Abstract

The purpose of the competition is to provide a common benchmark to demonstrate scientific progress in robotics in the field of Urban Search and Rescue. The rules of this competition are inspired by the rules of the RoboCup Rescue Robot League and Agent competition. As in the Robot League, a devastated area has to be explored for victims with a team of robots controlled by an operator. Compared the Robot League, the focus of the research is more focused on team work to accurately explore large areas and less on mobility. As in the Agent competition, the disaster situation is not known before a competition run. Compared to the agent league, the focus is more on the sensory and actuation level and less on planning. This year the Technical Committee is looking forward to see cooperation between heterogeneous robots, as for instance a ground robot and an air robot.

1 Context

A gas explosion in a railway station has damaged a highly populated area. There are many victims. Sending in human rescue operators is postponed until the chemical mixture in the thick smoke is analyzed.

The Incident Commander in charge of rescue operations at the disaster site, fearing new explosions from a burning train, has asked for teams of robots to immediately search the interior and exterior of the railway station for victims.

The mission for the robots and their operators is to find victims, determine their situation, state, and location, and then report back their findings in a map of the area and a victim data sheet. The robots are considered expendable in case of the disaster gets worse.

2 League Objectives

The major goal of this competition is to encourage intuitive operator interfaces that can be used to monitor and control multiple heterogeneous robots in a challenging environment. Over the past two years, teams in the league have demonstrated that simple video streams and remote control are not enough. What is required is autonomous navigation and situation awareness for most of the robots; to allow the operator to concentrate on the robot in the most critical situation.

This year, ground robots may still be remotely operated, although autonomous capabilities should improve overall performance considerably. The introduction of the AirRobot will allow fast identification of locations to be inspected by the ground robots. Yet, the control of the AirRobot is difficult to automate, and the operator will need most of its attention to fly this robot.
on visual clues. This will leave the rest of the robot team on their own, to find traversable path to the locations indicated by the operator/AirRobot combination.

The introduction of the OmniDirectional camera will stimulate the introduction of navigation algorithms based on visual clues. The OmniDirectional camera is extensively used in the RoboCup Soccer League and a number of robots in the RoboCup Rescue Robot competition [2, 1].

3 Performance metrics

Each team will be judged on the map they will deliver after a competition run. The map has to be georeferenced in the GeoTiff format (identical to the format used in the Robot competition). This allows to compare the maps against the ground truth. The map may contain multiple overlays, indicating the information gathered from the environment. One overlay of the map will have a fixed color scheme, equivalent with the 2007 rules, to allow automatic processing of the exploration measure. A second overlay will contain a vector diagram, with a symbolic drawing indicating important locations on the map. Although this overlay should also be georeferenced, this overlay will only be judged on skeleton quality, and not on metric quality. The other overlays have a free format and can be used to provide additional information collected from the environment. The value of the additional information will be manually evaluated by the jury and can result in a bonus. The formula of the score $S$, as indicated in equation 1, has three components:

1. One can get up to 50 points for the exploration efforts $E$
2. One can get up to 50 points for the mapping quality $M$
3. One can get up to 20 points per victim $V_i$ found

To compute the overall score $S$ the collected points are divided by $H^2$, where $H$ is the number of human operators. For scoring purposes a team member is counted as a human operator as soon as a human:

- Starts a robot, enters initial points, or perform any operation needed for the successful start of the rescue mission
- Actively drives a robot around
- Stops a robot before the run is over (for example, to prevent it from bumping into victims)
- Is involved in any way in the victim recognition process

According to the above definition, each team will be charged at least one human operator for the robot setup, which means that $H \geq 1$ is guaranteed.

$$S = \frac{E \times 50 + M \times 50 + \sum i V_i \times 20}{(H)^2}$$

(1)

- The exploration effort $E$ is automatically determined based on the provided map. This map is analyzed for the area indicated as Cleared on the map (i.e. green in the overlay with the fixed color scheme) and indicated as Free (i.e. white in the overlay with the fixed color scheme). Those two areas are combined into a single value based on a weighted scheme ($0.6 \times \text{Cleared} + 0.4 \times \text{Free}$). The team which has explored the largest area will set the standard and will be awarded the entire 50 points. The explored area of the other teams will be scaled relative to largest explored area, and this percentage will be used to determine the number of exploration points. The number of exploration points will linearly decrease to 0. A 5 point penalty will be given (up to the maximum value achieved for the exploration) for each unreported victim that exists in an area reported as Cleared (see the issue about missed victims in the victim points section). Bumping into walls or other features during exploration carries no penalty; however some structures may be unstable and could collapse.
• The mapping quality $M$ is based on the following criteria:

**Utility** One of the main objectives of providing a map is to create the ability for a first responder to utilize the map to determine which areas have been cleared, where hazards may be located, and where victims were trapped. 10 Points will be granted by the judges. The points will be distributed by making a relative comparison of all maps on the utility measure. Missing standard attributes (for example no robot paths) will be penalized (indication: one point per missing attribute).

**Skeleton quality** Map skeleton reduces a complex map into a set of connected locations. For example, when representing a hallway with numerous doorways, a skeleton may have a line for the hallway and symbols along that line that represent the doors. A map may be inaccurate in terms of metric measurements (a hallway may be shown to be 20 m long instead of 15 m long), but may still present an accurate skeleton (there are three doors before the room with the victim). The category allows the judges to award 10 points based on how accurately a map skeleton is represented. The accuracy is determined by following the skeleton. False positives (gateways that do not exist) and false negatives (gateways which are obscured by non-existing obstacles) will be penalized (indication: one point per severe error).

**Metric quality** The accuracy of the map when compared to ground truth. The provided georeferenced map will be overlaid with the ground truth. 10 Points will be granted based on this measure. Inaccuracies will be penalized (indication: one point for 0.5 meter shift of large sections of the map).

**Attribution** One of the reasons to generate a map is to convey information. This information is often represented as attributes on the map. Important information for first responders is related with information on the location of victims, the location of obstacles, and the paths that the individual robots took. Standard attributes are already rewarded in the Utility measure. This measure is meant for innovations in information representation, setting the standard for next year. The points will be distributed by making a relative comparison of all additional information on the maps on the attribution measure.

**Grouping** higher order mapping task is to recognize that discrete elements of a map constitute larger features. For example the fact that a set of walls makes up a room, or a particular set of obstacles is really a car. 10 Bonus points will be awarded for annotating such groups on the map.
• The search and localization of victims is the prior task of the Virtual Robot team. The points earned for this task ($\sum_v V_v \times 20$) can easily surpass the exploration effort $E$ and mapping quality $M$ when more than 5 victims are found. For each victim found, the following information should be provided:

**Location**  The estimated center of the victim in the same georeferenced coordinates as used for the map. Based on the difference between the estimated location and the ground truth up to 5 points will be awarded. The precise form of the reward function can be adjusted in between competition rounds to reflect the accuracy that can be attained by the best team (indication: one point per 0.5 meter).

**Identification** Each victim correctly reported is rewarded with +5 points. When no information about a victim is provided and a victim is present in the Cleared area, a −5 penalty is given (false negative). When victim information is provided too far from any actual victim location (no localization points could be given), the victim is judged as incorrectly reported, and a −5 penalty is given (false positive).

Note that the same victim may be seen from multiple locations with multiple sensors. This often results in multiple nearby observations of body parts, which should be grouped to single report. Care should be taken that this grouping is performed carefully, to prevent the classification of nearby victims as one. When multiple victim reports are provided for a single victim, the report with the shortest distance to the true victim is taken into account to calculate the reward. All other reports are taken into account as false positives. In this special case the −5 penalty is scaled linearly with the localization error. False positives so far from the actual position that no location points could have been given, get the full −5 penalty.

**Attribution** One of the reasons to search and localize is to convey information. Points will be awarded for including information on the observed body parts, pictures of the victim, movement of the victim and status of the victim. Up to 10 points per correctly reported victim can be granted by the judges that reflected their feelings on the utility of this information.

**Uncertainty** The team could provide a probabilistic estimate $P_i$ with its victim report. This estimate $P_i$ indicates of the chance there is really a victim at that location, and is used to reduce penalties for false reports. On the other hand, it also reduces all the rewards gained. When no estimate is given, an estimate of $P_i = 1$ is assumed.

**Uncontrolled bumping** Each victim touched by a robot will incur a penalty of 5 points. If victim Jane is touched by robot A, the team will be penalized 5 points. If the same robot touches the same victim multiple times, no additional penalties will be counted. However, it later on robot A bumps into victim Mark, an additional 5 penalty points are charged. The same applies if victim Jane is touched by robot B. Bumping into victims is automatically detected and logged by the server.

All information used for scoring should be turned in no later than 15 minutes after the competition run is completed. Late information will not be accepted for scoring purposes.

**IMPORTANT:** even if a team runs with 10 robots, in the end only a single file can be submitted. The operator that started the robots must prepare this file. Any other person that manipulates robot result files will count as an additional operator for scoring purposes. It is up to the team to decide whether a comprehensive merged file or the best among the individual files should be submitted. Multiple layers of information are allowed and even encouraged, as long as they are georeferenced, and the two obligatory overlays are present.
4 Competition runs

During the competition, indoor and outdoor urban search and rescue scenarios will be encountered. The day before the run, the teams will be given basic information about the scenario. This basic information will include the origin and location of the disaster (i.e. chemical spill in a large terminal), possible dangers (i.e. a mud slide made part of the area difficult traversable), simple georeferenced maps of the area (not guaranteed to be up to date) and the start locations of the robots on that map.

In response to this input, teams will be required to submit to the referee the ini file describing each robot that will be used for the mission. Submissions are binding, i.e. no changes to the robots will be allowed. The organizing committee will then review these files to make sure that they meet budgetary constraints as well as include realistic platform sensor combinations. Teams submitting files that do not pass such inspection will be forced to compete with standard platforms, i.e. those shipped with the latest USARSim distribution. Only robots validated by NIST will be allowed to be used in the competition. The list of accepted robots and sensors is reported in this document as appendix. Note that not every combination is possible. The referee reserves the right to disallow any unrealistic combination of robots and sensors.

During the competition the organizers will provide two sets of machines (from now on each set will be called cluster). USARSim will be run in client mode on the cluster. Each team will run its client code on its own machines. A single TCP/IP cable will be provided to the team to connect to the cluster. One of the two clusters will be used by the team currently competing, while the second one will be used by the team setting up for the following competition round. Each team has 30 minutes to setup on the cluster currently being unused. The run starts at the scheduled time. If a team is not ready, time will start anyway. Robots are provided with batteries that will operate for 20-25 minutes. At the prescribed start time, the robots will be instantiated in the world. The robots must wait for a 'start' command to be issued before beginning their exploration. The robots are responsible for monitoring their battery condition. Information not reported and logged before batteries expire will not be counted towards the total score. All robots must be spawned at the same time, though teams can decide to activate them at their convenience.

All communications (operator-robot and robot-robot) will use the Wireless Communication Server WSS\(^1\). Notice that this includes the connection to the image server. In this way the operator base station can only send commands to a robot and will obtain measurements and video images from a robot only when that robot is in radio contact. The location of the operator base station and the wireless cutoff strength are provided as a-priori data. During the competition all socket communication towards the robots is logged, to be able to check for TCP-packages that bypass the Wireless Communication Server. Teams that violate this policy are immediately disqualified.

5 Open source policy

The winning teams are required to provide a fully functioning copy of their software to the organizers before the final ceremony. Other teams are encouraged to do the same. The software will be posted on (or linked from) http://www.robocuprescue.org givin proper credit to the authors. Source code for the 2006 and 2007 competition is available at the aforementioned webpage.

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\(^1\)The WSS is developed and documented by Max Pfingsthorn in 2008. The WSS simulate wireless network links in a disaster setting. In a disaster settings network links are not guaranteed, which forces robot-control developers to deal with the main issues of unreliable wireless links, such as either multi-hop routing to the operator or autonomous behavior of the robots. During the competition, the WSS will operate with the DistanceOnlyPropagationModel.
6 Résumé

The intention of the competition is to stimulate research in robotics that allow autonomously and safely explore significant parts of the environment providing high quality maps and demonstrating the capability to actively search and localize victims (or clear environments) using robot models consistent with the state of the art. The organizing committee has the obligation to make the competition a challenging but fair challenge. NIST personnel neither involved nor affiliated with any of the participating teams and institutions are part of the organizing committee. In case of protests or objections, after having consulted the relevant parties, the final word is up to them.

7 Acknowledgments

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References


Appendix A: File Formats

Start locations

Before each run, each team will receive a text file containing the starting position (x,y,z) and orientation (roll, pitch, yaw) for the operator base station and each robot. Position coordinates are to be expressed in meters, while orientations will be in radians. The file will consist of as many lines as robots, and each line will be composed by the line number followed by the robot starting point and orientations.


A priori maps

Prior to the competition, georeferenced maps will be provided. The map format will be GeoTiff. It should be noted that the maps may not be up to date and may therefore contain errors due to renovations, blocked passages, etc. This map will indicate the locations of obstacles (indicated in black). Further, an estimate is given how challenging a certain area will be with respect to mobility, communication and victim detection. The following color scheme is used:

- Red channel is for mobility
- Blue channel is for communications
- Green channel is for victims

In each color channel, four values have a predefined meaning:

- 0 is reserved for untraversable areas (obstacles)
- 85 is low level of difficulty
- 170 is medium level of difficulty
- 255 is high level of difficulty

Robots should only conscious enter an area with high level of difficulty for mobility if they are able to navigate step-field-like areas, steps and stairs, constricted spaces, avoid holes and drops, true 3D areas. Robots should only enter areas with high communication difficulty when they have active relay strategies. Robots will not have direct communication while in this area and obstructions exist that prevent driving the robot back into range. At the highest level of difficulty of victim detection one can expect significant victim occlusion (entombed or hidden), many false alarms and moving victims.


Obligatory color scheme

Each team should provide a single file with a map in GeoTiff format with one overlay with the following colors (RGB coordinates are provided assuming color components are coded in a single byte):

- Non traversable - Black RGB(0,0,0)
- Cleared (=traversable, and victim free) - Green RGB(0,255,0)
- Uncleared (=traversable but not necessarily victim free) - White RGB(255,255,255)
- Unexplored - Blue RGB(0,0,255)
• Victim location - Red RGB(255,0,0)

This overlay will be used to automatically determine the explored area.
Other georeferenced overlays in the file can be used to convey additional information (for instance the robot paths) in private color schemes.

Victim file

The teams should provide a single text file containing the discovered victims (Victim file from now on). The victim file should contain the locations of each discovered victim (x,y,z) in a reference frame consistent with the map file (see previous section) and the given start locations. The victim file format is as follow: each line of the text file should contain (in sequence) a victim id (assigned by the team) and the position (in meters), a specification how the victim was discovered (VICTIM if the victim sensor is used, VISUAL if the victim sensor is not used) and the probability that there is a victim at that location (normalized between 0 and 1). The last line of the file should contain the string END. An example of valid victim file which reports two possible locations of victims, one location where enough confidence is build to classify it as victim, another location that is classified as FALSE_ALARM. Additional information about those victim locations, as for instance pictures, should be starting with victim id as provided in the Victim file.

Victim1, 2.3, 5.6, 0.0, VICTIM, 0.7
Victim2, 7.0, 4.4, 0.0, VISUAL, 0.4
END
Appendix B: Allowed robots and sensors

Teams can use combinations of the following robots:

- AirRobot
- ATRVJr
- Hummer
- P2AT
- P2DX
- Talon
- Telemax
- RugBot
- Zerg

Teams can use combinations of the following sensors:

- Encoder
- GPS
- Hokuyo
- INS
- Odometry
- OmniCamera
- RobotCamera
- SickLMS
- Sonar
- VictSensor
- RFIDSensor
- TouchSensor

Sensor load will be examined. For example, a Zerg cannot carry a SickLMS. An AirRobot has not enough on-board computing power for a VictSensor. The technical committee reserves the right to disallow any unrealistic combination of robots and sensors. Prior to the competition\(^2\), the technical committee will publish a number of logical configurations that can be used during the competition.

Note that not all robots and sensors will be available for every scenario. The teams should for instance be prepared for an outdoor scenario where no wheeled robot is available, or an indoor scenario where no flying robots can be used.

\(^2\)Posted to the mailing-list on July 3th, 2008