RoboCupRescue - Robot League Team CASualty (Australia)

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Abstract. This document describes the “CASualty” entry into the 2006 RoboCup Rescue competition. The entry consists of two primary vehicles, the tracked articulated rescue vehicle CASTER, and the wheeled differential drive robot HOMER. The vehicles are equipped with a range of state of the art sensors for mapping, localization and victim identification, and are capable of navigating and autonomously mapping unknown environments, detecting and locating human victims, and identifying the victim states.

Introduction

CASualty is a team representing 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.

The RoboCup Rescue team aims to bring together several strands of Autonomous Systems research from within CAS and NICTA in a single highly specialized application.

The robot team consists of two primary vehicles, CASTER: a Yujin RobHaz DT-3 articulated tracked vehicle (see figure 1), and the custom built HOMER (High-speed Obstacle Mapping and Exploration Robot, see figure 2). CASTER will be tele-operated and is primarily intended for the more difficult Orange and Red arenas, while HOMER will be run autonomously in the Yellow arena.

Although tele-operated, CASTER will use autonomous modules for localization and mapping as well as victim searching, as an aid to the operator. It is fitted with a number of sensors for 2D and 3D localization and mapping, including Hokuyo URG laser rangefinders, and a CSEM Swissranger 3D range sensor mounted on a pan-tilt unit. Victim identification is further aided by the use of numerous cameras, a thermal camera, and a stereo microphone.

HOMER will operate primarily in autonomous mode. Localization and mapping will be carried out via a Hokuyo URG laser range finder. Victim identification will be carried out using vision-based techniques, aided by an IR camera, and an audio microphone.

Fig. 1. CASTER: a RobHaz DT-3 tracked vehicle, with remote control station.

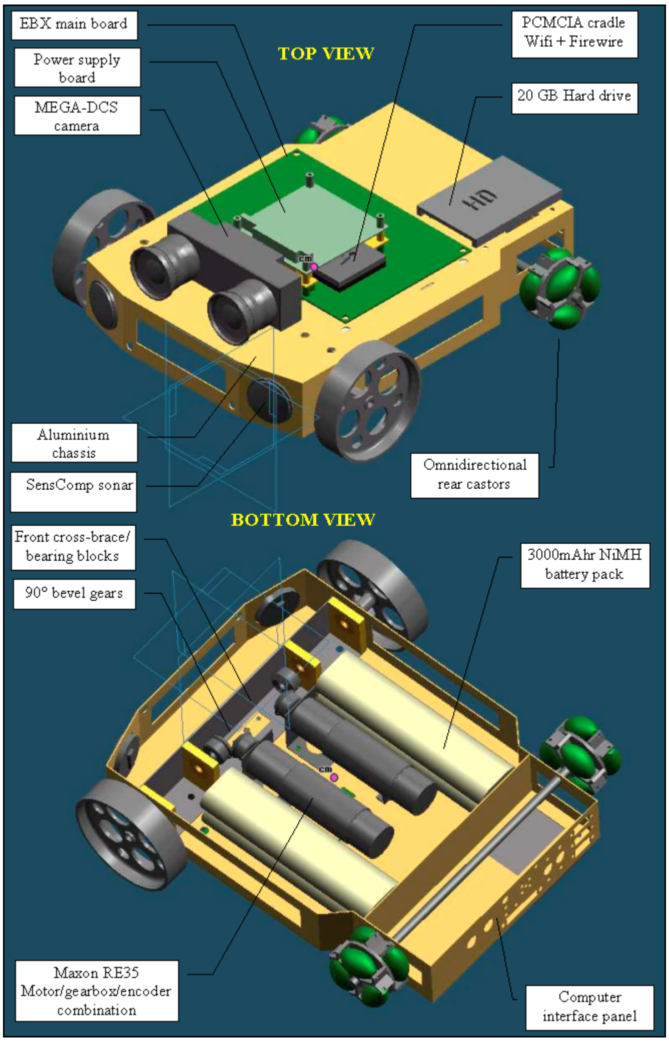

Fig. 2. the autonomous High speed Obstacle Mapping and Exploration Robot (an earlier version using stereo vision instead of laser).

1. Team Members and Their Contributions

The following are the principal CASualty team members. Asterisks (*) denote team members who will be part of the on-site team in Bremen.

Team Leaders:	Mohammed Waleed Kadous*, Jonathan Paxman*
Technical design and support:	John Zaitseff, Weizhen Zhou
Algorithms:	Sarath Kodagoda*, Raymond Sheh*, Jaime Valls Miro*, Tarek Taha, Oliver Thane, Hue Tuan Thi
Team Mentors:	Prof Claude Sammut*, Prof Gamini Dissanayake

In addition, we would like to thank the following people for advice at various stages of the project: Maurice Pagnucco, Charles Willock, Xianhang Zhang, Michael Trieu, Mario Cheng, Dinesh Gurram, Matthew Rozyn.

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

The team of robots will be centrally operated via a wireless enabled laptop. The operator station can be fully setup within ten minutes.

3. Communications

The robots are currently configured for use with 802.11a wireless networking

4. Control Method and Human-Robot Interface

The CASualty plan for the 2006 RoboCup Rescue competition involves a dual approach of tele-operation (with partially autonomous modules) and full autonomy. We plan to use the tele-operated CASTER and REDBACK robots in the orange and red elements, and the fully autonomous HOMER in the yellow elements and autonomous area.

An integrated interface application has been developed, which allows a single operator to maintain control over a number of autonomous and tele-operated robots. The application also integrates mapping information from the vehicles and generates a single global map.

5. Map generation/printing

Representation of 2D maps:
It is proposed to represent the 2D map using occupancy grids (OG). Victims and landmarks are located within the map by associating them with the range data. Inertial measurement is used as an aid to mapping, by correcting for tilt (when 3D scans are available), or by increasing the uncertainty of 2D range data produced from non-horizontal poses.

Scan matching:
The Robocup rescue arena is a generally static environment. In this type of situation, laser based scan matching [3] can provide good quality localization information, which can be used to compensate for errors in the robot odometry. Matched scans can provide the basis for an accurate occupancy grid map.

Integration:
The mapping component of the operator interface performs statistical optimisations in order to align map elements from each robot.

6. Sensors for Navigation and Localization

CSEM Swissranger: a 2.5D/3D time-of-flight LADAR camera [3] mounted on a pan-tilt unit onboard CASTER. This camera provides a 160x124 depth image at 30fps, to a distance of 7.5 metres and a resolution of 5mm. It also provides a near infrared reflectance image from the same sensor. We intend to take advantage of the high frame rate afforded by this camera in order to rapidly generate dense 3D maps and to provide the primary means of robot localisation and 3D map building. We do not plan to use odometry from the tracked robots except to determine if the robot is likely to be stationary.

Hokuyo URG Laser Rangefinder: The Laser rangefinder returns accurate distance measurements in the 240° horizontal field of view at a resolution of up to 0.35°. The maximum scan rate is 10Hz. A rotated URG may also be used to generate 3D scan data.

7. Sensors for Victim Identification

ThermoVision Micron IR thermal camera: This lightweight, compact 160x128 pixel thermal infrared (7.5 – 13.5 micron) camera is a key component of the victim identification system. When calibrated with respect to the Videre stereo camera, it is possible to localize heat sources very precisely within the Rescue arenas. Thermal imaging is expected to be one of the primary methods of victim detection. In autonomous mode, identified heat sources are filtered for temperature and size before being labelled as potential victims. In tele-operated mode, the thermal image is relayed to the operator and may be viewed in conjunction with the optical image. Potential victims (as identified by the autonomous system) are flagged to the operator. Thermal imaging has the advantage of enabling victim identification in dark areas of the arena where the optical image is very poor, and of locating partially or completely occluded victims.

Videre cameras: The optical cameras are an important component of the victim identification system. In autonomous mode, the optical image is processed by a skin detection algorithm (which can detect a wide range of skin types in a range of lighting conditions), and a shape detection algorithm that can detect some instances of hands, feet and heads within the optical image. In tele-operated mode, the optical image is fed back to the operator (who may switch between the left and right camera view). The operator may choose to run the autonomous victim identification algorithms as an aid to victim identification.

Microphone: A stereo microphone mounted with the cameras will be used to assist in the identification of the state of victims. In tele-operated mode, the sound from the microphones will be fed back to stereo headphones worn by the operator. In autonomous mode, very simple processing (thresholding and filtering) will be used to estimate whether a sound of the appropriate frequency range is collocated with the victim.

8. Robot Locomotion

CASTER: uses a tank-like track arrangement that is steered differentially using tracks. The rubber tracks are ribbed to improve traction over rough terrain. However, unlike most tanks, the DT-3 consists of two articulated sections. The rear section is similar to a conventional tank. The front section consists of a triangular track path. This allows the DT-3 to traverse tall obstacles such as stairs. The locomotion of the DT-3 will be controlled via direct manual control (tele-operation).

HOMER: is a differentially driven wheeled robot. The front wheels are driven by Maxon RE-35 motors, through GP-32C gearboxes. The robot is capable of high speeds up to 2m/s, but will be limited to very low speed operation for Robocup. The rear omni-directional wheels result in relatively stable, predictable behaviour (compared to caster wheels and other options). HOMER is not equipped to handle rough terrain, and will not be suitable for the orange and red arenas.

9. Other Mechanisms

Secondary robot:
The team is considering the possibility of deploying a secondary robot, dubbed "RedBack", based on the MGA "Tarantula" RC vehicle. This vehicle would be used in conjunction with CASTER in the orange and red arenas. As a small, lightweight, low-cost, highly mobile robot, it may be used to explore unstructured areas inaccessible to CASTER due to dangerous drops or other physical constraints. Situational awareness is also improved with the addition of a 3rd person view that a secondary robot affords. Featuring two pairs of driven, tracked flippers (see figures), this fully equipped robot can climb stairs with slopes in excess of 45º and obstacles up to 40cm in height and 20cm in width, self-right, run inverted and rise to provide a ground clearance of 20cm. It is also ruggedised to withstand rolls and falls and is extremely lightweight at around 6kg. Equipped with a small PC, wireless LAN and a colour camera, this robot may be tele-operated and has the potential for semi and fully autonomous operation. Planned additions for situational awareness, mapping and victim identification include additional cameras, rangefinders, microphones and accelerometers.

10. Team Training for Operation (Human Factors)

When operating in autonomous mode, HOMER does not require human intervention. Nevertheless, the operator should be trained in the tele-operation of HOMER so that intervention can take place if required. Operator training for tele-operation of HOMER or CASTER requires roughly a day of familiarisation with the controls. In addition, it is planned that the operator will be practising in a rescue arena with earlier versions of the tele-operation software. Training includes instruction on the mechanisms of the various sensor and actuator modules, and the relative value of the data provided by each module.

11. Possibility for Practical Application to Real Disaster Site

Two RobHaz DT-3 robots have been deployed as a military tool in Iraq. It is expected that the DT-3 may soon see use in real disaster situations, as a tele-operated vehicle.

HOMER is not designed for a real disaster scenario, as mechanically it is only suitable for flat terrain. The sensing and intelligence technology on HOMER however is expected to be fully transportable to more robust platforms capable of performing in real disaster scenarios.

12. System Cost

All items listed in US dollars (conversion rate used 1AUD=0.77USD).

TOTAL SYSTEM COST: USD$96,000

CASTER

KEY PART NAME: RobHaz DT-3
MANUFACTURER: Yujin Robotics
COST: $60,000
WEBSITE: http://www.tribotix.com/Products/Yujin/RobHaz/RobHaz.htm
DESCRIPTION/TIPS: DT-3 remote control robot, including remote control station.

KEY PART NAME: Hokuyo URG Laser
PART NUMBER: URG
MANUFACTURER: Hokuyo
COST: $1500

KEY PART NAME: Swissranger
MANUFACTURER: CSEM
COST: $7,700
WEBSITE: http://www.csem.ch/detailed/p_531_3d_cam.htm
DESCRIPTION/TIPS: Swissranger is a pulsed infrared time of flight sensor. It provides a 160x124 depth image which may be used to map the 3D environment. As an active sensor, it is not dependent on external lighting conditions.

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.

HOMER:

HOMER is a custom built robot, constructed at the University of Technology, Sydney. Prices for some components are listed below . The value of in-house fabrication and technical work is difficult to estimate.

KEY PART NAME: Motors and Gearboxes
PART NUMBER: RE-35, GP-32C
MANUFACTURER: Maxon
COST: $450x2

KEY PART NAME: Libretto Laptop

PART NUMBER:	U100
MANUFACTURER:	Toshiba
COST:	$3000

KEY PART NAME:	Hokuyo URG Laser
PART NUMBER:	URG
MANUFACTURER:	Hokuyo
COST:	$1500

Other items: 2x Hewlett Packard HEDS-5540 two channel quadrature encoder, Magnevation H-bridge 3A DC servo motor (2x) board (R121-MTR-DRV-KIT from Acroname) [$65], 2x SensComp 600 series SmartSensor sonar [2x $55], 6x Metal Hydride (NiMH) 3000mAhr 7.2V 350g [6x $30].

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