www.mobilerobotics.warwick.ac.uk

WMG Innovative Solutions | ITCM Innovative Technology for Custom Machinery | WARWICK IMRC Innovative Manufacturing Research Centre | HARWiN INTERCONNECT DESIGN & MANUFACTURE | maxon motor driven by precision

WARWICK MOBILE ROBOTICS

WMR

Introduction

Warwick Mobile Robotics (WMR) is an ongoing student research project for the Warwick Manufacturing Group (WMG). WMG is an institution within the University of Warwick, dedicated to improving organisational competitiveness through the application of technology innovation. Each year, the WMR team compete in the Robocup Rescue League, a global competition which tests robots' search and rescue abilities in a simulated disaster environment. The WMR team have chosen this competition as it provides not only an exciting engineering challenge, but a socially significant real world application for mobile robots.

Aims & Objectives

- Enter 2010 European Robocup Rescue League with the goal of winning the competition
- Redesign the robot chassis utilising sophisticated composite materials
- Redesign the robot arm for improved mobility and articulation
- Redesign the robot head for the inclusion of more sensors
- Improve the power to weight ratio of the robot for better range
- Design and manufacture an entirely new self-navigating robot for the competition's autonomous section
- Develop mapping ability of both robots through the use of LiDAR technology

Publicity

Publicity is extremely important to WMR both in raising the profile of the project among the wider community and as a tool for securing vital sponsorship and funding. WMR publicises through a wide range of mediums including its website (*www.mobilerobotics.warwick.ac.uk*), monthly newsletters and public displays and demonstrations. The team have secured sponsorship from custom machinery and product solutions firm ITCM, Warwick Innovative Manufacturing Research Centre (WIMRC), interconnections design and manufacture firm Harwin, Warwick Manufacturing Group (WMG), motor firm Maxon Motors and the University of Warwick School of Engineering.

Finance & Sponsorship

To date, we have secured a budget of £17,000. This was achieved with the help of our sponsors listed in Table 1. We also have a sponsorship deal with Maxon Motors, who are supplying all 8 motors for the tele-operated robot. Table 2 gives a summary of the main project costs. This leaves £10,700 for further developments.

Funding	Budget
School of engineering	£1,200
WMG	£4,550
IMRC	£5,000
ITCM	£2,000
Harwin	£1,200
Carried forward from previous year	£3,000
Total	16,950

Table 1
Sources of funding

Items	Cost
LiDAR	£800
Maxon motors (x5)	£2,500
PC	£500
Carbon fibre materials	£250
Track gears	£200
Competition expenses	£2,000
Total	£6,250

Table 2
Major project costs

Project Management

The management hierarchy begins with the project supervisors monitoring progress throughout the year. The project leader then creates a work plan based on consultations with the team and staff. These tasks are delegated amongst the mechanical and electronic teams who then send job requests to the technical staff. Funding is overseen by the finance officer.

To assess and manage the progress and to deliver the weekly objectives 2 weekly meetings were held throughout the project. The first meeting at the beginning of the week was a briefing and the end of week meeting a progress report. The flow of the meetings can be expressed as in the flow diagram on the right.

WMR management hierarchy

Meeting topic flow

Timeline

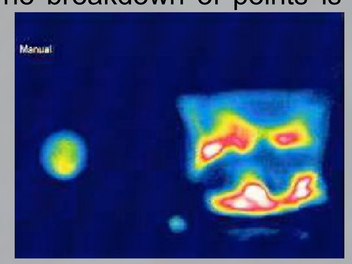
05.10	Project Handover: Initial consultations
15.10	System testing: De-construction & Re-construction
23.10	Submit Team Aims and Objectives
26.10	Design & Production of Autonomous Chassis
27.10	Re-Design of Tele-operated chassis
16.11	IBM Demonstration
23.11	Robot arm design: Concepts & Mechanical studies
11.01	Manufacturing: Tele-operated chassis & Robot arm
15.02	Final system testing: De-bugging & Testing
14.04	RoboCup Rescue German open
27.04	Submission of Final Report
14.05	Oral Presentation
21.06	Singapore World RoboCup Rescue Finals

2009-2010

Competition

The competition consists of negotiating a simulated disaster environment to test the robots mobility, autonomy and range of sensors. Points can be scored in several ways, all of which involve finding and identifying victims. The breakdown of points is explained below.

$$\underbrace{\text{VICTIM SITUATION (5)} + \text{VICTIM STATE (15)} + \text{VICTIM TAG (10)} + \text{MAP QUALITY OF WALLS (10)} + \text{MAP LOCATION OF VICTIM (10)}}_{\text{50 POINTS POSSIBLE PER VICTIM FOUND}} - \underbrace{\text{ARENA/VICTIM BUMPING (10)}}_{\text{PENALTIES PER EVENT}}$$



Thermal imaging of victim

Competition Arena

The arena consists of 3 different areas:

YELLOW ARENA

For autonomous navigation and victim identification

- Random maze of hallways and rooms
- Continuous pitch & rolls ramps (15°)
- Directional victim boxes with and without holes

ORANGE ARENA

For robots capable of structured mobility

- Random maze of crossing pitch and roll ramps (15°)
- Stairs (45°,with 20cm risers)
- Ramp (45° with carpet)
- Pipe steps(20CM)
- Confined Spaces (50-80cm under elevated floors)
- Directional victim boxes with holes only

RED ARENA

For robots capable of advanced mobility

- Random maze of step-field pallets
- Directional victim boxes with and without holes

Victim with tag

Partially visible victim

Sensors

VICTIM IDENTIFICATION

Network web-cams provide the visible spectrum images back from the robot. These are used as the primary aid to driving the tele-operated robot.

Infra-red cameras detect areas of heat and display them in the visible spectrum using representative colours for the thermal range.

CO_2 sensors are used to measure the CO_2 concentration in the air. As the concentration rises the output voltage changes in proportion with the rise, producing varying voltage levels for different concentrations and thus a measurement of the ambient concentration.

AUTONOMOUS MAPPING TECHNOLOGY

LiDAR sensors use a laser to progressively scan the environment, measuring the time taken to receive the reflected light back to the device. Building a series of these data points will allow mapping of the environment and aid navigation.

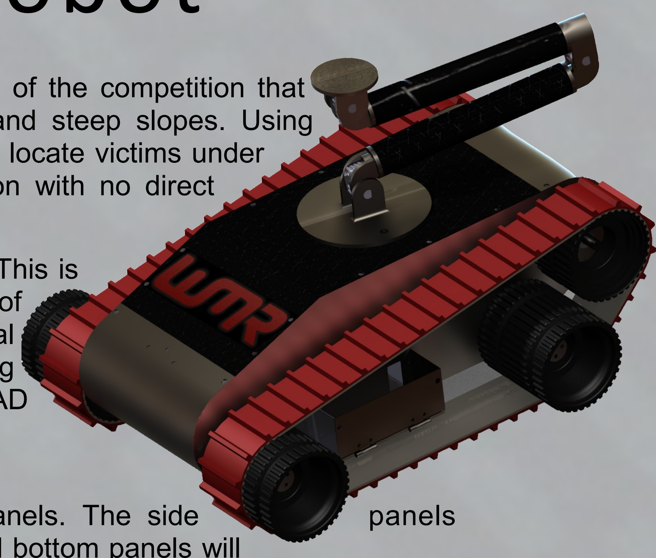
Tilt sensors are able to measure the angle of roll and pitch away from a zero datum at any given time. This is done using a three axis STM accelerometer and an on-board micro processor. As the robot pitches and rolls, the tilt sensor detects it and via software, feeds control pulses to the gimbal.

A **gimbal** counters those movements, thereby maintaining a level platform at all times regardless of the robot orientation. This stable platform is used to mount the LiDAR.

Tele-operated Robot

The tele-operated robot is designed for the sections of the competition that require good manoeuvrability over uneven terrain and steep slopes. Using large tracks and flippers it can negotiate obstacles to locate victims under the operation of a controller from a wireless position with no direct visibility of the robot.

Every component has been modelled in Solidworks. This is essential for establishing the optimum configuration of components (from the positioning of electrical components and wires to the optimum fan cooling arrangement). It is also necessary for creating the CAD files used directly in the laser cutting process.



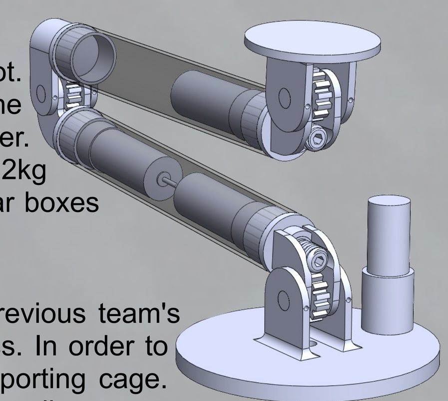
Tele-operated Robot

Chassis

The tele-operated chassis will be made from 6 panels. The side panels will be made from 0.9mm laser cut steel. The top and bottom panels will be made from 6-layer carbon fibre, made in-house. A main priority in the re-design of the tele-operated robot was weight reduction. Carbon fibre provides high strength to weight properties ideal for this application. This will offer a large weight reduction (approx 5kg) over the previous years design. The panels will be connected using rivet-nuts - allowing quick access to the internal components of the robot.

Arm design

A completely new arm has been designed for the tele-operated robot. This will offer greater mobility of the robot head, which supports the network camera, the IR camera, the CO_2 sensor and a simple gripper. The arm, made from carbon fibre tubes, has been designed to support 2kg at a reach of 1m. The arm makes use of Maxon Motors, planetary gear boxes and worm gears to provide the 5 degrees of freedom.

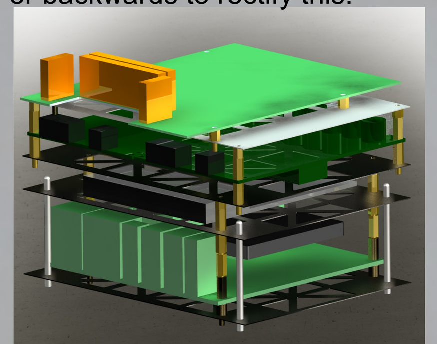


New robot arm design

Electronics

Access to the electronics, for upgrade and problem solving is key. Previous team's have found removal and insertion a very tricky and time costly process. In order to rectify this the electronics will be assembled in a stack, within a supporting cage. Some circuit boards have been removed and some rotated to allow *all* electronics to be in the cage. The base of the cage has a number of connectors (provided by HARWIN). When the cage is located on the retaining pins and placed into the robot, the connectors will mate thus connecting all the relevant sensors, motors and other components to the control electronics.

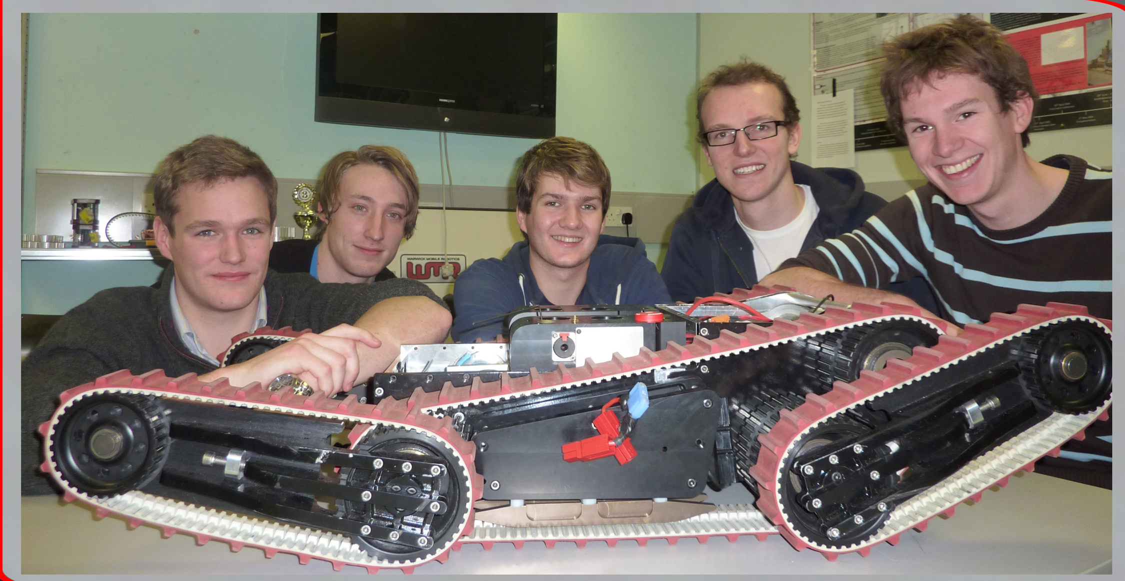
Individual control of each of the motors is key to accurately control the arm. To achieve this control each of the motors in the arm will effectively be turned into high power servomotors. Servomotors consist of four main parts: motor, gears, control circuitry, encoder (potentiometer). The control circuitry knows what position the motor is in by checking the voltage output from the potentiometer. If the servomotor is not at the correct angle, the control circuitry drives it forwards or backwards to rectify this.



Electronics Stack

Rapid Prototyped Robot Head

The robot head is attached to the end of the robot arm and houses the infrared camera, webcam, CO_2 sensor, microphone, speaker, LED light array, and fan. Its purpose is to protect these components from collisions and dirt in a modular and visually appealing way. The head is to be manufactured using the stereolithography rapid prototyping method. This method produces a finished part with intricate geometries, which is nearly identical to the CAD model, with the use of a high precision laser of 0.1mm resolution. A part can be produced within hours and the material is light, has a smooth surface finish and is non-permeable.



Autonomous Robot

During the initial stages of the project, a decision was made by the team to enter two robots, each specifically designed to meet the requirements of the zones in which they will compete. This meant designing and manufacturing an entirely new robot capable of self-navigation, mapping and indentifying the state and location of victims. In order to reduce the magnitude of the task, the robot was designed to use many of the existing spare components available to the team. In addition, the software design was largely outsourced to a team of Warwick University Computer Science students.

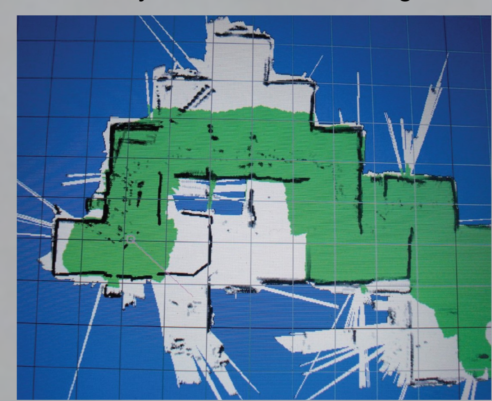
Autonomous Robot

Chassis

The autonomous robot is made of 0.9mm sheet steel, which is cut using a laser cutter based on a SolidWorks 2008 CAD model. The steel is formed into the desired shape using a sheet metal hand brake and secured using rivets. The robot design gives the computer science team flexibility to implement various hardware components necessary for autonomous operation, and is sufficient to master the relatively flat terrain during competition.

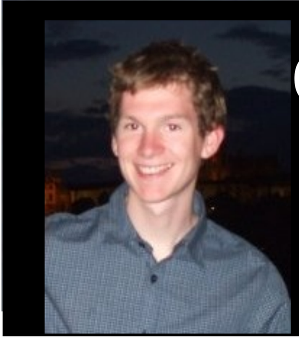
Electronics

A new internal computer was purchased for the robot to run the software and process the LiDAR data. The main sensor on the robot will be a LiDAR unit, allowing SLAM capabilities and fully autonomous navigation. SLAM (Simultaneous Location and Mapping) is the technique whereby the robot will build a map of its surrounding environment and keep track of its location. Using progressive LiDAR scans of the area in front of the robot as it moves, the software will create and update an internal map. This map can later retrieved for any subsequent navigation.



LiDAR mapping of competition arena

The main focus is on keeping the system as similar as possible to that of the tele-operated robot to ensure compatibility and porting of software between the two robots. This will make it possible for future teams to combine the capabilities of the two robots and create one fully-functional system.


Oliver Batley

Paul Davis

Aleksa Starovic

Oliver Mulcahy

Dean O'Shea

Tom Astley

Matt Winterbottom

THE UNIVERSITY OF WARWICK