Urban Search and Rescue Robotics

Warwick Mobile Robotics

Robotics for teleoperated rescue operations in unstable or unsafe environments

School of Engineering

The Team

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RoboCup Competition

RoboCup Eindhoven 2013

Below: WMR at last year's RoboCup

- Every year the WMR team enters The RoboCup Rescue, an international competition that tests robots' search and rescue abilities in a simulated disaster environment.
- Last year's team retained both the best mobility and best manoeuvrability titles due to the unique double flipper design.
- Building on previous year's knowledge and experience, this year the team aims to compete in the **World RoboCup Rescue 2013** championship in the Netherlands.

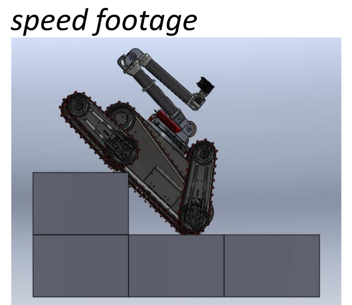
Sponsorship

- Obtaining funding and experience from sponsors has been key in allowing us to develop and improve the robot
- A partnership has been formed with Remotec, part of Northrop Grumman. Through this, expertise is shared and also in the future to use their testing equipment to see how the updated robot performs.

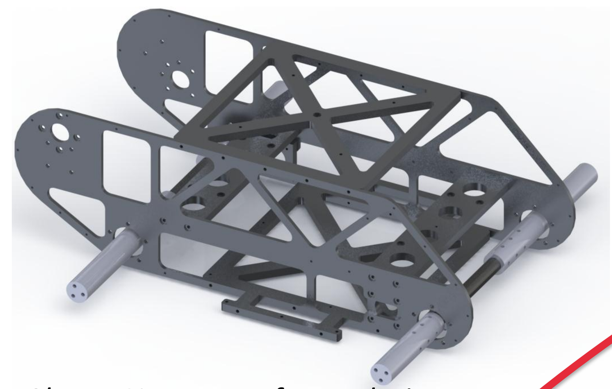
Outreach

- The team attended the Imagineering Fair in Coventry to promote WMR with other engineering companies (for potential sponsorship) and also to encourage engineering amongst young people.

Above: Clip from high speed footage



Above: SolidWorks simulation



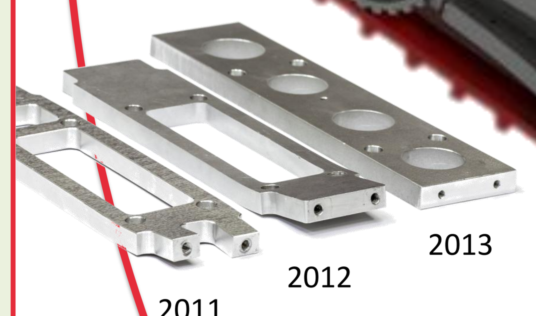
Above: New space frame design

Space Frame Design

This year a new design for the chassis has been developed as it was found that the old steel shell excessively twists and deforms under load. This led to vibrations which meant the camera and sensor feedback was of poor quality. The new space frame has been designed to cope with loads quantified during the testing and modelling phase. The chassis is 5 times thicker than the old design, however, using aluminium 6082-T6 (heat treated and aged) as the new material has reduced the overall weight by 35% and increased strength significantly. High Impact Polystyrene (HIPS) was chosen as the shell material due to its exceptional impact resistant properties, low price and ease of formability.

Flipper Clamps

Flipper motors are attached to the chassis using clamps which connect to both sides. Year on year clamp strength has proven to be an issue due to poor estimation of loading conditions. 2012 model clamps were found to be capable of withstanding 12kN of force. After analysing the data from the physical drop tests and calculating the force amplification down the flipper and its chain drive, the force on the clamp was found to be around 15kN. With this in mind, the team improved the design by using a higher tensile strength material (Al 6082-T6) and eliminating stress raising geometry.

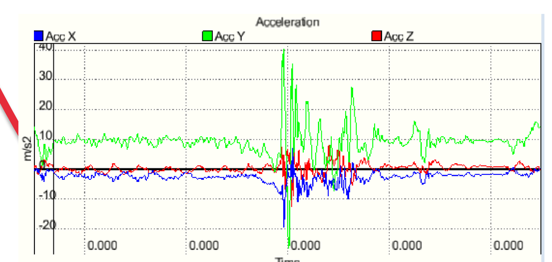


Above: Flipper clamp design evolution

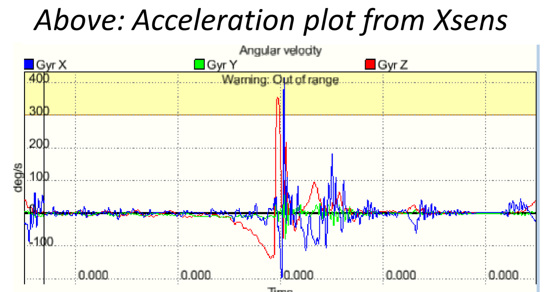
System Modelling and Testing

The team has simulated the robot performing at its limits in two ways:

- **Physical drop test** – using WMR's step fields, an Xsens accelerometer was attached to the robot and it was driven off different heights and inclines of the steps. This was filmed using a high speed camera so that the effects could be seen visually.
- **SolidWorks modelling** – the full assembly of the robot was simulated to drive off step fields in the programme. The graphs produced allowed analysis of the maximum forces and accelerations encountered on the robot.



Above: Acceleration plot from Xsens



Above: Angular velocity plot from XSens

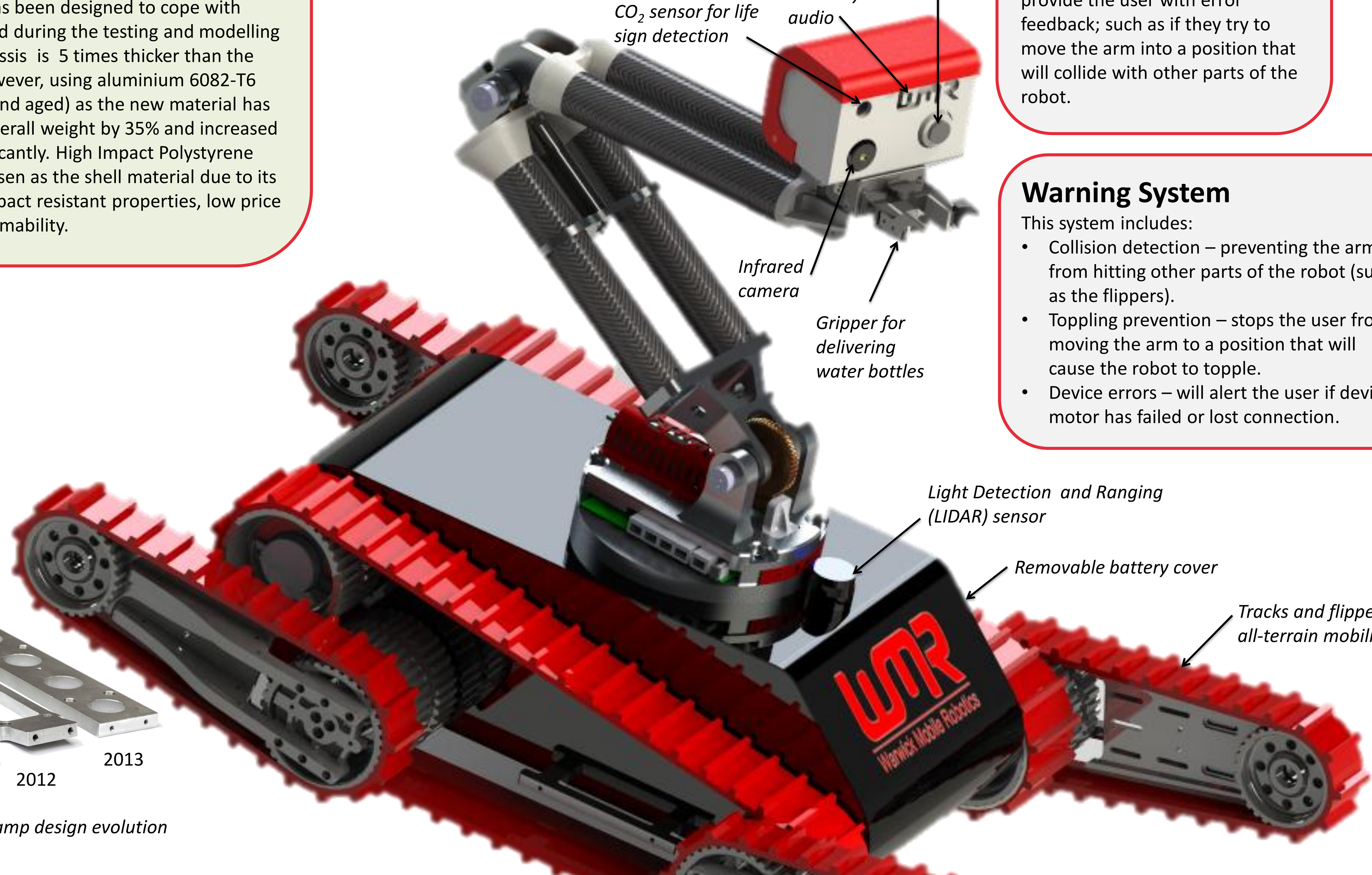
Head

ELECTRONICS

- A microcontroller will be introduced for switching and control of components.
- Infra-red camera and webcam will be maintained.
- The CO_2 op amp circuit has been redesigned with the inclusion of a filter to remove high frequency noise.
- The gripper placed on the underside of the head will be controlled by the microcontroller's specific PWM output.

DESIGN

- Weight saving (approx. 600g) by using a 3D printed shell and removing unnecessary devices from the head - maintaining strength and reducing vibrations.
- Enable quick and easy access to key components and electronics,.



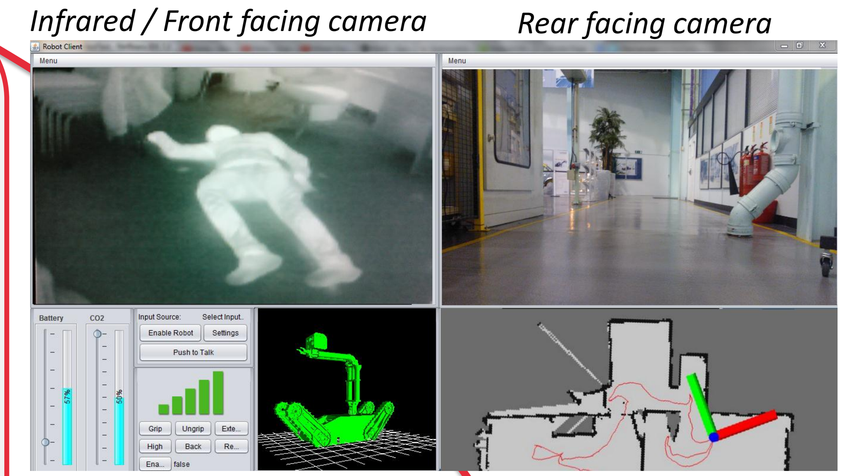
Inverse Kinematics

To make use of the arm intuitive, inverse kinematics models have been implemented. This will allow the user to 'fly' the head – where the movement of the arm is based upon where the head is looking.

3D Representation

The 3D representation of the robot will be a valuable tool to feedback information to the driver to help them understand the current position of the robot arm, flippers, Centre of Mass as well as the robots current orientation in space. This is important as the driver is in a remote location from the robot. The model will also provide the user with error feedback; such as if they try to move the arm into a position that will collide with other parts of the robot.

Infrared / Front facing camera *Rear facing camera*



Sensor readings *3D model* *LIDAR generated map*

Mapping

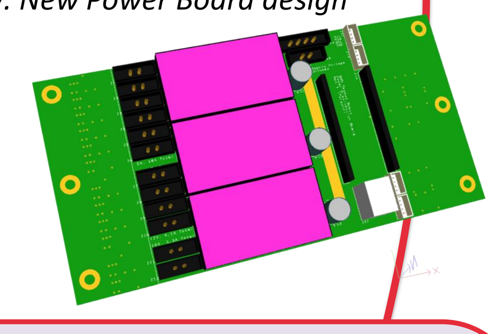
A LIDAR (Laser Detection and Ranging) sensor can be used to build a map of the robot's surroundings using a Simultaneous Localisation and Mapping (SLAM) algorithm. This involves comparing each LIDAR scan to the previous one and combining them based on similar features detected. This allows an offset to be calculated and robot position in the map to be determined. Such a map would be very useful in a disaster scenario, for example, it could be used by emergency responders to locate victims marked on the map by the robot.

Warning System

This system includes:

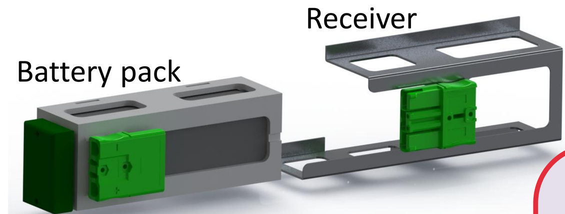
- Collision detection – preventing the arm from hitting other parts of the robot (such as the flippers).
- Toppling prevention – stops the user from moving the arm to a position that will cause the robot to topple.
- Device errors – will alert the user if device/ motor has failed or lost connection.

Below: New Power Board design



Power Board

The old power distribution board is too large to fit in the redesigned chassis. The new power board is more compact, uses high-reliability Harwin connectors and clearly labels the available voltages and polarities to make connecting devices simple. The power supplies have also been upgraded from 30W to 50W to ensure reliability even under heavy load.



Above: New battery enclosure

Battery enclosure

A new battery pack has been designed which allows batteries to be easily inserted and removed from the robot. Batteries are now located at the front of the robot rather than the sides, allowing it to safely traverse puddles and loose dirt.

Battery Monitoring

Previous years had only used an external alarm unit to warn users when a cell's voltage was too low, which did not provide any information to the operator station. A new battery management circuit has been designed which will protect against both over- and under-voltage, short-circuit and excessive discharge current. The circuit also includes a fuel-gauge that tells the robot how much charge remains in the battery.

Timeline

- 1.10.12 Project Commences
- 4.10.12 SWOT Analysis Conducted
- 10.10.12 Initial Testing using WMR step fields
- 20/21.10.12 Imagineering Fair
- 31.10.12 Remotec Visit
- 8.11.12 Drop Testing with Xsens accelerometer
- 13.11.12 Battery Enclosure Designs finalised
- 20.11.12 Dynamic Systems Analysis
- 26.11.12 Head Enclosure Designs Finalised
- 6.12.12 Chassis Designs submitted for manufacture
- 18.1.13 Head Electronics Finalised
- 23.1.13 Shell Designs Finalised
- 25.1.13 Battery Monitoring Electronics and Power Board Finalised
- 29.1.13 Inverse Kinematics Code Finalised
- 5.2.13 Mapping Software and GUI Completed
- 2.5.13 Report Submitted
- 6.5.13 Group Presentation
- 24-30.5.13 World RoboCup Competition

Aims and Objectives

The aims are:

- To enter the 2013 Robocup World Rescue Championships in Eindhoven, Netherlands
- Improve the robot's reliability and ease of maintenance
- Progress the design from the current prototype model towards a viable commercial product
- To assess the possibility of WMR becoming its own entity and make the platform viable for commercial release.

To achieve these aims the team must:

- Raise enough sponsorship to enter the Robocup Rescue World Championships
- Remove any weaknesses identified over the past year with the tele-operated robot
- Improve upon the current electronics, mechanics and software
- Test the robot in a more real world situation by utilising external testing facilities.