RoboCup Rescue 2009 - Robot League Team Team CASualty (Australia)

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Abstract. This document describes the "Team CASualty" entry into the 2009 RoboCup Rescue competition. Our 2009 entry builds on our previous three entries (2005, where we came third overall and 2006, where we made the semi-finals in the main competition and came second in the autonomous competition and in 2007, where we reached the finals). This year we are focusing on autonomous traversal through the arena and will be bringing three robots, one based on the iRobot Negotiator, one based on iRobot's PackBot and one based on the Volksbot platform. We will demonstrate several new methods for autonomous traversal of rough terrain and SLAM for unstructured environments.

Introduction

Team CASualty represents the ARC Centre of Excellence in Autonomous Systems (CAS), which is a collaboration between the Australian Centre for Field Robotics at the University of Sydney, the Artificial Intelligence Research Group in the School of Computer Science and Engineering at the University of New South Wales and the Mechatronics and Intelligent Systems Group at the University of Technology, Sydney. Team CASualty has had considerable success in past competitions, coming third in 2005; reaching the semi-finals in 2006, where we also came second in the autonomy competition and reaching the finals in 2007.

The robot team currently consists of three primary vehicles (Figures 1 and 2):

- **Negotiator and Volksbot:** Using both an iRobot Negotiator and Volksbot RT as bases, we have added identical additional sensing and computational capabilities that permit either tele-operation or autonomous operation.
- **Packbot:** A PackBot has also been equipped with an additional sensor package and computers.

In addition to our mobile platforms, Team CASualty makes use of a variety of advanced sensors for mapping and victim identification, as well as highly effective, integrated user interfaces for multi-robot control and mapbuilding. This year we also intend to demonstrate autonomous behaviours within the orange and red areas of the Rescue arena.

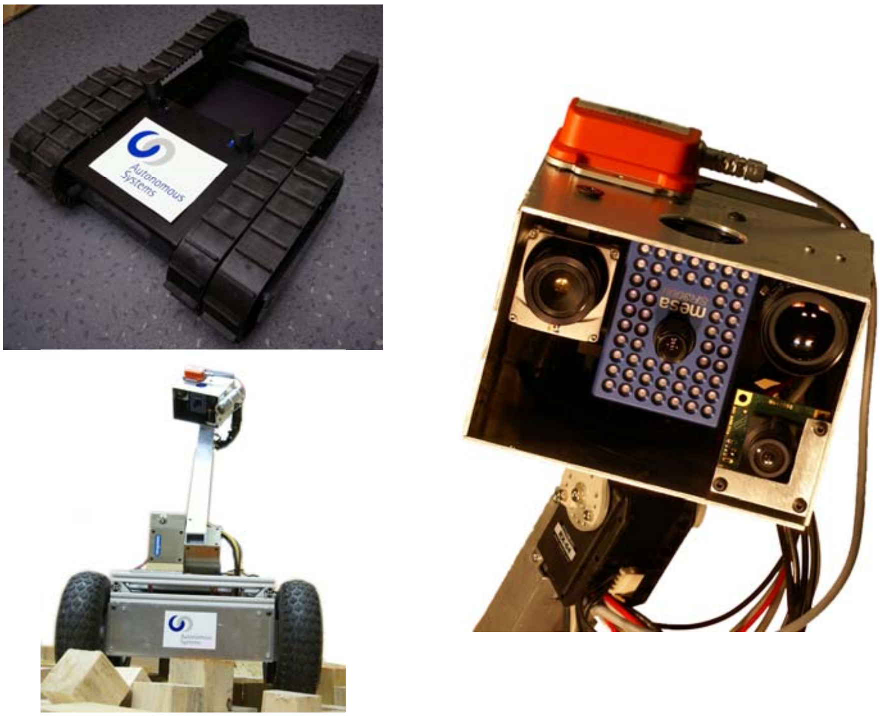

Fig. 1 Negotiator, Volksbot and sensor head

Fig. 2 PackBot

1. Team Members and Their Contributions

The core team this year consists of:

- Adam Milstein SLAM
- Raymond Sheh Autonomous terrain traversal
- Rudino Salleh Hardware and mechanical design
- Matthew McGill Software engineering and infrastructure
- Reza Farid Exploration
- Jaime Valls Miro SLAM
- Alen Alempijevic SLAM and victim identification
- Nathan Kirchner Hardware
- Zhan Wang SLAM
- Jack Wang SLAM and victim identification
- Gamini Dissayanake Advisor, strategy, planning
- Claude Sammut Advisor, strategy, planning
- Bernhard Hengst Advisor, strategy, planning

2. Operator Station Set-up and Break-Down (10 minutes)

Our equipment deployment arrangements currently consist of:

- Negotiator, Volksbot and PackBot robots, both powered on and in idle state, waiting on trolleys.
- An 802.11a (5GHz) Access Point. The robots connect to this automatically once it is activated.
- Two portable laptop computers that have all software already configured.
- A portable battery-powered printer for producing maps and victim photographs.
- An emergency radio controller in case the wireless network fails.

This is similar to our setup for 2007 where the set-up and break-down times were around 6 minutes.

3. Communications

As in previous years, Team CASualty will be using an Enterasys RoamAbout AP4102 combined 802.11a/b/g wireless LAN access point for primary communications. This access point can be configured to only operate in 802.11a (5GHz) mode and can be channel locked. We will bring a highly directional 90º antenna that can be installed to boost signal whilst minimising signal leakage to adjoining league areas.
We are also investigating the use of a Spektrum DSM spread spectrum radio control unit, operating on 2.4GHz, for the purpose of remote emergency stop. Due to its extremely low power and bandwidth, we do not anticipate any interference with other equipment.

Rescue Robot League		
CASualty (Australia)		
Frequency	**Channel/Band**	**Power (mW)**
2.4GHz – 2.4835GHz	Spread spectrum	10mW
5GHz - 802.11a	802.11a channels (nominally Ch52)	100mW (3,000mW with external antenna)

4. Control Method and Autonomous Terrain Traversal

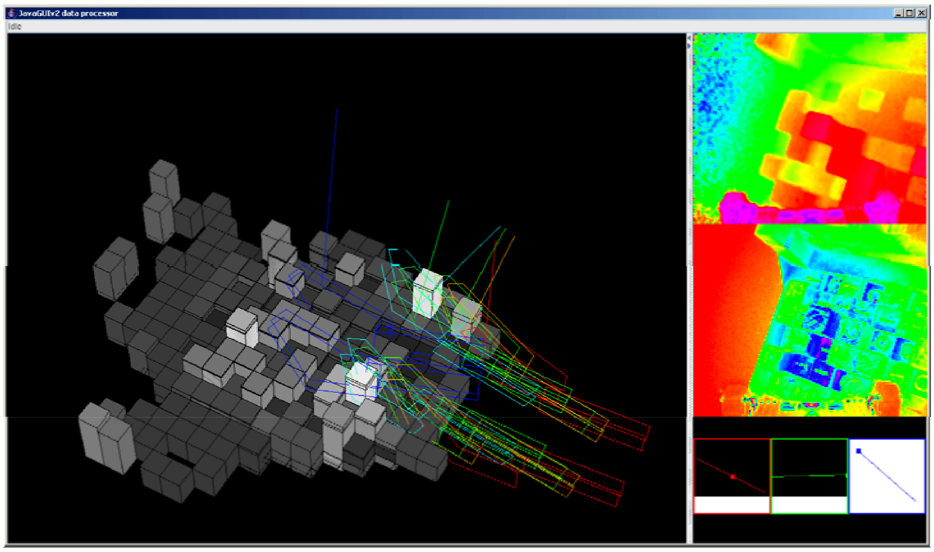

Fig. 3 Terrain model extractor

Our user interface builds on our previous entries [2], which allowed a single operator to control multiple robots. An innovation that we intend to demonstrate this year is the autonomous traversal of step fields. The methods combine planning and machine learning methods [3-5]. A human operator demonstrates the act of driving a robot over a variety of step fields. Our feature extraction (fig. 3) and machine learning techniques are able to detect and classify features observed through the robot's terrain sensors, match them with the operator's actions and generate a policy for controlling the robot. Our aim is to use this policy to allow the Negotiator to autonomously traverse step fields and stairs that were not encountered during initial training.

A further refinement of this approach is to import the terrain model (fig. 3) into a physics simulator. This allows the robot to test planned trajectories in a virtual world before attempting to execute the plan on the real robot. Furthermore, by running a modified A* search, the robot is able to try different trajectories and project ahead the path that is most likely to produce progress in the desired direction. A drawback of this method is that planning can be quite slow. However, if the situations and actions that the planner produces as input to a machine learning program, this can construct a fast lookup for decision making that only requires the planner to be run in novel situations.

5. Localization and Mapping

One of the difficulties with operating the rescue robot remotely is that it is sometimes difficult for the operator to determine the position of the robot. It is also difficult to understand the layout of the problem area given only the robot's sensor data. We intend to implement a SLAM (Simultaneous Localization and Mapping) algorithm which will maintain the robot's position and simultaneously develop a map of the environment which has been observed. The operator will be able to control the robot with reference to its position in this map and will also be able to use the map in order to plan the robot's activities.

SLAM is a difficult problem in the Robocup Rescue environment because the estimate of the robot's motion, which is usually obtained from the wheel encoders, is highly inaccurate on a non-regular surface. We intend to substitute a visual tracking algorithm for simple odometry in order to determine the relative offset between subsequent robot poses. This should give us an accurate enough position estimate that standard algorithms for SLAM can be used. This algorithm will be applied to a down-angled depth field sensor. Aligning the depth field in subsequent scans should also produce the height change in the robot's position, something that is necessary for generating a three dimensional map.

Based on this tracking algorithm, we will use an implementation of fastSLAM for occupancy grid maps to correct the robot's position and update the map. By using an occupancy grid map containing multiple height information for each cell, we should be able to maintain a three dimensional map of the environment sufficient to represent multiple levels. This map will provide the estimated sensor readings required by fastSLAM while allowing the necessary map updates to be performed efficiently. It should also be possible to cache sections of the map for efficient use of memory.

By separating the position tracking algorithm from the rest of fastSLAM, we allow a distributed implementation. Since a SLAM solution often requires a significant amount of processing, this algorithm can be performed on a remote machine while position tracking is performed onboard the robot. Thus, for short periods the robot can track its own position while receiving periodic corrections from a base station when communications are available. This system further lends itself to allowing the robot to drive itself temporarily if operator control is not available.

6. Sensors for Navigation and Localisation

Hokuyo URG-04LX Laser scanner: This lightweight (<200g) linescan LIDAR provides range data through a 220º scan in 0.3º increments at 10Hz, up to a distance of 4m. Its small size allows it to be mounted on a servo that rotates its scanplane to form 3D scans [6]. This sensor forms an important part of the mapping and autonomy subsystems of both Negotiator and PackBot.

CSEM SwissRanger SR3100: This range camera provides a 176x144 pixel range image at 30fps up to around 7m, based on time-of-flight. This information can be used to build a 3D point cloud that is very useful for mapping and overcomes many of the issues with simple 2D laser scanners. It is used on both platforms.

Robot Arm: Both platforms have a robot arm that allows the sensor package to be raised up to obtain a higher view. The sensors are mounted on pan-tile units that are used to obtain 360˚ panoramas, as well as directing attention to particular places.

Heading/attitude sensor: The negotiator will use Xsens MTI heading/attitude sensors. These sensors provide 3DOF orientation to a high degree of accuracy, assisting in automatic map generation and situational awareness.

Wide angle and long focus cameras: Both platforms use a variety of video cameras to obtain wide angle view for navigation and close-up views for inspection of objects.

7. Sensors for Victim Identification

ThermoVision Micron IR thermal camera: This lightweight, compact 160x124 pixel thermal infrared (7 – 14 micron) camera is a key component of the victim identification system. When calibrated with respect to the colour camera, it is possible to localise heat sources very precisely within the Rescue arenas. Thermal imaging played a large part in our success last year and this year is expected to be no different. Thermal imaging has the advantage of enabling victim identification in dark areas of the arena where the optical image is very poor, locating partially or completely occluded victims and adding to available victim information.

Cameras: The optical cameras are an important component of the victim identification system. Both platforms are equipped with a number of colour cameras to allow them to identify victims including a long focal length camera, capable of better than 20:20 vision.

Microphone: Microphones will be used to assist in the identification of the state of victims and provide additional information as to the robot's movements and surroundings. The sound from the microphones will be fed back to headphones worn by the operator.

8. Robot Locomotion

Negotiator and Packbot robots have very similar drive mechanisms. They are both differentially steered vehicles cleated rubber tracks. Both have tracked, driven arms mounted on the forward shoulders, allowing the robots to climb over obstacles of moderate size and to climb stairs.

9. Team Training for Operation (Human Factors)

Operator training for teleoperation of the robot team requires roughly a day of familiarisation with the controls although additional practice is expected to improve the operator's effectiveness. Training includes instruction on the nature of the robot platforms the robots' articulation and robot arm, and the relative value of the data provided by each sensor. Our studies indicate that this approach is feasible and that operators with ten minutes of practice with the robot were able to learn enough to drive it around a simple maze [7].

10. Possibility for Practical Application to Real Disaster Site

The PackBot was designed for military use and the Negotiator for law enforcement, so both platforms have been ruggedized for practical use. The sensor package and computers have been added by us and are not designed for extreme environments but are reasonably robust. Further engineering would be required for practical applications.

11. System Cost

All amounts in US Dollars

KEY PART NAME: Negotiator
MANUFACTURER: iRobot (previously RoboticFX)
COST: $57,000
WEBSITE: http://www.irobot.com/sp.cfm?pageid=138
DESCRIPTION/TIPS: Tracked robot remote control/autonomous robot

KEY PART NAME: Volksbot
MANUFACTURER: Fraunhofer IAIS
COST: $7,500
WEBSITE: http://www.volksbot.det
DESCRIPTION/TIPS: Four-wheel-drive robot remote control/autonomous robot

KEY PART NAME: PackBot Explorer
MANUFACTURER: iRobot
COST: $135,000
DESCRIPTION: Tracked robot remote control/autonomous robot

KEY PART NAME: Laser rangefinder
PART NUMBER: URG-04LX
MANUFACTURER: HOKUYO
COST: $1,600
WEBSITE: http://www.hokuyo-aut.jp/products/urg/urg.htm
DESCRIPTION/TIPS: Used to obtain accurate 2D range information.

KEY PART NAME: Camera
PART NUMBER: Guppy F080C
MANUFACTURER: AVT
COST: $1,000
WEBSITE: http://www.alliedvisiontec.com

KEY PART NAME: ThermoVision Micron IR Camera
MANUFACTURER: FLIR Systems
COST: $13,000
WEBSITE: http://www.indigosystems.com/product/micron.html
DESCRIPTION/TIPS: Excellent detection of heat sources.

KEY PART NAME: MESA SwissRanger SR-3100
MANUFACTURER: MESA
COST: $9,500
WEBSITE: http://www.swissranger.ch

KEY PART NAME:	IMU
PART NUMBER:	MTi
MANUFACTURER:	XSens
COST:	$2,500

KEY PART NAME:	Onboard Computer
PART NUMBER:	UX92
MANUFACTURER:	Sony
COST:	$3,200

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