we give an overview of what our team developed for this year. We concentrated to the developing of our SLAM algorithm, image enhancement, autonomous navigation, and multi robot exploration techniques. The experience we gain from virtual robot competition will allow us to improve algorithms for our real robots.

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