Towards heterogeneous robot team path planning in dynamic search and rescue scenarios

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Our research focuses on effective operation of heterogeneous robotic group that could carry out point-to point navigation in GPS-denied dynamic environment, applying a mixed local and global planning approach, and such instruments as planning in belief space and SLAM. In this paper we introduce our heterogeneous group robots and their modelling in ROS/Gazebo, and briefly describe Homotopy based high level planner solution.

Key Words: path planning, autonomous mobile robot, search and rescue, dynamic environment, UAV, UGV, Voronoi diagram

1. Introduction

Currently, one of the actual problems of robotics deals with interaction between the unmanned ground robots (UGV) and unmanned aerial vehicles (UAVs). A heterogeneous group of robots, which work as a team, can significantly improve information acquisition about environment and solve various tasks of transportation logistics, reconnaissance, and search-and-rescue due to different sensory system features of the robots and different operational space.

Our research is targeted to investigate collaboration aspects between a heterogonous group comprising a UGV and a number of small-size UAVs, focusing on operation in uncertain environments. The latter could be completely unknown, include dynamic scene or objects, or represented by an outdated and imprecise map. To facilitate a reliable autonomous operation, robots will collaboratively perceive the surrounding environment and infer their own states, and plan high-quality actions and paths while taking different sources of uncertainty into account. In this research we will investigate theoretically and experimentally such a multi-robot collaborative framework, with the aim to advance the state of the art in multi-robot autonomy under uncertainty. Our main objective is to develop collaboration strategies between robots equipped with vision and additional sensors such that these can autonomously operate given only partial and possibly uncertain information regarding the environment. To that end, we will build upon recent progress in simultaneous localization and mapping (SLAM) and belief space planning, and explore multi-robot belief space planning approaches that take into account the uncertainty in the environment and are expected to facilitate efficient collaboration between robots. In particular, such a framework will allow UAVs and the UGV to devise proper motion to improve localization and mapping even in lack of GPS signal.

The rest of the paper is organized as follows. Section 2 introduces the robots which is used in our research. Section 3 presents a brief overview of path planning methods for autonomous vehicles in dynamic environment. Section 4 describes our approach to the problem solution. Finally, we conclude and describe our future work in Section 5.

2. System setup

For experimental work we use one UGV “Engineer” and three UAVs AR Drone. Mobile robot “Engineer” (Fig. 1) is a crawler robot created by Russian company “Servosila”[1] which designs and produces a range of mobile robots, servo drives, robotic control systems and software for them.

“Engineer” robot has a durable lightweight metal body, hardened electronics and a package of sensors. The body of "Engineer" is based on a pair of crawlers, which are responsible for the locomotion. Two sub crawlers in the front use a single servo and thus could not be driven independently of each other; they act additional support when the robot traverses rough environments, climbs stairs or needs to maximize its height in order to reach some highly placed goal with a manipulator. This manipulator is located in the center of the main body and enables the robot to perform various engineering operations. Two links and 3 joints combined with a rotating gripper provide good flexibility in autonomous and teleoperational modes. Robot’s head, which contains a power computer and a number of sensors, is located just above the gripper. The set of sensors includes front view pair of cameras for stereovision, a rear view camera, an additional front view camera with optical zoom, GPS/GLONASS receiver, and an inertial sensor unit (6DoF MEMS IMU). Optionally, thermal and laser sensors could be mounted. The robot is also equipped with a powerful light and speaker. The communication of the robot with the teleoperator is carried out via WiFi or special radio modem channel.With a mass of 25 kg in its maximal configuration the robot could be carried in a backpack by one person. The robot is able to operate on its LiFePo4 battery 4 to 15 hours while achieving speeds of up to five km/h. The small size of the robot enables it to traverse doorways, narrow passages and openings inside damaged buildings or outdoors.

A produced by “Parrot” company[2] *AR.Drone 2.0* quadrotor UAV (Fig.2) in the past decade became one of the most popular UAV platforms for research due to its relatively low cost and broad field of applications with a large number of projects’ code in ROS repositories. Equipped with 720p-30fps HD front camera the robot

1 Servosila, mobile tracked robot “Engineer” http://www.servosila.com/en/mobile-robots/index.shtml

2 Parrot, ArDrone 2.0, http://ardrone2.parrot.com/

can successfully perform local obstacles avoiding, while additional GPS module is responsible for global positioning. IMU with a 3-axis magnetometer supports automatic pitch, roll and yaw stabilization and assisted tilting control. An ultrasound telemeter provides with altitude measures for automatic altitude stabilization and assisted vertical speed control. A pressure sensor allow altitude measurements at any height. Directed downward low-resolution camera helps in visual landing on landmarks and other primitive operations.

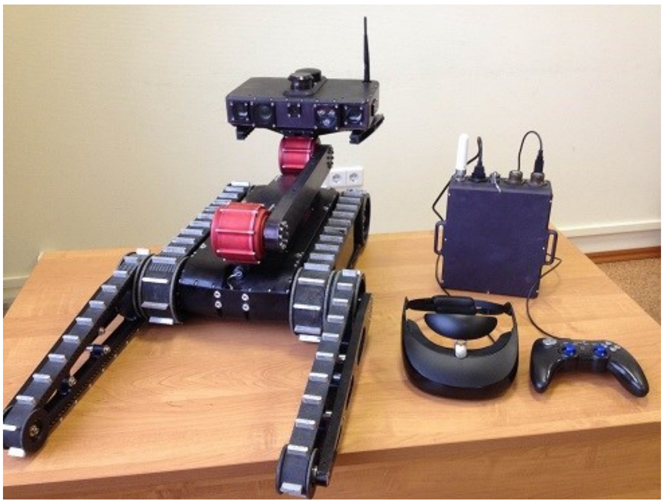

Figure 1. Tracked robot "Engineer"

Figure 2. AR.Drone 2.0

3. Path planning approach

Path planning is the act of finding a path from some starting configuration S to goal configuration G. The objective of a path planner is to provide a continuous path from S to G, which will avoid all obstacles and minimizes some positive cost metric [4]. Classical path planning methods usually involve a global or a local path planner. A global path planner exploits a precise map of the environment, which is available to the planner a priori, and the path planning process generates a hazard-free path in the off-line mode and its main concern is to provide a computationally effective scheme for the particular cost metric (e.g., [5]). On the opposite, a local path planner is a purely reactive on-line planner that collects sensory information and acts based on its analysis (e.g., [6]).

Each of these two classical approaches has its own strong and weak points and, while in the past robotics researchers were mainly developing them separately, a more effective approach would mix them together in order to strengthen their advantages and compensate for the pitfalls (e.g., [7]). Moreover, the recent appearance of affordable swarm-type UAV and UGV robots on the market made it possible to develop a more reliable global (e.g., [8]) and local path planning (e.g., [9]) approaches by efficient use of multiple agents working toward a common goal.

In uncertain environments of search and rescue or surveillance scenarios pure global path planning is of a little use because previously detailed maps become outdated and imprecise due to dynamic changes and precise positioning is impossible due to the lack of GPS signal. However, often it is the case that some global data about the environment is still available: plans of the buildings, a bird eye view map of the scene (e.g., obtained by a fleet of unmanned flying drones over the site) or abstract sketches by survivors. In such circumstances, the team of UAVs and UGVs could re-build the outdated map dynamically while moving toward the specified target and initially use this outdated map.

We are developing Homotopy based high level planner (e.g., [10,11,12]) that utilizes the helpful global data of the outdated map and select pareto optimal trajectory classes based on user-tuned minimization criteria. Further, the selected class trajectory will be applied by the pilot system and actively combined with sensor based local path planning.

The robotic team will create a detailed map and further update it on the fly as the team moves toward its target. The global re-planning will take place dynamically taking into an account dynamic changes of the environment and objective function, which will contain various optimization criteria such as path length, curvature, safety, stealth, energy efficiency etc. combined together and available for dynamic selection of coefficients for each separate criteria within the function (e.g., [8,13,14]).

To construct a global road map Hierarchical Generalized Voronoi Graph [1] method is applied. Next, the map is update locally in real-time in order to introduce newly discovered obstacles [2] taking into account UAVs and UGV updates within the joint belief space [3]. The path planning simulation is under development in ROS Indigo and Gazebo 2.2 environment.

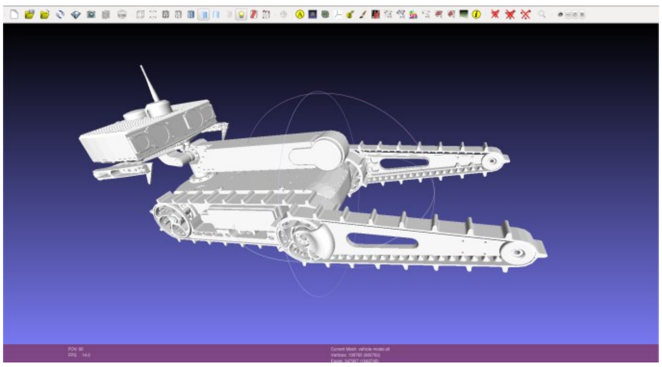

Figure 3. CAD model of “Engineer” robot

We used a CAD file (fig.3), which was provided by "Servosila" company in order to build a corresponding simulation of the crawler robot in Gazebo (fig. 4 demonstrates current state of the model).

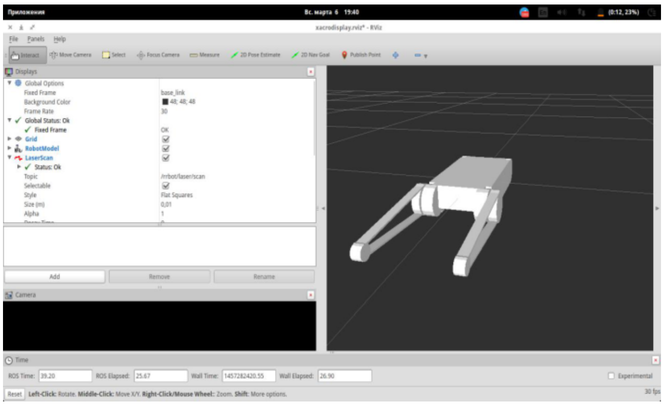

Figure 4. The model for algorithms prototyping

4. Conclusions

Our research is focused on the creation of effectively operating heterogeneous group of robots that could carry out point-to point navigation in possibly GPS-denied uncertain dynamic environment, applying a mixed local and global planning approach, and such instruments as planning in belief space and SLAM. In this paper we introduced the robots which will form the heterogeneous group and briefly described Homotopy based high level planner solution. Next step of our research is to test our approach in simulation and then to verify it experimentally with the robots in a real-world scenario.

5. Acknowledgments

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