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RoboCupRescue - Robot League Team CASualty (Australia)

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Abstract. This document describes the "CASualty" entry into the 2005 RoboCup Rescue competition. The entry consists of two primary vehicles, the tracked articulated rescue vehicle RobHaz DT-3, 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, the 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). The DT-3 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, the DT-3 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 a SICK laser rangefinder, CSEM Swissranger 3D range sensor, and a Videre Stereo camera mounted on a pan-tilt unit. Victim identification is further aided by the use of an IR camera, CO_2 sensor and an pair of microphones.

HOMER will operate primarily in autonomous mode. Localization and mapping will be carried out via a Videre Stereo camera pair. Victim identification will be carried out using vision-based techniques, aided by an IR camera, CO_2 sensor and an audio microphone.

Fig. 1. The RobHaz DT-3 tracked vehicle, with remote control station.

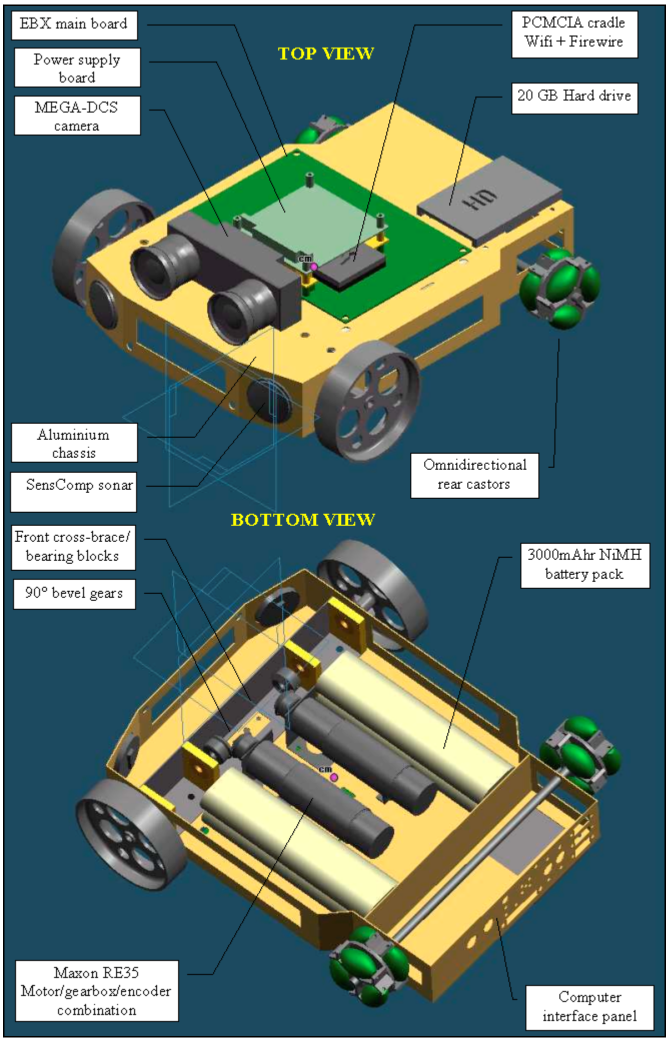

Fig. 2. the autonomous High speed Obstacle Mapping and Exploration Robot.

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 Osaka.

Team Leaders:	Mohammed Waleed Kadous*, Jonathan Paxman*
Technical design and support:	John Zaitseff, Weizhen Zhou*
Algorithms:	Sarath Kodagoda*, Malcolm Ryan, Raymond Sheh*, Jaime Valls Miro
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 DT-3 will be fully operated via the pictured remote control station, or a wirless enabled laptop (the switch may be necessary to accommodate 802.11a communications). The operator station can be fully setup within five minutes. HOMER will be operated via a wireless enabled laptop computer, and can also be setup within five minutes.

3. Communications

The robots are currently configured for use with 802.11b wireless networking. In the light of advice strongly encouraging the use of 802.11a, we will be making every effort to switch to 802.11a prior to the Osaka competition.

4. Control Method and Human-Robot Interface

The CASualty plan for the 2005 RoboCup Rescue competition involves a dual approach of tele-operation (with partially autonomous modules) and full autonomy. We plan to use the tele-operated RobHaz DT-3 robot in the orange and red arenas, and the fully autonomous HOMER in the yellow arena.

The DT-3 will be fully operated via the pictured remote control station, or possibly an enhanced version. HOMER will be operated via a wireless enabled laptop computer.

In fully autonomous mode, HOMER does not require any input from the operator, but will continuously display data via the operator laptop, and the operator will have the ability to intervene at any time, switching to tele-operation mode.

5. Map generation/printing

Stereo Vision based SLAM:
Stereo vision with proper calibration provides good depth information in short range. When the objects are further away, the stereo vision provides less accurate depth information. This sensor has the capability of detecting many visual features that are not detected by other sensors. Carefully selected features (using SIFT [1] or any other method) can be used to incorporate in SLAM [2] providing good quality feature maps. Further, assuming vertical surfaces, an occupancy grid based map can be generated using stereo vision data.

Representation of 2D maps:
It is proposed to represent the 2D map using occupancy grids (OG). Once the victims are identified, they can be included in the OG in a different colour and/or with a unique number. There will be an ambiguity, if the arena has several levels as there is no information about the height. However, this can be avoided by generating several equi-altitude maps as the arena may have only few of them. In this situation, either the user has to decide it manually by visualization or we may need to mount an IMU to find different levels.

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.

3D mapping:
We are developing techniques based on the Iterative Closest Point (ICP) algorithm [4,5] for generating useful 3D maps from the CSEM SwissRanger (see figures). A combination of careful filtering and suitable optimisations cater for the camera's high framerate, narrow field of view and unusual noise characteristics and will enable us to perform 3D SLAM whilst the robot is in motion over unstructured terrain, without operator intervention.

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 the DT-3 robot. 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.

SICK Laser Rangefinder: The Laser rangefinder returns accurate distance measurements in the 180° horizontal field of view at a resolution of up to 0.25°. The maximum scan rate is 75Hz, but in order to reduce power consumption the device may be polled at a much lower frequency if desired. The SICK laser is very heavy (4-5kg), and will only be available on the DT-3.

Videre Stereo Camera Pair: The stereo camera is employed in HOMER as the primary range sensor, and in the DT-3 as the primary optical sensor. It is capable of providing up to 30 frames per second at a resolution of up to 640 by 480. With dual 1.3 megapixel CMOS progressive scan sensors and wide angle (3.5mm) Rainbow lenses, it is capable of providing dual images at up to 30fps and a resolution of 640x480 per image. Images can be post-processed using stereo analysis software libraries supplied by SRI International's Small Vision System (SVS). These libraries are used to obtain a 'point cloud' from a stereo image. This cloud is an array of 3D points where surrounding obstacles are identified in the image. HOMER uses this information to build 2D maps of the space around it, which are in turn employed for navigation and exploration. The DT-3 makes limited use of the stereo range information to support the other ranging sensors.

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 pair of microphones mounted with the stereo camera 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.

CO_2 sensor: A CO_2 sensor located on the front of the robot will detect high concentrations of CO_2. This will be used to aid in determining the state of a victim which has already been located. We propose to use the Val-tronics 2008 sensor, which has a range of 0-1% (approx 10,000 ppm).

8. Robot Locomotion

RobHaz DT-3: 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

Whiskers: The team is investigating the possibility of tactile sensors (whiskers) mounted on piezoelectric sensors. This is intended to overcome the difficulty of detecting highly reflective or transparent barriers. The design initially being examined is based on the research of Russell [6].

Possible 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 DT-3 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 the DT-3 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 the DT-3 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

DT-3

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: Laser rangefinder
PART NUMBER: LMS 291-S05
MANUFACTURER: SICK
COST: $6500
WEBSITE: http://www.sickusa.com/
DESCRIPTION/TIPS: Used to obtain accurate 2D range information. Size and weight is a significant drawback.

KEY PART NAME: CO_2 sensor (shared with HOMER)
PART NUMBER: 2008DHL 1%
MANUFACTURER: Val-tronics
COST: $450
WEBSITE: http://www.val-tronics.com/

KEY PART NAME: Stereo camera (one each on DT-3 and HOMER)
PART NUMBER: MEGA-DCS
MANUFACTURER: Videre Design
COST: $1600
WEBSITE: http://www.videredesign.com/
DESCRIPTION/TIPS: Used to obtain 3D depth information, and as a general optical sensor. Firewire interface.

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:	Motherboard, RAM, CPU
PART NUMBER:	VSBC-8
MANUFACTURER:	Versalogic
COST:	$2000

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], Diamond Systems PC/104+ Jupiter-MM power supply board [$320], Prestico PC/104+ dual CardBus cradle (PCM-255) [$290], Belkin F5U512 PCMCIA Firewire adaptor [$80], Avaya WorldCard 802.11b wireless ethernet PCMCIA adaptor [$70], Fujitsu 20GB laptop hard drive [$150], 2x SensComp 600 series SmartSensor sonar [2x $55], 6x Metal Hydride (NiMH) 3000mAhr 7.2V 350g [6x $30].

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