Robocup Rescue - Virtual Robots Team
MRL (Iran)
Team Description Paper for RoboCup 2012 Mexico City

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Abstract. This paper describes the main features of the MRL Virtual Robots team which intends to participate in Robocup 2012 competitions. Virtual Robots is an environments that a combination of state of the art algorithms of Robotics and Artificial Intelligence fields are needed to deal with its challenges. In the following we describe our approach for the main challenges such as Simultaneous Localization and Mapping (SLAM), Autonomous Exploration, Multi Agent Coordination and Exploration, Communication Infrastructure, Controller, Victim Detection and etc.

Keywords: Localization, Mapping, Exploration, Multi Agent, Victim Detection.

1 Introduction

Nowadays Robotic and Artificial Intelligence are in the center of attention of many researchers. USARSim provides us with an environment in which the conjunction of these two fields occurs. In this environment, a disaster (usually an earthquake) is being simulated in indoor and outdoor scenarios. The goal is to gather a map of a previously unknown environment which would provide information about the situation, victims, damages and etc. To overcome the goal, a combination of the state of the art algorithms of different fields needs to be implemented. These fields include Localization, Mapping, Machine Vision and Image Processing, Robot Navigation, Robot Communication, Multi-Robot Exploration andCoordination, Modeling and etc. In this paper, we describe our approaches to these different challenges which we would use to participate in Robocup 2012 Virtual Robots Competitions.
Our team members and their contributions in team are:

- Edris Esmaeili : AI Developer, Autonomous Exploration, SLAM
- Sanaz Taleghani : SLAM, Motion planning, Multi Agent Exploration

- M.Hosein Shayesteh : AI Developer, Communication Infrastructure, Message Passing, Multi Agent Exploration, Victim Detection
- Amir Panah : Victim Detection and Controller
- Fatemeh Sistani : Moving Victim Detection
- Saeid Samiezade : Multi Agent Exploration
- Mohsen Akbaritabr : Multi Agent Exploration, Software Developer

2 Localization and Mapping (SLAM)

Scan matching as a basic part of SLAM has a key role in localization and even mapping of mobile robots. Our innovative method named ICE [1, 2] matching presents a quick and also an accurate method to solve the challenges of this problem. Novelty in defining new features, matching mechanism and new state estimation approach congregated in this method creates a robust practical technique. Comparison with some high quality scan matching methods such as WSM, MbIcp from different viewpoints illustrates the performance of ICE matching. It was applied besides Grid based mapping (ICEG) to generate fine-tuned maps to compare with slam methods (Fig.1). To compare these methods, the computation time and the mean square error of the localization were considered as measurement tools. Although some methods have an accurate localization processes, they are not suitable for online application because of their high computational time. But, the elapsed time for generating the map with ICEG is useful for online utilization.

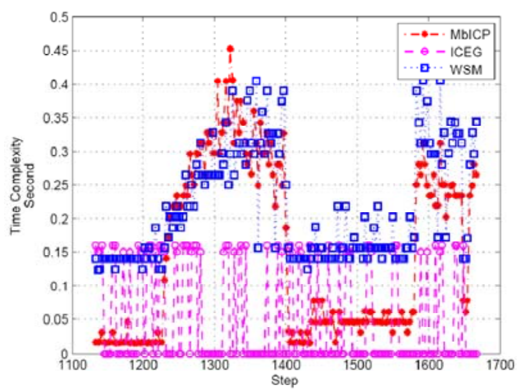

Fig. 1. Time Complexity of ICEG, WSM, MbICP.

3 Autonomous Exploration

Previous year we had used a multi layered grid map (MLEGM) [3] whose cells are represented by 3 abstract layers which is calculated by range finder's free beams and visual information and also information received by other sensors' data. This algorithm has some benefits from other exploration algorithms which work with information of single sensor such as frontier exploration or hill climbing exploration and etc.

3.1 RRT-Connect Motion Planning

Motion planning may be stated as finding a path for a robot, such that the robot may move along this path from its start position to goal position without colliding with any obstacles or other robots in the environment. An RRT is basically a data structure and algorithm which efficiently searches non convex high-dimensional spaces. The way RRT is constructed can be given as follows:

- Start with the initial pose as the root of a trees
- Select a random state in anywhere or in the direction of the target pose
- Find the closest node in the current trees
- Extend that node toward the target if possible

As other various RRT algorithms, we implemented RRT-connect because it expands two trees towards each other, one from the start node, and the other from the goal node. They interchange the roles of expanding-towards-the-other and expanding-randomly. The algorithm terminates ones a connection is established between trees. It is faster than RRT algorithm. Figure 2 illustrates the result of RRT-Connect algorithm.

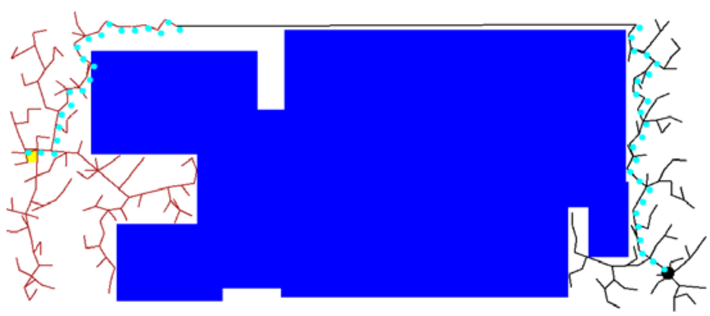

Fig. 2. Result of RRT-Connect

3.2 Multi Agent Exploration

In this section, we describe our fully autonomous method for multi agent exploration. Taking advantage of frontier approaches [4], leads us to propose a new model with idea of role-based exploration [5] with some novelty. At first, robots spawn nearby base station in unknown map. The Visible frontiers calculated in communication range [6] and robots derive to branches with a chain. It represent with a tree called exploration tree. In each branch, the leaf robot is explorer and its parents called as relay. We define number of robots in each branches, depend on path cost from explorer to its assigned frontier. The Explorer goes to explore and its relays, follow it. When explorer gathers enough data, gives them to its parent robot and set a rendezvous point to meet each other next time. The Relays have to bring data to base station. Each relay iterates this process until base station receives data. When an explorer achieves its assigned frontier, three different states may happen. Following diagram illustrates these three states.

1. Reach to a dead-end. It means there is no new frontier(like end of a room or closed area)
2. Reach to 1 new frontier.
3. Reach more than 1 frontier.

Figure 3 shows robot's behavior in branch. When a robot reaches its rendezvous point, it will stay for T time (T depend on path cost and must be calculated). If it doesn’t meet its parent/child, it can remove lost robot from its branch. The lost robot can be added to each branch of first robot encounters in communication range. Each robot has a list of all frontiers (visited or assigned) and share it with all robots in communication range to inform each other. This point helps the base station to make correct decisions and increase algorithms performance.

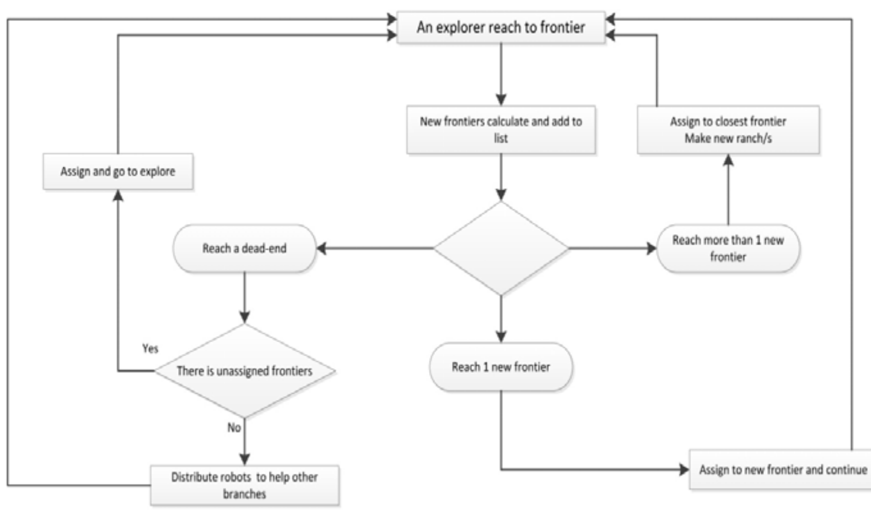

Fig. 3. Multi agent exploration state diagram

4 Communication Infrastructure

The following diagram shows our proposed architecture of communications infrastructure. The most important duty of this architecture is to control exchanged images and messages between USARSIM and robots. As it can be seen, this architecture contains three main controllers: simulation link, image server link and internal communication manager. Each main controller has its own tasks. The simulation link section handles sent and received messages from USARSIM. The duty of image server link part is to deal with received image from USARSIM. The Internal Communication Manager is divided into three parts (Network Manager, Communication Graph and WSS Control Link).

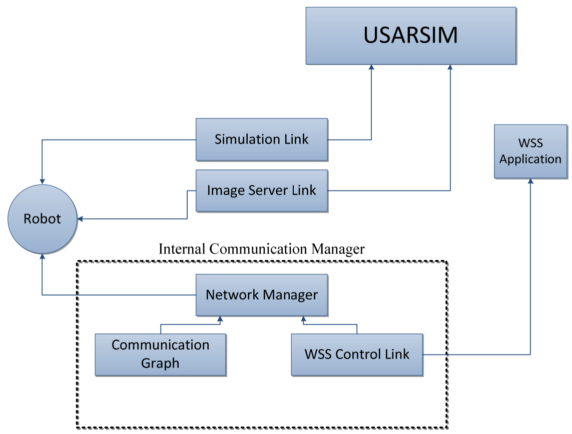

Fig. 4. Architecture of our communication infrastructure

The Network Manager is placed in top of the internal communication manager hierarchy which directs received packets from WSS Control Link in addition to controls two its sub-layers. WSS Control Link layer controls sending and receiving packets via WSS application and robot controllers, after receiving them; this layer sends those packets to the Network Manager. Communication Graph layer implements routing table for sending and receiving packets between two distant robots. On this layer we make a dynamic graph according to DV (Distance Vector) algorithm. These tables will be updated via particular messages at specific times whenever some of the links are lost or some messages cause valid changes on the table. When a change occurs, each robot must send its table to neighbors.

Destination	Connected	Interface	Hop(s)
A	False	NULL	0
B	True	NULL	1
C	True	A	3

Table 1**.** DV Table of robot A

First column in table 1 demonstrates how the specific link to the destination robot is connected or disconnected. The second column expresses which of the neighbors is between the main robot and destination robot, if the interface robot was equal to the main robot; this fact indicates there is a straight link to the destination. The third column shows how many robot we have got to arrive to a destination. This column will help us to get more efficient paths for routing.

5 Victim Detection

The detection of victims in the disaster area and building map is an important task for fully autonomous application. Therefore, it should be possible to give rescue virtual robots the capability to detect victims and landmarks autonomously, alerting the human operator as required. For detecting victims, the sensors provide information of the environment. Camera images can be used to automatically detect victims, independent from the Victim sensor provided by USARSim, as indicated in [7]. For the victim detection test, the robots must find, identify, and report the location of as many victims in the allotted time. The environment used for this test will not present mobility challenges but will present perception challenges. We will check be based on a HOG algorithm based Body Detection approach [8,9]. To examine such autonomous recognition, we have implemented an existing object recognition approach that uses a HOG algorithm to find known objects in a given image [10,11, 12]. In figure 5 exist two state of victim detection.

Fig. 5. Automated body detection

5.1 Motion Detection for Moving Victim detection

One of the simplest ways for detection of changes between two image frames $f(x,y,t_j)$, $f(x,y,t_i)$ that have gotten at time t_i, t_j, is comparison between two images pixels. This work is named the difference between images. We can use variant ways of Accumulative Difference Image (ADI) for extracting motion object from sequential images. It is better to consider tree types of ADI, absolute, positive and negative [13].

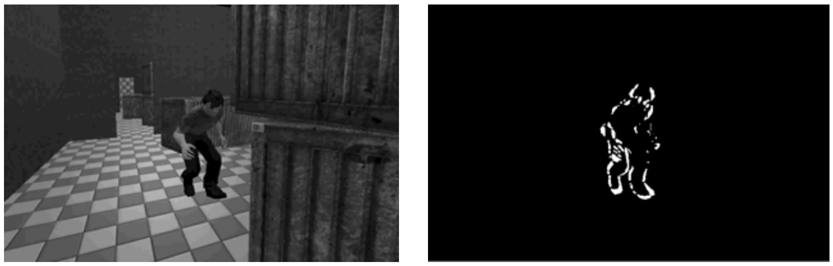

Fig. 6. Victim Detection by its motion

6 Robot Control

The control of underactuated systems is an open and interesting problem in controls although there are a number of special cases where underactuated systems have been controlled; there are relatively few general principles [14]. A fixed requirement on the system is the free exchangeability of underactuated and actuated joints, which can be realized by using a modular design. The mathematical description uses the Linear Complementarities Problem formulation in order to handle the equations of motion with inequality constraints [15].

We assume a comfort with linear algebra, ODEs, and MATLAB. Also, we are used Unscented Kalman Filter for handle of robot linearization process. Figure 7, shows the results of difference states for robot control. This work based on UT3, also is performed on UDK recently.

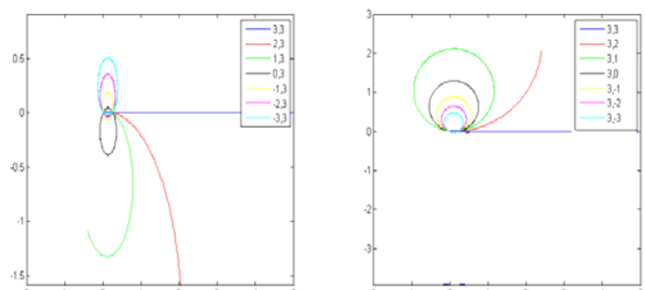

Fig. 7. Examples for motion of robot control

7 Conclusion

Our six years of working experience in Virtual Robots field lead us to an innovation about the SLAM problem, Autonomous exploration, controller and some other different method gradually. These methods are still in progress, but the promising results which we got from these methods encourage us to continue our work.

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