EdinBots Team Description Paper for Rescue Simulation League 2018

Calum Imrie, Hugo Sardinha, Ingo Keller, Sabina Jedrzejczyk, Siobhan Duncan and Vibhav Bharti

Abstract

The following document presents the Edinbots team as well as our intended strategy to compete on the Virtual Robot Competition in the scope of the RobotCup 2018 Rescue Simulation League. Our strategy will derive concepts from the field of Swarm Robotics to both collaborative mapping and searching tasks, in a comprehensive and integrated manner. Mapping will target the construction of a Vornoi Diagram explicit differentiating between occupied and free areas, while searching will be based on extensions of the Particle Swarm Optimization for maximizing search area and simulated stigmergy as means of sharing key features of the map on the ground. Lastly, victim detection will be done by carry out a range of classification techniques based on the various different features of the victims: temperature, movement, shape and sound.

1 Introduction

Urban Search and Rescue (USAR) missions pose a challenging environment for humans and robots alike. Classically, multiple operators would control a single or multiple robots. This has its limitations and the trend is shifting towards more autonomy as the robotics community progresses. This allows operators more mission supervision thus they can focus on disaster assessment than teleoperation.

USAR tasks are inherently highly distributed and as such there are multiple advantages in applying swarm techniques over multi-robot system or single robot systems [1]. These include: system robustness to individual agent failure; scalability to large numbers of agents which are distributed in the environment; self-organization replacing the need for a central control architecture; superlinearity - where the whole is greater than the sum of it's parts. For this reason we propose a swarm based mapping and searching strategies for USAR.

2 System Overview

The high-level description of our system is depicted in Figure 1. This shows a layered architecture for implementation of proposed algorithms. This makes it easy to adapt the system to real scenario if required. At the top level, Swarm mapping optimizer & victim search optimizer are controlling the global strategy for the overall scene. The data from this level is also relayed to the operator frond-end GUI for monitoring or for supervision in semi-autonomous case.

Table 1: The team members and their contributions

Team Member	Contribution
Calum Imrie	Swarm based search, ground coordination
Hugo Sardinha	Swarm based mapping, collaborative SLAM
Ingo Keller	Victim detection and visual perception
Sabina Jedrzejczyk	Swarm based mapping, webmaster
Siobhan Duncan	Swarm based search, virtual pheromones
Vibhav Bharti	Victim detection, localization

At the middle level, standard robot suites are running for individual agents. The primary objective of the state machine is to run mapping & searching in parallel. The state changes to victim localization & parking once an alive victim is detected. The lower level system is mostly for controlling the interfaces and communicating with other robots and ground station.

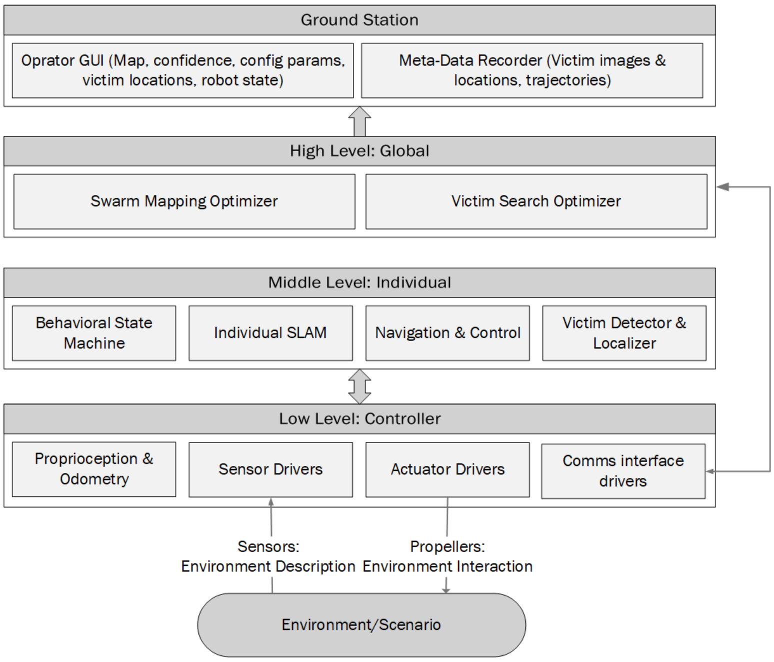

Figure 1: System Architecture

2.1 Robot Operating System

The Robot Operating System (ROS), due to the ability to abstract the robotic architecture and focus on algorithm development, is becoming the *de facto* approach to develop software applications for robotic platforms [2].

In the context of multi-robot applications, such as our own, ROS enables their development in two ways. In a more centralized approach, different *namespaces* can be used to establish the individual robot simulations, running on the same underlying *rosmaster* process, depicted in Figure 2, which due to its simplicity is a more convenient approach in simulation.

On a more decentralized manner, ROS allows the establishment of connections between different *rosmasters*, also enabling real world applications. This package was developed by authors in [3], depicted in Figure 3, and works with two main nodes:

- **Master Discovery**: Periodically sends multicast messages to the common network to make the other possible ROS masters aware of its presence, and also detect any other ROS masters available.
- **Master Sync**: Checks the local roscore for changes in the local network, and notifies tall other

In summary, all the above considerations show how ROS is a powerful and reliable tool that encompasses the necessary structures of communication in a multi-robot environment.

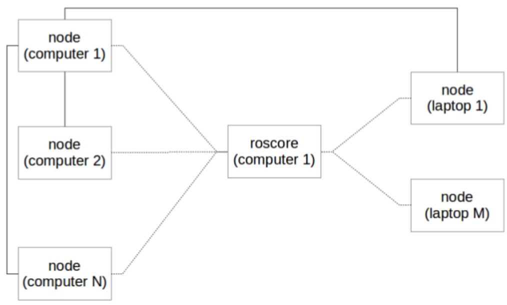

Figure 2: Single *roscore* approach

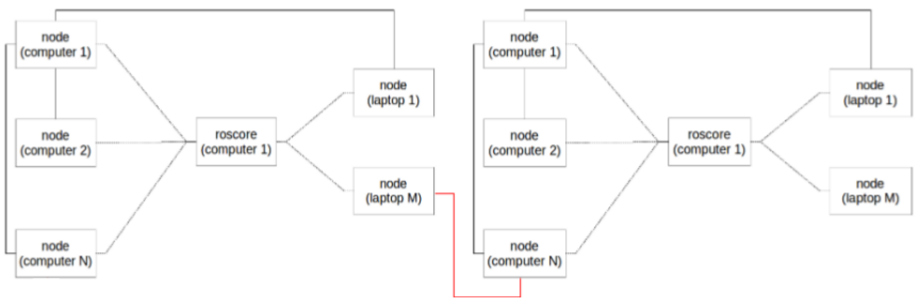

Figure 3: Mutliple *roscore* approach

2.2 Human Swarm Interaction

The ideal swarm-human interaction set-up is one where the swarm is allowed to work autonomously but the user can inject knowledge and guidance into the system, in oder to improve it's performance [4]. The human operator interacts with the swarm by sending data to, or controlling, a single agent in the system. This gives a single user very little control over the entire swarm system, however it allows the human operator to guide a robot to a target, or encourage it to explore a certain area, and other agents may follow.

This is the architecture we are using as we plan to keep one ground robot stationary, acting as a ground station, interacting both with the swarm, as a member of the swarm, and with the human operator.

2.3 Operator GUI

USAR operations need to provide the operator and the response teams with a quick situation awareness of the scene. Thus it is important to think from operator's perspective and what to include in front-end GUI. Baker et. al. [5] have come up with important guidelines to design an efficient user interface to reduce user cognitive load and increase awareness. The ROS 'rqt' package provides native support for GUI development and we plan to take its advantage. A quick analysis in to USAR problem, more specifically Robocup, we think following elements should be included into GUI.

1. Global map of the scene with confidence level of each section.
2. Location of each agent with confidence ellipses.
3. Location and type of victims.
4. Configuration tools for mission-specific parameters.
5. Robots current state and health.

3 Swarm Mapping Algorithm

Mapping the environment will be the first step in our swarm approach to plan the rescue of victims. We will do this by employing classical Swarm Intelligence coordination strategy on lower level, such as the one used for bird flocking [6]. On higher layer of software we will implement an objective function rewarding the maximization of the total mapped area, to ensure the UAVs do not simply fly aimlessly.

Tackling the mapping problem will rely, in an initial stage of the task, on aerial mapping of the environment. The purpose of this initial sweep is to assess, in quick manner, main routes for further search on the ground. Furthermore, this mapping is meant to be done online, following the principles of the authors in [7]. In this paper, authors build a topological probabilistic map of the environment and their work is particularly important since it addresses the key problems of online mapping namely:mapping with unknown data associations, raw sensor measurements, mapping cyclic or repetitive environments and generating a map with collaborative robot.

Furthermore we will include in our approach the work carried out by authors in [8] which derive a probabilistic method for the construction of topological maps for a swarm of robots in a GPS-denied environment and with no other global localization. These works will be particularly important in mapping an indoor environment.

Another issue with the aerial mapping will be to identify the pathways for the ground robots to follow. We plan to load this extra computational effort onto the ground station where a learned model to identify these paths is running. Since this are images though, before classification a SIFT algorithm would be employed to ensure the identification is carried out in good estimate of the map.

Increasing the reliability of the final topological map will be carried out with an approach inspired by authors in [8]. This work builds on [7] by using uncertain position data obtained by robots to construct a probability function that indicates the presence of obstacles. This is then subject to a persistent homology technique to segment obstacle regions and at last a graph-based wave propagation algorithm is applied to the apparent obstacle-free region to create a Generalized Vornoi Diagram, which in turn will enable the search occurring on the ground.

4 Searching

4.1 Swarm Searching Algorithm

The particle swarm optimization(PSO) algorithm is a global optimization algorithm for solving problems where solutions can be modeled as a point in an n-dimensional space. More recently this algorithm has been applied to robotics problems which can be described as an optimization problem. For example searching for a target or dispersing for optimal coverage of a space.

The RDPSO [9, 2] is based on the original PSO algorithm and as such contains a search space, a population of agents, an optimal solution, agents are aware of their pose and individual solutions, and there is a both local and global fitness function to evaluate solutions. However in contrast to the standard PSO, RDPSO contains multiple dynamic sub-swarms which divides the entire population into smaller networks. This allows for the number of particles exchanging information to remain local, rather than a global communication network, allowing the algorithm to scale to larger numbers.

We propose to use the RDPSO to control the search behaviour of our swarm, which has already been implemented in ROS by the Authors in [10].

4.2 Stigmergy

"Stigmergy is an indirect, mediated mechanism of coordination between actions, in which the trace of an action left on a medium stimulates the performance of a subsequent action" – Francis Heylighen [11].

The authors in [12] showed that repellent pheromones allowed the swarm to converge to a solution much faster and cover more area, than the same search strategy without any pheromones.

We propose to use a repellent stigmergy method, similar to that found in [12], where virtual pheromone markers are placed on the shared map of the environment, diffusing and evaporating over time. These virtual pheromones encourage the swarm to explore the entire environment by maximizing the distance between robots in order to maximize the global coverage whilst looking for victims. This strategy will allows us to track a fitness function which represents the coverage of the swarm during the search phase, where $Coverage = \frac{\#TilesVisited}{\#TotalTiles}$, which can be fed into our PSO based search strategy.

	Swarm Robotics	**Multi-robot System**
Population Size	Large range of possibilities, can be dynamic	Small
Control	Decentralized	Centralized
Scalability	High	Low
Homogeneity	Homogeneous, or multiple groups containing large numbers of homogeneous agents	Homogeneous or Heterogeneous

Table 2: An overview of the difference between swarm robot and multi-robot systems

4.3 Victim Detection & Classification

The robot will be actively detecting the victims. Since detection requirements in simulation are not challenging, simple algorithms are used. A detector will be trained to do initial detection of victim in camera. Victim's heat can be assessed by the thermal camera later. A detector will also be trained to detect the sound of the victim. This can be special case where the robot notes its own location as localizing just by audio might not be possible. Can trigger special search until a victim is found/localized. The victims need to be classified into either alive or dead. From perspective different sensors table 3 can be formed describing different characteristics of victims. The classification problem is simply solved by assuming an initial state of victim as dead. If any of the sensors are triggered the state is switched to alive.

Victim	**thermal camera**	**visual camera**	**Sound**
Alive	high heat	hand wave	'help me' shouts
Dead	cold	motionless	no sounds

Table 3: Victim classification features and employed sensors

4.4 Localization

The findings of Smith & Cheesman and Durrant-Whyte [13, 14] that contributed to initial development of SLAM are still used in approximating uncertainty of features as viewed from a different coordinate reference. Assuming victims as special flagged features, the same methods being used for mapping can also maintain confidence in position of the victims. However, since the primary mapping sensor (LiDAR) is different from victim searching sensors (cameras, microphone), a different model is needed to maintain right confidence in victim's location.

Since detection in simulation is straight forward, we can assume detected victim to be a point in space (victims head or torso). Considering intrinsic camera parameters are available, the extrinsic parameters for a single camera can be obtained by change in robot state from an instant 'k' to $'k + 1'$ (equation 1). The rotation matrix can be obtained by converting obtained difference in Euler angles to rotation matrix. The obtained extrinsic matrix solves the triangulation of victim. Once the location is found a suitable nearby position can be serve as spot for parking the robot.

$$\begin{bmatrix} T_{3x1} \\ R_{3x1} \end{bmatrix} = X_{k+1} - X_k \tag{1}$$

5 Conclusion

Urban Search and Rescue is a clear trend in scientific research. Particularly by employing a multi-robot, where each agent (or set of agents) have particular characteristics and can therefore perform complimentary tasks, which is expected to lead to a higher victim recovery rate. By bringing together the concepts of swarm robotics into a heterogeneous robotic swarm in a comprehensive approach, from initial mapping and to victim classification, our team intends to show that merging different state-of-the-art techniques is a valuable approach to the broader problem. Furthermore, we believe that in our approach there is also the potential for a scientific contribution in the field of

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