RoboCup 2008 – Rescue Simulation League
Virtual Robot Team Description
CSU_YunLu (China)

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Abstract. The CSU_YunLu team aims at the development of an intelligent team of heterogeneous robots that explore an unknown environment quickly and completely while map it accurately. To make each robot know how to response clearly and regularly, a common system structure is designed to guide robots’ behavior. Under this structure, an A-SLAM approach is proposed to conquer the challenges in mapping and localization such that the robots can map and locate the environment accurately. To realize high quality and efficiency of the exploration, an ADPPE exploration strategy is used to make each robot be responsible of different area and search for targets with path planning. Furthermore, to prevent repeated explore among robots, cooperation is adopted by using a teamwork algorithms, which enable the whole team work harmoniously and efficiently.

1 Introduction

The Virtual Robot competition aims to foster research in cooperative multi-robot systems engaged in urban search and rescue missions. Robots and sensors used in the competition closely mirror platform and devices currently used in physical robots. These features attract us deeply and we built the CSU_YunLu team last year for this competition.

As a young team in this new area without any experience, there are many difficulties for us to accomplish the tasks required in the competition. According to the challenges the competition brings in designing the system structure and team strategies, we aims to develop the CSU_YunLu team of heterogeneous robots to explore as quickly and completely as they can while map the environment accurately.

Our team is made up with two types of robots: the P2DX and the Talon. Both P2DX and Talon are equipped with frontal range scanners and sonars, INUs, RFID and victim sensors, but they are different in mobility capabilities, which makes the team adapt to environmental features well.
To guide robots’ behavior, we designed a common system structure for the heterogeneous robots, in which different functions are defined. Under this structure, an A-SLAM approach was proposed to map and locate the explored environment with high accuracy, while an ADPPE exploration strategy was adopted for efficient exploration. Furthermore, the cooperation among robots was considered enhance the quality of the exploration.

2 System Structure

Both the two types of robots adopt a same structure shown in fig.2. The function of each module is described as follows.

- **Environment**: The Environment module represents the 3D physical information of the disaster environment, which mainly includes normal furnishings in a building, obstacles, victims etc.
- **Perception**: For the robots, the Perception module is used for the robots to sense the outside environment by various sensors, such as laser range scanner, INU, odometry sensor, sonar and Laser Scanner readings, and RFID.
- **Mapping & Localization**: By processing the data of image or distance which are from the Perception module, the Mapping & Localization model is used to build up an accurate metric map, in which the global location of the explored surrounding is determined and the surroundings information...
explored respectively by each robot into a whole are integrated.

- **Info-Storage**: The *Info-Storage* stores the latest explored environment information which comes from the *Mapping & Localization* module, including the location of the victims, the blocked roads, house structure, etc. The *Info-Storage* can be used by all the robots to determine their next action. Also, the information it stores can be increased and updated.

- **Victim Detection/Obstacle Detection**: These two modules are used to recognize and locate the victims or the obstacles. By the sensors, combining with the useful information having been acquired, the robots can easily detect the victims and the obstacles.

- **Navigation and Exploration**: According to the recognized victims or obstacles, integrating with other useful information, the robots use the *Navigation and Exploration* module to make decision for their consequent actions. If the robots find out a victim, to obtain more accurate image and some other data, they will get near to the victim according to the *Move towards Victim* sub module. If there have obstacles nearby, the *Avoid Obstacle* sub module is chosen. Otherwise, the robot will continue exploring the unknown environment with the guidance of the *Exploration* sub module is used to make.

According to the structure introduced above, each robot can be aware of what to do in the unknown environment for accurately and effectively exploration. Due to the clear functional framework defined in this system structure, it can be easily reused by other types of virtual robots and the physical robots in the real world with little modification in the functions realization.

### 3 Mapping and Localization

One of the main objectives of providing a map is to create the ability for a first responder to utilize the map to determine which areas have been cleared, where hazards may be located, and where victims were trapped. Simultaneous Localization and Mapping (SLAM) \(^{(1)}\) is a vital technology for autonomous mobile robots. Recently hybrid grid-based and topological representations for mapping have obtained good results. This paper adopted the hybrid SLAM algorithm with aligned scans, which called A-SLAM, so that the robot can keep track of its location by maintaining a map of the physical environment and an estimate of its position on that map accurately.

SLAM needs to compute the link \(\xi\) and a set of local sensor observations \(m'(i=1,\ldots,n)\) of environment. In 2-dimensional space, \(\xi=(x, y, \Phi, \Gamma)\), that is four variables: coordinate \((x, y)\) of robot, \(\Phi\) is the estimated orientation difference, and estimation’s covariance matrix \(\Gamma\). For the multi-robot scenario, similar benefits apply, the displacement information present in the links is independent of any global coordinate frame, and so collaborating robots can easily exchange parts of the graph without further processing. Now the main challenge is to gather the information necessary to construct \(\xi\). Like in most current SLAM methods, laser pre-aligned scans are used as the main source of mapping information in A-SLAM.
We chose the Weighted Scan Matcher (WSM) \cite{2} for localization, and we just use the pre-aligned scans obtained in horizontal direction, which allows us to use existing odometry-corrected 2D localization algorithms like the one employed by Montemerlo\cite{3}. The Loop-Closing is adopted to reduce the accumulated error in the process of mapping, while a new link is inserted into the graph by computing the displacement between the two overlapping nodes.

The main challenge of mapping is how to merge the disconnected partial maps in a meaningful way. Incidentally, this process is described in detail in Fig.3. And the loop closing technique can be used to detect overlaps in two disconnected maps. Map merging is done by computing a transformation between the two overlapping regions once by scan matching. Subsequently, one of the two maps is transformed as a rigid body and moved so that the two overlapping parts fit. Optionally, a loop closing operation may be run to refit the two maps for improving accuracy.

The A-SLAM provides a spatial context for the interpretation of current and past observations and enables higher level reasoning, control, and cooperation. The map delivered may also provides an intuitive representation with which the robot can convey its findings to humans. For this purpose the visualization of the map may be augmented with any kind of extra information that the robot is able to infer.

4 Area distributing and path planning-based exploration

To guarantee search efficiency for victims, the robots must explore the unknown environment as quickly and completely as they can while minimize overlapping of explored areas. To achieve this goal, we proposed an Area Distributing and Path Planning-based Exploration (ADPPE) strategy, in which each robot is responsible for

![Fig.3. Multi-Robot Mapping](attachment:image.png)
exploration by path planning in a disjointed area predefined and modified in real-time according to the latest map information shared with others.

When exploration begins, a set of different initial azimuths for exploration are pre-assigned evenly for the robots, which helps to avoid overlapped area during their respective exploration. The robots explore towards their azimuths and keep that roughly unchangeable until they reach the boundary of the surroundings. In this case, they will turn clockwise until there are unknown surroundings for them, and move towards the opposite azimuth of the original. During the exploration, if the surroundings are never explored before, they will stop for a moment, rotate their cameras to search for victims and acquire surroundings image data. Otherwise, they will move straightforward ahead.

Because that the areas explored by other robots are changed in real-time, to be aware of the latest unexplored surroundings and make corresponding modification on one’s exploration directions, the robot will share a common real-time map information provided by the Info-Storage which enable it to determine its exploration direction without conflicting with others.

To identify the victims, the reports from the victim sensors are verified. According to Skin Detection \cite{4} approach and the help of human operator, the victims can be detected correctly. Additionally, path planning is used to enable the robots to move towards the victims or other targets safely. Generally, the robots change their body direction pointing against their targets and move towards the victims. If the readings of the sonar or laser range scanners are lower than a safety threshold, it means there are obstacles nearby, so the robots need to avoid obstacles. There are three conditions: when the obstacles are located at one side of the robots, the robots turn to opposite direction; when the obstacles are at their both sides, they move ahead only if the alleyway is safe in front; If there are obstacles in front of them, the robots need withdraw to the place without obstacles and turn backwards, then chose other directions to move. Otherwise, when the readings are higher than the safety threshold, the robots can move towards the target smoothly.

By the ADPPE strategy, the robots can explore regularly in the unknown environment. However, to realize the real-time modification during the exploration, an efficient cooperation among robots is required, which will be introduced in the next section.

5 Cooperation

In order to successfully explore and navigate in the area and to avoid duplicate efforts in searching the same areas, robots need to coordinate the team robots. In this paper we tend to adopting the teamwork algorithms \cite{5} to coordinate the simulated robots. The algorithms are encapsulated into a reusable software proxy. Each team member has a proxy, here we call it Machinetta\cite{6}, with which it works closely, while the proxies work together to implement the teamwork. The Machinetta include state-of-the-art algorithms for role allocation, information sharing, task de-confliction and adjustable autonomy, and it is very suitable for the needs of USAR system.
The Machinetta software consists of five main modules, three of which are domain independent and two of which are tailored for specific domains. The three domain independent modules are used for coordination reasoning, maintaining local state and adjustable autonomy. The domain specific modules are used for communication between proxies and communication between a proxy and a team member. The modules interact with each other only through the local state with a blackboard design thus, e.g., new adjustable autonomy algorithms can be used with existing coordination algorithms. The coordination reasoning is responsible for reasoning about interactions with other proxies, thus implementing the coordination algorithms. The adjustable autonomy algorithms reason about the interaction with the team member, providing the possibility for the team member to make any coordination decision instead of the proxy.

6 Conclusion

The CSU_YunLu Virtual Team works in the well designed system structure and has the robots guided effectively. Through the proposed A-SLAM approach, the robots can map the explored environment and locate it accurately, while the ADPPE exploration strategy enables them to explore quickly and completely. In addition, the robots can use the teamwork cooperation algorithms to avoid much wasted efforts and enhance the exploration efficiency.

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References