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Competing in the RoboCup Rescue Robot League

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RoboCup Rescue is an international competition in which robots compete to find disaster victims in a simulated earthquake environment. It features both a Rescue Simulation League (RSL) which is entirely computer simulated, and a Rescue Robot League (RRL) with real robots and a test arena. This paper will describe the experience gained sending an undergraduate team to compete in the Rescue Robot League at the RoboCup German Open in 2008 and 2009. The design of the test arena and the rules of the competition will be outlined; as will the approaches taken by different teams; and the competition results.

Introduction

The RoboCup Rescue Robot League is a competition for Urban Search and Rescue robots – robots designed to locate survivors in an earthquake-damaged building. Robots score points by locating simulated victims in a number of 'zones', such as a yellow autonomous operation zone, a red high mobility zone, and others. In some zones robots may only score by operating entirely autonomously, while in other zones teleoperation is permitted. Mapping is rewarded in all areas of the course.

Rescue Robot League competitions take place as part of several RoboCup competitions; in 2009, open competitions were held in Iran, Germany and Japan; while the RoboCup world championship – which is held in a different country each year – was held in Austria.

The test arena design and competition rules are organised by the American National Institute of Science and Technology (NIST). Among other things, NIST define standards and test criteria for urban search and rescue robots, to provide guidance to rescue organisations in the US. RoboCup Rescue both allows competitors to test their robots, and allows organisers to test their test standards. As a result of this, though the core requirements of the competition are consistent from year to year, new challenges are regularly added.

Competition Rules

Competitions start with several preliminary rounds, in which every team competes. In each round, each team performs a 20 minute 'mission', exploring the maze with their robots, attempting to identify as many victims as they can. Teams may run as many robots as they like simultaneously, but only one human operator is permitted.

Operators may look at the course beforehand, including knowing the positions of victims in advance, but operators have no view of the course or their robot while the mission is in progress.

After the preliminary rounds (of which there are usually 4 or 5), the total number of victims found by each team is used to select the teams to compete in the finals. The finals use a more nuanced scoring system, taking into account the number of signs of life detected (Form, motion, heat, sound, CO2), the detail level provided by the sensors, and the quality of the map produced.

Two additional awards are available; the best in class autonomy award, for the robot finding the most victims autonomously, and the best in class mobility award, for the robot finding the most victims in the red area of the course.

Arena Design

Competition test arenas are constructed from 1.2m x 1.2m 'tiles', with an obstacle on each tile. This may be as simple as a 10° slope, or as complicated as a 45° staircase. The arena at one recent competition was constructed from 35 tiles, and measured 10m x 6m. Course edges and divisions are created with vertical wooden

Figure 1 - Test course used in 2008 German open competition. To the top of the picture, the yellow autonomous area can be seen; at the center and bottom the red area can be seen, including full cubic step fields and a 45° ramp; to the lower right, two orange half-cubic step fields can be seen; to the upper right, the blue pick and place area can be seen. No radio drop-out zone was present at this competition.

'walls' 1.2m high. In some competitions these are smooth and vertical; in others they may slope or have non-smooth features.

The arena 'tiles' are arranged into five colour-coded areas.

The yellow area is the simplest to traverse. The floor has 10° slopes throughout, and the area may feature dead ends and a figure of eight. The slopes are arranged so that there are no steps up or down, except at the edges of the yellow area. Victims in the yellow arena may only be scored by robots operating autonomously.

At the 2009 German open, the yellow area victims were visible through an opening approximately 150mm high and 400mm wide; at the 2009 world championships some victims were harder to see.

At the edges of the yellow section, where other sections start, there may be obstacles such as downward steps. The operator can intervene to stop the robot at these points, but after the operator intervenes, no further autonomous-only victims may be scored in the mission.

The orange area of the course presents intermediate-difficulty mobility challenges, and can be scored by all robots, be they autonomous or teleoperated. Orange area victims are located through 150mm diameter holes, requiring directed perception and illumination to see inside.

Obstacles in the orange area include 15° slopes, which may have steps between them; stairs; a 45° carpeted ramp; and half-cubic step fields.

Step fields are obstacles constructed from unsecured wooden blocks packed between four fixed borders. This means of attachment leaves the blocks loose, to simulate rubble, but allows for a repeatable course configuration by using a standard arrangement of blocks. Competition step fields take two forms; half-cubic step fields, containing blocks from 25mm high to 200mm high; and cubic step fields, containing blocks from 50mm high to 400mm high.

The red area of the course is the most complicated to traverse. It contains full cubic step fields, and victims located through 150mm diameter holes.

In some competitions, the stairs and 45° ramp were part of the red area; in more recent competitions they have been moved into the orange area.

The blue area of the course tests robots' manipulators, by providing a number of payloads which can be lifted and moved for additional points. These include wooden cubes with loops on the top (measuring 90mm on each side), small radios, and plastic 500ml water bottles, on surfaces 500mm or 1000mm from the floor.

The blue area is a recent addition to the test arena; currently the manipulation tasks carry a score equal to finding two victims, but this may be revised in the future.

The yellow/black area of the course is known as the radio drop-out zone, and must be traversed autonomously; but it can only be accessed by crossing orange or red mobility obstacles. It is intended to encourage robots which combine autonomy with high mobility. At the 2009 German open the radio drop-out zone consisted only of inclined planes; at the 2009 World championship, blocks simulating rubble were also present.

Two victims, who may be scored autonomously or through teleoperation, are located past the radio drop-out zone.

Some additional obstacles have been introduced to the course; in some missions at the 2009 German open, newspaper was strewn across all zones of the course; this increased wheel slip, and one robot was disabled by paper drawn into its tracks' drive pulleys.

At the 2009 world championship, a full size Renault Clio was placed in the course, between the yellow and red areas. While robots in the yellow area had to drive around the front of the car, robots in the red area could find two victims hidden in the rear of the car.

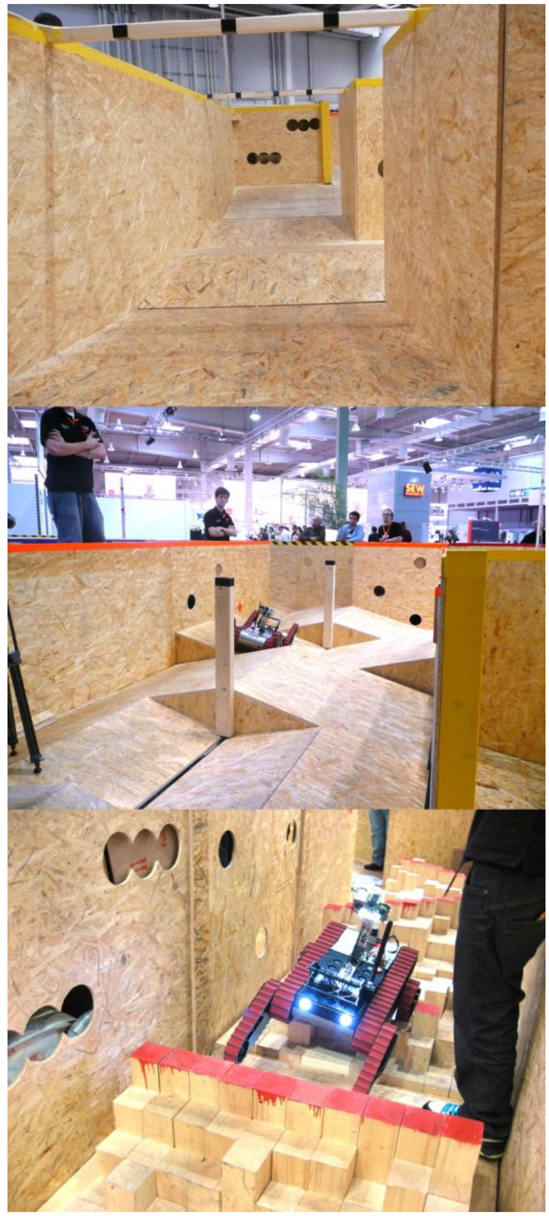


Figure 2 - Yellow (top), orange (middle) and red (bottom) areas at the 2009 German open competition.

Simulated victims are distributed throughout the course, with four in each of the yellow, orange, and red areas, two in the radio drop-out area, and the equivalent of two victims for completing the blue area manipulation tasks.

The simulated victims take the form of dolls, with heat, sound and CO2 sources. Some victims may also display motion. A hazardous material sticker and a vision system test sticker are placed near each victim, to evaluate the robot's image detection capabilities.

Robot designs and approaches

Different teams approach the competition differently, with some teams focusing more on mechanical design and mobility, while other teams are more interested in autonomy. Many teams are active in both areas, and some teams operate an autonomous robot and a mobility robot at the same time.

Several teams use the competition as a test arena and development deadline for their own objectives, rather than aiming to maximise the number of victims found. For example, a team might prefer to find one victim autonomously instead of finding two victims under teleoperation.

Standard robot platforms

Some teams choose to use an off-the-shelf robot platform; Universität Paderborn's GETbot and Universität Koblenz-Landau's Resko are both based on the Pioneer 3 AT platform; Universität Darmstadt's robot is based on a remote control model car. Despite being restricted to the yellow area of the test arena, Universität Koblenz-Landau won the 2009 German open competition, finding more victims than any other team.

Off-the-shelf platforms are not restricted to autonomous robots; at the 2009 world championships, Team CASualty from the University of New South Wales and the University of Technology, Sydney fielded a Fraunhofer IAIS Volksbot, and an iRobot Negotiator, coming joint first for "Best in class autonomy" with the former and placing second in "Best in class mobility" with the latter.

Custom robot platforms

Of the high-mobility robots, most of which are specially designed for the competition, the most common design employs tracked flippers.

Robots using a single pair of flippers are operated by Team CASualty, Thai team iRAP_PRO, and Iranian team YRA.

Robots using two pairs of flippers are operated by iRAP_PRO, Japanese teams NIIT Blue and Pelican United, Iranian teams Pasargad and Resquake, Austrian team Robo-Rescue-Team, and British team Warwick Mobile Robotics (WMR).

Unconventional robots with flipper-like designs include Iranian-Malaysian collaboration AriAnA & AVA which combines a flat tracked flipper with a triangular tracked flipper; and Iranian team MRL, which uses a single triangular flipper.

Several other designs have been used in RoboCup Rescue robots. The Mexican robot Cuerbot, which has a design based on the Fraunhofer IAIS VolksBot XT, uses six wheels, four of which are mounted on a pair of arms. Robots fielded by German team Jacobs Robotics, have a large tracked body and an adjustable rear 'wheelie bar' which can be lowered when ascending steep slopes. Mesa Robotics demonstrated their Matilda robot base, a wedge-shaped tracked robot with neither flippers nor a wheelie bar.

Robot arms

In the competition's orange and red arenas, victims may only be visible through a 150mm diameter hole, which can be anything from 170mm to 900mm above the floor. Several robots are fitted with arms to position sensors at these openings.

Some of these arms are comparatively simple; Team CASualty use a single-segment arm with one rotational joint at the base and a pan/tilt head. More complicated designs include iRAP_PRO, which has two rotational joints at its base, a rotational elbow, a prismatic forearm, and a roll/tilt head; and AriAnA & AVA, with a two-segment arm carrying a pan/tilt head with a second roll/tilt head attached to it.

Jacobs University have experimented with fitting robots with off-the-shelf Neuronics Katana robot arms.

Sensors for mapping

Due to the requirement to produce a 2D occupancy grid map of the arena, and the fact the arena is sloped throughout, many teams have LIDARs mounted on gimbals, allowing them to

Figure 3 – A gimballed LIDAR used on Universität Koblenz-Landau's Resko robot.

be kept flat when traversing pitch and roll ramps. MEMS accelerometers are employed to detect the robot's pitch and roll to perform this compensation. At present, the majority of teams use Hokuyo URG-04LX and UTW-30LX LIDARs, though some larger robots use SICK sensors. The small Hokuyo sensors can be gimballed using servo motors, with Hitec and Dynamixel two popular suppliers.

Some teams, such as Jacobs University and Team CASualty also gather range data with Mesa SwissRanger 3D cameras.

Many robots are also fitted with ultrasound distance measurement sensors. Though the current test arena does not include many light reflective or absorbent surfaces, the addition of such sensor obstacles is often discussed. Most robots also use odometry, although odometry is less reliable in the mobility sections of the course, where track or wheel slips can occur.

Sensors for victim identification

Video cameras are widely used, although for different reasons; teleoperated robots use video for operator feedback, while some autonomous robots use machine vision to recognise victims. Uppsala Universitet use omnidirectional vision with a spherical mirror, while Jacobs University employ stereo vision.

Due to the directed vision requirements of the course, most robots either have arm-mounted cameras, or have cameras able to pan and tilt.

Thermal cameras are also popular for victim identification, particularly on autonomous robots. Small cameras which do not require active cooling, such as FLIR Micron and ThermalEye OEM cameras, are most widely used. A few robots avoid thermal cameras - Uppsala Universitet use four Devantech TPA 81 Thermopile array sensors, scanning them horizontally through 180°, and iRAP_PRO use a Raytek Thermalert IR temperature sensor.

Simulated victims include sound sources, and many robots include a microphone and speaker system. However, competitions are often held in noisy environments, making identification of victims by sound alone impractical; as such microphones are usually used as a secondary means of victim identification only.

CO_2 sources are also placed by each simulated victim, and some robots carry CO_2 sensors as a secondary means of victim identification.

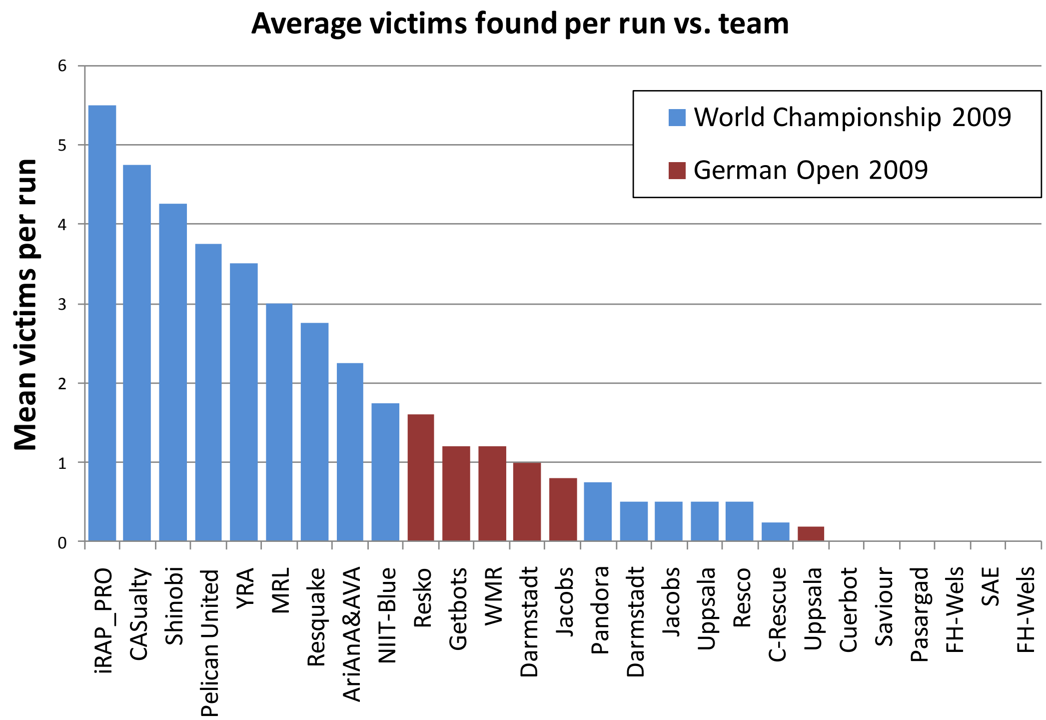
Competition results

The preliminary rounds of competitions, in which all teams are represented, offer the simplest comparisons between teams.

In the 2009 German open, 7 teams were present, and in the preliminary rounds 5 missions were performed by each team. Resko, who would go on to win the competition, scored 8 victims in 5 missions, an average of 1.6 victims per mission. Getbots and WMR, who would place second and third respectively, both scored 6 victims, or 1.2 victims per run. The four remaining teams averaged 1.0, 0.8, 0.2 and 0.0 victims per run.

The preliminary rounds were followed by finals, in which Resco won first place, Getbots second, and WMR third. Best in class autonomy was awarded to Resco, while best in class mobility was awarded to WMR.

At the 2009 world championships 20 teams were present, and 4 preliminary missions were performed by each team. iRAP_PRO, who would go on to win the competition, scored an average of 5.5 victims per run; 6 teams averaged 3 or more victims per run; and 9 teams averaged at least 1 victim per run. Resco, who won the German open, autonomously locating 1.6 victims per run, scored only 0.5 victims per run in the more complicated world championship autonomous area.



After the semi-finals and finals, iRAP_PRO placed first, Pelican United second, and MRL third. Best in class mobility was won by Pelican United, with Team CASualty second and Shinobi third. Best in class autonomy was won by Team CASualty, with Pelican United second and RRT Uppsala third.

Discussion

It has been our team's experience that competing in the RoboCup Rescue Robot League provides a useful means for testing robots' autonomy and mobility capabilities. The particular benefits derived include:

- The NIST-designed test methods have been developed to represent the demands placed upon urban search and rescue robots in the real world; and have been developed in collaboration with rescue robot users.
- Fixed competition dates encourage good project planning, and discourage the project from falling behind schedule.
- The competition provides a more extensive set of tests and challenges than space constraints would allow us to organise ourselves.
- The independently designed and administered tests ensure fair evaluation of robots' capabilities, by ensuring tests represent real-world requirements and that test protocols are reliably followed.

However, the earthquake-damaged building simulated by the competition arena is in some ways not representative – for example, there is no water, sand, mud, dust, or gravel to contend with. A team concerned with such obstacles could devise their own tests in those areas, in addition to the competition.

Conclusions

The RoboCup Rescue Robot League is an international competition for urban search and rescue robots, organised by NIST as part of RoboCup competitions. Robots compete to locate simulated disaster victims in a test arena which simulates an earthquake-damaged building. The test arena contains areas suitable for both autonomous and teleoperated robots.

A variety of robotic platforms are used by the competition's competitors, with tracked-flipper designs popular among teams aiming for high

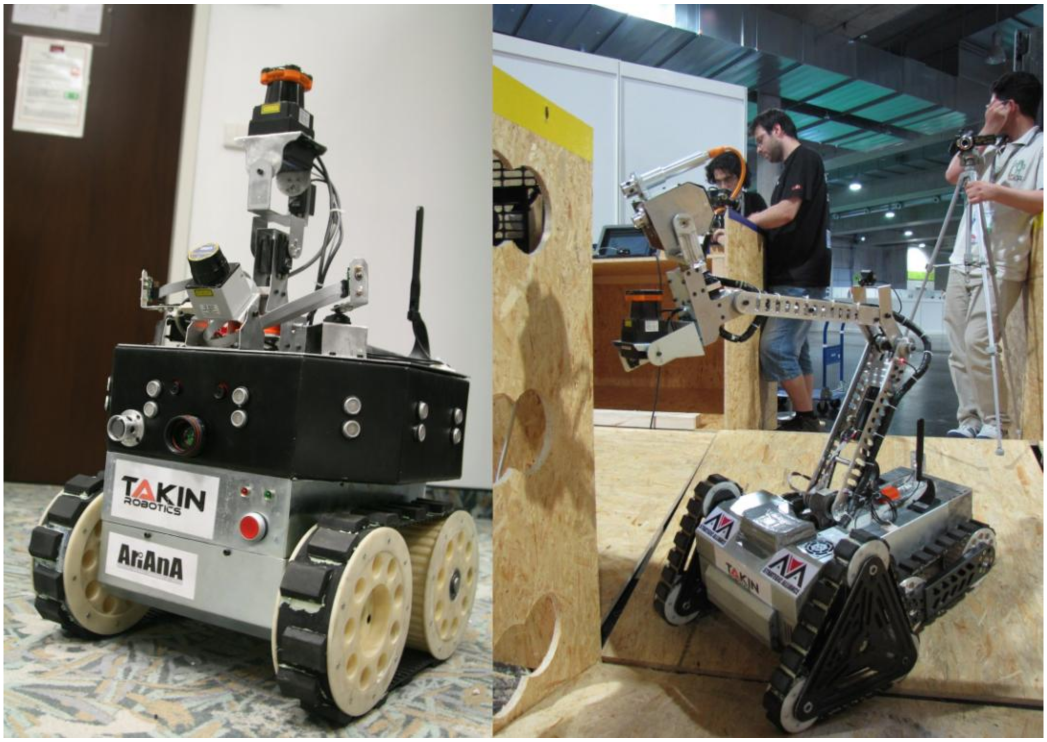


Figure 4 - Robots fielded by team AriAnA & AVA; one autonomous (left) and one high mobility (right)

mobility, but several other designs also present. Some sensors are common to almost all robots, including video cameras, gimballed LIDARs, MEMS inclinometers; and thermal cameras.

Acknowledgments

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Several photographs in Appendix A were generously provided by Amir Hossein Soltanzadeh of team AriAnA.

Appendix A: Robot Designs

The teams and robots seen at RoboCup Rescue Robot League competitions in 2009 include:

AriAnA & AVA

A joint team from Iran and Malaysia, AriAnA & AVA use two robots, shown in Figure 4. The left robot is fitted with a gimballed LIDAR supported by two servo motors, and an inclined LIDAR at the front. At the front left and right are TPA81 Devantech thermal sensors, which can be panned by servo motors. An orange Xsens MTI Inertial Measurement Unit (IMU) can be glimpsed on top of the robot, below the LIDAR gimbal.

The team's high mobility robot, shown on the right, has distinctive triangular flippers (Mahbadi2009, Sharifah2009), along with a rear set of standard flippers, both with wide-toothed tracks. No fixed tracks are present on the robot's body. The robot features an arm with rotational base and elbow joints; and the head includes a pan/tilt sensor head and a roll/tilt LIDAR gimbal.

In addition to a camera in the front of the sensor head, small cameras can be seen on the rear of the head and at the elbow; these offer improved views to the operator when guiding the sensor head to look through openings, and when driving backwards.

As with the team's autonomous robot, an orange Xsens MTI IMU can be seen atop the robot.

The team competed at the 2009 World Championships, finding on average 2.25 victims per mission, qualifying for the competition's semi-final.

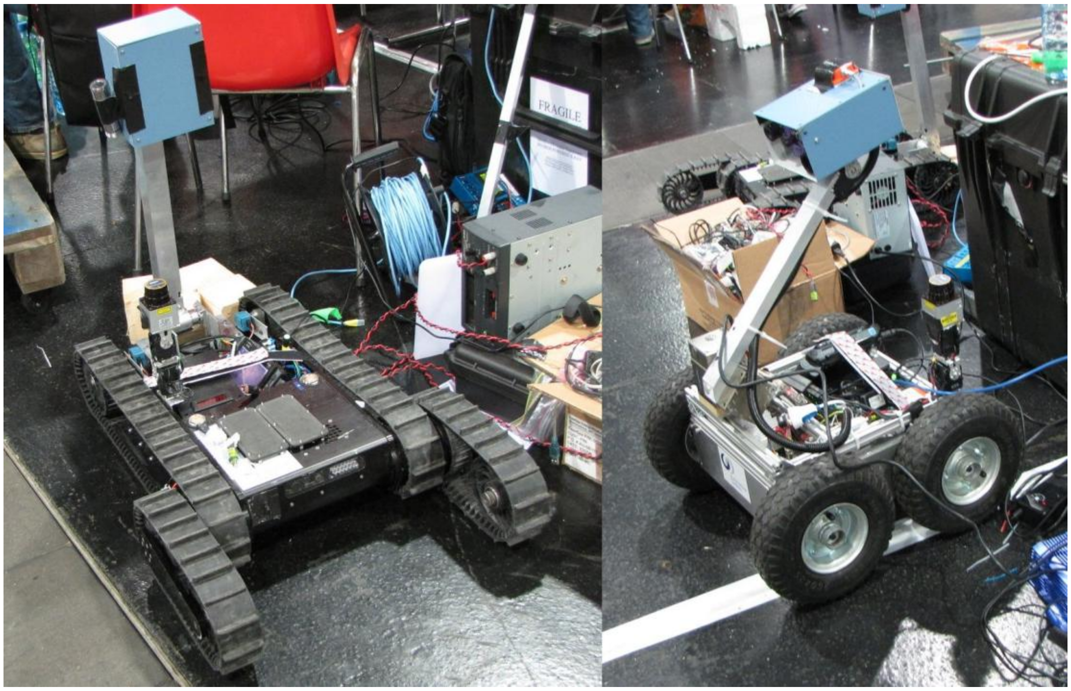

Figure 5 - Robots fielded by Team CASualty; an iRobot Negotiator (left) and a Fraunhofer IAIS Volksbot (right)

CASualty

Comprised of members from the University of New South Wales and the University of Technology, Sydney, Team CASualty took two robots to the 2009 world championships; an iRobot Negotiator and a Fraunhofer IAIS Volksbot (Sheh2009), shown in Figure 5.

The iRobot Negotiator features a single set of tracked flippers, and fixed tracks on the body of the robot. The tracks have narrow teeth.

Both robots are fitted with LIDARs gimballed with servo motors, and single-segment arms carrying pan/tilt sensor heads.

The right robot's sensor head carries a CSEM SwissRanger SR3100; a ThermoVision Micron IR camera; a video camera; and an Xsens MTI heading/attitude sensor.

Team CASualty competed in the 2009 world championships, identifying an average of 4.75 victims per run in the preliminary stages, placing first in best in class autonomy and second in best in class mobility.

C-Rescue

C-Rescue from Chukyo University attended the 2009 World Championships with the robot 4Legs, a walking robot with tracks on the final sections of each leg (Shimizu2009).

The robot, shown in Figure 6, includes three rotational joints and one track on each leg, and a prismatic arm with a pan/tilt base and head. 21 motors are employed to achieve this motion; 4 servo motors per leg, 2 servo motors at the base of the arm, 2 servo motors at the head of the arm, and one motor to extend the prismatic arm.

The robot sensor head carries two cameras, a CO_2 sensor, a temperature sensor and a microphone. The robot also carries a 3-axis accelerometer and compass. C-Rescue is one of the few robots not to carry a LIDAR.

C-Rescue attended the 2009 world championships, averaging 0.25 victims per run in the preliminary rounds.

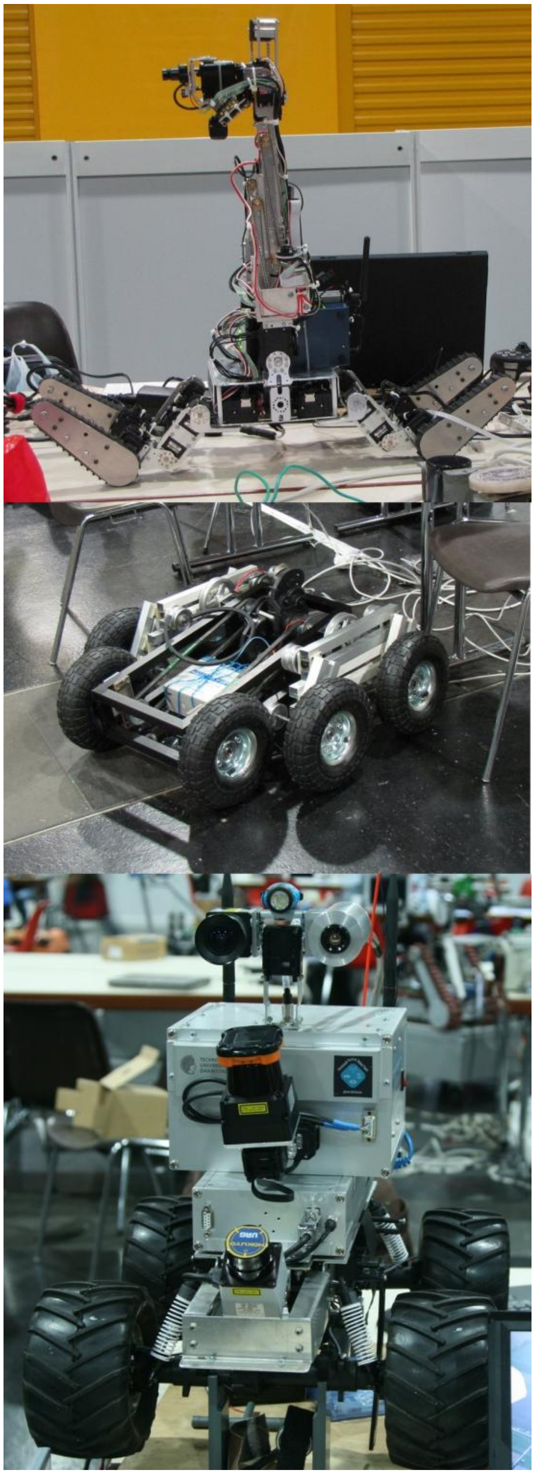

Figure 6 - C-Rescue (top), Cuerbot (middle) and Darmstadt (bottom) robots.

Cuerbot

Cuerbot, is a six-wheeled robot developed at Instituto Tecnologico de Nuevo Leon and Universidad TecMilenio, Las Torres.

The robot, shown in Figure 6, is based on a six-wheeled Fraunhofer IAIS Volksbot XT robot (Lopez2009). On each side are three wheels, one fixed to the main chassis and two fixed to a rotatable arm, allowing the robot to raise the front wheel while lowering the middle wheel, such as to ascend a step.

The robot carries cameras, CO_2 and temperature sensors, as well as a MEMS accelerometer.

Cuerbot competed at the 2009 world championships, but did not score any victims.

Darmstadt Rescue Robot Team

Darmstadt RRT, from Technische Universität Darmstadt, Germany, took part in both the 2009 German open and the 2009 world championships with their remote control car based robot, Monstertruck.

The Kyosho Twin Force radio controlled car base, shown in Figure 6, has four wheel drive and steering, with a single drive motor and steering servos front and back (Andriluka2009). Two LIDARs, one inclined and one gimballed with servo motors, are fitted to the front of the robot; and an Analog Devices ADIS16350 IMU and a Hitachi HM55B compass are used, along with odometry, for position estimation.

Victim identification is performed with machine vision to recognise hazardous material labels, and confirmed with a ThermalEye 3600AS thermal camera. Both victim identification cameras can be tilted with a servo motor.

At the 2009 German open Darmstadt RRT scored an average of 1 victim per run, while at the 2009 world championships they scored an average of 0.5 victims per run.

GETbot

GETbot, produced by Universität Paderborn, Germany, is based on a Pioneer P3-AT mobility platform.

The robot, pictured in Figure 7, carriers a thermal camera and video camera on a servo

Figure 7 - GETbot (top) and iRAP_PRO (middle and bottom) robots.

motor pan/tilt mount, and a LIDAR on a pitch/roll gimball. An Xsens MTI IMU, combined with odometry, provide the robot's pose estimation.

GETbot competed in the 2009 German open, scoring an average of 1.2 victims per run, taking second place.

iRAP_PRO
Thai team iRAP_PRO, from King Mongkut's University of Technology North Bangkok (KMUTNB), Thailand, attended the 2009 world championships with three robots (Uschin2009).

Two of the team's robots are shown in Figure 7; one with a single set of tracked flippers and one with two sets of tracked flippers. Both robots also have fixed tracks on the body of the robot. Each track is comprised of a steel chain attached to aluminium u-section segments, with cylinders of hosepipe attached to form closely packed medium-sized teeth.

Both robots have arms featuring two rotational joints at the base; a rotational elbow; a prismatic forearm; a roll/tilt head; and a two-pronged gripper.

The third iRAP_PRO robot, designed for autonomous operation, has a tracked design without flippers and with no arm.

Sensors used for navigation include a compass, a three-axis accelerometer, and an IR displacement sensor. All three iRAP_PRO robots carry LIDARs, raised on poles atop the robot, without gimbals.

For victim identification, video cameras are used, along with an IR temperature sensor, a CO_2 sensor, and a microphone.

Small additional cameras are also fitted to the robot; cameras facing forward and backward are present on the LIDAR support pole, and a camera fitted on the forearm helps guide the sensor head into tight spaces.

iRAP_PRO competed in the 2009 world championships, scoring an average of 5.5 victims per run to take first place in the competition.

Jacobs Robotics
Jacobs University (formerly called International University Bremen) operate three robots built on their Rugbot platform (Schwertfeger2009).

The Jacobs robots use rubber tracks with widely-spaced teeth, wrapped around large pulleys. The large pulleys allow the Jacobs robot to ascend steps without lifting itself with flippers. The robots employ a rear flipper as a 'wheelie bar' to allow the robot to ascend stairs. However, while most robots in the competition have toothed,

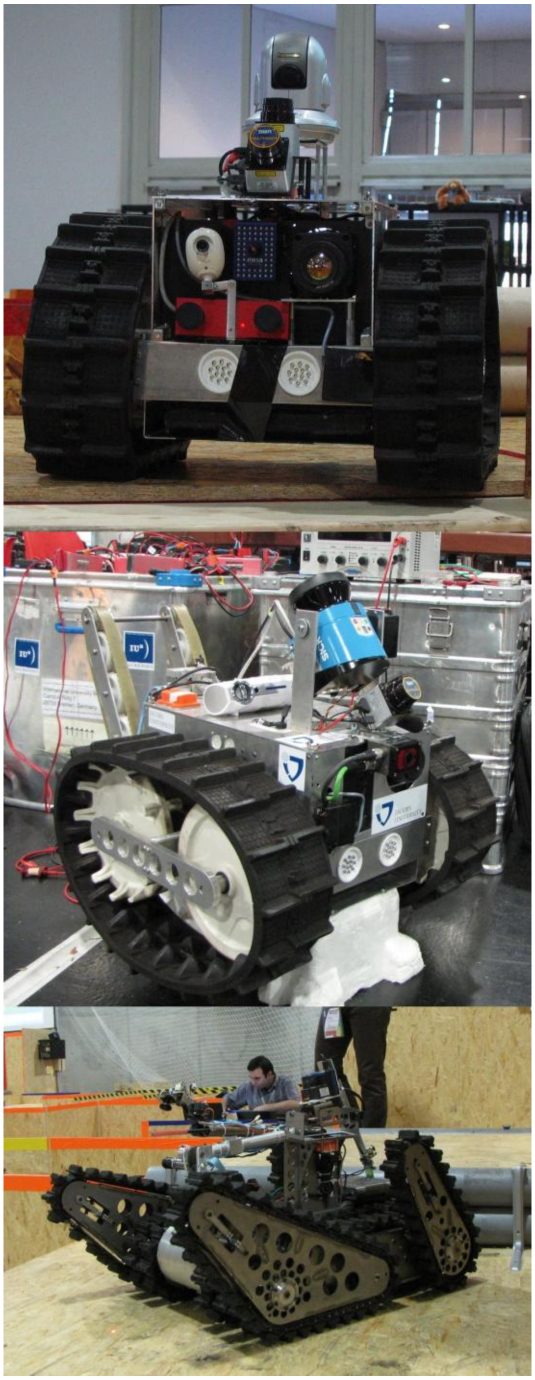

Figure 8 - Jacobs University (top, middle) and MRL (bottom) robots.

driven tracks on their flippers, with the flippers the widest part of the body, the Jacobs robot's rear flippers are not driven, do not have teeth, and are narrower than the robot's main tracks. This design is shown in Figure 8.

The three Jacobs robots are equipped with different sensors, as can be seen in Figure 8. The top robot is equipped with two non-gimballed LIDARs, one flat and one inclined, a pan-tilt-zoom camera, a thermal camera (FLIR A20), a stereo camera, and a CSEM SwissRanger. The middle robot, on the other hand, carries a large blue SICK S300 LIDAR (tilted by a servo motor), an inclined LIDAR, a thermal camera, and a set of loudspeakers. Both the robots shown carry Xsens MTI sensors for positioning, and gather odometry.

CO_2 sensors are present on both robots, and machine vision can detect victims by shape, by motion, and by hazardous material stickers.

Jacobs University attended both the 2009 German open and the 2009 world championships; at the former they scored an average of 0.8 victims per run, while at the latter they scored an average of 0.5 victims per run.

MRL

MRL, from the Azad University of Qazvin, Iran, fielded two robots at the 2009 world championships; a four-wheeled robot designed for the autonomous section, and a high mobility robot designed for all areas of the course (shown in Figure 8).

The high mobility MRL robot uses front and rear tracked flippers, and fixed tracks running down the length of the body (Shahri2009). While the rear flippers use a conventional flat design, the front flippers are triangular. The tracks follow a similar chain-backed construction to iRAP_PRO, in this case with a flexible rubber layer and medium-spaced rubber teeth atop that. The robot also features an arm with rotational base and elbow joints, and a pan/tilt head.

For navigation, the MRL robot carriers a gimballed LIDAR and an Xsens MTI IMU, and includes cameras, sonar, and odometry.

In addition to a camera on the robot's pan/tilt arm, the robot carries forward and backward facing cameras on a small rear pole, and has a pan/tilt/zoom IP camera mounted on the main chassis.

For victim identification, machine vision is used for motion detection and face recognition; and a thermal camera and microphone allow the detection of heat and sound respectively.

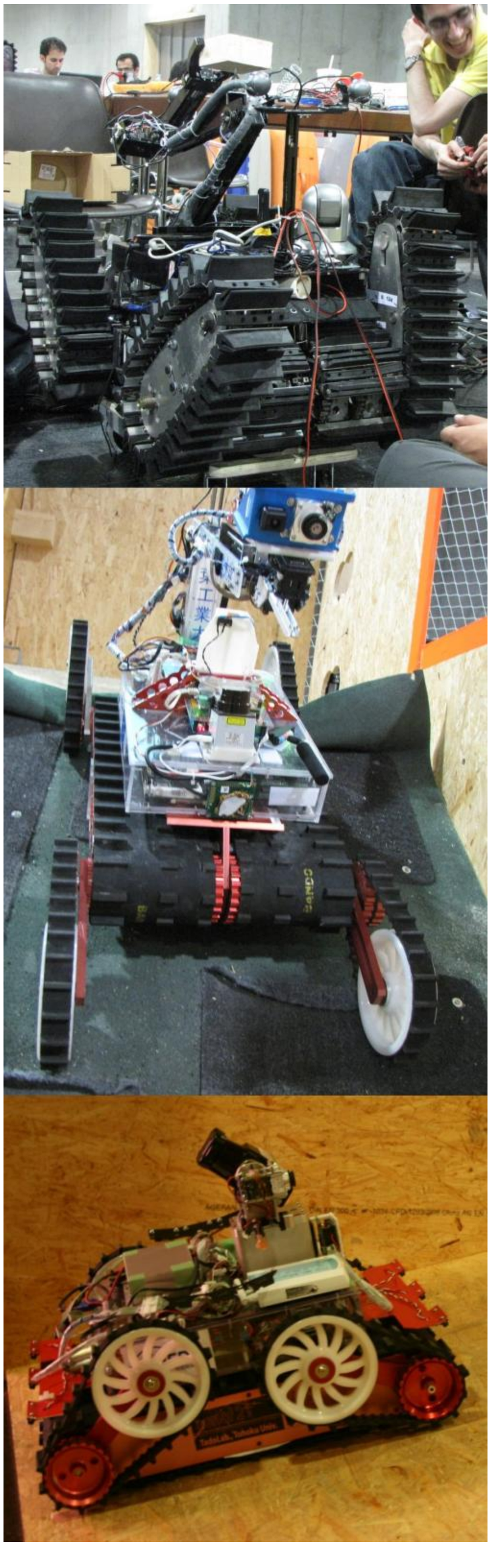

Figure 9 - Pasargad (top) and Pelican United (middle, bottom) robots

MRL’s four-wheeled autonomous area robot was similarly equipped, with a gimballed LIDAR, IMU, odometry and sonar.

MRL competed at the 2009 world championships, finding an average of 3 victims per run in the preliminary rounds, and placing third overall after the finals.

Pasargad

Pasargad, from Amirkabir University of Technology, Iran, took part in the 2009 world championships with their robot ASAME 2, shown in Figure 9.

The robot features four tracked flippers, and tracks running the length of the body (Ravandi2009), which also cover the entire width of the body. The tracks are similar in style to the iRAP_PRO tracks, backed by metal chains, with aluminium u-section bars supporting thin, fin-like rubber teeth. The robot includes a three-segment arm, with sensors on the middle segment and a two-prong gripper on the top segment. In some configurations the robot also has a rear vertical bar with left- and right-facing cameras.

For mapping, the robot carries a LIDAR on a gimbal with three degrees of freedom; an accelerometer; and gathers odometry, compass, and ultrasound data.

Victim identification sensors include TPA81 Thermopile Array thermal sensors; a CO2 sensor; and a Panasonic BB-HCM580 pan/tilt/zoom IP camera.

Pasargad competed in the 2009 world championships, but did not identify any victims.

Pelican United

Pelican United, from Tohoku University, Japan, entered two robots into the 2009 world championships. These are pictured in Figure 9.

Both robots feature two pairs of tracked flippers, and fixed tracks on the body which cover the body’s entire width. These tracks are rubber, with wide-spaced moulded teeth. One robot has an arm, consisting of a fixed vertical section, a rotational joint, and a prismatic section, carrying a pitch/roll head with a two-prong gripper (or, at other times in the competition, a single hook).

Figure 10 - Resko@UniKoblenz (top) and RRT Uppsala (bottom) robots

While the robot with an arm has its LIDAR at a fixed inclination, the robot without an arm has its LIDAR gimballed, to perform 3D scanning. A 3-axis accelerometer and gyroscope is present on each robot (Ohno2009).

A pan-tilt-zoom camera, a thermal camera, and a CO2 sensor are also used on each robot.

Pelican United took part in the 2009 world championships, scoring an average of 3.75 victims per run; they placed second overall after the competition finals, took first place for best in class mobility, and took second place for best in class autonomy.

Resko@UniKoblenz

Resko@UniKoblenz, from Universität Koblenz-Landau in Germany, operate a robot based on a Pioneer P3-AT chassis. The team also compete in RoboCup @home using the same chassis, albeit with a different set of sensors.

Odometry and sonar are present on the Pioneer chassis, and the robot also carries a gimballed LIDAR, and uses a dual axis accelerometer to gather tilt and roll information (Pellenz2009).

Cameras and a microphone are used for victim detection, and the robot also carries a thermal camera aimed at a servo-motor-rotated mirror, allowing a 200° thermal scan.

Resko@UniKoblenz competed in the 2009 German open, scoring an average of 1.6 victims per run and taking first place, the first team to do so operating entirely autonomously. They also won the best in class autonomy award.

At the 2009 world championships, with its more complicated autonomous section, the robot found an average of 0.5 victims per run.

RoboCup Rescue Team Uppsala

RRT Uppsala, from Uppsala Universitet, Sweden, took part in both the 2009 German open and the 2009 world championships with their two robots, Surt (shown in Figure 10) and Rym. Both the Uppsala robots are three-wheeled designs (Nordfelth2009).

Both robots carry gimballed LIDARs, accelerometers (3DM-GX1 or LIS302DL), ultrasound sensors, and gather odometry.

For victim identification, both robots carry servo-rotated thermopile arrays, cameras and microphones. The robot Surt also includes an omnidirectional vision system to identify hazardous material labels.

Figure 11 - WMR (top) and FH-Wels (bottom) robots.

At the 2009 German open, Uppsala scored an average of 0.2 victims per run; at the 2009 world championships Uppsala scored an average of 0.5 victims per run, and took third place in best in class autonomy.

Warwick Mobile Robotics
WMR, from the University of Warwick, UK, took part in the 2009 German open with their robot, shown in Figure 11.

The robot features front and rear tracked flippers, and fixed tracks on the sides of the robot; the tracks are conveyer-belt style, with a T20 inside profile and with widely-spaced teeth machined into the outer rubber.

The robot's arm has a rotational base joint, a rotational elbow, and a pan/tilt sensor head.

Navigation sensors include a fixed-angle LIDAR, odometry, and two cameras for teleoperation.

Victim identification sensors, mounted on the sensor head, include a video camera and a thermal camera.

At the 2009 German open WMR scored an average of 1.2 victims per run, taking third place overall, and won best-in-class mobility.

RoboCup Rescue Team FH-Wels
RRT FH-Wels, from the Upper Austria Unversity of Applied Sciences, attended the 2009 German open and the 2009 world championships with their robot, shown in Figure 11.

The robot has front and rear tracked flippers, with T20 belts, with short (undriven) tracks fixed to each side, between the flippers (Edlinger2009).

The robot includes a three-segment arm, with two rotational base joints, rotational elbows between its three segments, and a pan/tilt head. The arm can reach to 1.2m above the ground.

Navigation sensors include a fixed-angle LIDAR and an Xsens MTI IMU, along with cameras and odometry. Victim identification sensors include stereo vision cameras, a thermal camera (FLIR A320) and temperature sensor (TPA 81), a microphone and a CO_2 sensor.

RRT FH-Wels attended both the 2009 German open and the 2009 world championships, but did not score any victims at either event.

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