



RoboCupRescue Robot League

Progress Update and Future Directions



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Ehsan Mihankhah, K.N. Toosi University of Technology, Iran (TC)

Raymond Shea, University of New South Wales, Australia (TC)



RoboCupRescue Robot League Regional Open Competitions



Championships

- 2001 Seattle, USA
- 2002 Fukuoka, Japan
- 2003 Padua, Italy
- 2004 Lisbon, Portugal
- 2005 Osaka, Japan
- 2006 Bremen, Germany
- 2007 Atlanta, USA
- 2008 Suzhou, China
- 2009 Graz, Austria

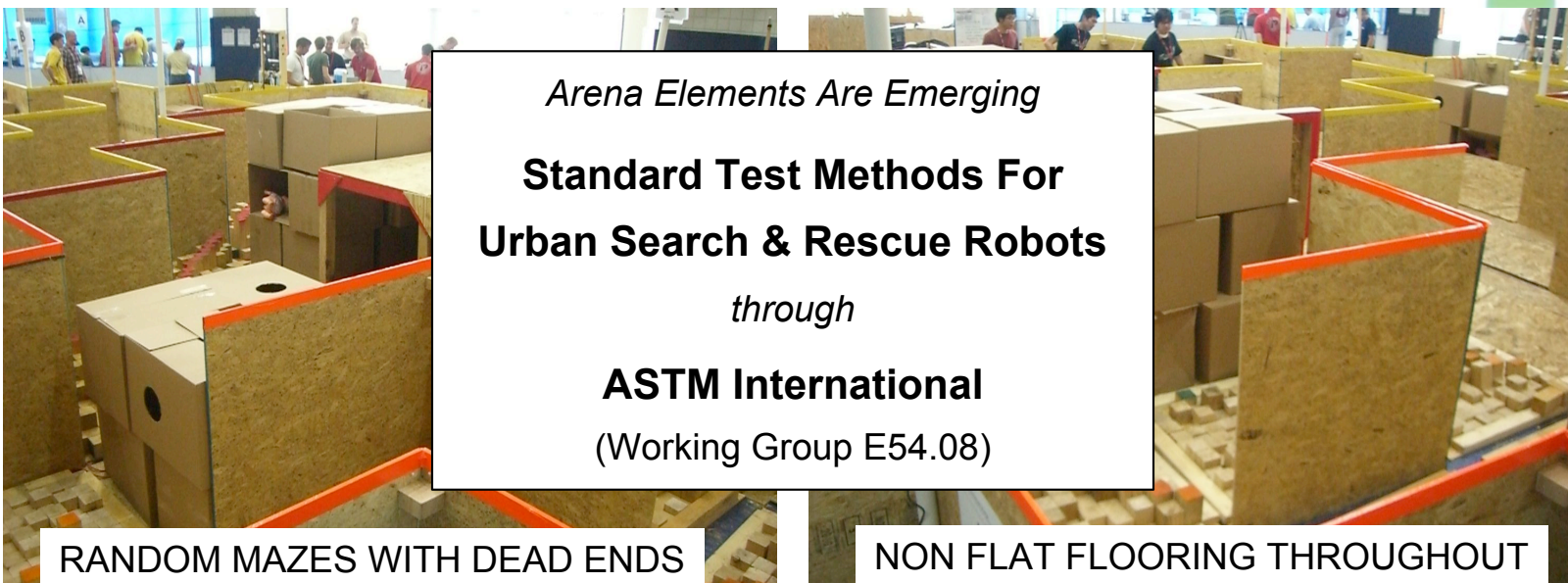
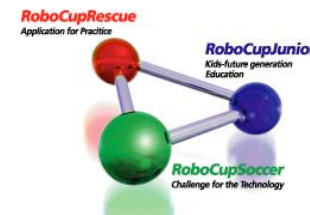


Regional Opens

- China
- Germany
- Iran
- Japan
- Mexico
- Thailand
- USA



RoboCupRescue Robot League Arena Elements to Standard Test Methods



RANDOM MAZES WITH DEAD ENDS

NON FLAT FLOORING THROUGHOUT



REMOTE OPERATOR STATION



VIDEO AND TRACKING DISPLAYS



RoboCupRescue Robot League Regional Qualifying Arena

NIST

(10M x 7.5M WITH 1.2M WIDE HALLWAYS)

YELLOW ARENA

FOR AUTONOMOUS NAVIGATION AND VICTIM IDENTIFICATION

- RANDOM MAZE OF HALLWAYS AND ROOMS
- CONTINUOUS PITCH & ROLL RAMPS (15°)
- DIRECTIONAL VICTIM BOXES WITH AND WITHOUT HOLES

ORANGE ARENA

FOR ROBOTS CAPABLE OF STRUCTURED MOBILITY

- RANDOM MAZE OF CROSSING PITCH & ROLL RAMPS (15°)
- STAIRS (45°, WITH 20CM RISERS)
- RAMP (45° WITH CARPET)
- PIPE STEPS (20CM)
- CONFINED SPACES (50-80 CM UNDER ELEVATED FLOORS)
- DIRECTIONAL VICTIM BOXES WITH HOLES ONLY

RED ARENA

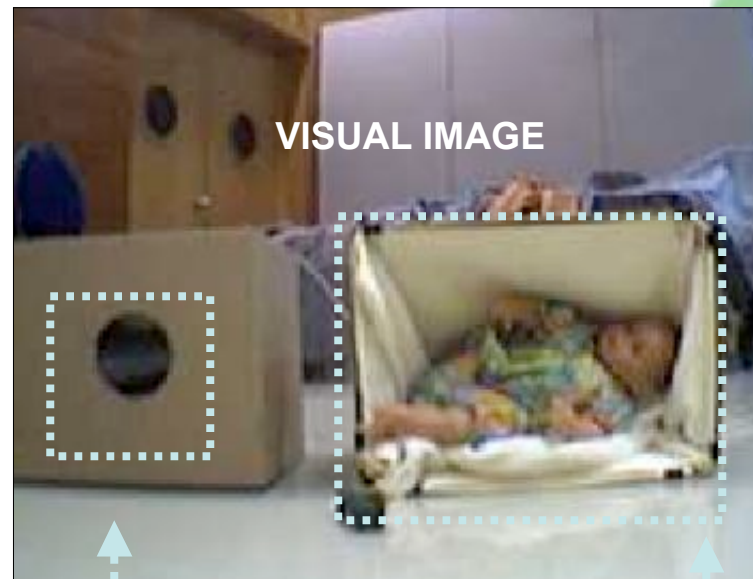
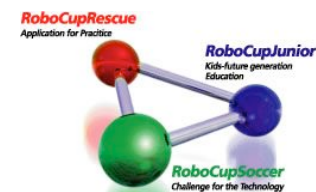
FOR ROBOTS CAPABLE OF ADVANCED MOBILITY

- RANDOM MAZE OF STEPFIELD PALLETS
- DIRECTIONAL VICTIM BOXES WITH AND WITHOUT HOLES

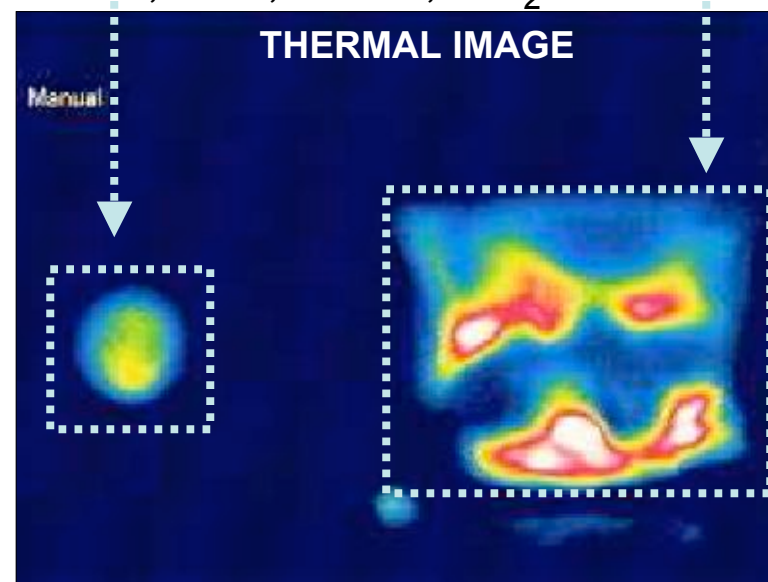




RoboCupRescue Robot League Simulated Victims - Unchanged

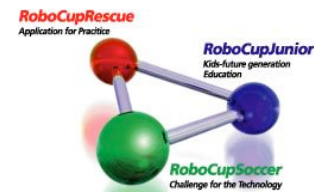


Signs of life: human form, motion, heat, sound, CO₂





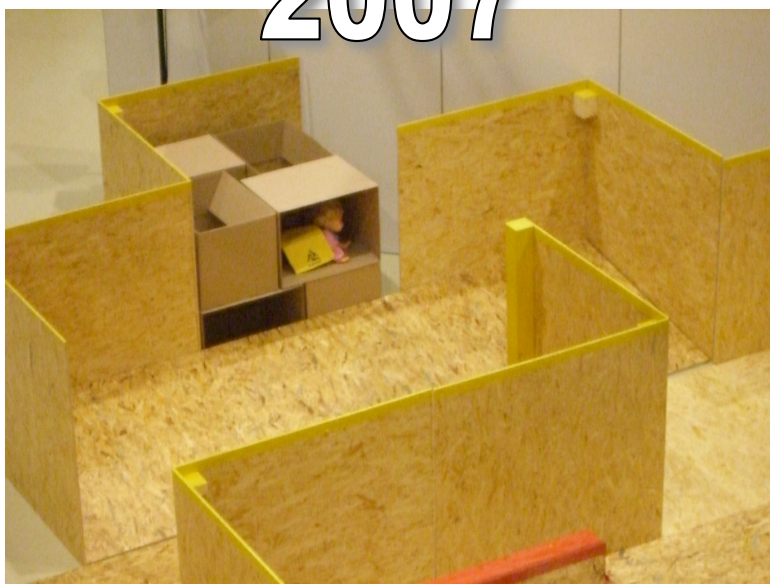
RoboCupRescue Robot League Yellow Arena - Getting More Difficult!



2007

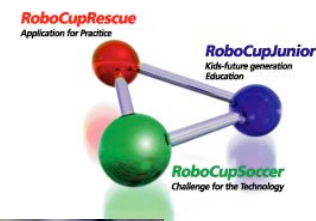


2008





RoboCupRescue Robot League Orange Arena - Getting More Difficult!



2007



2008





RoboCupRescue Robot League Red Arena - Getting More Repeatable!



2007



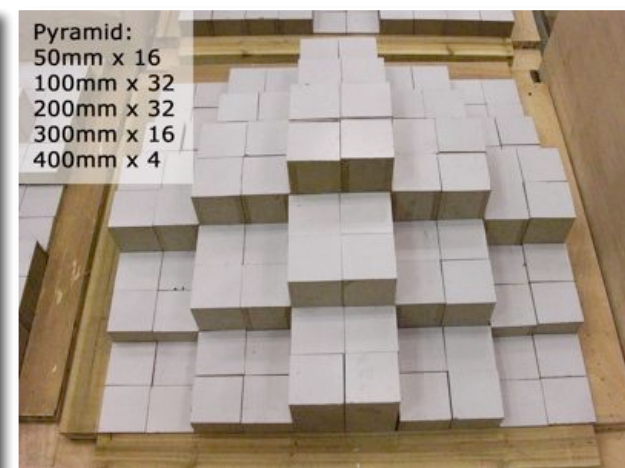
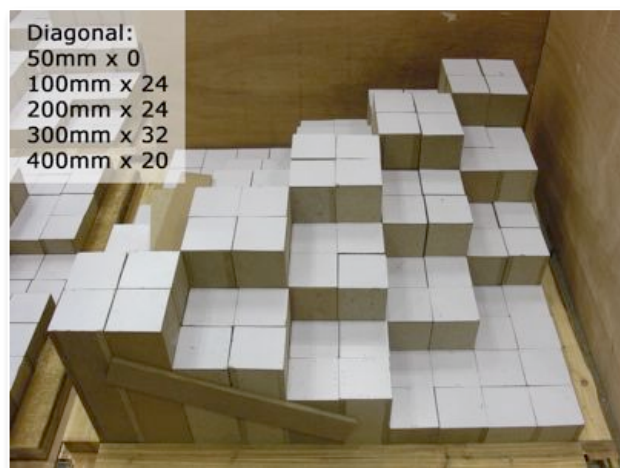
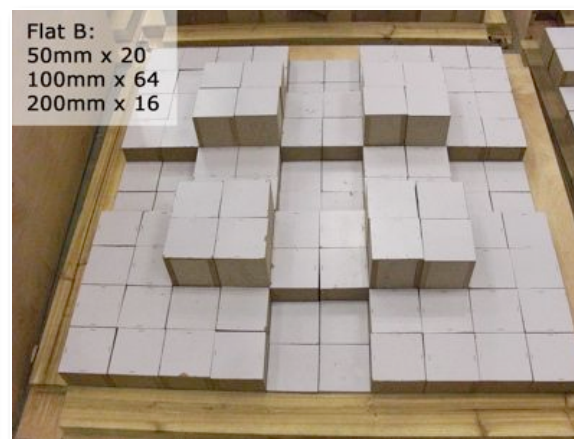
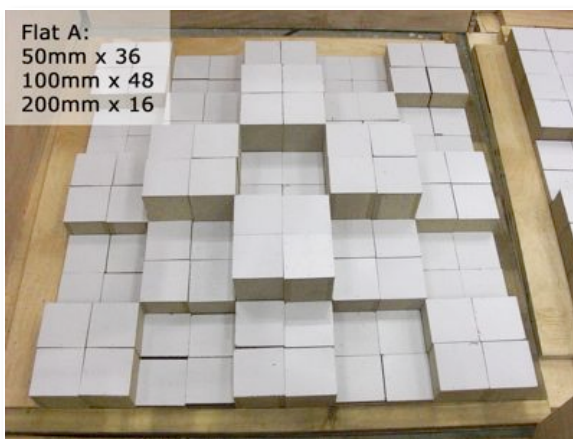
2008





RoboCupRescue Robot League

Red Arena - Symmetric Stepfield Pallets





RoboCupRescue Robot League

New Blue Arena - Mobile Manipulation - Directed Perception



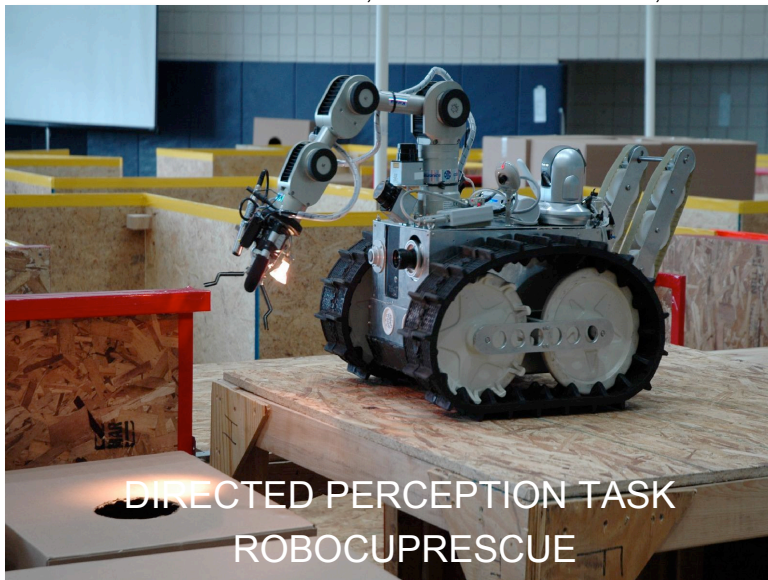
DIRECTED PERCEPTION TASK
ROBOCUPRESCUE

TEAM: CEO MISSION II, UNIV. THAI COMMERCE, THAILAND



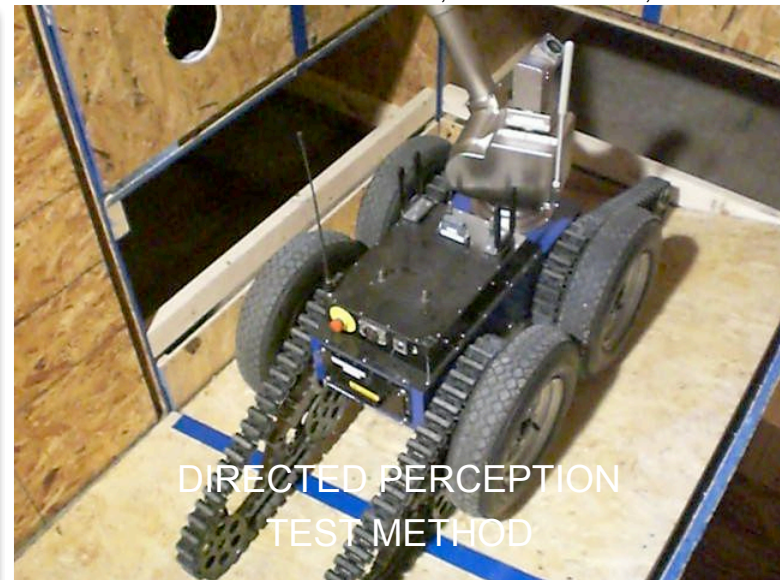
DIRECTED PERCEPTION
TEST METHOD

TELEMAX, TELEROB GMBH, GERMANY



DIRECTED PERCEPTION TASK
ROBOCUPRESCUE

TEAM: JACOBS UNIVERSITY, GERMANY



DIRECTED PERCEPTION
TEST METHOD

TELEMAX, TELEROB GMBH, GERMANY



RoboCupRescue Robot League

New Blue Arena - Mobile Manipulation - Grasping Dexterity



PICK AND PLACE TASK IN
ROBOCUPRESCUE



GRASPING DEXTERITY
TEST METHOD

TELEMAX, TELEROB GMBH, GERMANY



PICK AND PLACE TASK IN
ROBOCUPRESCUE



GRASPING DEXTERITY
TEST METHOD

TELEMAX, TELEROB GMBH, GERMANY



RoboCupRescue Robot League Scoring Metric (2008)



REMOTE OPERATOR STATION: Only one team operator is allowed in the operator station at any time, but teams may switch operators as necessary during missions.

(4) YELLOW ARENA VICTIMS: Autonomous robot navigation and victim identification scoring only. Directional victim boxes, open or with holes, stacked two high on continuous ramps.

(4) ORANGE ARENA VICTIMS: Directional victim boxes, mostly with holes, stacked three high on crossing ramps, also located on elevated flooring and under confined spaces.

(4) RED ARENA VICTIMS: Directional victim boxes, open or with holes, stacked two high on stepfield pallets

$$\begin{array}{ccccccc} & \text{50 POINTS POSSIBLE PER VICTIM FOUND} & & \text{PENALTIES PER EVENT} & & \\ \hline \text{VICTIM SITUATION} & + & \text{VICTIM STATE} & + & \text{VICTIM TAG} & + & \text{MAP QUALITY OF WALLS} & + & \text{MAP LOCATION OF VICTIMS} & - & \text{ARENA/VICTIM BUMPING} \\ (5) & & (15) & & (10) & & (10) & & (10) & & (10) \end{array}$$

----- 2009 Discussions -----

NEW BLUE ARENA: Equal to possibly (2) victim for payload, pick and place tasks!

NEW RADIO DROP-OUT ZONE: Equal to possibly (2) victims for autonomous negotiation of hallway beyond stepfield pallets requiring advanced mobility AND autonomus navigation with teleoperative victim identification at far end of hallway when radio comms is re-established!



RoboCupRescue Robot League 2007 Awardees



20 teams from 8 countries:

Australia, Germany, Iran, Japan, Mexico, Sweden, Thailand, and USA.

MIXED INITIATIVE CHAMPIONSHIP AWARDS

Teams with the highest cumulative scores from 7-10 missions receive 1st, 2nd, 3rd place awards

- 1st:** INDEPENDENT, KING MONGKUT'S INST. OF TECH. BANGKOK, THAILAND
- 2nd:** PELICAN UNITED, CHIBA INSTITUTE OF TECH. & TOHOKU UNIV., JAPAN
- 3rd:** CEO MISSION, UNIV. OF THE THAI CHAMBER OF COMMERCE, THAILAND

BEST-IN-CLASS: MOBILITY

Robots that found the most Red Arena victims throughout and scored the most points in mobility missions

- 1st:** PELICAN UNITED, CHIBA INSTITUTE OF TECHNOLOGY, JAPAN
- 2nd:** SHINOBI, THE UNIVERSITY OF ELECTRO-COMMUNICATIONS SGI, JAPAN
- 3rd:** INDEPENDENT, KING MONGKUT'S INST. OF TECH. BANGKOK, THAILAND

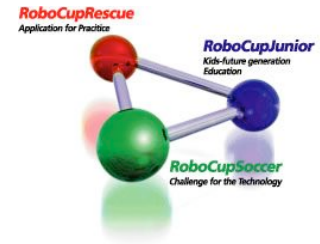
BEST-IN-CLASS: AUTONOMY

Robots that found the most Yellow Arena victims throughout and scored the most points in mapping missions

- 1st:** RESKO, UNIVERSITAT KOBLENZ UND LANDAU, GERMANY
- 2nd:** JACOBS RESCUE ROBOT, JACOBS UNIVERSITY BREMEN, GERMANY
- 3rd:** RFC UPPSALA, UPPSALA UNIVERSITY, SWEDEN



RoboCupRescue Robot League 2008 Awardees



18 teams from 9 countries competed:

China, Germany, Greece, Iran, Japan, Mexico, Sweden, Thailand, USA

MIXED INITIATIVE CHAMPIONSHIP AWARDS

Teams with the highest cumulative scores from 7-10 missions receive 1st, 2nd, 3rd place awards

- 1st:** PLASMA-RX, CHULALONGKORN UNIVERSITY, THAILAND
- 2nd:** MRL, AZAD UNIVERSITY OF QAZVIN, IRAN
- 3rd:** RESQUAKE/RESKO UNITED, K.N. TOOSI UNIVERSITY OF TECHNOLOGY, IRAN
& UNIVERSITY OF KOBLENZ AND LANDAU, GERMANY (COLLABORATING)

BEST-IN-CLASS MOBILITY AWARDS

Robots that found the most Red Arena victims throughout and scored the most points in mobility missions

- 1st:** PLASMA-RX, CHULALONGKORN UNIVERSITY, THAILAND
- 2nd:** RESQUAKE, K.N. TOOSI UNIVERSITY OF TECHNOLOGY, IRAN
- 3rd:** MRL, AZAD UNIVERSITY OF QAZVIN, IRAN

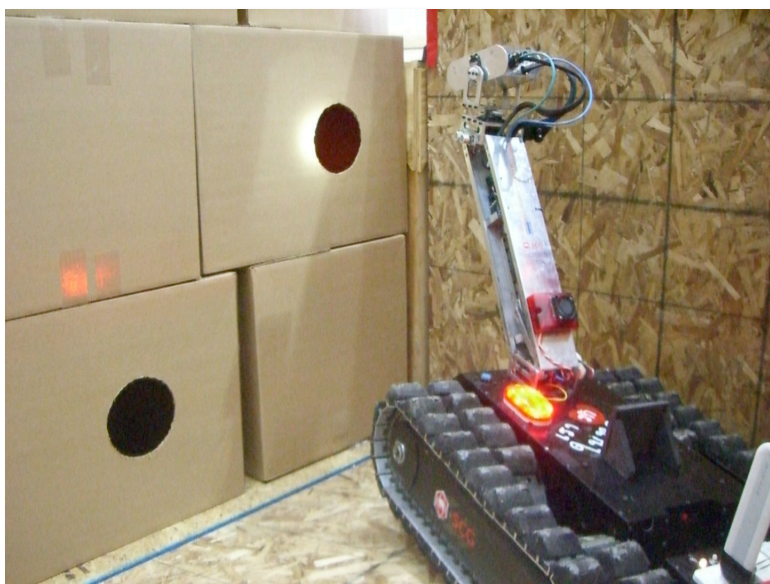
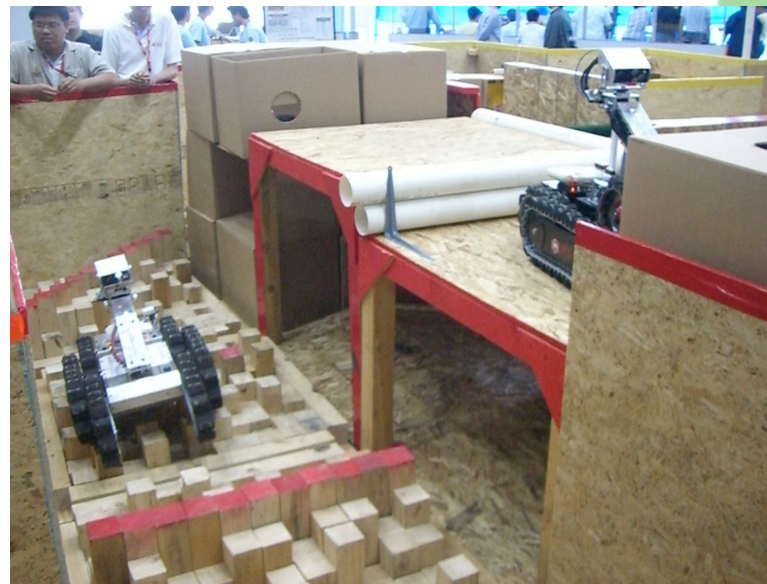
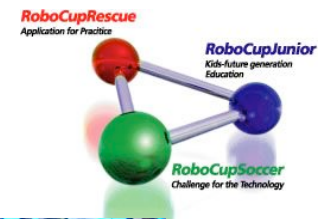
BEST-IN-CLASS AUTONOMY AWARDS

Robots that found the most Yellow Arena victims throughout and scored the most points in mapping missions

- 1st:** RESKO, UNIVERSITY OF KOBLENZ AND LANDAU, GERMANY
- 2nd:** RFC UPPSALA, UPPSALA UNIVERSITY, SWEDEN
- 3rd:** PELICAN UNITED, CHIBA INSTITUTE OF TECHNOLOGY & TOHOKU UNIVERSITY, JAPAN



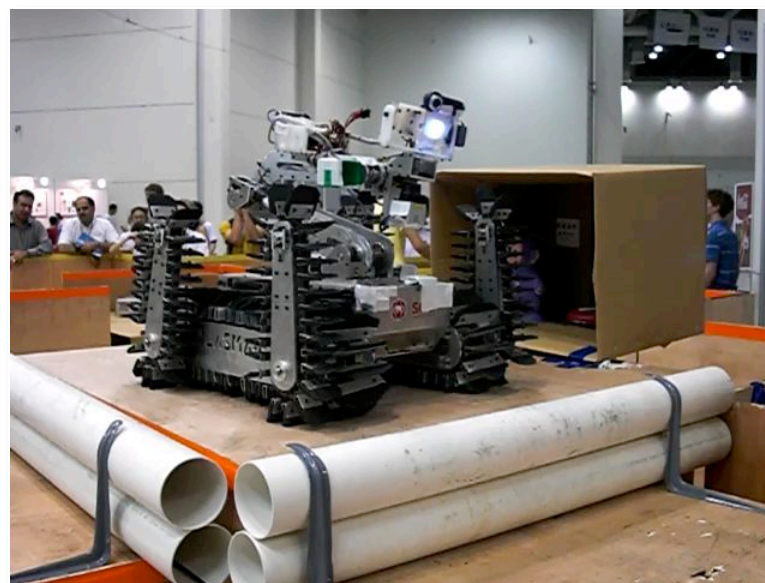
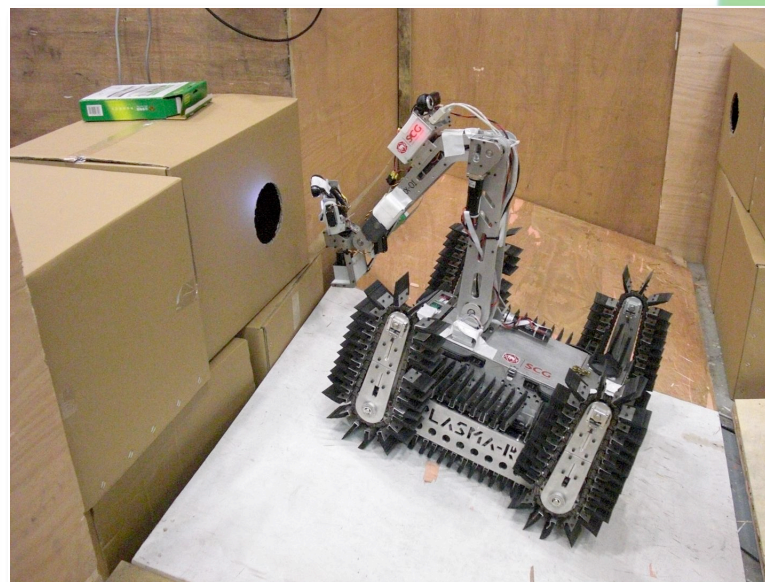
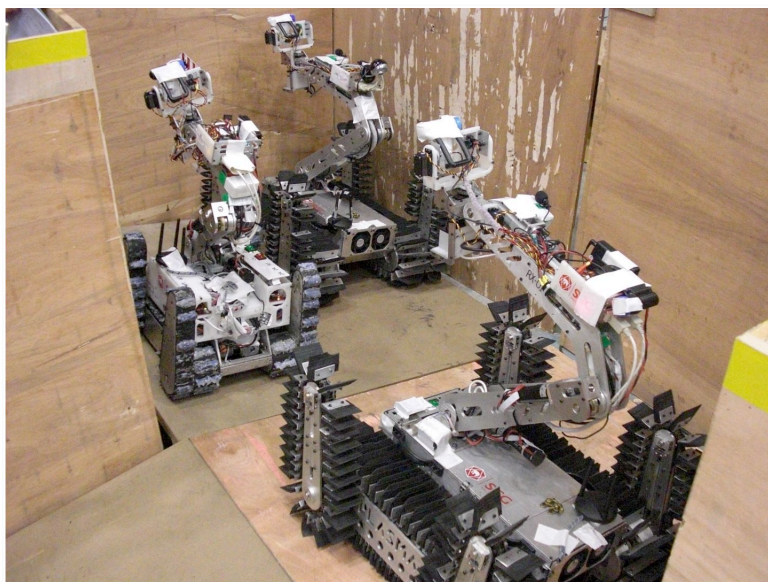
Independent, KMITNB, Thailand
2007: 1st Place Award & 3rd Best-in-Class Mobility





Plasma-RX, Chulalongkorn University, Thailand 2008: 1st Place Award, 1st Best-In-Class Mobility

RoboCupRescue
Application for Practice





Plasma-RX, Chulalongkorn University, Thailand
2008: 1st Place Award, 1st Best-In-Class Mobility



Thailand has 100+ teams that practice and compete in arenas like these



Bangkok, Thailand

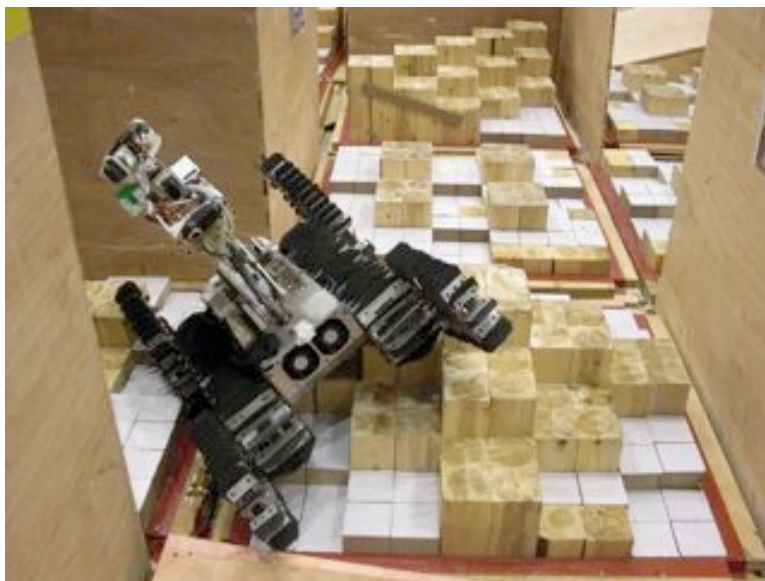
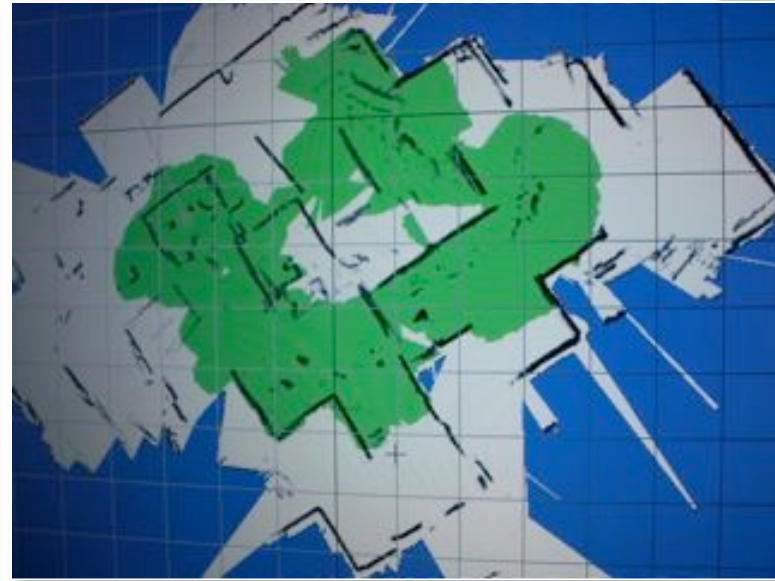
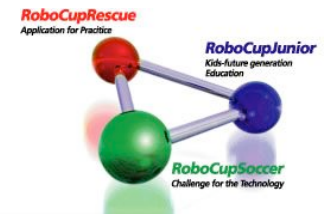


Plasma-RX, Chulalongkorn University, Thailand ***2008: 1st Place Award, 1st Best-In-Class Mobility***



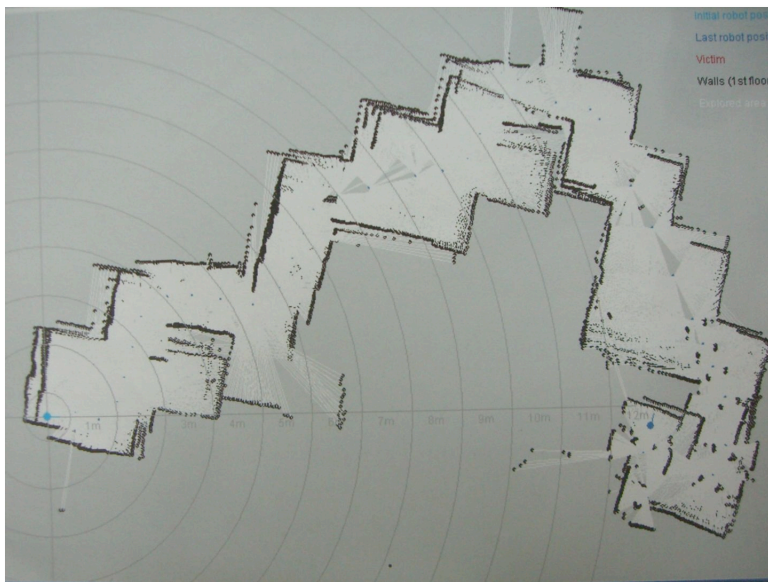
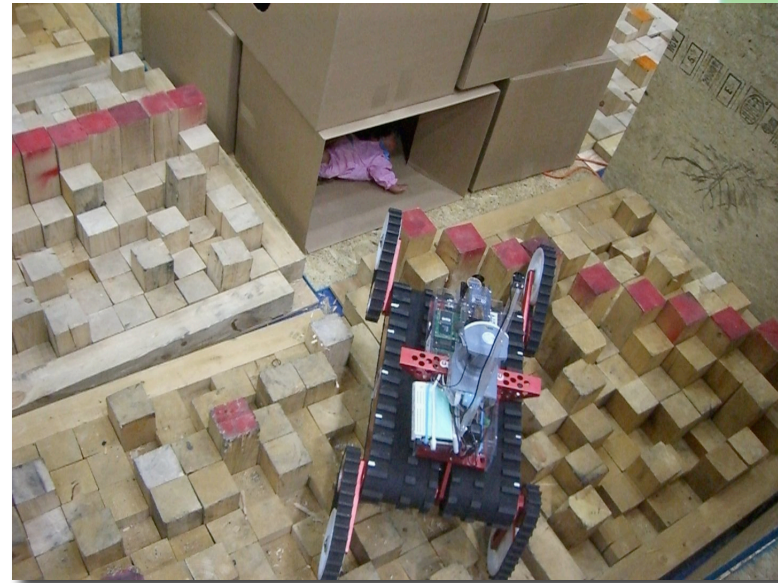
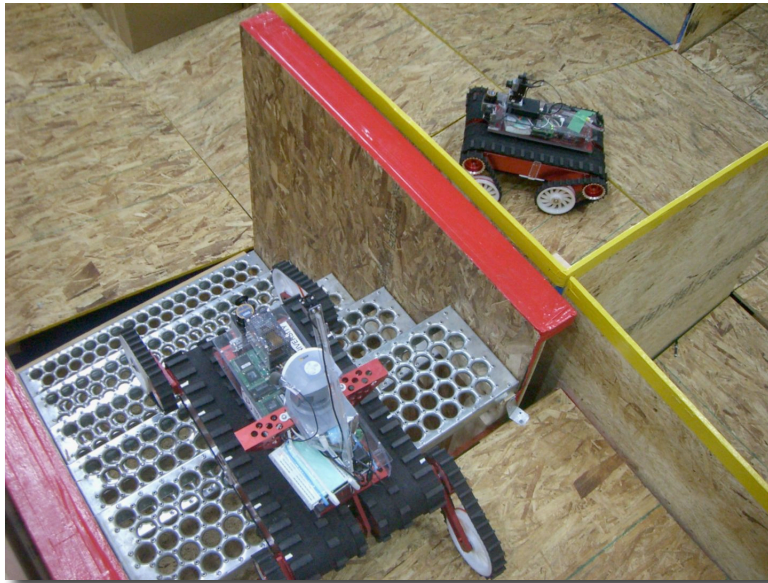
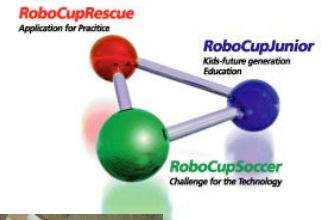


Plasma-RX, Chulalongkorn University, Thailand *2008: 1st Place Award, 1st Best-In-Class Mobility*



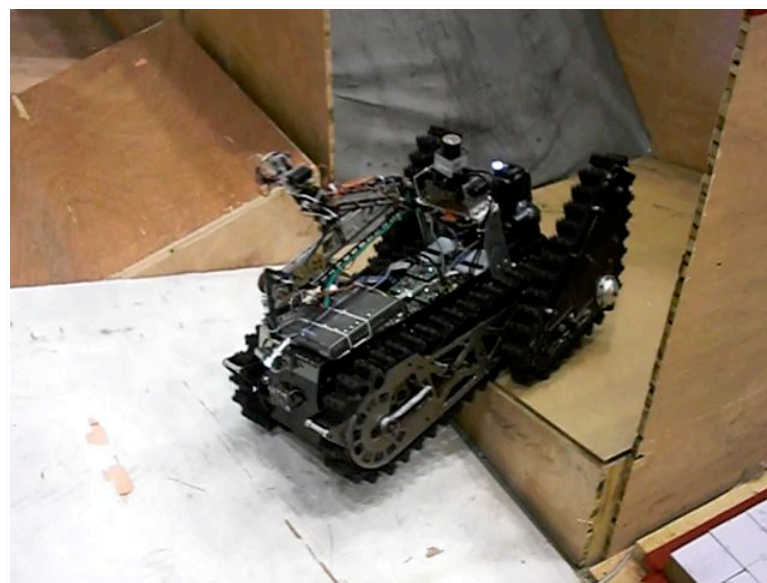
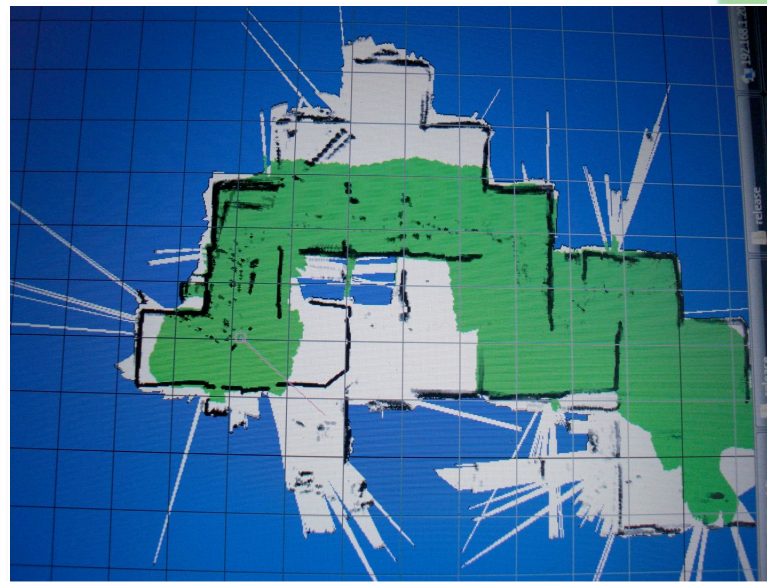
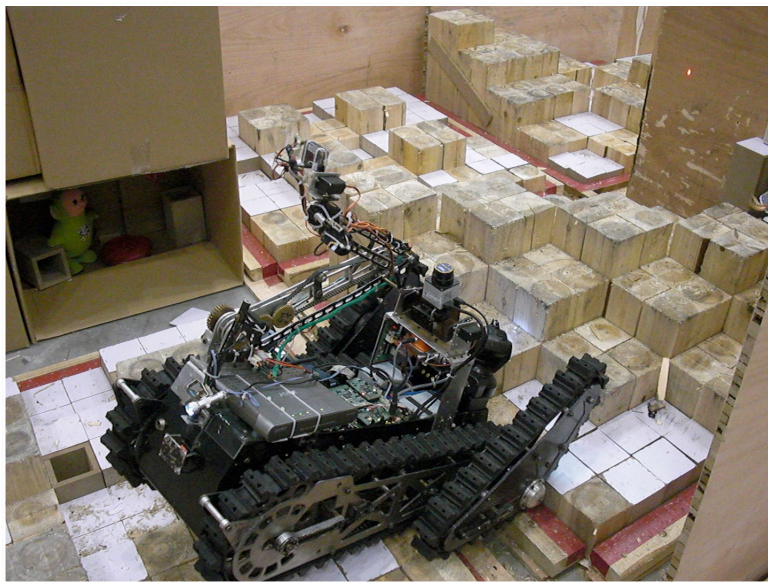


Pelican United, Chiba Inst and Tohoku Univ, Japan **2007: 2nd Place Award & 1st Best-in-Class Mobility**





MRL, Azad University Of Qazvin, Iran
2008: 2nd Place Award, 3rd Best-In-Class Mobility



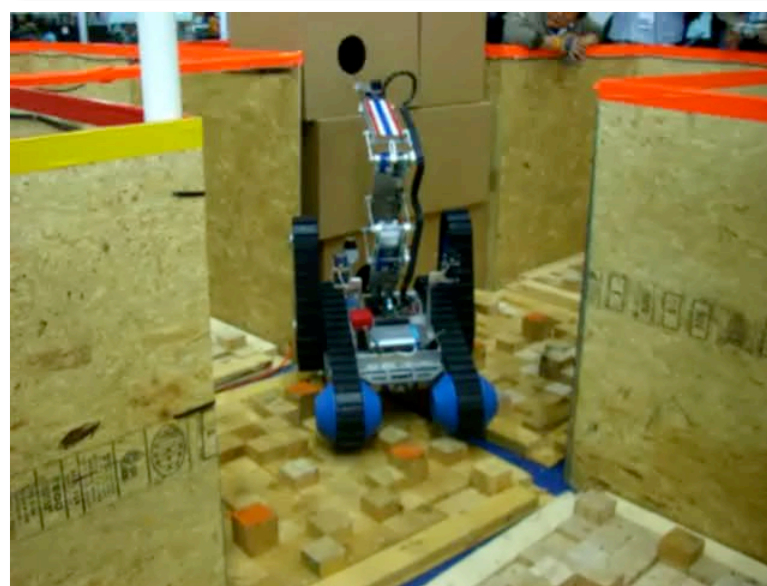
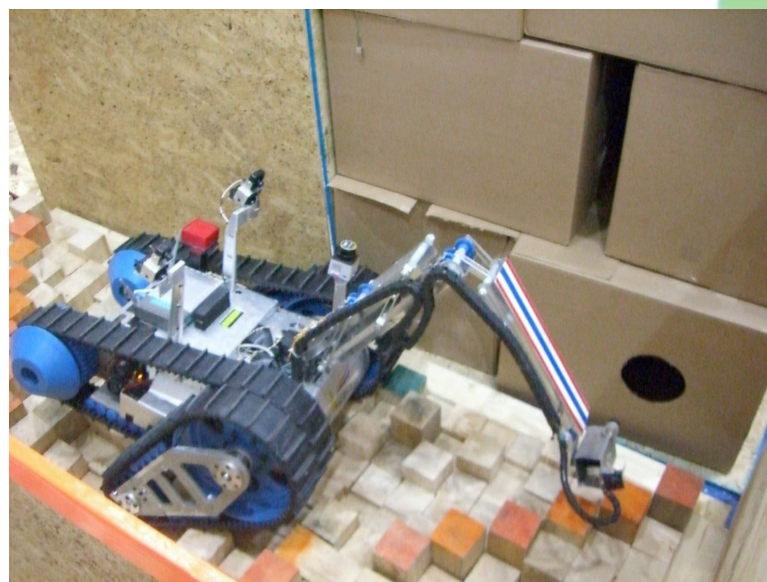
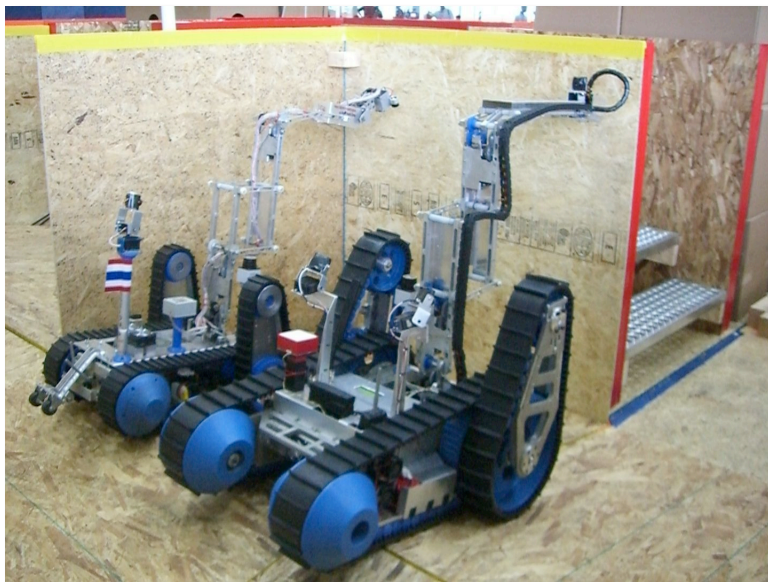


CEO Mission, Univ Thai Chamber of Commerce, Thailand *2007: 3rd Place Award*

RoboCupRescue
Application for Practice

RoboCupJunior
Kids-future generation
Education

RoboCupSoccer
Challenge for the Technology



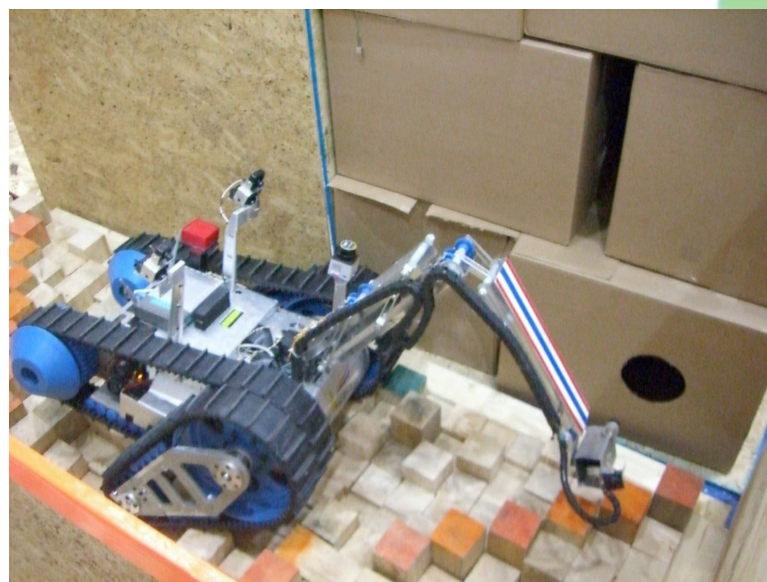
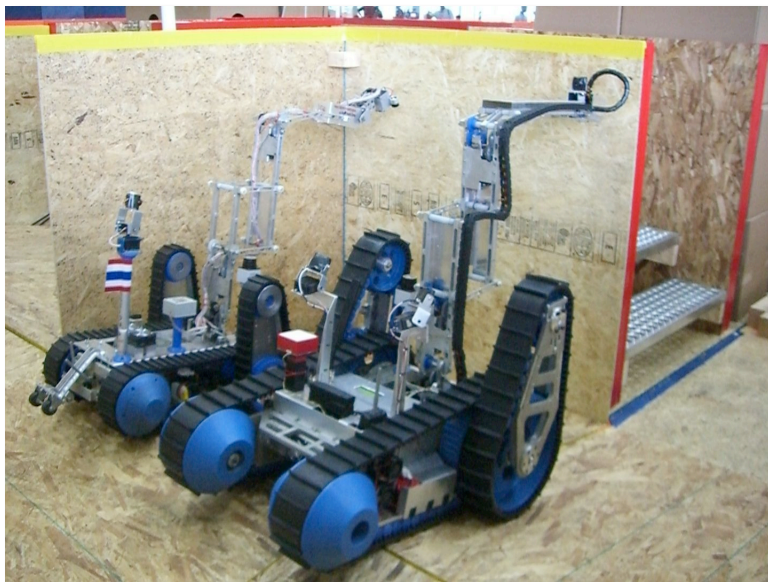


CEO Mission, Univ Thai Chamber of Commerce, Thailand 2007: 3rd Place Award

RoboCupRescue
Application for Practice

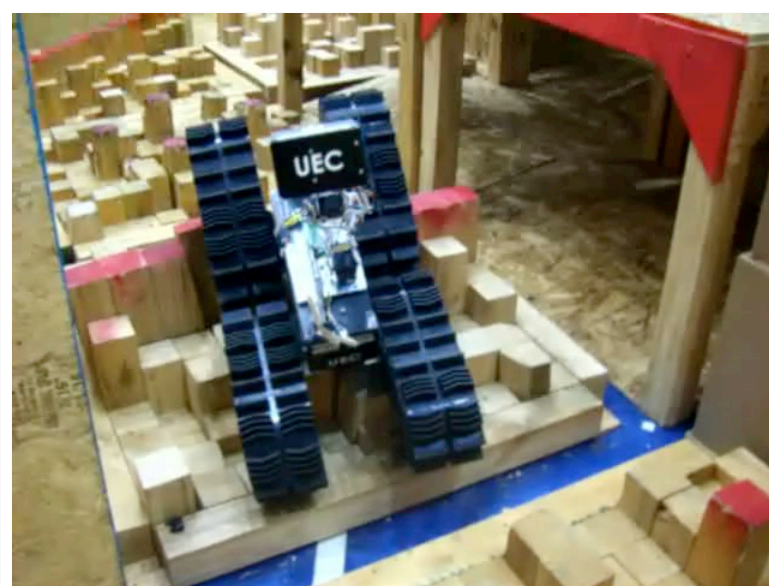
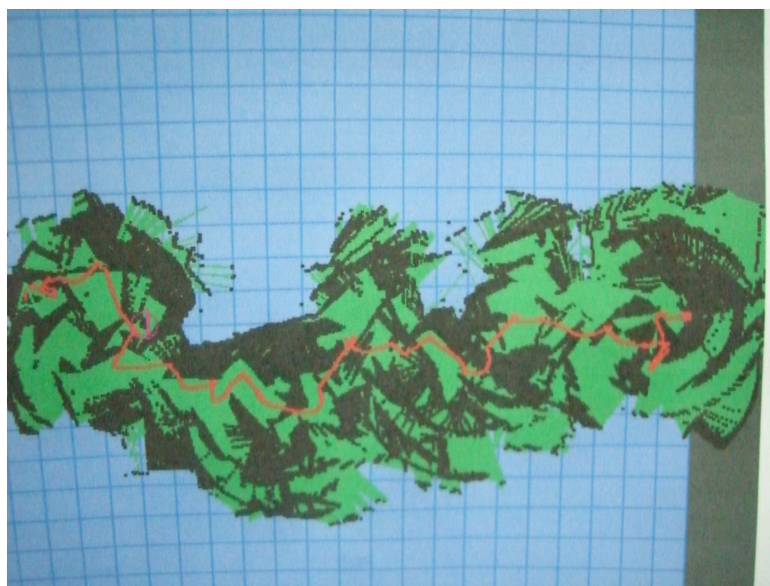
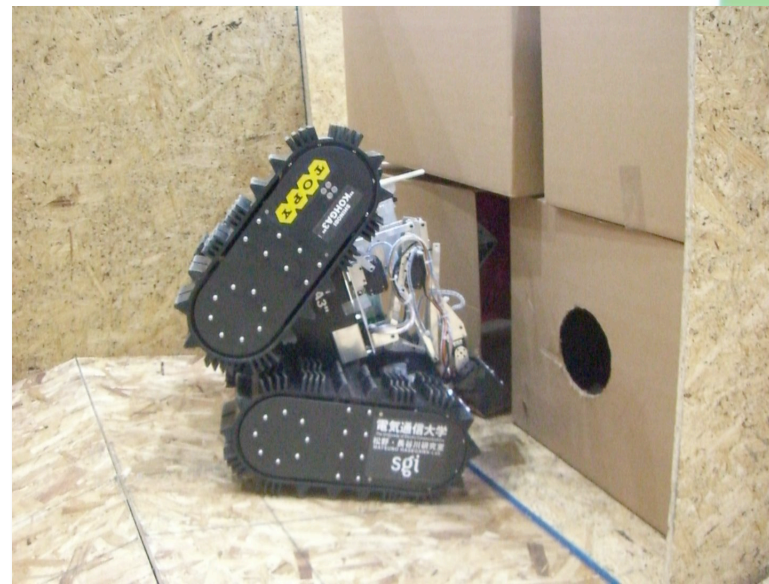
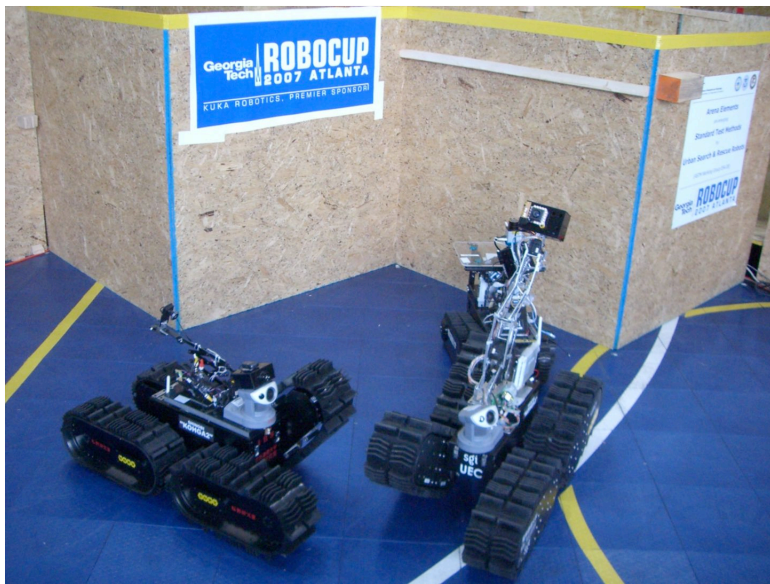
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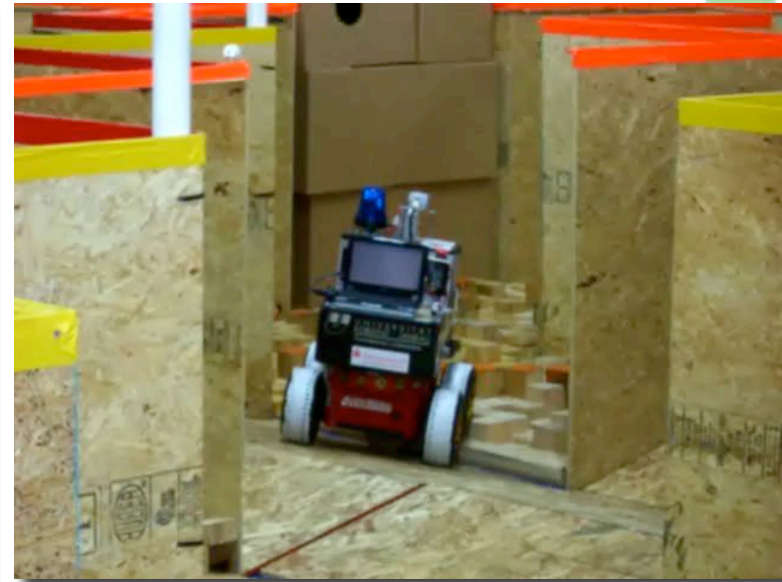
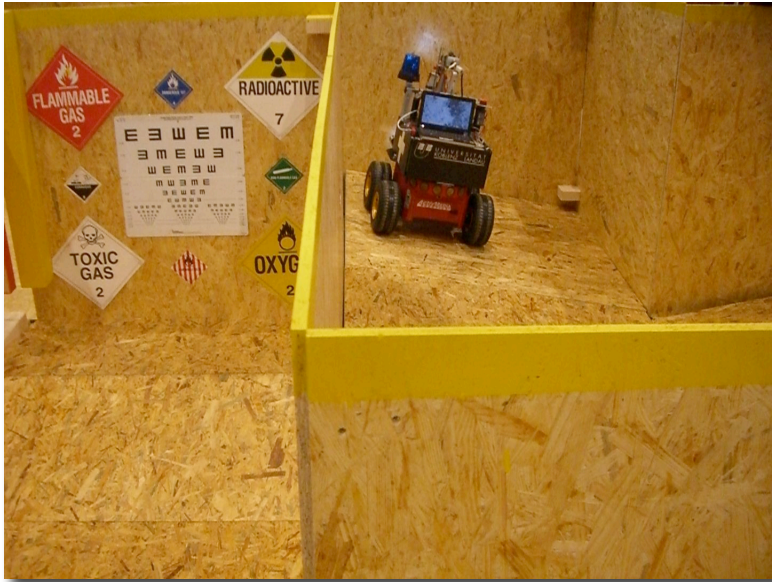


Shinobi, Univ of Electro-Communications, Japan *2007: 2nd Best-in-Class Mobility*



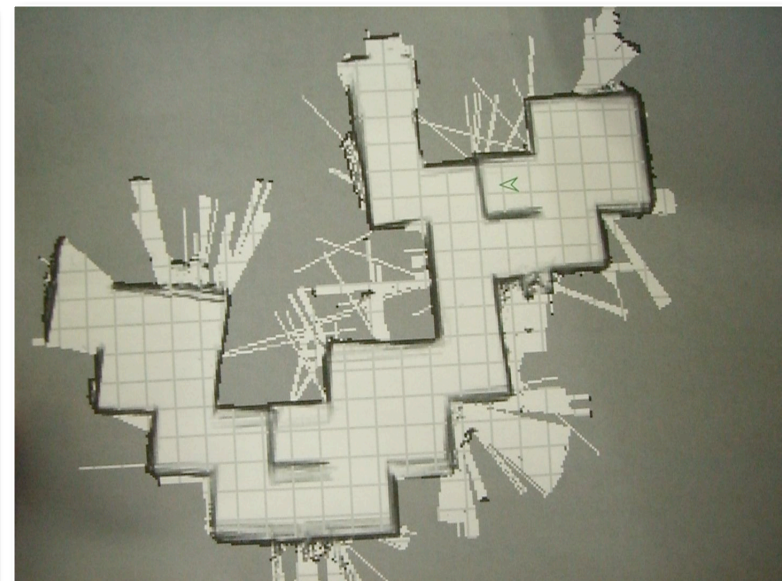
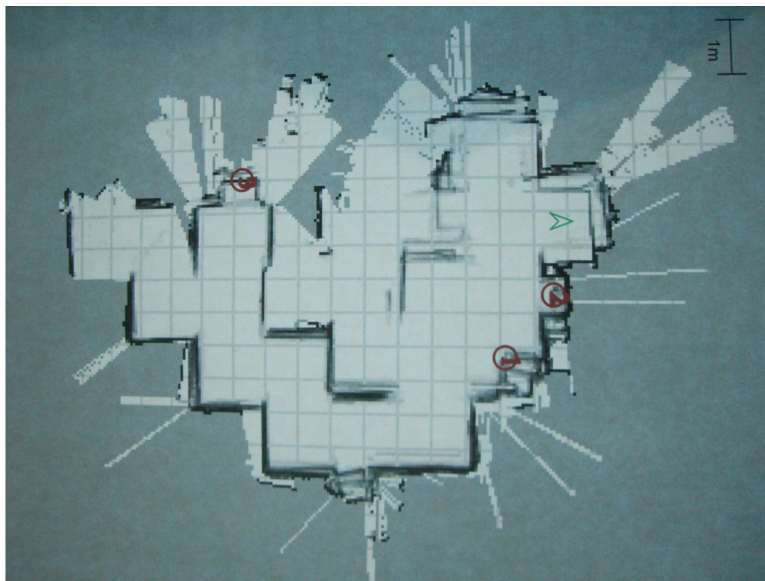
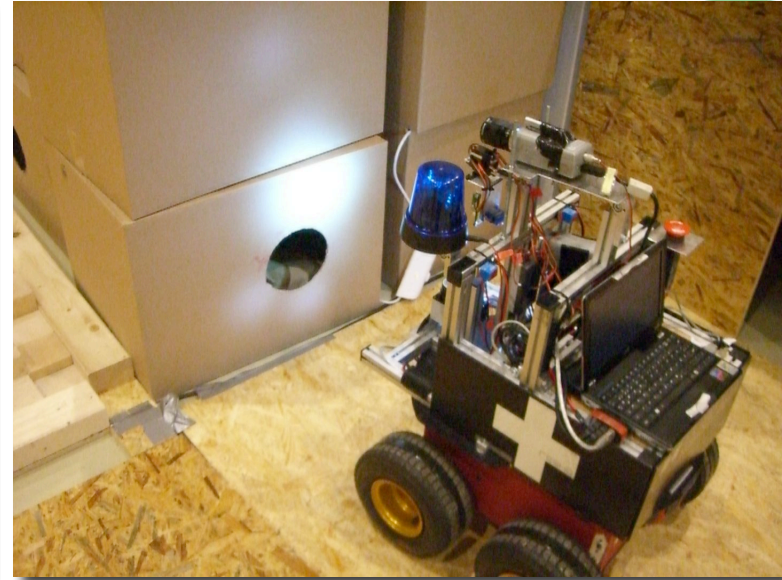
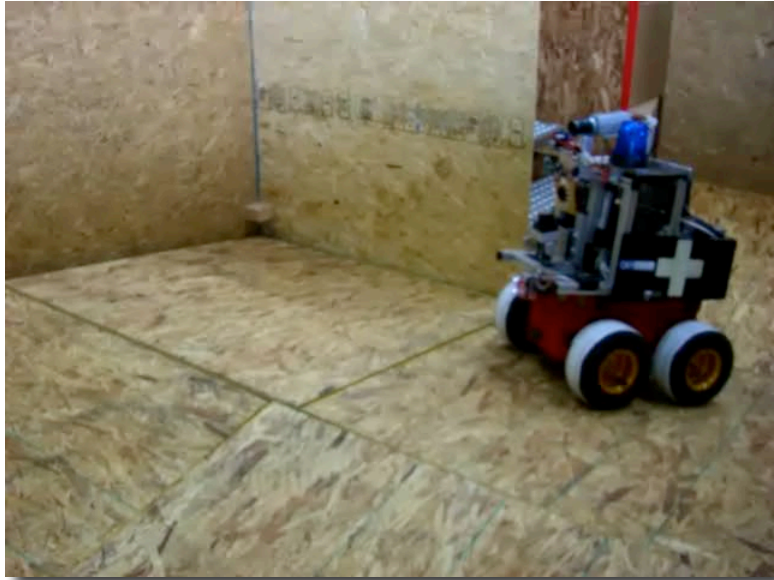


Resko, Univ of Koblenz and Landau, Germany 2007: 1st Best-in-Class Autonomy/Mapping



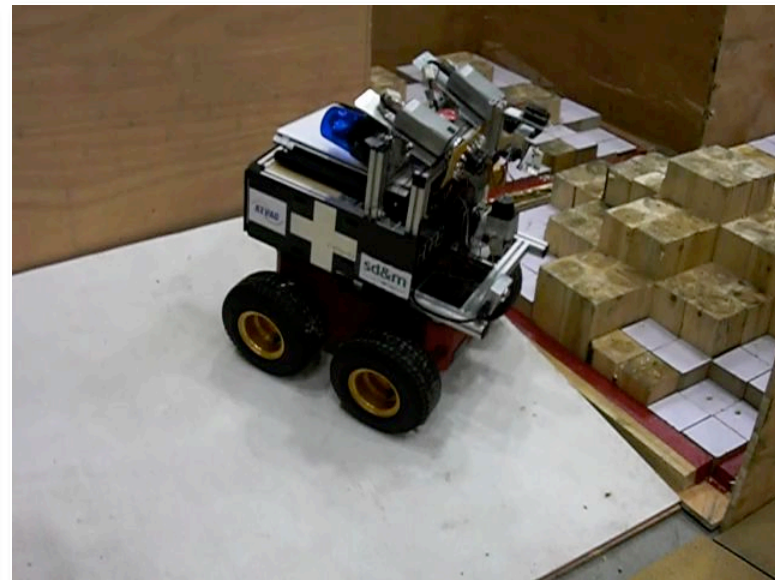
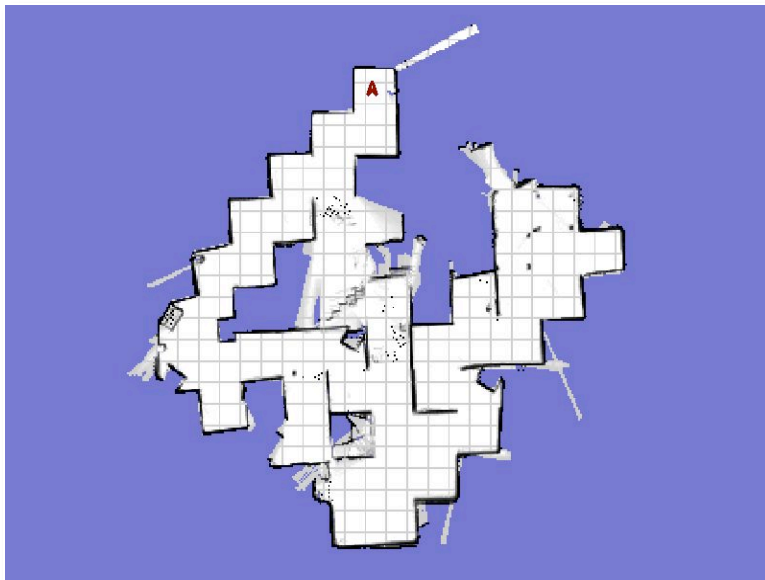
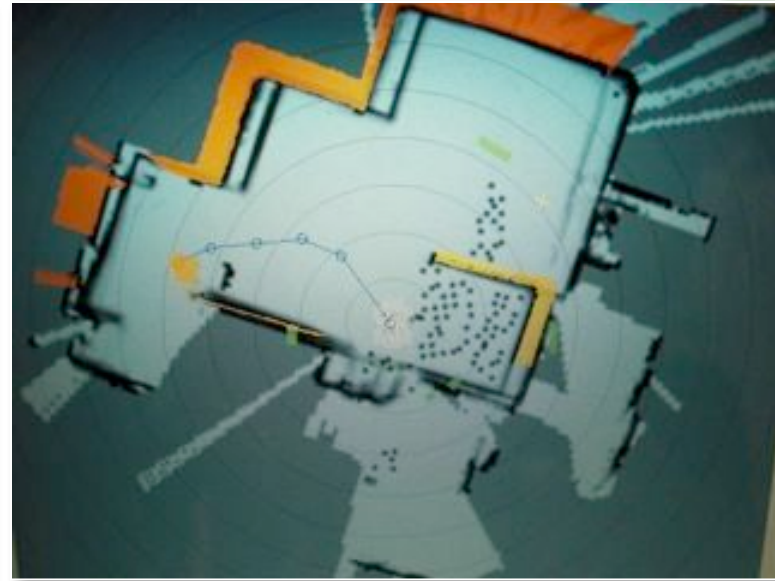
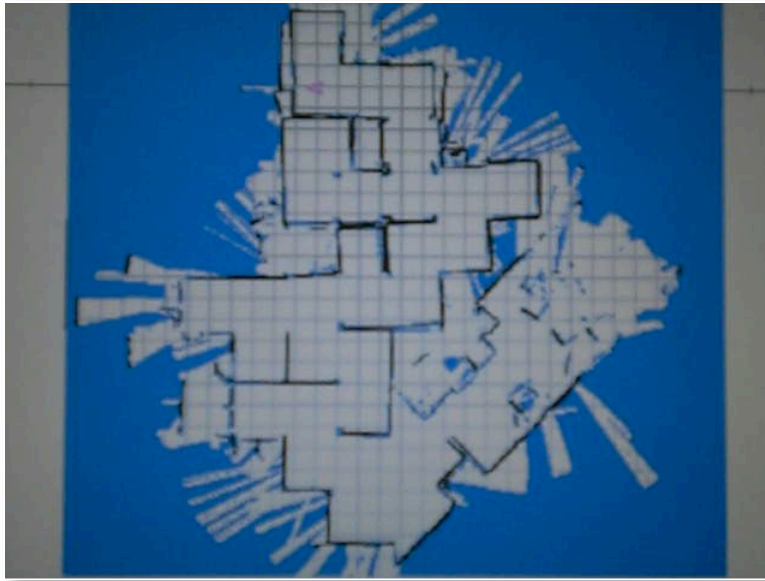
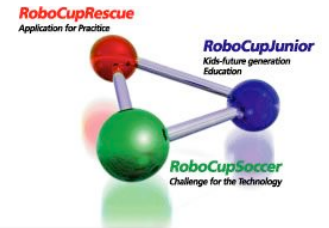


Resko, Univ of Koblenz and Landau, Germany
2007: 1st Best-in-Class Autonomy/Mapping





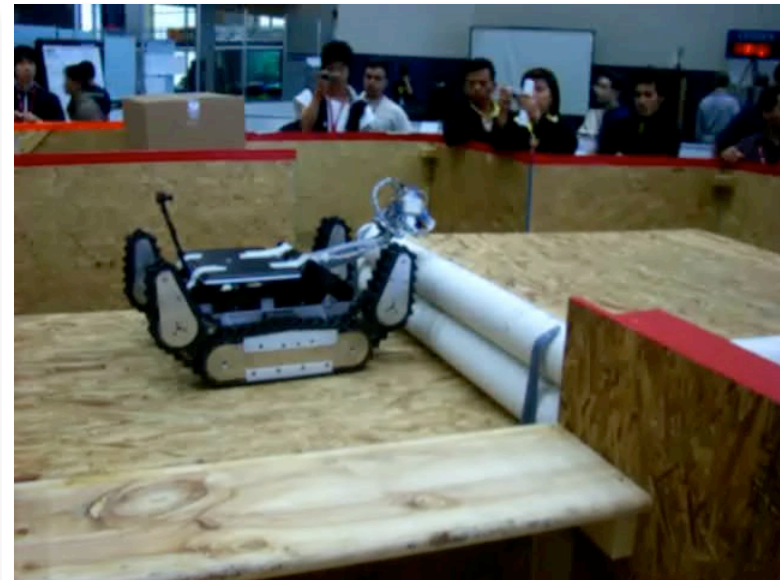
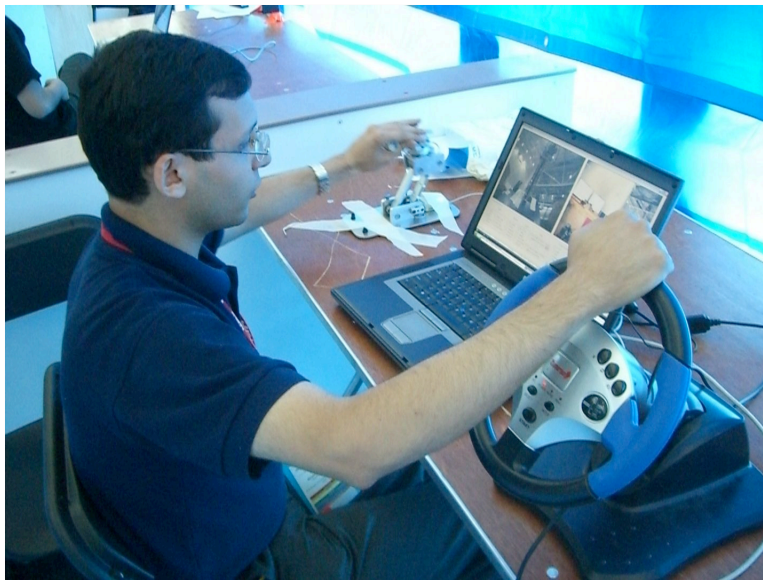
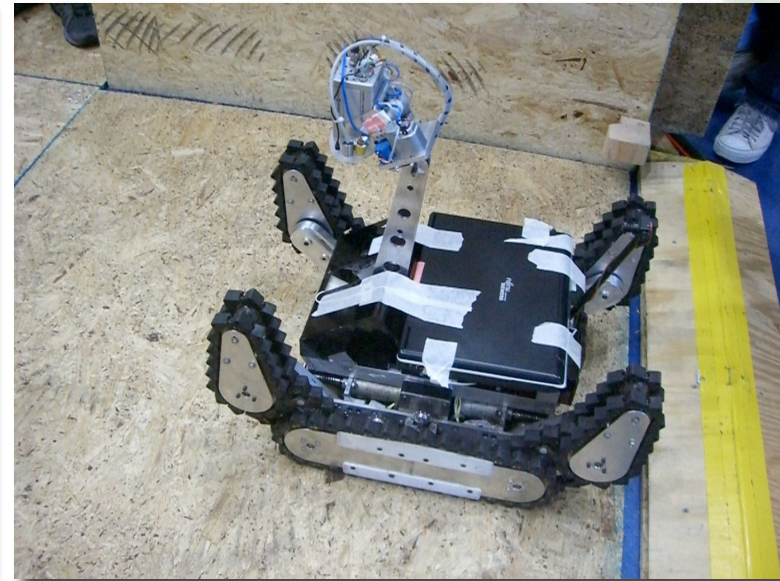
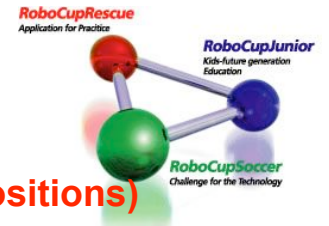
Resko, Univ of Koblenz and Landau, Germany
2008: 1st Best-in-Class Autonomy/Mapping





Resquake, K.N. Toosi Univ of Technology, Iran Innovative Operator Interfaces

(steering wheel, camera mast joystick, voice commands for preset flipper positions)



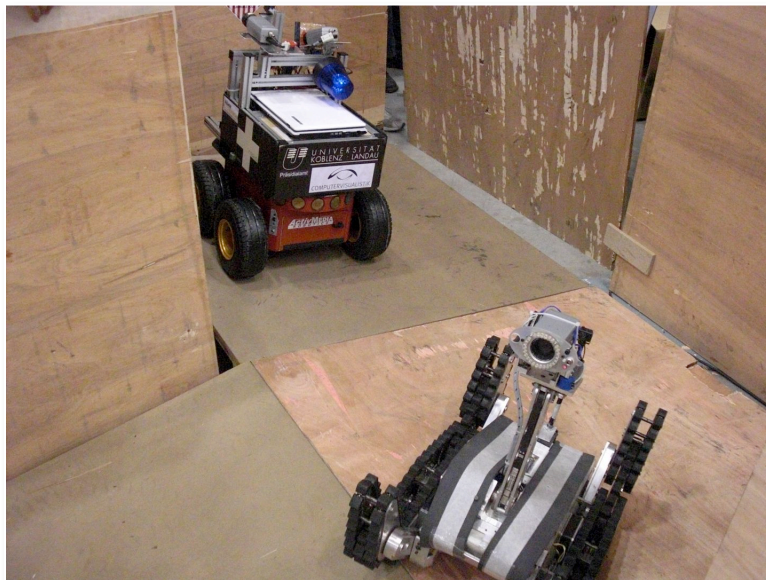
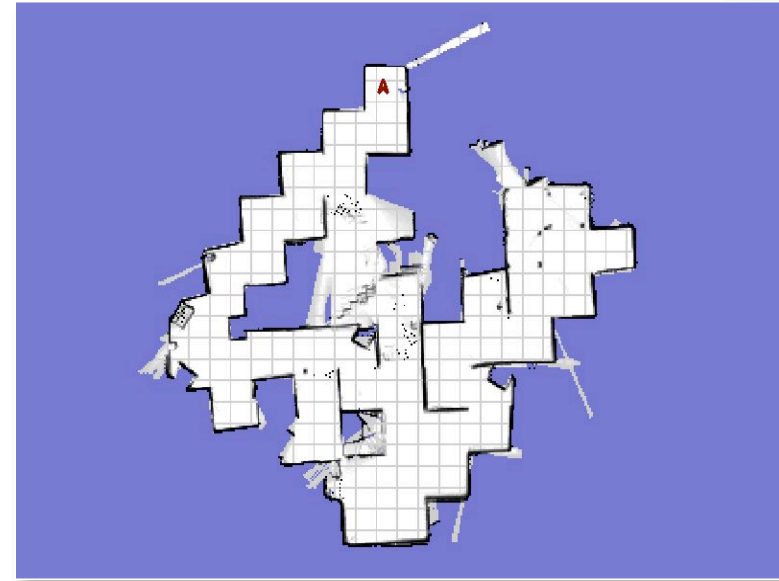
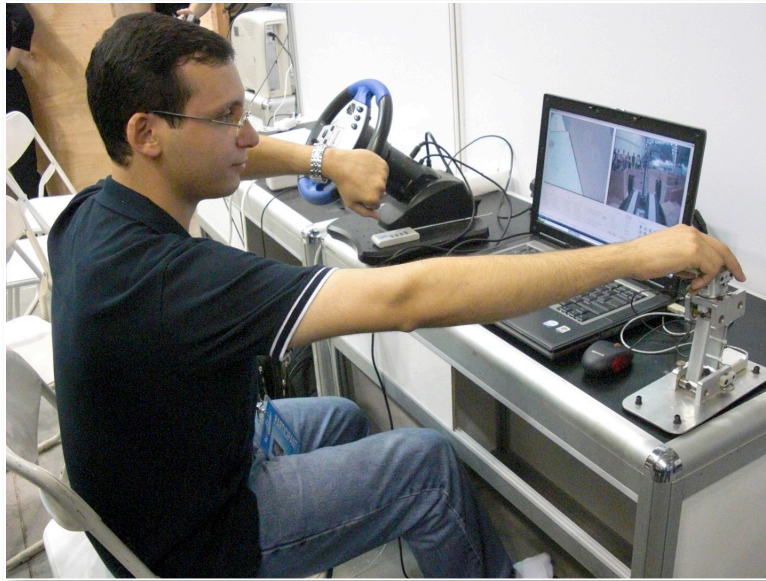


**Resquake/Resko United 3rd Place Championship,
K.N. Toosi Univ. Of Tech., Iran 2nd Best-In-Class Mobility,
& University of Koblenz, Germany 1st Best-in-Class Autonomy**

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Application for Practice

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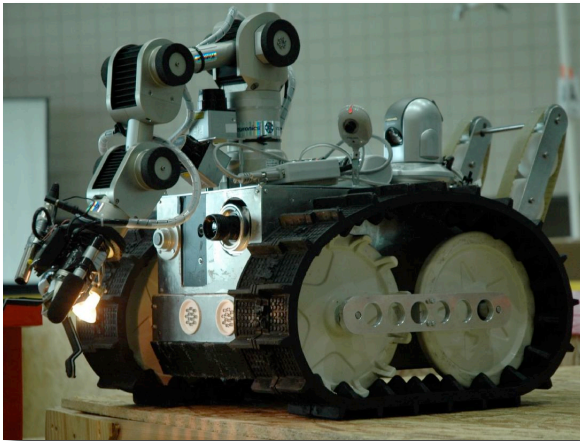




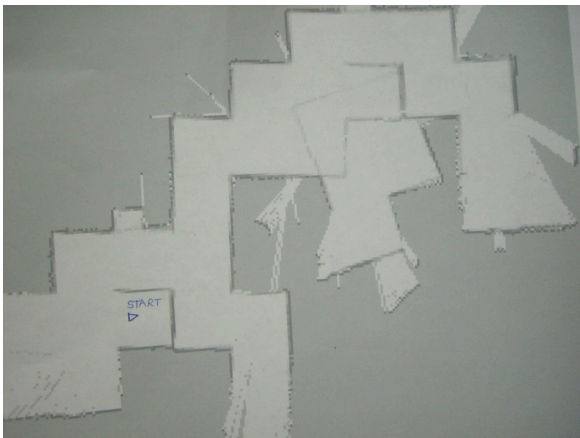
Jacobs Rescue Robot, Jacobs Univ Bremen, Germany **2007: 2nd Best-in-Class Autonomy/Mapping**



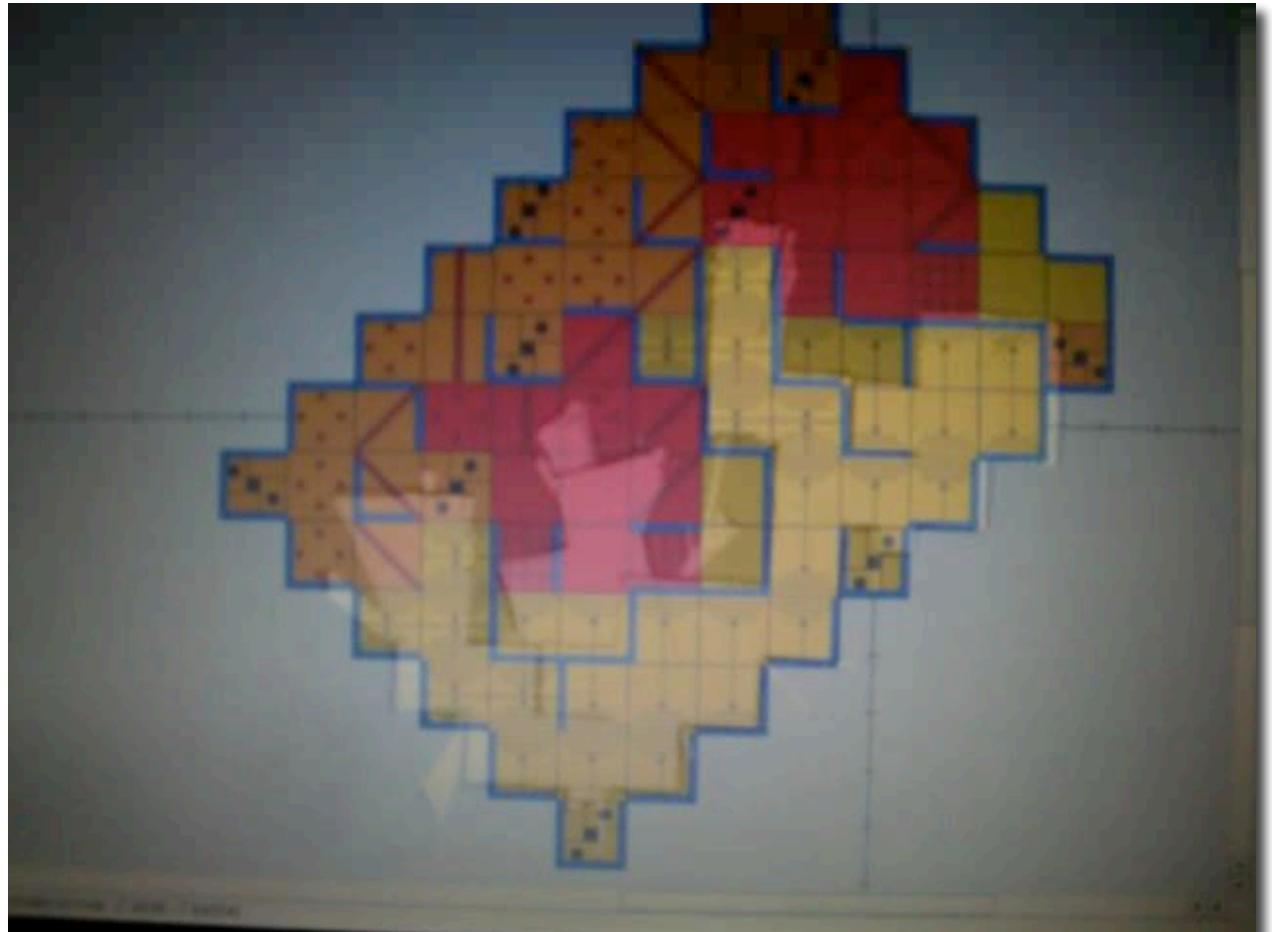
GEOTIFF map format allows direct comparison to ground truth arena layout.
RoboCupRescue teams are working on developing tools for quantitative evaluation of maps.



TEAM: RUGBOT, JACOBS UNIV, GERMANY



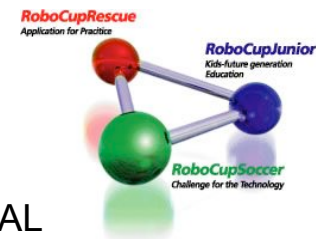
TEAM: RUGBOT, JACOBS UNIV, GERMANY



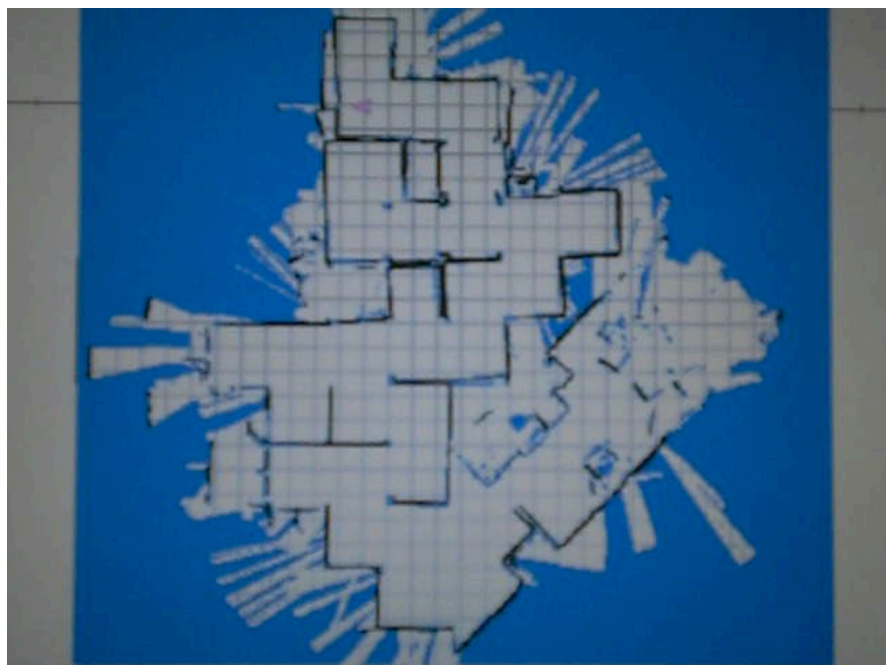
TEAM: JACOBS UNIV, GERMANY



RoboCupRescue Robot League 2008: Best-in-Class GeoTiff Maps

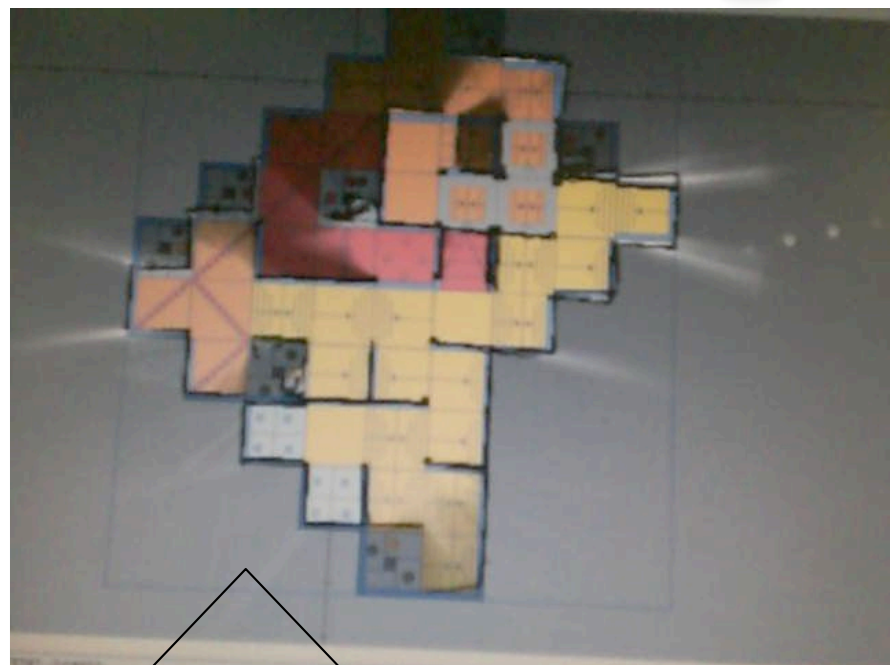


CURRENT GEOTIFF MAPS

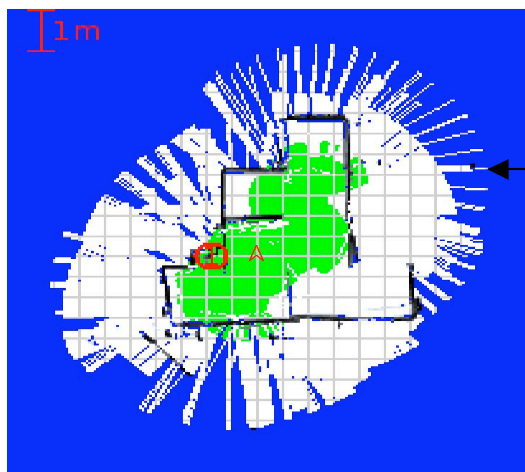


TEAM: RESKO, UNIV OF KOBLENZ AND LANDAU, GERMANY

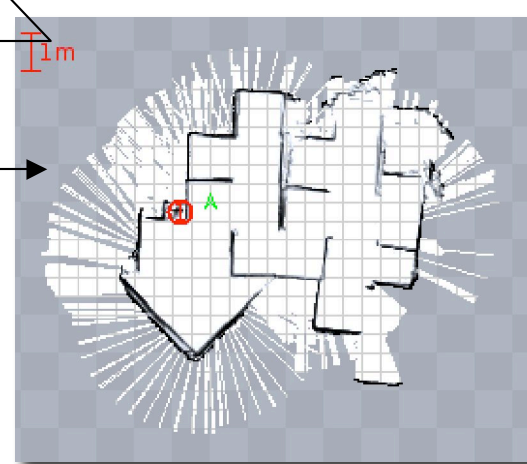
CLOSE TO THE GOAL



TEAM: RESKO, UNIV OF KOBLENZ AND LANDAU, GERMANY



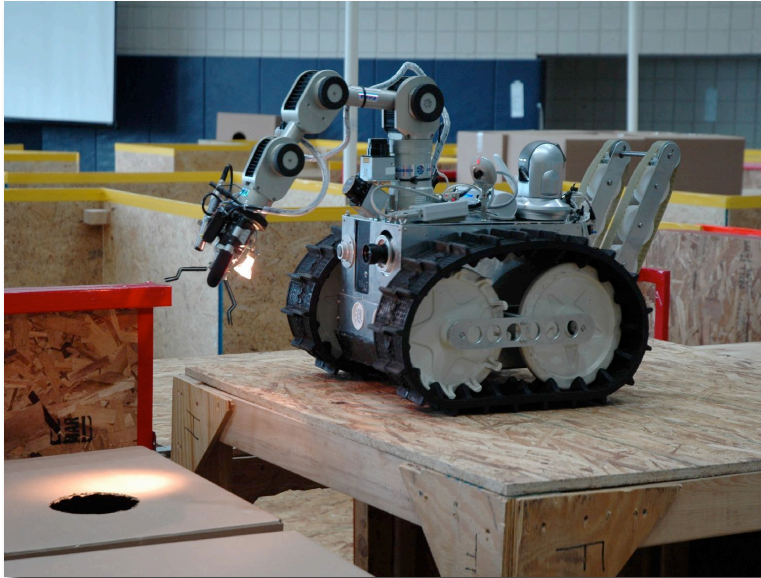
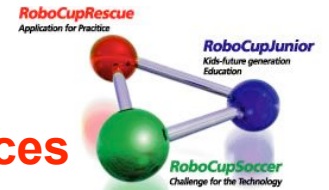
EXTRANEIOUS SCANS
SHOULD BE FILTERED,
COLORS TONED DOWN,
KEY FEATURES ADDED:
TEAM/EVENT, SCALE,
START POINT, VICTIMS and HAZARD
LOCATION ICONS





RoboCupRescue Robot League

Innovative Mobility, Sensors, Manipulators, and Interfaces



TEAM: RUGBOT, JACOBS UNIV, GERMANY



TEAM: RUGBOT, JACOBS UNIV, GERMANY



TEAM: RUGBOT, JACOBS UNIV, GERMANY

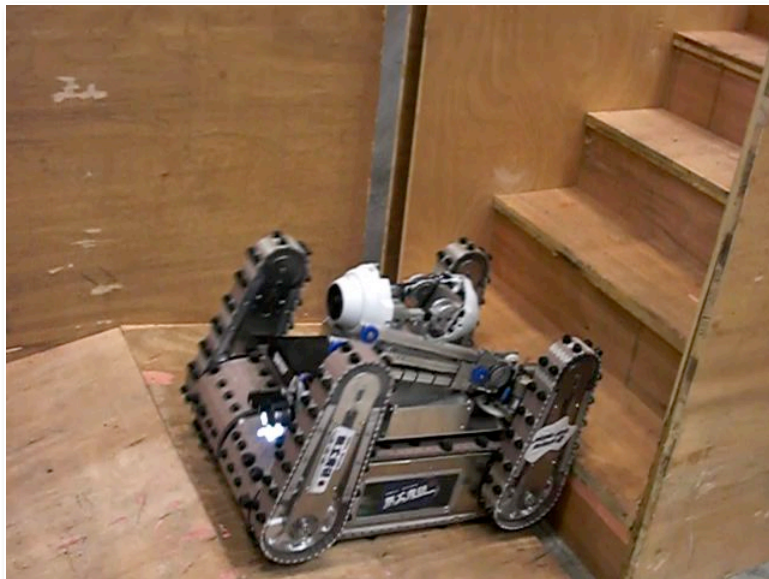
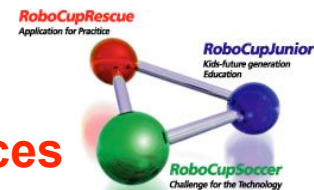


TEAM: RUGBOT, JACOBS UNIV, GERMANY

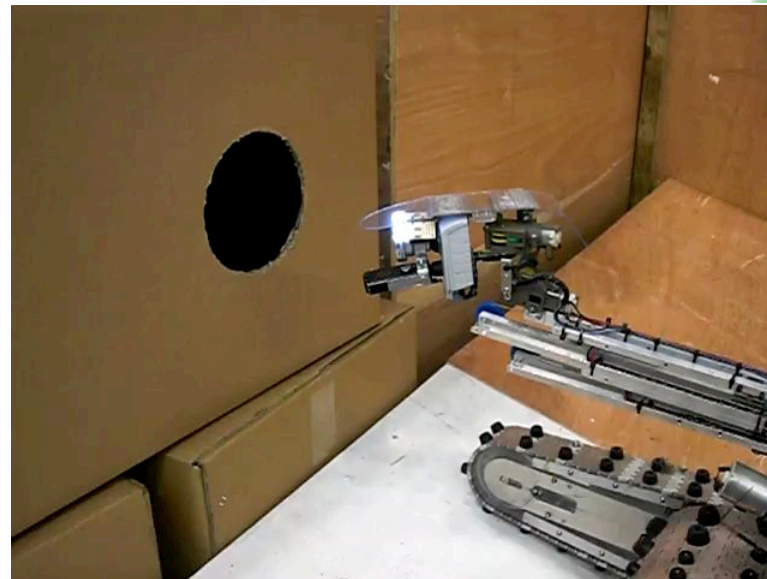


RoboCupRescue Robot League

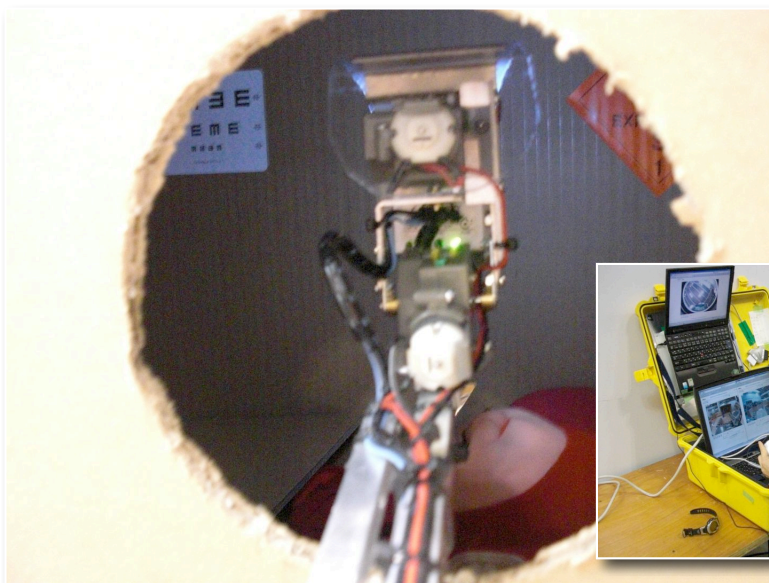
Innovative Mobility, Sensors, Manipulators, and Interfaces



TEAM: NUTECH-R, JAPAN



TEAM: NUTECH-R, JAPAN



TEAM: NUTECH-R, JAPAN



TEAM: NUTECH-R, JAPAN

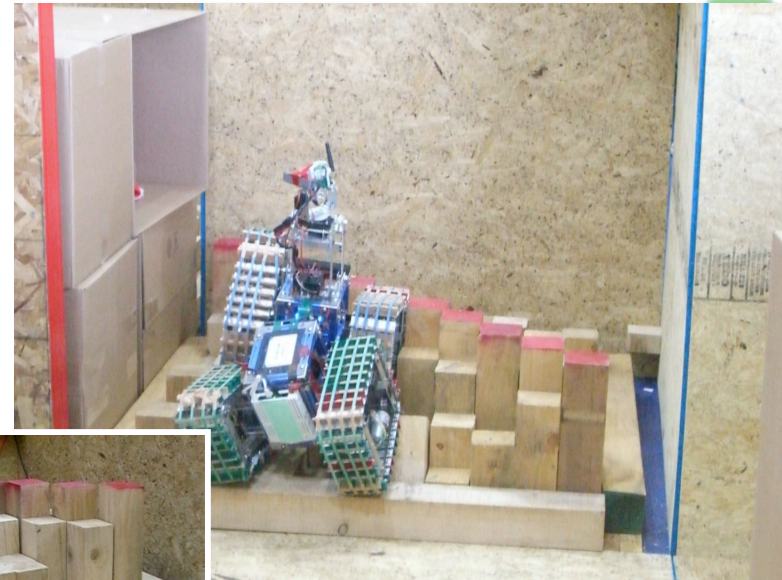


RoboCupRescue Robot League

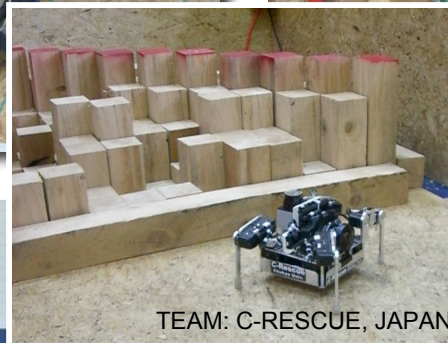
Innovative Mobility, Sensors, Manipulators, and Interfaces



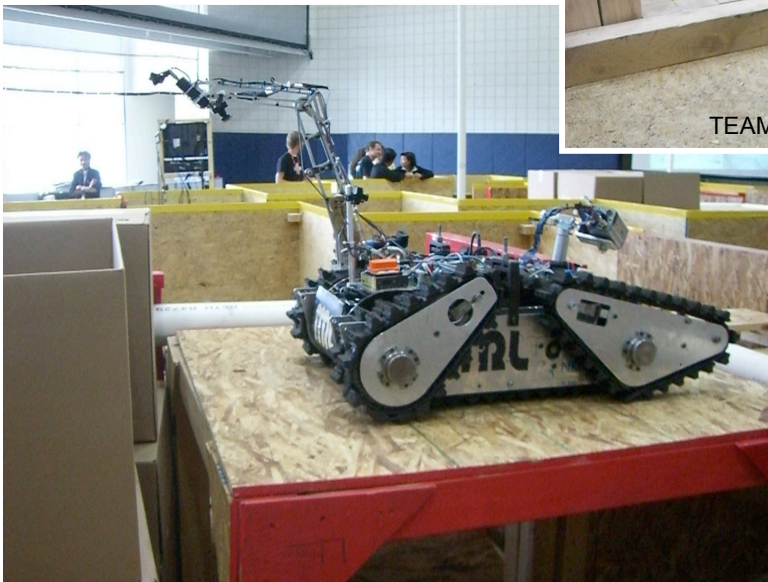
TEAM: INDEPENDENT, THAILAND



TEAM: NIIT-BLUE, JAPAN



TEAM: C-RESCUE, JAPAN



TEAM: MRL, IRAN

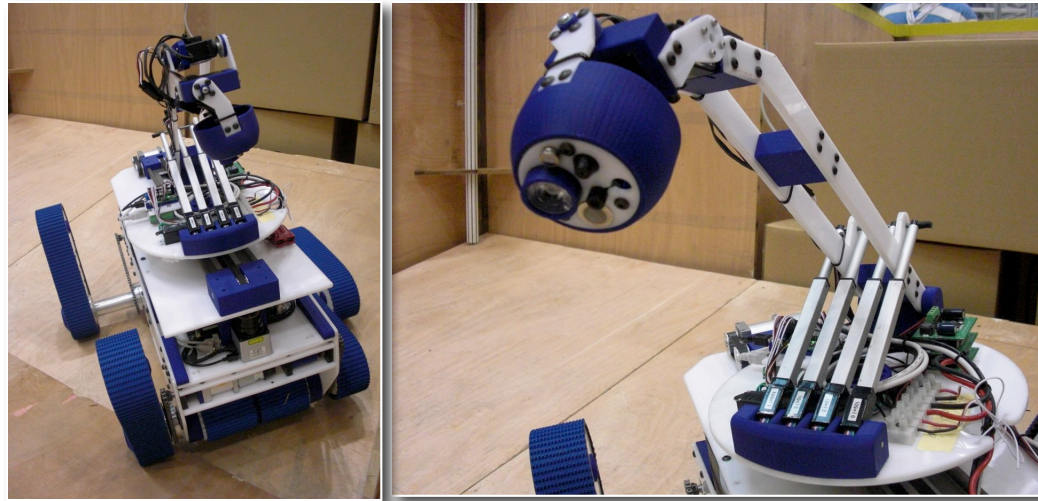


TEAM: CASUALTY, AUSTRALIA

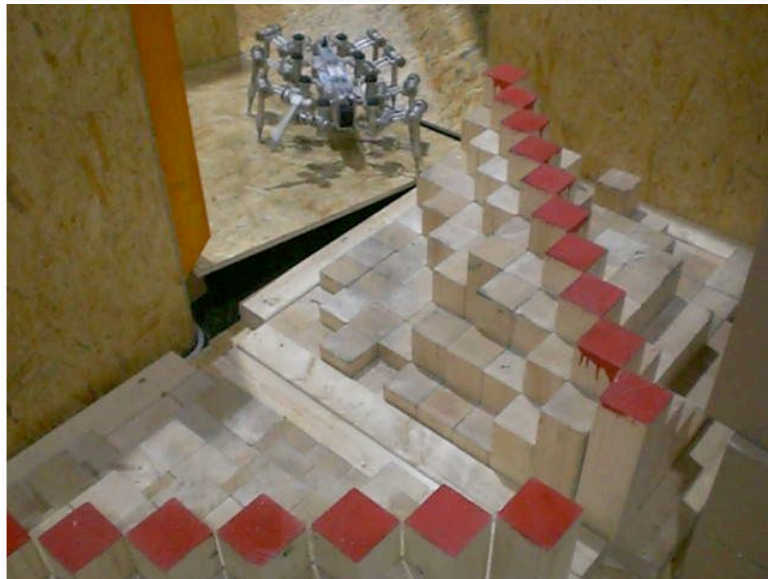


RoboCupRescue Robot League

Innovative Mobility, Sensors, Manipulators, and Interfaces



TEAM: RKRS, BENILDE ST MARGARETS HIGH SCHOOL, USA



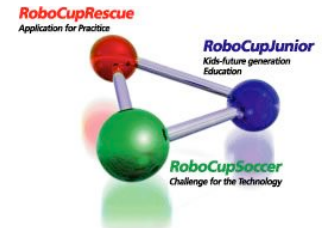
UNIV. OF BREMEN, GERMANY



UNIV. OF BREMEN, GERMANY



RoboCupRescue Robot League Accomplishments To Date

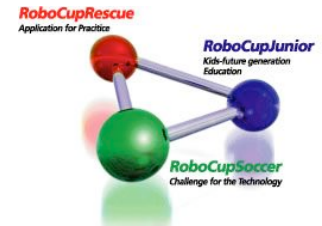


- Leverage of emerging standard test methods for response robots
- Non-flat flooring throughout the arenas challenging autonomy and mapping
- 2D GeoTiff maps with ground truth comparison (next year for scoring)
- Ultra wideband tracking of robot position within arena
- Quad-screen performance capture
 - Tracking position
 - Operator interface
 - Operator actions
 - Robot situation
- Capture and dissemination of sensor data sets
 - 3D range imagers
 - 3D rotating line scans
 - Thermal imagers
 - Stereo vision
- Winners contribute to NIST/DHS Response Robot Evaluation Exercises in with emergency responders in their training facilities





RoboCupRescue Robot League Roadmap



- Encourage autonomous behaviors on all robots
 - Many mixed-initiative teams already
 - Require for last victim in Orange and Red arenas?
- Mobile manipulation on uneven terrain (Blue arena)
 - Payload items (block, radio, water bottle)
 - Picking/Placing in field
 - Door opening (push/pull, assorted knobs)
- Integrate further with Virtual Robot Competition
 - Quantitative scoring of maps
 - Virtual test arenas from physical league
 - Physically test virtually effective capabilities
- Co-locate with @Home League to combine mapping missions, share household manipulation tasks (pre-collapse and post-collapse leagues)
- Minimize operator stations for operator deployment
- Encourage a bracket of common mobility platforms
- More regional opens and practice arenas
- Disseminate best-in-class implementations at camp
- Centralized repository of sensor data sets, etc.
- Publish, especially best-in-class implementations





RoboCupRescue Robot League

Rules at a Glance



New This Year:

- Victim placements will be known to the operators and audience prior to missions, and changed each round to ensure complete arena coverage over multiple missions.
- Resets allow fixing/replacing the robot at the start point but loss of accumulated victims, maps, and time.
- GeoTIFF map formats will be used to allow comparison of maps to ground truth arena configurations.
- Best-In-Class awards for autonomy and mobility will be given to robots that find the most victims in the Yellow and Red arenas plus focused task missions.

Arena Features: Yellow, Orange, Red

- Random mazes with non-flat flooring
- Ramp (45° to test torque, center of gravity, configuration)
- Stairs (40°, 20cm riser, 25cm tread depth)
- Stepfield pallets (full-cubic terrains)
- Confined spaces (ceiling blocks under elevated floors)
- Visual acuity (tumbling E eye charts, hazmat labels)
- Directed perception boxes with victims/targets inside

Simulated Victims: 4 per arena, 12 total

- The chair will place victims in two high and two low boxes per arena, in different locations each round.
- Signs of life: form, heat, motion, sound, and/or CO2
- “Trapped” are in boxes open on top
- “Void” are in boxes open to side
- “Entombed” are in boxes with view holes
- Tumbling E’s and/or hazmat labels are victim tags

Missions:

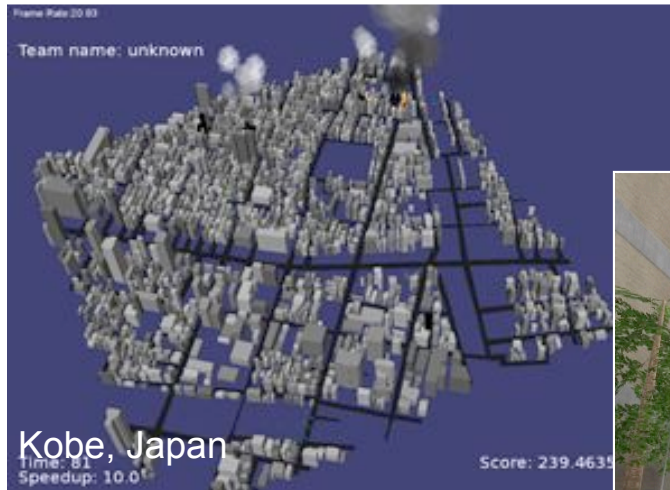
- Teams queue at paddock entry prior to scheduled start.
- 15/20/25 minute missions include robot placement at the start point and operator station setup. Each team is responsible for making sure victims are functional (heat, batteries, tags) prior to their mission start.
- Teams are allowed one operator at a time in station.
- Start points will be in the Yellow arena with all robots facing the same direction (“north” on your map).
- Yellow arena victims can be scored only by robots with autonomous navigation and victim identification. Operators may take over control at any time to drive into the Orange and Red arenas but must return to the start point to resume autonomous searches.
- Orange or Red arena victims can be scored by any robot and are accessible from the Yellow arena.
- Resets allow fixing/replacing the robot at the start point but loss of accumulated victims, maps, and time.
- Bumping penalties are assessed if the administrator must replace/fix arena elements prior to next mission.
- GeoTiff map quality and accuracy will be compared to ground truth in local segments from victim to victim.
- Highest cumulative scores from 7-10 missions will be awarded 1st, 2nd, 3rd place awards.
- Best-In-Class awards will be given to **individual robots** that do the following during all missions:
 - Autonomy: Find the most Yellow arena victims
 - Mobility: Find the most Red arena victims



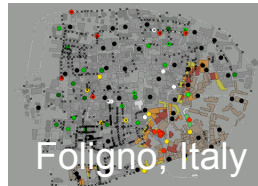
Three RoboCupRescue Competitions Complimentary Development Initiatives



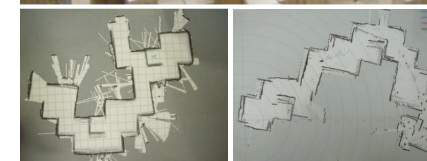
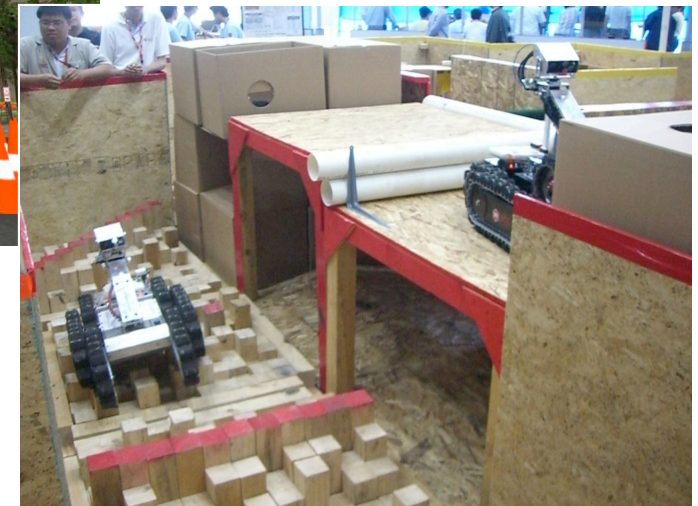
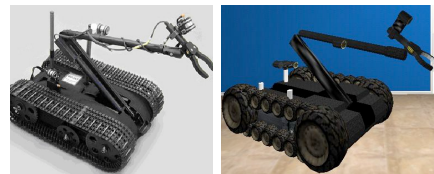
Simulation Competition
Citywide Logistics



Virtual Robot Competition
Multiple robots, larger scenarios



Real Robot Competition
*Advanced mobility, mapping on
terrains, assistive capabilities*



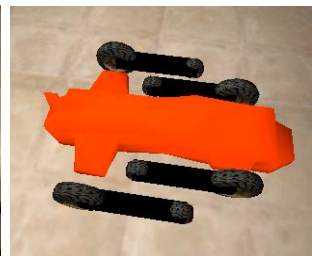
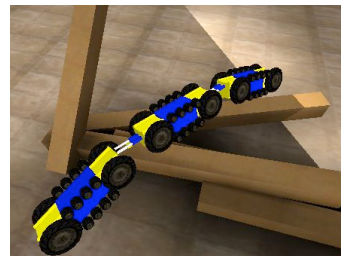
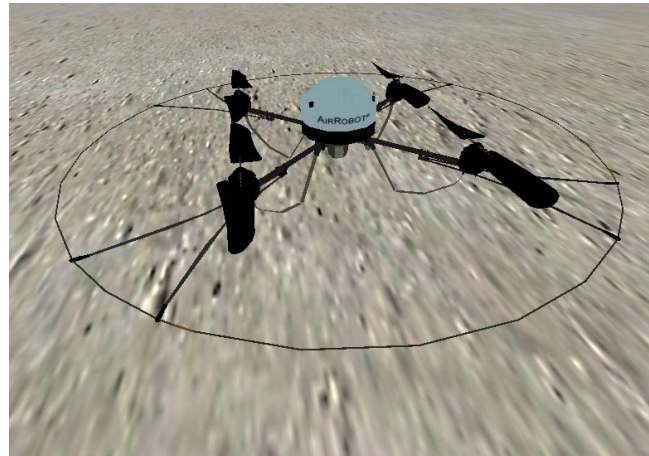
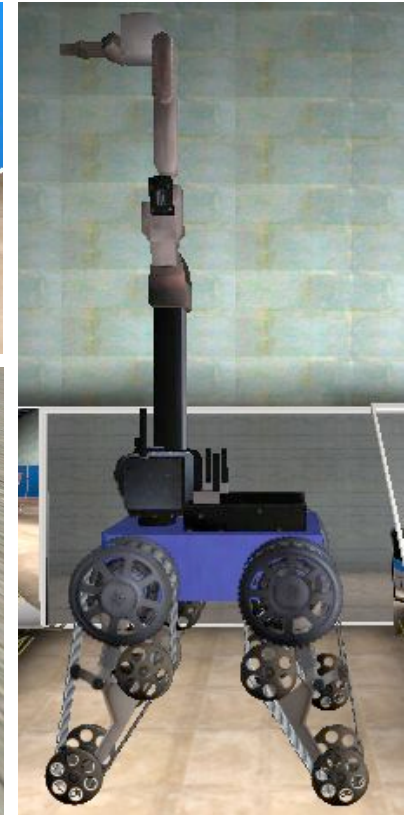


RoboCupRescue Virtual Robot Competition

Modeled Robots and Sensors

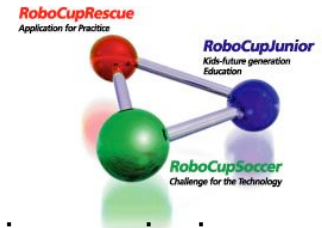


- Response robots
 - Talon
 - Telex
 - AirRobot
- Research robots
 - Souryu
 - Tarantula
 - ATRV-Jr
- Sensors
 - Cameras (pan/tilt, illumination)
 - Lline scan laser
 - Flash lidar
 - Acoustic
 - Touch
 - Odometry
 - IMU
 - RFID
- Model your own...

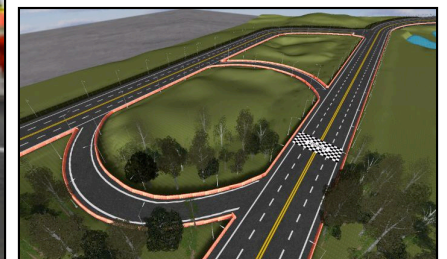
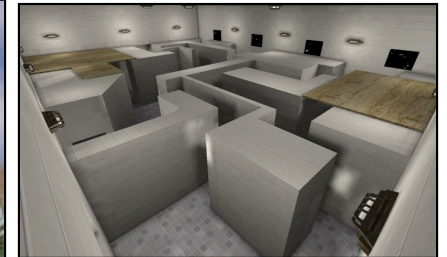




RoboCupRescue Virtual Robot Competition Modeled Environments (current)



- RoboCupRescue Robot League arenas as-built at each competition as preliminary mission
- Practice Environments
 - Emerging Standard Robot Test Methods (validated for friction)
 - Larger scenarios
 - Cooperative robot searches



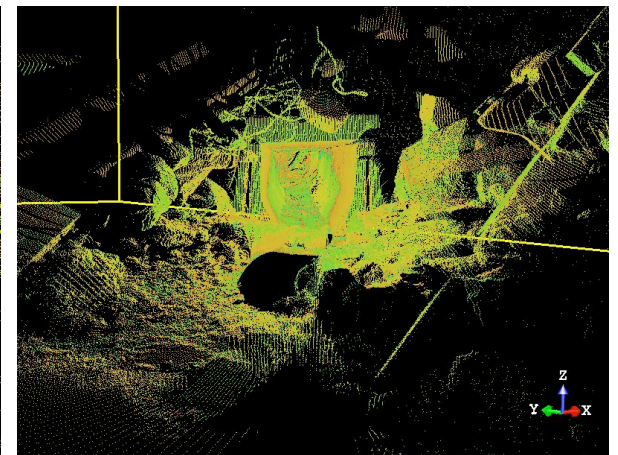
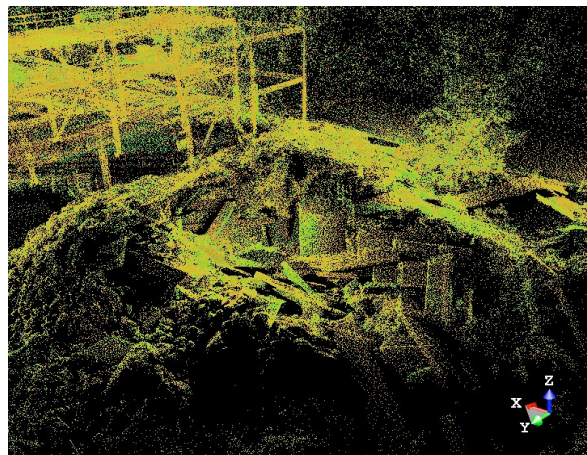
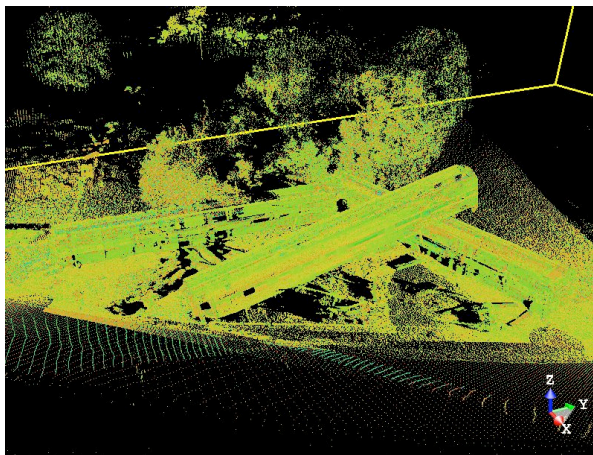
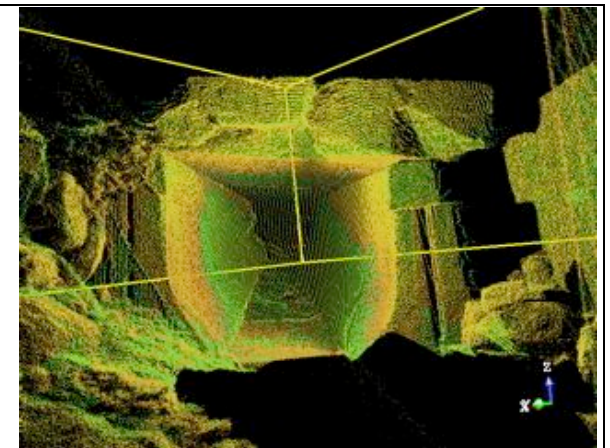


RoboCupRescue Virtual Robot Competition Modeled Environments (future)



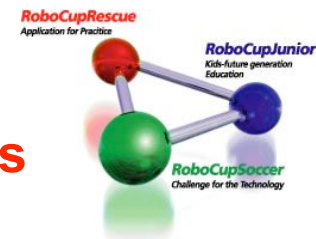
Working toward validation of laser scanned props from responder training sites

- Robot mobility development and refinement
- Robot behavior development and implementation of assistive features
- Responder training and practice





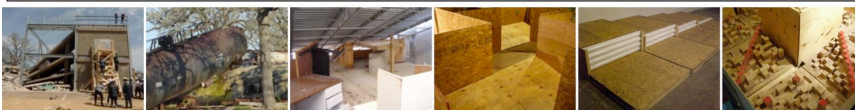
RoboCupRescue Robot League Winners Participate in Response Robot Exercises



Response Robot Evaluation Exercise

FEMA US&R Task Force Training Facility (TX-TF1)
Disaster City, College Station, TX
November 17-21, 2008
(including an ASTM E54.08.01 standards committee meeting Friday morning)

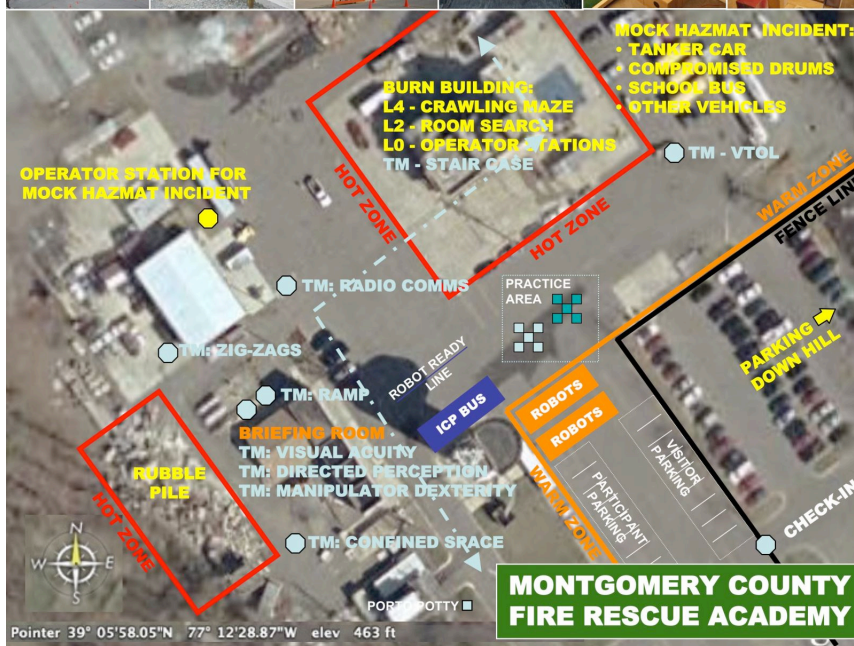
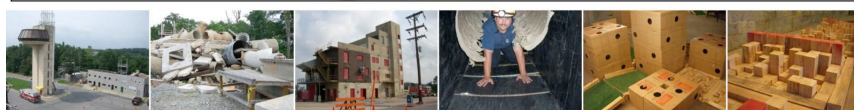
Sponsor: Bert Coursey, Science & Technology Directorate, DHS www.isd.mel.nist.gov/us&r_robot_standards
Test Director: Adam Jacoff, Intelligent Systems Division, NIST usar.robots@nist.gov



Response Robot Evaluation Exercise

MD-TF1 Training Academy
Rockville, MD
August 19-21, 2006
(with a standards meeting August 21, 2006)

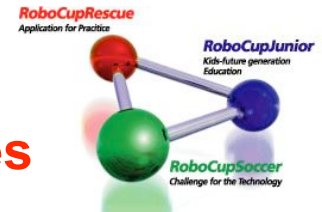
www.isd.mel.nist.gov/us&r_robot_standards usar.robots@nist.gov





RoboCupRescue Robot League

Winners Participate in Response Robot Exercises



Emerging Standard Test Methods For Response Robots

Logistics: Cache Packaging, Setup, Tools
 Sensors: Video: Acuity
 Sensors: Video: Field of View
 Sensors: Video: Spatial Awareness
 Sensors: Audio: Two Way Comms
 Sensors: Sonar: Resolution
 Radio Comms: Line of Sight
 Radio Comms: Non Line of Sight
 Radio Comms: Structure Penetration
 Human Factors: Check List Items
 Human Factors: Random Maze Search
 Energy: Endurance
 Mobility: Inclined Plane
 Mobility: Pipe Step
 Mobility: Gap Crossing
 Mobility: Stairs
 Mobility: Stepfield Terrain
 Mobility: Confined Space
 Manipulation: Directed Perception
 Manipulation: Grasping Dexterity
 Aerial (<2kg): Airworthiness
 Aerial (<2kg): Fixed Wing Orbits
 Aerial (<2kg): VTOL Station Keeping
 Aquatic: Station Keeping in Current





RoboCupRescue Robot League Winners Participate in Response Robot Exercises

