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

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https://github.com/cavayangtao/iusler

Abstract. This paper presents the research focus and ideas that the IUSLer robotics team will use to compete in the RoboCup Rescue 2023 - Virtual Robot Simulation. We 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 objective, 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 hope to participate in RoboCup Rescue 2023 - Virtual Robot Simulation for the first time, because we are expanding our research into the area of multi-robot perception and mission planning, and We think the challenge is an excellent opportunity to benchmark of our research results, as well as a best practice for our students. We are looking forward to continuing to participate in RoboCup Rescue 2023.

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 used a total of two robots, one is the P3AT robot responsible for mapping, and the other is the Quadrotor robot responsible for object localization and search. The whole block diagram of our system is shown in Fig.1

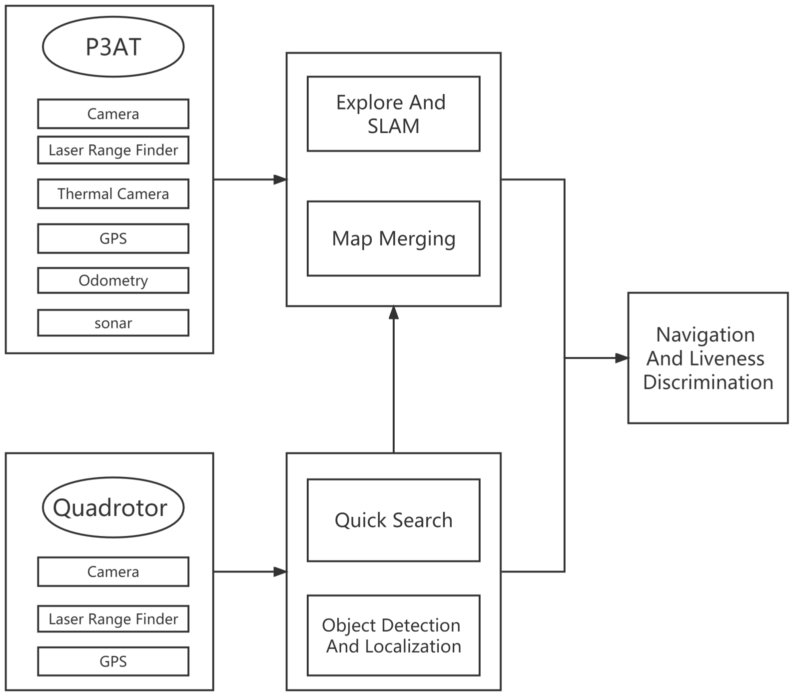


Fig. 1. System Diagram

4.2 SLAM and Map Merging

We currently mainly use Gmapping algorithm and cartographer [2] algorithm to achieve multi-robot map building. Gmapping [1] 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, can be used across platforms, and supports Lidar, IMU, Odemetry, GPS, Landmark and other sensor configurations.

4.3 Autonomous Navigation

After completing autonomous exploration, Simultaneous Localization and Mapping, the ground robot navigates to the victim's localization by listening to the object localization information published by the Quadrotor. We mainly use Nav2 package in ROS2 to realize robot path planning and goal navigation.

4.4 Autonomous Exploitation

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

4.5 Victim Detection

We improve the network structure based on YOLOv5. By fusing the features of visible light and thermal images, we can achieve the recognition of living and dead victims. The typical process is as follows: visible light and thermal images use convolutional neural networks to extract features; using external parameter calibration information, the feature map of thermal image will be connected with the feature map of visible light image corresponding layer; on each layer feature map, respectively calculate local information entropy of visible light and thermal images; information entropy map after convolution as weight and feature map for pixel multiplication to form a new feature map; finally different layers of feature maps will use one-stage detector for object detection, so as to better distinguish between dead and living victims.

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 overall task efficiency optimal or suboptimal, and coordinates the planning of ground robots and aerial robots.

4.7 Robot Models

We mainly plan to use two types of robots, one is P3AT (odometry, camera, battery, sonar, GPS, laser range finder, thermal camera) .P3AT is mainly used for building unknown maps by merging maps from multiple robots simultaneously. Another one is Quadrotor (camera, battery, GPS, laser range finder). Quadrotor is mainly used for searching victims by using its camera to identify objects and its high mobility to quickly scan the scene.

5 Module Descriptions

Module details. Cite the research where your approach is based on, and highlight the modifications that you have made to get it working in this context.

5.1 Mapping Method and/or SLAM Method and/or Multi-floor Mapping Method and/or 3D Mapping Method and/or Map Merging Method

We mainly use cartographer and Gmapping to achieve 2D mapping of unknown environments, and use map merging methods to achieve multi-robot collaborative mapping. At present, we have implemented single-robot SLAM based on cartographer and Gmapping on TB3 robot and P3AT robot respectively, and realized multi-robot simultaneous autonomous mapping and map merging.

5.2 Autonomous Exploration Method and/or Navigation Method

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

Navigation Method Navigation2 is a navigation framework and system based on ROS2, which contains multiple modules and plugins that can realize autonomous navigation for different types and scales of robots. We use Nav2 to navigate the ground robot to the coordinate position (this coordinate position is in the world coordinate system, which is the position of the victim located by the drone through a monocular or binocular camera) issued by the drone to the ground mobile robot.

5.3 Victim Detection Method

We improve the network structure based on YOLOv5. By fusing the features of visible light and thermal images, we can achieve the recognition of living and dead victims. The typical process is as follows: visible light and thermal images use convolutional neural networks to extract features; using external parameter calibration information, the feature map of thermal image will be connected with the feature map of visible light image corresponding layer; on each layer feature map, respectively calculate local information entropy of visible light and thermal images; information entropy map after convolution as weight and feature map for pixel multiplication to form a new feature map; finally different layers of feature maps will use one-stage detector for object detection, so as to better distinguish between dead and living victims.

5.4 Controlling Multi-Robots Method

We divide all the robots we use into two types, one is the quadrotor robot and the other is the ground mobile robot. The quadrotor robot is responsible for the fast search and accurate positioning of the victim, and the ground mobile robot is responsible for exploring and building unknown maps, and listening to the position coordinates of the victim sent by the quadrotor robot. Once the coordinates of the victim are heard, immediately dispatch the nearest ground mobile robot to go to search and rescue.

The Nav2 package in ROS2 implements control of multiple P3AT robots on the ground. The drones form teams of two, responsible for locating and identifying ground objects. They realize their position transformation by publishing coordinate transformations between them. Using improved YOLOv5 to identify the object's position in image coordinate system, and locate the object by using relative positions between two drones, and transform object from camera coordinate system to world coordinate system by coordinate transformation, and send coordinate of victims to ground rescue car. Finally assign tasks by nearest neighbor principle.

6 Technical Issues and/or Challenging Points

1. There is a lack of a fast way to explore the map. The current method only uses the autonomous exploration method integrated in ROS2 for robots. The accuracy and efficiency need to be improved.
2. The drone has a large localization error for ground objects, which is greatly affected by the recognition 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 robots and aerial robots. Ground robots are responsible for map building and searching, while aerial robots are responsible for object localization and fast searching. The task allocation between any two ground robots is not clear, and the efficiency needs to be improved.

7 Results

7.1 Autonomous Exploration

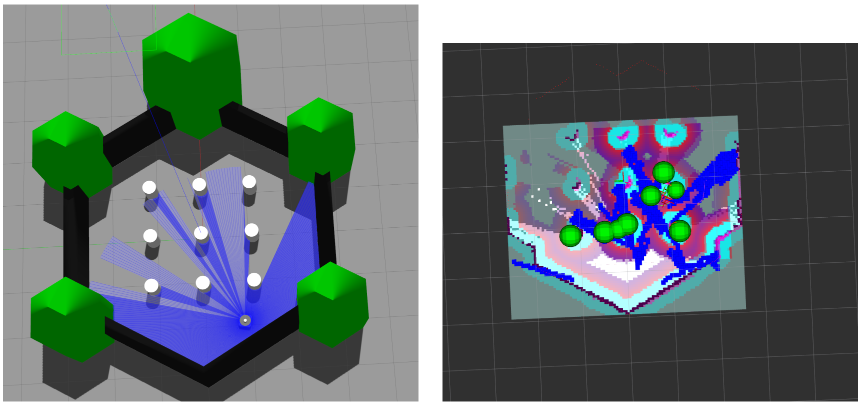
We have implemented autonomous exploration of TB3 robots in ROS2 Gazebo 11 environment, and synchronized cartographer or Gmapping mapping in the process of exploration. As shown in the Fig.2

7.2 SLAM and Map Merging

We used two TB3 robots to perform a map building method based on Gmapping in Gazebo 11 environment, and merged the maps built by the two TB3 robots in real time. The effect is shown in the Fig.3(a).

7.3 Victim Detection Method

We ported the YOLOv5 algorithm into the ROS2 framework, and achieved object detection of victims through the robot's camera in principle. In the future, we will optimize the algorithm, add thermal image features, and further distinguish between dead and alive victims. In Gazebo, we use the P3AT robot's RGB camera to recognize car.Images as shown in the Fig.3(b).



(a) TB3 robot autonomously explore in gazebo.

(b) Visualization in Rviz2.

Fig. 2. Autonomously Exploration of TB3 robot.

(a) Two TB3 robots merge maps while building.

(b) YOLOv5 ROS2 Detections.

Fig. 3. Autonomously exploration of TB3 robot.

8 Conclusions

In conclusion, we used two types of robots, one is P3AT, mainly used for building unknown maps and liveness discrimination, and the other is Quadrotor, mainly used for fast search and positioning of victims. We propose an improved method of YOLOv5, which fuses visible light images and thermal images for feature fusion, thus effectively and quickly identifying, locating and liveness discrimination.We also propose a method of using ground object localization method, that is, by using the transform matrix between two drones, combined with the recognition result of YOLOv5, to achieve fast localization of ground objects. In our framework, we lack an efficient task allocation method. In the future, we will focus on configuring an efficient task allocation method for multi-robot systems to improve the efficiency of searching and rescuing victims.

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