RoboCup Rescue 2023 Virtual Robot Simulation Team Description Paper NPU-IUSLer (China)

Binhong Liu and Tao Yang

Unmanned System Research Institute, Northwestern Polytechnical University, China
[binhongliu@mail.nwpu.edu.cn, yangtao@nwpu.edu.cn]
https://github.com/cavayangtao/iusler

Abstract. This paper presents the research focus and ideas that the IUSLer robotics team will use to compete in RoboCup Rescue Simulation Virtual Robot Competitions 2023. We will use multiple drones and ground robots to achieve a fast assessment of disaster situations. The victim is first searched and localized by a drone, and a ground robot arrives to distinguish if the victim is alive or not by the sensor-fusion method. Multi-robot autonomous exploration is used to quickly map the environment for subsequent path planning.

1 Introduction

IUSLer is a team that represents the Intelligent Unmanned Systems Laboratory (IUSL) at the Unmanned System Research Institute (USRI), Northwestern Polytechnical University (NPU), China, founded in 2020, aiming to participate in robotics competitions. Our team focuses on the research of perception [9][8][7], self-localization [4][5], and robot navigation [3] in changing environments. Under our research objectives, we have participated in a number of robot competitions including drone obstacle avoidance and F1TENTH autonomous racing (competitions under ICAUS 2021, 2022) in China. This year, we apply to participate in RoboCup Rescue Simulation Virtual Robot Competitions 2023 for the first time, because we are extending our research into the area of multi-robot perception and mission planning, and we think the challenge is an excellent opportunity to benchmark our research results, as well as a best practice for our students. We are looking forward to participating in RoboCup Rescue Simulation.

2 Team Members

The team members are from the Intelligent Unmanned Systems Laboratory (IUSL) at the Unmanned System Research Institute (USRI), Northwestern Polytechnical University (NPU), China. Current members include:

BinHong Liu, undergraduate student, team leader, mainly responsible for multi-robot localization and mapping.

Bohui Fang, undergraduate student, mainly responsible for human detection and tracking.

Zhen Liu, undergraduate student, mainly responsible for robot navigation.

Dexin Yao, undergraduate student, works with Binhong Liu in multi-robot localization and mapping.

Guanyin Chen, undergraduate student, works with Bohui Fang in human detection and tracking.

Yongzhou Pan, bachelor's student, works with Zhen Liu in robot navigation.

Dr. Tao Yang, Assistant Professor, founder and team advisor, mainly responsible for system integration.

3 Innovations

Several innovations we plan to apply in the competition:

For disaster rescue tasks, the collaboration of multiple drones and ground robots can achieve a fast assessment of disaster situations and reduce casualties. The drone obtains the location of the victim and transmits the information to the ground robots. Through distributed mission planning, the ground robot arrives for more accurate reconnaissance and carries out the rescue action. Since the victim is usually on flat ground, it's not difficult to calculate the victim's location with the object detection box in the image and the height information of the drone.

To distinguish if the victim is alive or not by the ground robot mounted with the RGB and thermal cameras, a typical process is first to detect a human using the advanced deep learning method, e.g. YOLOv5 [6], and then determine the victim's physiological state with a thermal camera. For more efficient and effective detection, it's possible to apply a sensor fusion method by connecting the corresponding feature maps extracted from the RBG and thermal images to form new feature maps. Finally, a one-stage detector head utilizes the new feature maps as input.

4 System Overview

4.1 System Diagram

We use two robots currently. One is the P3AT robot mainly responsible for mapping, and the other one is the Quadrotor robot mainly responsible for victim searching and localization. The whole pipeline of our system is shown in Fig. 1

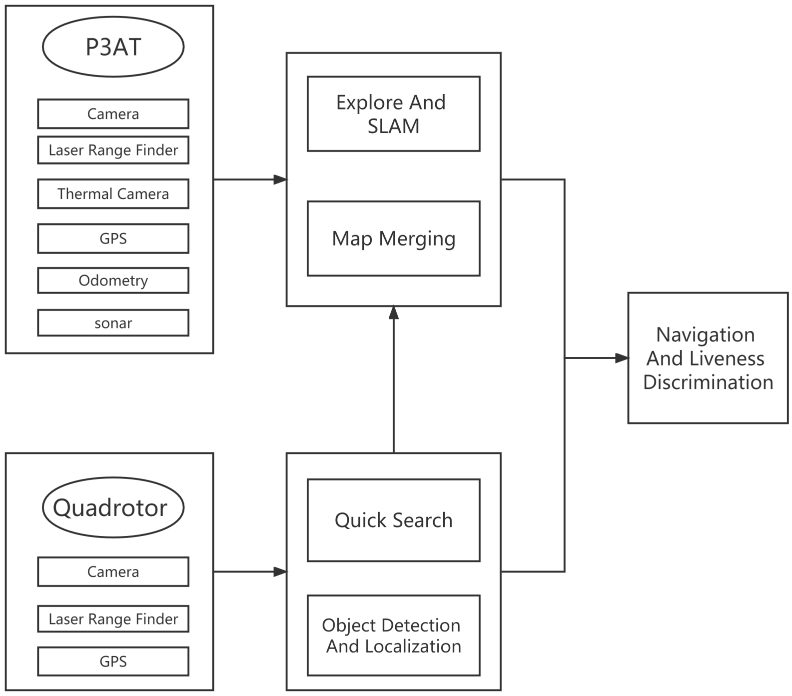


Fig. 1. System Diagram

4.2 SLAM and Map Merging

We use Gmapping [1] and Cartographer [2] to achieve multi-robot mapping. Gmapping is a laser-based SLAM (simultaneous localization and mapping) algorithm that can be used to create two-dimensional grid maps. It uses the RBPF (Rao-Blackwellized Particle Filters) algorithm, which separates the localization and mapping processes, and performs localization before mapping. Cartographer is a set of graph optimization-based laser SLAM algorithms launched by Google, which supports both 2D and 3D laser SLAM, and supports Lidar, IMU, Odemetry, GPS, etc.

4.3 Autonomous Navigation

After completing autonomous exploration and mapping, the ground robot navigates to the victim's location by listening to the object position published by the Quadrotor. We utilize the Nav2 package in ROS2 to realize robot path planning and navigation.

4.4 Autonomous Exploitation

We use the explore lite package in ROS2, which provides greedy frontier-based exploration. The robot will greedily explore its environment until no frontiers are found.

4.5 Victim Detection

We improve the network based on YOLOv5. Fusing the features of RGB and thermal images, recognition of living victims can be achieved.

4.6 Team Coordination

Team Coordination is actually a task allocation problem among multiple robots. It mainly includes how each robot decides on the next goal point for exploration and how robots communicate with each other. We will design a method that aims at the optimal overall task efficiency to coordinate the planning of ground and aerial robots.

4.7 Robot Models

We use two types of robots. One is P3AT mounted with the odometry, camera, battery, sonar, GPS, laser range finder, and thermal camera. P3AT is mainly used for mapping unknown environments by merging maps from multiple robots simultaneously. The other one is Quadrotor mounted with the camera, GPS, and laser range finder. Quadrotor is used for victim quickly searching.

5 Module Descriptions

5.1 Mapping Method

We use Gmapping and Cartographer for 2D mapping of unknown environments and use map merging methods for multi-robot collaborative mapping. Currently, we have implemented single-robot SLAM based on Gmapping and Cartographer on the TB3 robot and P3AT robot, respectively, and realized multi-robot simultaneous autonomous mapping and map merging.

5.2 Exploration and Navigation Method

We will use the explore lite package in ROS2, which provides greedy boundary-based exploration. The robot will greedily explore its environment until it finds no boundaries.

Nav2 is a navigation framework based on ROS2, which contains multiple modules and plugins that can realize autonomous navigation for different types of robots. We use Nav2 to navigate the ground robot to the victim position in the world coordinate, which is localized by the drone through a monocular camera.

5.3 Victim Detection Method

We improve the network based on YOLOv5. Fusing the features of RGB and thermal images, recognition of living victims can be achieved. The typical process is as follows: RGB and thermal images use convolutional neural networks to extract features; Using calibration information, the feature maps of the thermal image will be connected with the corresponding layer's feature maps of the RGB image; Local information entropy of the RGB and thermal images on each layer's feature map is calculated, respectively, and is used as a weight map for pixel multiplication to form a new feature map; Finally, a one-stage detector head uses these new feature maps as input to better distinguish if the victim is alive or not.

5.4 Controlling Multi-Robots Method

The drone is responsible for the fast positioning of the victim by searching following manually set navigation points. The ground robot is responsible for exploring the unknown environment and listening to the position of the victim sent by the drone for rescue tasks. The Nav2 package can implement control of multiple P3AT robots.

6 Technical Issues

1. There is a lack of a fast way to explore the environment. The current method only uses the autonomous exploration method integrated in ROS2 for robots. The accuracy and efficiency need to be further improved.
2. The drone's localization error for a ground object is greatly affected by the detection bounding box accuracy of YOLOv5.
3. There is a lack of a task allocation method among multiple robots. The current method simply divides the robots into ground and aerial robots for different tasks.

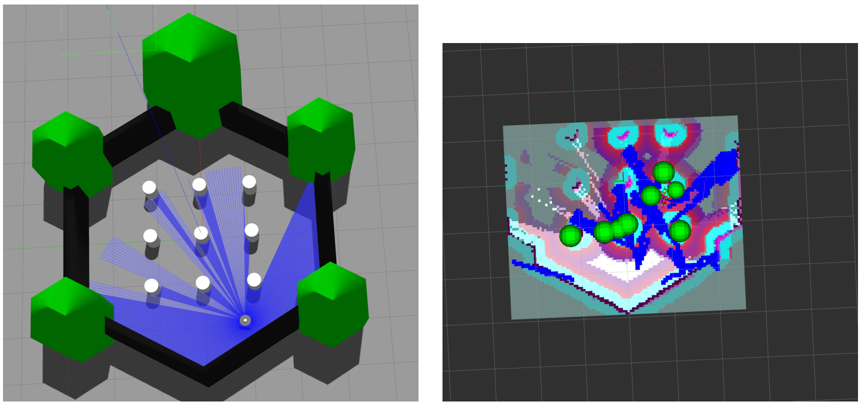
7 Results

7.1 Autonomous Exploration

We have implemented autonomous exploration of TB3 robots in ROS2 Gazebo 11 and synchronized Gmapping or Cartographer mapping in the process of exploration. As shown in the Fig.2

7.2 SLAM and Map Merging

We use two TB3 robots for real-time map merging based on Gmapping in Gazebo 11. The result is shown in Fig. 3(a).



(a) TB3 robot explores autonomously in Gazebo.

(b) Visualization in Rviz2.

Fig. 2. Autonomous Exploration of TB3 robot.

7.3 Object Detection Method

We implement the YOLOv5 algorithm into a ROS2 node and detect object through the robot's RGB camera. In the future, we will optimize the algorithm by fusing thermal image features to further distinguish is a victim is alive or not. The example in Fig. 3(b) shows the YOLOv5 detection result with the P3AT robot's RGB camera in Gazebo.

(a) Two TB3 robots merge maps.

(b) The YOLOv5 as a ROS2 node.

Fig. 3. Map merging and object detection.

8 Conclusions

In summary, we used two types of robots. Quadrotor is used for fast searching and positioning of victims. P3AT is used for unknown environment mapping and victim state recognition. An improved YOLOv5 which fuses RGB and thermal images' features for victim detection is proposed for further implementation. In the future, we will also develop an efficient task allocation method for the multi-robot system.

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