RoboCup Rapidly Manufactured Robot Challenge

Rules 2019 V1.5

These are the official rules for RoboCup Rapidly Manufactured Robot Challenge (RMRC). They are released by the RoboCup Rescue Technical Committee in conjunction with RoboCupJuniour Committee members. The English rules have priority over any translations.

It is the responsibility of each team to be aware of the latest rules. Please see http://comp.oarkit.org for the latest version of this rules document, the change log and any last-minute and at-competition amendments. There will be no allowances made for teams that are disadvantaged due to working off an old version of the rules.

Additional information regarding the RMRC (tutorials, construction, past events), see http://comp.oarkit.org.

This document is still a draft! While the content is there, we are fixing formatting and numbering, removing duplicate and contradictory information and making it easier to read. Please post suggestions to http://list.oarkit.org/!

There are several points in here that are still open to discussion! These are marked as such but we also welcome discussion on other points in this document. Again please post suggestions and comments to http://list.oarkit.org/!

Scenario

The RMRC paves the way for just-in-time, custom purpose, low cost robots for actual deployment. Two major issues with current response robots are that they are necessarily a compromise as they must carry out many different missions and they need extensive, unique spare parts inventories and associated logistics. In a deployment scenario, an RMRC robot will consist of a logistics unit, such as a shipping container, containing an inventory of standard parts, 3D printers, feedstock and a catalogue of robot designs and software. When disaster strikes, such as an earthquake or industrial accident, the perfect robot can be produced by the responders on-the-spot, using performance data gathered within the standard test methods to make their decision. These robots will be inexpensive, easy to repair and similar in their control methodology. It is hoped that the best robots from the RMRC may become the prototypes that, along with their developers, feed into a future Open Response Robot Kit.

Edit by: Raymond Sheh, Gerard Elias, Graham Stock, Archer Losely, Amy Eguchi.

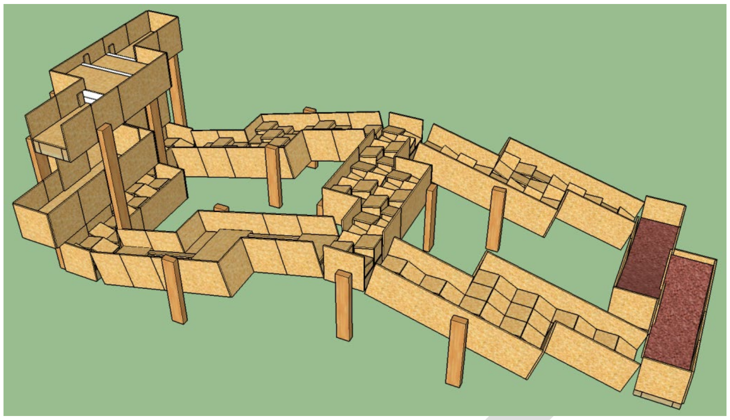

Figure 1: Sample configuration of arena

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Summary

The main objective of the RMRC is to advance the state-of-the-science in small, lightweight, rapidly manufactured response robots. To this end, we conduct challenging and fair competitions that inform teams about the tasks necessary to be effective for responders and guide development towards open research problems. We also need to measure progress in our robotic systems to highlight breakthrough capabilities that responders can understand and appreciate. Ten or more successful repetitions begin to indicate a reliable capability. A series of trials across a suite of complementary tests begin to evaluate the system.

The RMRC challenge format closely resembles Response Robot Exercises. These have been effective in communicating capabilities between robot manufacturers and responders. Each robot will be evaluated in standard and prototypical DHS-NIST-ASTM International Standard Test Methods for Response Robots.

Performance in the preliminary rounds demonstrate functionality, reliability, operator proficiency, and autonomous/assistive capabilities. Several teams are able to simultaneously deploy their robot in multiple test lanes and score points for each lap undertaken. These scores are normalized to a maximum of 100 points per lane depending on the best scoring team in that lane. This scoring method encourages breadth of capability, excellence in capabilities that many teams possess and development of new capabilities.

The resulting scores will qualify them for a "deployment" into a more complicated scenario in the Finals. This will also enable concurrent testing opportunities for more robots to capture statistically significant performance and encourage testing in more complex or difficult settings, challenging robots beyond their comfort level to compile more points. Teams may bring multiple robots to the preliminary rounds to see which does better however all scoring is performed per-robot and they will not be allocated more opportunities to test. Therefore, doing so risks splitting their score.

The Finals will provide an opportunity for teams to demonstrate their abilities to overcome a series of test methods in the overall arena for the best performing robots. Each qualified team is allowed to bring one robot to the finals. The arena will consist of all the same test apparatuses as in the preliminaries. The layout of the finals arena will be decided by the teams that qualify for the finals. Teams may start their robot in any location and traverse the arena in any order.

The RMRC incorporates a standardised process for practicing and measuring league capabilities throughout the year, with challenges being the public demonstration of those capabilities and sharing of results. So we encourage you to build and practice these tests during your development. Then demonstrate your capabilities at challenge time for scores.

This structure will help our league communicate emerging capabilities to responders and allow them to guide such capabilities toward deployment. Local responders may come watch the challenge and potentially demonstrate their own robots. This will familiarise them with the test methods and our emerging capabilities, making RoboCup Rescue a leading incubator for robots and test methods worldwide.

Terminology:

- Test Method: A combination of a test apparatus, test procedure and test metric developed under the ASTM International E54.09 Subcommittee on Homeland Security Applications: Response Robots. Note that the RMRC may use prototypical test methods as well as ones that have been standardised.
- Test: An instantiation of a Test Method specific for RMRC. Robots complete tests to score points.
- Trial: A robot performing a test within a certain time, generally 5 minutes in RMRC. Robots may perform multiple trials in the same test but only the best will count.
- Task: A component action of a trial that, if successful, results in a point being scored. In general, the score for a trial is the sum of the tasks successfully completed within that trial.
- Bay aka Lane: A test that is laid out in the pattern shown in Figure 3. Note that not all tests occur in bays/lanes.
- Terrain: A uniform or repeating surface pattern filling a bay, such as gravel.
- Obstacle: A specific non-repeating surface pattern filling a bay, such as a step.
- Lap: A task within a bay consisting of any part of the robot touching one end wall while fully within the end 60 cm of the bay, and then the other end wall while fully within the other end 60 cm of the bay. During finals when bays are interconnected, exiting one bay and entering another is also considered a valid start/end of a lap.
- OC (Organising Committee): The organisers of the RMRC, made up of members of the RoboCup Federation Executive Committee, RoboCupRescue Robot League Technical Committee, RoboCup Junior Committee and their delegates.

1. Test Suites

The RMRC is designed around standard robot test methods that evaluate each robot's capabilities individually in a systematic way. The RMRC consists of several robot tests which are structured into four suites:

- Manoeuvring (§1.1)
- Mobility (§1.2)
- Dexterity (§1.3)
- Sensing (§1.4)

There are an additional two special tests.

- All robots must, by the end of the first day, pass through the Configuration Management and Sensor Calibration test (this is separate from the Sensing tests in §1.4). No points are awarded for this test.
- During the finals, an additional drop test is added as the only example of the Durability test suite. This test does not appear in the preliminaries to avoid prematurely damaging the robot.

Information regarding each of these suites is included below. Note that the sample test suites shown are example configurations only and may have altered configurations during the challenge.

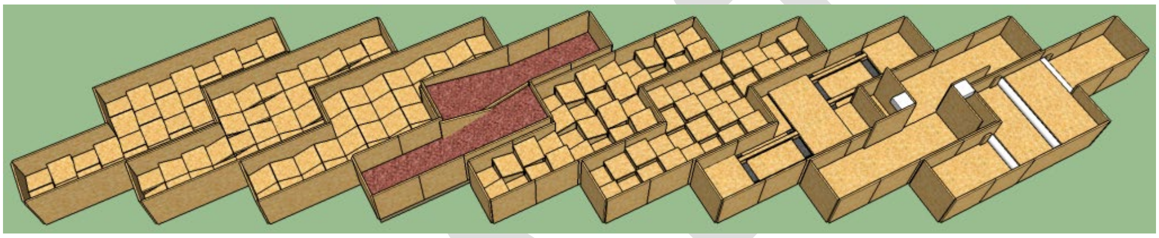


Figure 2: Sample of robot testing suites

All ordinary bays are 1.8m (6ft) in length and minimum of 30 cm (1ft) in width. New in 2019, we will also be offering *a selection* of these bays in a 60 cm scale (ie. each dimension of the bays, terrains and obstacles doubled compared to that listed below, including the height). These will be considered completely separate tests. Further details to come, particularly as to which terrains will be offered in this scale. See Figure 15 for an example. Please visit http://list.oarkit.org to keep up to date and to offer your suggestions!

The surface is made of Oriented Strand Board (OSB), Plywood or similar. The bays generally have walls of wood or clear plastic to confine the movements of the robot. Robots should not rely on the walls to aid in their movement through the bays. For some tests, walls may be removed to prevent larger robots from gaining an unfair advantage. In such a case, the robot falling out of the terrain will be considered a reset.

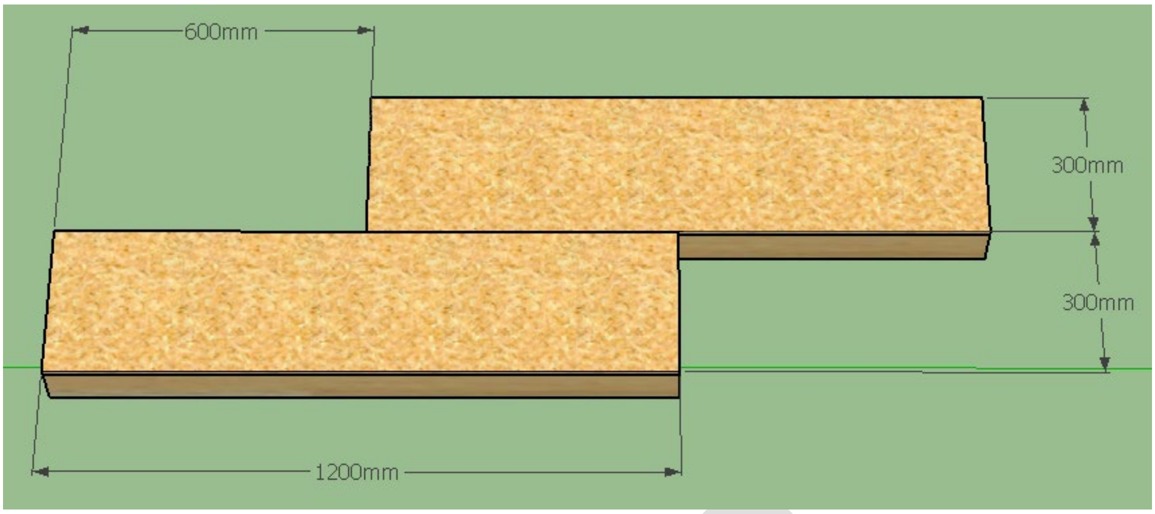


Figure 3: Standardised Testing Bay

For further information on construction of ground robot tests, refer to http://oarkit.intelligentrobots.org/home/the-arena/v1-0-arena/

1.1 Manoeuvring

Four basic terrains and obstacles test manoeuvring capabilities. All robots should be capable of performing these tests as they focus on the ability of a robot to be precisely controlled relative to its surroundings. For teleoperated robots, these test methods shall be completed in forward and reverse driving orientations. Due to the cost of sensors often required for autonomous operation (and, thus, the difficulty in replicating them on both ends of the robot), fully autonomous robots may turn around if they can. The metric in these tests is the number of laps completed.

1.1.1 **Centre**: A slalom with turn width (gap between centre walls) set to 120% of the robot's diagonal dimension in its smallest practical driving pose, to the nearest 2cm (measured during the Configuration Management and Sensor Calibration test), challenging a robot's awareness of interactions across it's width.

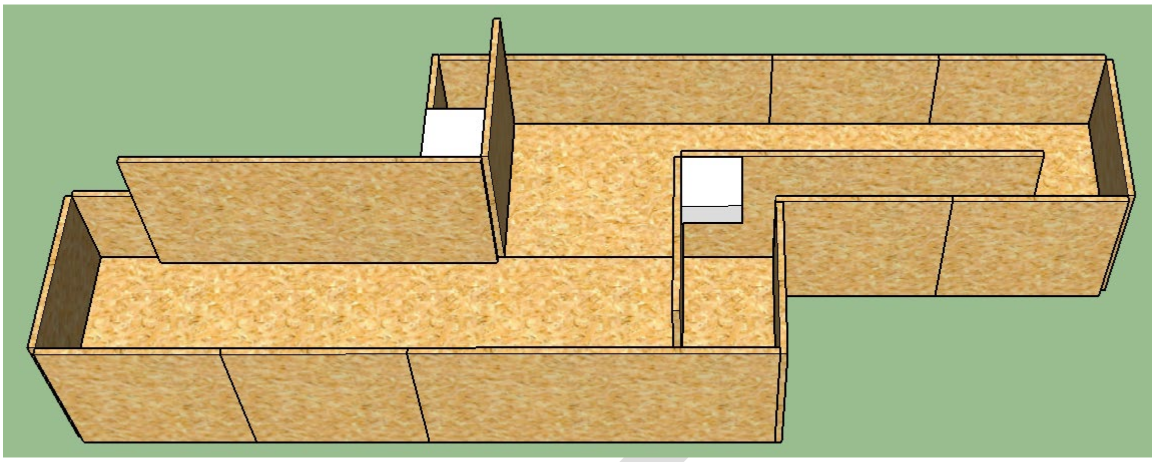


Figure 4: Centre (aka Slalom) Testing Method

1.1.2 **Align**: Two bars (25 mm width) to cross. These are set so that their centrelines match the robot's outer ground contact width (measured during the Configuration Management and Sensor Calibration test). The robot's track or wheel outer edges will be centred on each rail to limit left/right error similarly for various locomotion designs. Note that robots, particularly wide ones, should not take advantage of the walls to aid in this test. The walls may be removed to prevent this. For robots that are not an even width between the ground contacts at the front and the back (eg. robots with flippers or tricycle robots) the OC should set up the apparatus such that, as reliably as is practical, the robot should fall off the bars if it deviates from a straight path by more than 12.5mm.

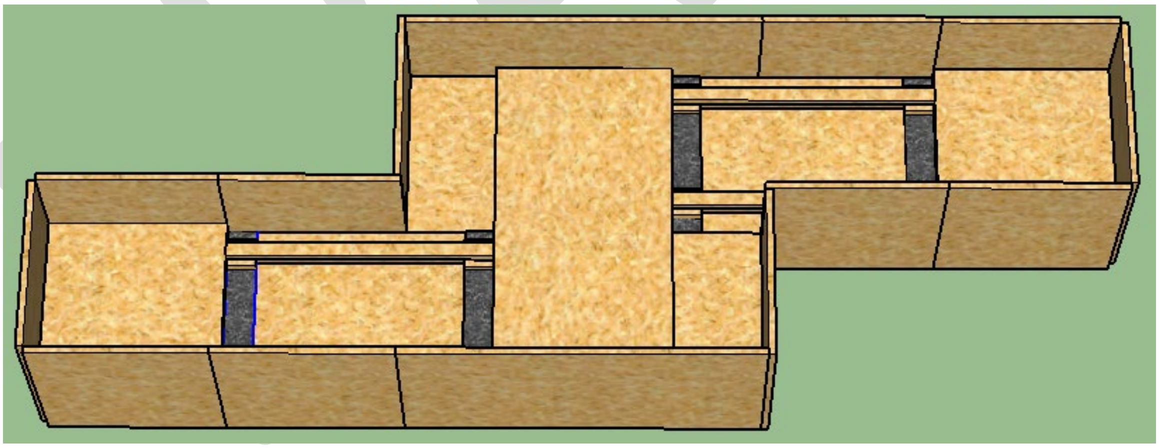


Figure 5: Align Testing Method

1.1.3 **Traverse**: A 30 degree inclined OSB surface to follow line in a zig-zag pattern both forward and reverse. For RMRC this may consist of an otherwise flat lane that is tilted at 30 degrees.

Figure 6: Traverse Testing Method (Major Arena Method Pictured)

1.1.4 **Crossover aka Crossing Ramps**: A field of 15 degree ramps with a discontinuity to cross over.

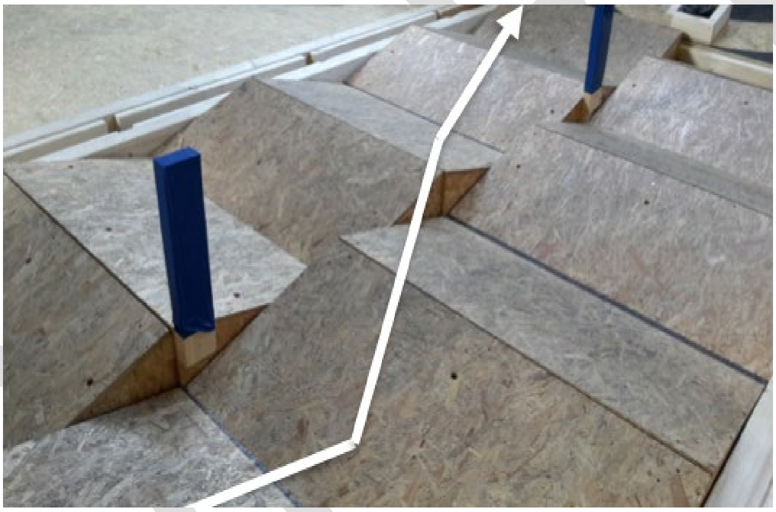


Figure 7: Crossover Testing Method (Major Arena Method Pictured)

1.2 Mobility

For testing a robot's mobility capabilities, there are four tests driving over terrains and obstacles with medium to hard difficulty, and all tests are considered for a robot to win Best in Class Mobility. Robots are able to turn around if they cannot overcome the terrain or obstacle in reverse. Again, the metric is the number of laps completed.

1.2.1 Hurdles: A 5 cm tall rolling pipe obstacle to climb and descend. Note that the centre pipe may also be turned 90 degrees. Robots should start at the end with a single pipe step.

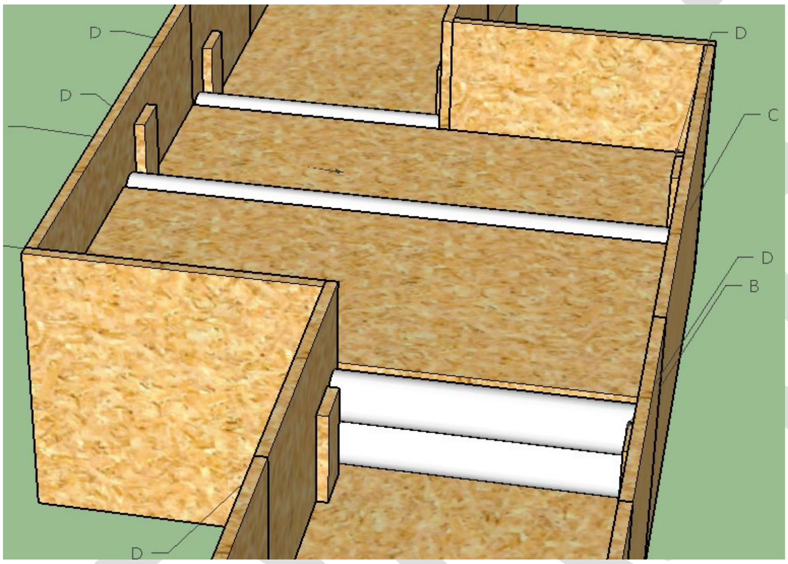


Figure 8: Hurdles Testing Method

1.2.2 Sand/Gravel Hills: An alternating hill terrain with 15 degree slope. Note that for RMRC, this may be implemented as one half sand, one half gravel.

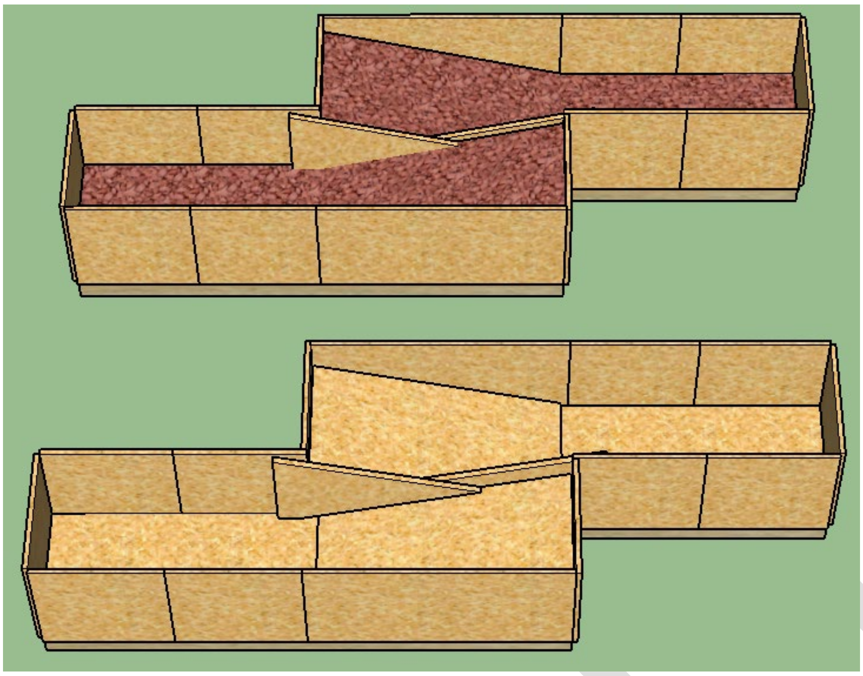


Figure 9: Sand/Gravel Hills Testing

1.2.3 Stepfields: A diagonal hill terrain consisting of 15cm square steps made from posts with flat tops. Each height increment is 5 cm.

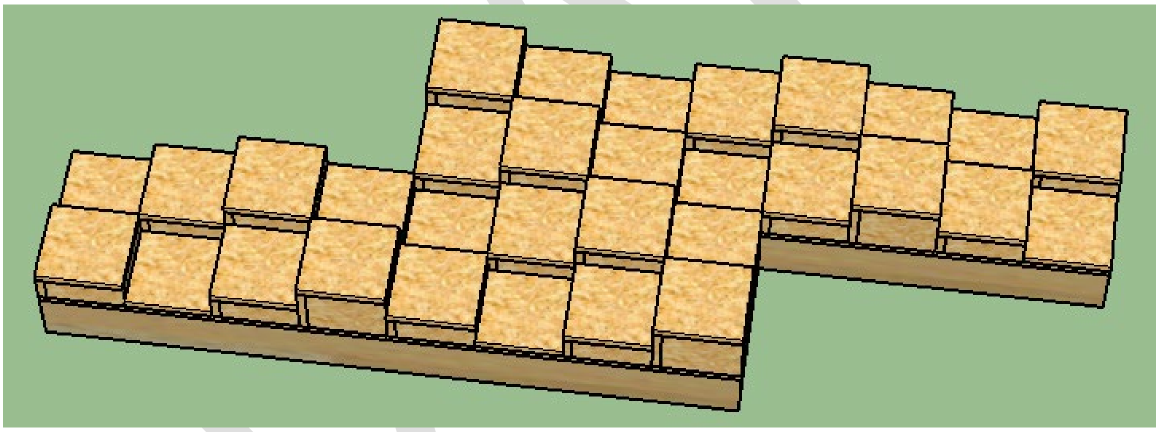


Figure 10: Stepfields Testing Method

1.2.4 Elevated Ramps: Diagonal hill terrain consisting of 15cm ramps with sloped tops (similar to the DARPA Robotics Challenge). Each height increment is 5cm and the ramps are sloped at 15 degrees.

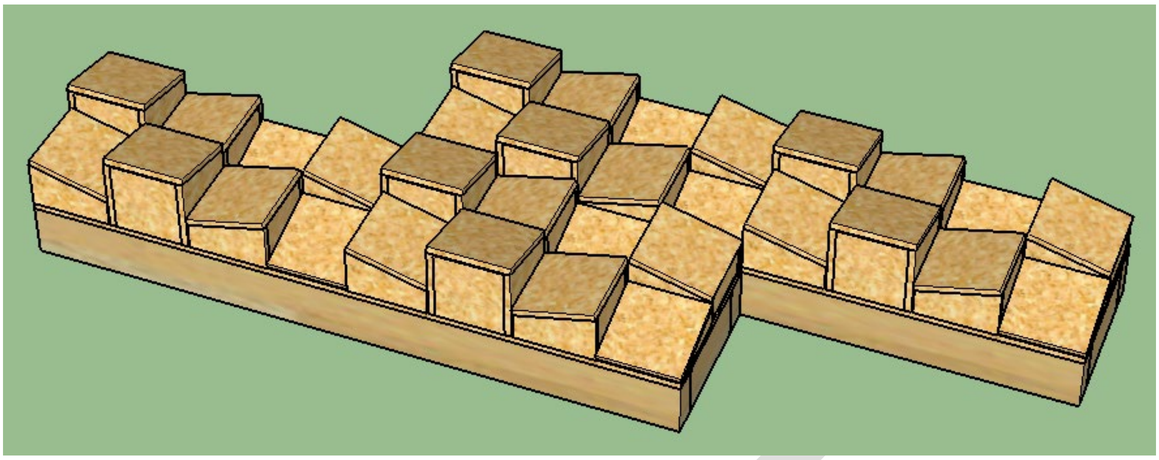


Figure 11: Elevated Ramps Testing Method

1.3 Dexterity

There are four tests for dexterity and inspection. All tests are considered for a robot to win Best in Class Dexterity. Unlike terrains, all four tests of dexterity are performed in the same location but are scored separately.

The tests to be performed are precision touch, rotation, extraction and inspection as shown in Figure 12. The pipes are 5 cm (2 in) in length and 2.5 cm (1 in) in diameter. Extract and rotate caps have 8 facets which are approximately 1 cm (0.5 in) wide. The dexterity board shown in Figure 12 is 15 cm (6 in) on each side.

Each test consists of completing the relevant operation up to nine times, once in each of the nine pipe locations on the dexterity board shown in Figure 12. The four dexterity boards, one per test, are arranged on a 180 cm (6 ft) terrain board with 30 cm (12 in) crossing ramps as shown in Figure 13. The assignment of dexterity board to terrain board corner is arbitrary. Having one board per task reduces the need for human intervention during the test trial. The purpose of the terrain board is to introduce complexity for robots that do not have enough degrees of freedom or reach in their arm to complete the test from a fixed position.

The robot starts in the middle of the terrain board and scores a point for every pipe at which a touch, rotate, extract or inspect task is performed. The robot may drive around the board but falling off the board or otherwise requiring human intervention results in a reset. Knocking a pipe off the board results in no score for that task. Pipes will not be replaced until the next reset. Robots may score a task in the same pipe multiple times in a trial but they must disengage from the dexterity board between repeated attempts by returning to the middle of the terrain board.

Figure 12: (L) The four dexterity tests: Inspect, Precision touch, Rotate and Extract. (R) The nine locations on a dexterity board where the test is to be performed.

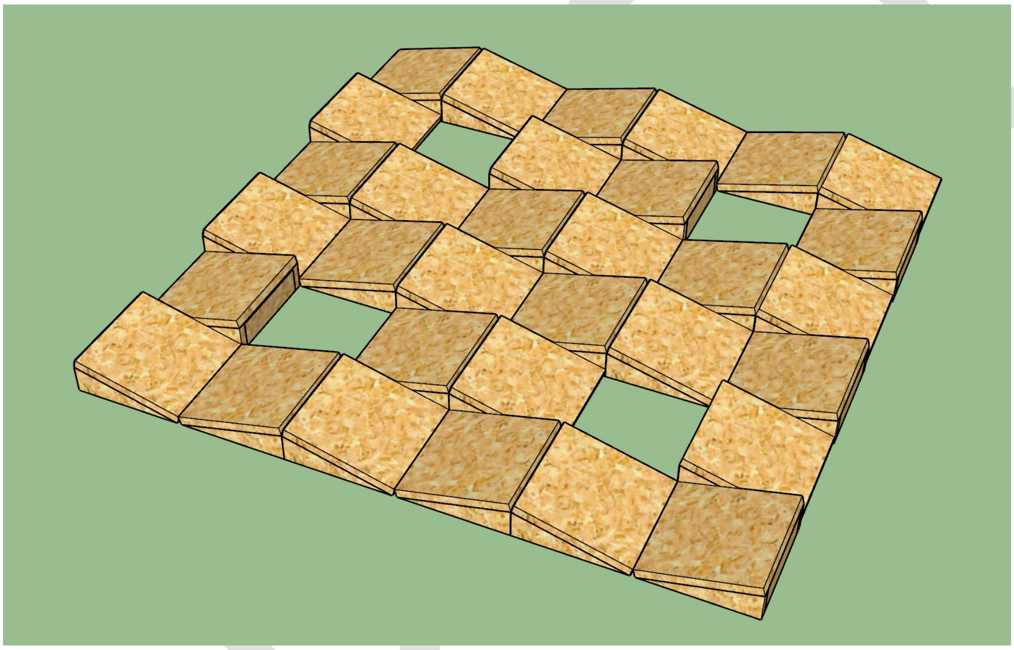
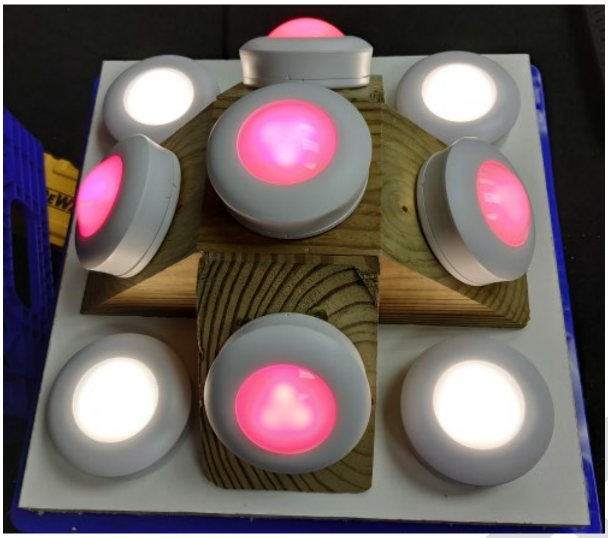


Figure 13: Terrain board on which dexterity tests are performed. Note that the 15 degree ramps are 30 cm (12 in) on each side, twice the size of the normal 15 cm (6 in) RMRC ramps. The four dexterity test boards are placed in the blank spaces.

The four tests are as follows:

- Precision touch: Using a designated point on the robot, precisely touch the 1 cm diameter centre target.
  - ***PROPOSAL: A less precise but wider reaching button test as an addition or replacement.*** This involves 9 battery operated "touch lamps", of the type one puts in wardrobes and cupboards and can be turned on and off by tapping them. Visit http://list.oarkit.org to discuss.



- Rotate: Using the robot's manipulator, rotate the octagonal cap at least 90 degrees. Note that it is up to the operator to declare when the task is completed as maintaining sufficient situational awareness to observe this is part of the task. No point is awarded if the operator is incorrect in this declaration (but the task at that location cannot be re-attempted if the operator declares that it has been completed until the robot returns to the middle of the terrain board). No one should communicate the state of the task to the operator until the overall trial is complete.
- Extract: Using the robot's manipulator, extract the cap and place it into a 15 cm (6 in) box placed on the terrain board. The team may place this box wherever they like but they cannot move/replace it if the robot moves or knocks it (unless the team wishes to call a reset, eg. if the robot moves it to a location where it can no longer be accessed or knocks it off the terrain board).
- Inspect: Using any camera on the robot, inspect the Landolt-C optotypes inside the pipe and correctly determine the direction of the 2mm optotype. Note that the interior of the pipe may not be well lit.
    - ***Proposal: Operationally significant objects in each pipe to identify instead? Discuss at http://list.oarkit.org.***

1.4 Sensing

NOTE: This replaces the Exploration section in Major since, in RMRC, we would like to focus more on developing advanced sensing on these smaller platforms and few (if any) teams have mapping and/or map-based autonomous exploration capability. ***Should we still have some Exploration/Mapping in here? Discuss at http://list.oarkit.org.***

1.4.1 Sensor Test: A standard 30 cm (12 in) crate with several sensor tests as shown in Figure 14 is placed in front of the robot. The tests are Visual/Thermal Acuity (the black areas of the Landolt-C optotypes are heated), Motion (the disc with black spot rotates), Colour Acuity, Hazmat Label, Audio Acuity and CO2. The purpose of the crate is to both limit the access of the robot to the test artefacts as well as to introduce complex lighting to the problem.

Motion must be automatically detected. The display to the operator should show a smooth indication of detected movement around the moving black spot. Indicators should not appear in other areas of the image that do not correspond to moving objects in the environment.

The hazardous materials labels must be automatically detected and recognised. The location and identity of the labels should be indicated in the video displayed to the operator. No objects that are not hazardous materials labels should be indicated and the same region should not be indicated as multiple labels. There should be no operator intervention in the detection and recognition of the labels.

Proposed points allocation is as follows. Tests marked (operator) require the operator to observe and interpret their OCU display. Tests marked (automatic) need to be interpreted automatically. **(POINTS ALLOCATION OPEN TO DISCUSSION, see http://list.oarkit.org to participate!)**

- Visual Acuity (operator): 1 point for correctly identifying the orientation of the 8mm gap, 1 point for the 3.2mm gap, across 2 Landolt Cs yields 4 points total.
- Thermal Acuity (operator): 1 point for detecting the presence of heat, 1 point for the 20mm gap, 1 point for the 8mm gap, across 2 Landolt Cs yields 6 points total.
- Motion (automatic): 2 points for detecting and tracking the black spot, across 2 disks yields 4 points total.
- Colour (operator): 0.5 points for correctly identifying each coloured square, across 5 colours, across 2 labels yields 5 points total.
- Hazmat (automatic): 3 points for correctly identifying each label, across 2 labels yields 6 points total.
- Audio acuity (operator): 8 letters/numbers read out, 0.5 points for each correctly identified, 4 points total. Note that this does NOT need to be done automatically. Expect conversational volume levels (easily understood by a typical human in the same position as the robot) in ambient noise typical of a convention/competition environment (ie. general noise but not necessarily cheering).
- CO_2 (operator): 2 points for demonstrating an increase in CO_2 level when a CO_2 source is exposed to the robot (eg. human breath or compressed CO_2 canister).
    - This year we will permit teams to release the CO_2 source anywhere (including up against the robot). In future years, this will be released from the back of the crate and robots will need to detect the rise in concentration from the front of the crate.

Figure 14: Crate with sensor tests, clockwise from top left: Visual/Thermal Acuity, Motion, Colour, Hazmat, Visual/Thermal Acuity, Motion, Colour, Hazmat. Note that the dexterity manipulation object in the centre is ignored for RMRC as dexterity manipulation is evaluated elsewhere. Audio acuity (a speaker playing a computer-generated voice speaking numbers and letters) and CO2 are not visible in this picture.

1.4.2 Survey Acuity Test: This test is conducted within the 60 cm scale continuous or crossing ramps terrains. A large number of QR codes of different sizes, with features ranging from 10 mm down to 0.5 mm in size, are fixed to the walls from ground level up to a height of 60 cm. An example is shown in Figure 15. One point is awarded for each unique QR code that is decoded. The robot may follow an arbitrary path around the terrain bay. The OCU must display the identity and picture of each code that is decoded in realtime (eg. by placing a crosshair or bounding box around the code and displaying the identity next to it or in an adjacent console window) and save the identities and pictures of the codes to a file. It must do so without operator intervention (ie. the process that detects and recognises codes should always be running), the operator merely drives the robot near the codes so that they can be detected and recognised. To avoid having the scoring process slow down the trial, scoring may be performed on the file rather than in real time.

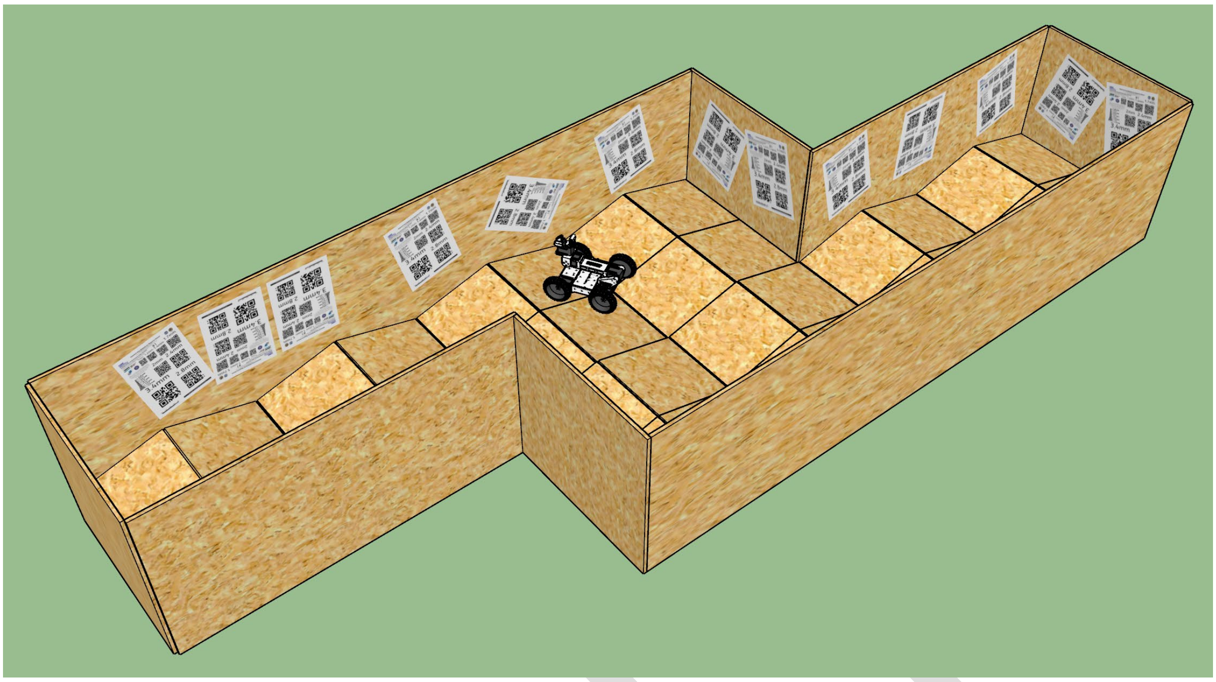


Figure 15: An example of the Survey Acuity test, with an Emu Mini robot for scale. The terrain shown in this case is 60 cm clearance, continuous ramps. The arrangement of QR codes will be randomized and each code will be unique.

1.5 Configuration Management and Sensor Calibration: This test establishes the identity of the robot and capability of its sensors. This test may be performed any time from the availability of the test (during practice time) until the end of the first day of preliminary rounds. Teams may avoid taking up a preliminary timeslot by performing this test during the practice days. No points are awarded for this test, it only needs to be performed once and does not require any particular preparation on the part of the team (apart from making the working robot available).

This test consists of the following steps:

- Photographs of the robot and control unit from the front, top, side, oblique and details in front of a metered background.
- Measurement of the robot and control unit's dimensions and weight. In particular:
  - The diagonal length of the robot when in its smallest practical driving configuration, as used in the Centre test.
  - The width of the ground contact of the robot, as used in the Align test.
- Enumeration of the various features and characteristics of the robot.
- Measurement of the robot's visual acuity.
- Measurement of the robot's video latency.
- Calibration of the Survey Acuity test method.

Further details of the specific measurements will be made available closer to the competition.

1.6 Drop Test (Durability): This test is only performed during the Finals to avoid excessive wear on the robots. Teams have the option to start the robot from a platform at 0.5 m (worth 1 point) and 1.5 m (worth 2 points) above a flat terrain board. The normal reset rules apply, the robot must be able to continue with the rest of the maze without human intervention (eg. flipping the robot back over).

2. Robots

Robots in the RMRC can be operated under two categories, Autonomous and Teleoperated. Robots are compared together as they compete the exact same test. A repetition generally consists of successful completion of a terrain or obstacle from start zone to end zone, or as defined in Section 1 for tests that do not involve traversal (eg. sensors or dexterity).

A robot may be in more than one class. The classes are defined by:

- **Autonomous Robot**: A robot that completes a repetition without intervention by a single operator in a remote operator station. Any repetition (which is a subtask such as driving from the start zone to the end zone or the other way) that requires operator intervention is considered a teleoperation repetition. Note that the autonomy itself may be on board the robot or it may be on the operator station computer. While this is less representative of deployment situations (where autonomy may be needed in the event of a communications break), for RMRC we wish to allow all teams to attempt autonomy, even if they do not have access to suitably high powered embedded computers.
- **Teleoperated Robot**: A robot that completes a repetition with any intervention by a single operator in a remote operator station.

2.1 Control

2.1.1 Robots may be autonomous (no operator) or remotely controlled. Operators must be out of sight of the arena and so they can only see through the robot's sensors. All radio transmissions must be 802.11a or 802.11c.

2.1.2 No Bluetooth communication is allowed. Specific network guidelines will change from year to year depending on country regulations where the challenge is being held. Please check www.robocup.org for the latest regulations.

2.1.3 Robots must be started manually by the operator.
2.1.4 Robots may utilise various maze navigation algorithms. Any use of map information obtained prior to the run (eg. movements predefined based on known locations or placement of features in the field) is prohibited.

2.1.5 A robot must not damage any part of the field in any way. Any damage to the arena that requires human intervention to maintain fairness will result in a reset.

2.1.6 Robots should include a stop/pause button so they may be easily stopped/paused by the team members to avert any potentially damaging or illegal robot actions.

2.2 Construction

2.2.1 Robots must be manufactured such that a reasonably well equipped high school or makerspace will be able to recreate their entry. In addition to 3D printing and laser cutting, this may include basic CNC machining equipment, basic PCB fabrication, etc..

2.2.2 Components and board modules that may be plausibly provided to high schools through grants, sponsorship or as samples are also allowed. In contrast, we consider items such as custom ICs, high precision SLS printing and the like to be generally out of reach of a reasonably well equipped high school or makerspace. If in doubt, please consult with a member of the OC or post to http://list.oarkit.org with any concerns or questions.

2.2.3 Teams are, in general, discouraged from using unmodified, professional, off-the-shelf robot platforms (eg. those used by government and military first responders). Teams who have access to such platforms (eg. due to collaborations with responder organisations) and wish to make use of them need to demonstrate their own innovations in their qualification Team Description Materials (TDM) (this may include comprehensive testing of the robot platform).

2.2.4 For the safety of participants and spectators, only lasers of class 1 and 2 are allowed. This will be checked during inspection. Teams using lasers must be able to show the sensor's data/information sheet.

2.2.6 Communication must be as per the guidelines outlined in §2.1, and as per regulations for country in which the challenge is to take place in a given year. Robots that do not comply will not be allowed to operate until they are made compliant.

2.2.7 Robots may incur damage by falling off the field, or making contact with field elements. The organising committee cannot anticipate all potential situations where damage to the robot may occur. Teams should ensure that all active elements on a robot are properly protected with resistant materials. For example, electrical circuits must be protected from all human contact and direct contact with other robots and field elements.

2.2.8 When batteries are transported or moved, it is recommended that safety bags be used. Reasonable efforts should be made to ensure that robots avoid short circuits and chemical or air leaks.

2.3 Team

The broader RRL is a Major, Open competition and consists mainly of teams of university research students at both undergraduate and postgraduate level. The RMRC extends this to include high school students.

2.3.1 Teams must be made up of a minimum of 2 students, and may include up to 6 students (between the ages of 13 and 19 on July 1st in the year of the competition). Only students are allowed to act as operators, as outlined in §3.1.

2.3.1 Each team may be accompanied by up to 2 mentors (1 mentor for teams of 3 or fewer students, no age restriction).

2.3.2 Each team may bring multiple robots to the challenge, however each robot will be scored individually and only one robot from each team may qualify for the finals.

2.3.3 A student can be registered on only one team.

2.3.4 Each team member will need to explain their work and should have a specific technical role. They are expected to have a working knowledge of the rest of their team's entry outside of their specific role.

2.3.5 A team is only allowed to participate in one competition, and is not permitted to enroll in multiple leagues.

2.3.8 Chaperones are not allowed to be with the students during the challenge. Mentors are allowed to be in the team areas and to work with the students during the competition.

2.4 Documention

2.4.1 Team Participation Form (TPF):

The first step in the qualification process is to complete and submit the TPF. Each team wishing to qualify must produce the following information. Note that this information (apart from contact information) may be released publicly.

- Team Name
- Organisation
- Country
- Contact person
- Email
- Telephone number
- Estimated number of students
- Estimated number of mentors
- Estimated number of robots

Please consult the announcements at http://comp.oarkit.org for specific and additional information required for any given year, and the method by which this information should be submitted to the Organising Committee.

2.4.2 Team Description Materials (TDM)

The TDM closely mirrors the goal of the Team Description Paper (TDP) from the Major competition, in a form that allows greater flexibility so that it is easier for high school students to take part. Teams may submit their materials in the form of a traditional TDP which follows the Major format (available from www.RoboCup.org). Please see the announcements at http://comp.oarkit.org for specific information about deadlines and other TDM requirements.

The TDM should have the following information. Note that this document will be released publicly.

- Logistical info
    - Team Name
    - Organisation
    - Country
    - Contact person
    - Team public contact email
    - Team website (if present)
- Introduction summarising:
    - The team.
    - The technical aspects that it focuses on.
    - System description, describing:
    - Hardware.
    - Software.
    - Communications.
    - Human-robot interface.
- Application, describing:
    - Setup and packup of your robot and operator station.
    - Mission strategy.
    - Experiments and testing that you have done or will do.
    - How the particular strengths of your team are relevant to applications in the field.
- Conclusion, summarising:
    - What your team has learned so far.
    - What you plan on doing between now and the competition.
- Appendix containing:
    - One table per robot outlining the components and estimated cost of your robot.
    - At least one picture, 3D rendering or technical drawing of your robot.
    - Be sure to highlight particular features of your robot.
    - A list of software packages, hardware and electronic components that you have used, or plan to use, particularly those from the Open Source community, through the Open Academic Robot Kit or otherwise.
    - A list of software packages, hardware and electronic components and designs that you have, or plan to, contribute to the Open Source community, through the Open Academic Robot Kit or otherwise.
- References (to other work that you have made use of).

2.5 Qualification and Inspection

2.5.1 Students are required to submit an updated TDM prior to the competition. This document is scored and the resulting score used as a multiplier for the preliminary competition. Please see the announcements at http://comp.oarkit.org for specific information regarding timing and requirements for this TDM.

2.5.2 All teams must follow the qualification process outlined by the OC prior to competition. Qualification will follow this sample timetable. Please see http://comp.oarkit.org for specific dates.

February - Team Participation Form (TPF) due.
March - Qualification TDM due.
April - Notification of Qualification.
June - Updated TDM due.
June/July – RoboCup Competition & Symposium

2.5.3 All teams must share all their resources during the qualification process. This competition is open source and as such teams will receive a multiplier onto their preliminary score based on their open sourced documentation. See http://comp.oarkit.org for specific details of what is required in terms of shared documentation.

2.5.4 The robots will be scrutinized by a panel of referees before the start of the tournament and at other times during the challenge to ensure that they meet the constraints described in these rules.

2.5.5 Students will be asked to explain the operation of their robot in order to verify that construction and programming of the robot is primarily their own work. Unlike in other Junior competitions, in RMRC, mentors are allowed to assist in the design and construction of the robots but the students still need to demonstrate both a working knowledge of the entire robot system as well as knowledge in at least one specific aspect of the robot's design, construction and/or operation.

2.6 Violations

2.6.1 Any violations of the inspection rules will prevent the offending robot from competing until modifications are made and the robot passes inspection. Please pay particular attention to radio restrictions.

2.6.2 Any violations of the rules may be penalised by disqualification from the competition or may result in a loss of points at the discretion of the referees, officials, organizing committee or general chairs. Sanctions against individuals may include exclusion from the competition and team areas for a period of time.

3. Competition

The competition is structured as follows:

Before the competition (see Section 2 for further details):

- Team Participation Form (TPF):
  - At a time to be announced, usually mid-February, team leaders should submit their intent to compete. The details required and method of submitting this will be announced on the mailing list, in general it consists of information about the team identity and size that is submitted via an online form.
  - This information is used for planning purposes. Teams that do submit a TPF are not obliged to join us should they change their mind. Teams that do not submit a TPF may still decide to join at a later date if they otherwise qualify for an invitation to the World Championships but only if there is space. This may delay the issuing of the invitation to compete.
- Qualification Team Description Materials (TDM):
  - At a time to be announced, usually mid-March, team leaders must submit their Team Description Materials (TDM). This is a set of information, in the form of a document, blog post, video and/or similar, that describes their team, their robot and their strategy. See competition announcement for specific details. While we are flexible about the format, it should be easy to find the requested information.
  - This information is used to select teams to be invited to the World Championships. We recognise that not all teams will have a working robot at this point; well justified plans and ideas are also acceptable.
  - Teams may also be prequalified on the basis of performance in previous competitions (eg. finalists in the previous year). Such teams should submit a document, via the same channels and to the same deadline as the Qualification TDM (eg. by email or online form) that declares their intent to qualify based on this performance. Exceptions may be made if the previous competition takes place after the Qualification TDM deadline (eg. regional opens held in the same year).
- Updated TDM:
  - At least 2 weeks prior to the start of the World Championships, teams must submit an Updated TDM.
  - This document will be scored based on how useful it is for helping a new team learn about and replicate something innovative that the team has done. A scoring criteria will be published shortly. This score is then used as a multiplier for the preliminary scores in the competition.
  - Teams that do not submit an Updated TDM will be scored on their Qualification TDM (or 0 if they were prequalified and chose not to submit a Qualification TDM). Thus, while not, strictly speaking, compulsory, all teams should submit an Updated TDM to be competitive, including those pre-qualified due to performance in previous competitions.

- The TDM should be in a format that can be archived, eg. by printing to PDF or downloading the video. It should be licensed in a manner that allows it to be distributed (eg. via a Creative Commons license).

At the competition:

- Preliminaries
  - Many teams run concurrently in separate test method apparatuses. This maximises the amount of time available for teams to compete, demonstrate their capabilities and score points.
    - During the end-of-day team leader meeting, teams take turns nominating their run slots for the following day's preliminary competition and populating the scoreboard with their timeslot nominations.
  - In random order, teams take turns nominating a timeslot and test for a run.
  - Nominations must conform to the following constraints:
    - Teams can only nominate once in each timeslot.
    - The maximum number of nominations for a given timeslot depends on the number of referees available.
    - Some apparatuses are shared between tests and thus a team nominating for one precludes another team nominating for the other in the same timeslot.
  - Nominations end when no team wishes to nominate for any more timeslots or there are no more timeslots left that satisfy the above constraints.
  - At any time during competition, up until 10 minutes prior to a timeslot, two team leaders may approach the OC and request to transfer or swap a timeslot. This will be noted on the score board.
  - At any time during the competition, up until 10 minutes prior to a timeslot, a team leader may approach the OC and request to swap a timeslot to a different test as long as the apparatus is available and the above constraints are satisfied.
    - Each timeslot is 10 minutes and includes 5 minutes for operator set up/teardown and 5 minutes of operation. Teams that demonstrate working autonomy during practice are allowed a double timeslot (although they will still only have 5 minutes to set up).
    - The goal is to score as many points as possible in the test methods. In general, you get one point for getting from the start zone to the end zone and another point for the way back from the end zone to the start zone (and so on). See individual test details for the scoring metric.
    - A cumulative score resulting from the best score in each of the testing methods, normalised to the best score achieved by any team in that test, are added up for the qualification. See §3.1 for details.
- Finals
  - Each team has exclusive access to the arena.
  - Scores are based on an arena score for traversing obstacles and terrains, and a sensors and dexterity multiplier for performing sensing and dexterity tasks.
  - The goal is to score the maximum number of points in a single run without reset. See §3.2 for details.

3.1 Preliminaries

The preliminaries consist of each team running their robot(s) through the test methods multiple times and collecting points (per robot). Each trial is for a single robot; while teams may wish to bring multiple robots be aware that this will split their available timeslots. Entry into the finals is decided per robot so this may reduce their chances to enter the finals.

The preliminaries follow this basic structure:

3.1.1 At the team leader meeting prior to each half-day, the testing schedule is determined as outlined above.

3.1.2 During each run, the referee will start the run timer when the team leader declares that the team is ready or after 5 minutes, whichever is first. The run stops after a subsequent 5 minutes. This will happen regardless of if the team is ready or present. Timeslots will not be delayed, it is up to the team to swap with another at least 10 minutes prior to the start of their timeslot if they are unable to run.

3.1.2a If anyone physically touches/moves the robot or arena during a run (eg. robot falls out of the terrain, robot gets stuck, tether gets pulled), a reset is called. This means that the robot is placed back at one end of the terrain, the scores for that run reset and then the run continues. Each 'reset' results in a separate 'mini-run' (or 'mini-mission' in RRL Major terminology). The score of the best 'mini-run' becomes the score for the whole run.

3.1.3 During each run, each team must also provide an observer to confirm the score reached by the judge.

3.1.4 At the end of each run, both team observer and operator must sign off on the score reached by the judge. Any concerns in scoring are to be raised immediately with the judge and a member of the OC.

3.1.5 All test methods must be attempted with the robot in an identical configuration. For instance, running with an arm for dexterity tests and then removing it for mobility tests is not allowed. Teams who wish to make changes to their robot during the competition may request this of the OC on the understanding that, especially if the change is not due to damage sustained during competition, this may be considered a completely different robot and reset all scores achieved up until that point.

3.1.6 At the end of each half-day, scores for all teams and testing methods will be visually recorded in a central location (generally on a large piece of paper that represents the scoreboard). A representative from each team must check their recorded scores for that half-day and raise any concerns with a member of the OC by no later than the end of the next team leader meeting. All scores on the score board at the end of each team leader meeting are considered finalised.

3.1.7 At the end of the final round of preliminaries, the judges will amalgamate all scores for each testing method and, for each team, multiply their total score by the score they received for their Updated Team Description Materials (Updated TDM). For teams who have completed a test multiple times, only their highest score will count. The cutoff for qualification into the finals will be decided based on the distribution of scores at the end of the preliminaries. The aim is to qualify between 3 and 6 teams into the finals based on finding a significant gap in the score distribution.

3.1.8 Scoring

- Every team can repeat a test, as often they want if it is available and the team has a free time available. Only the best result will be kept for the task and team.

- All scores will be normalized per test method, so that the best team in that test gets 100 points. This calculation is done after all teams have completed all tests in the preliminary round. The other teams get points proportionally. Example: For test method Dexterity 1: If team A scored 20 points and team B scored 10; then at the end of the preliminaries the score of team A will be set to 100 and the score of team B to 50. This way, for each test method the best team gets 100 points.
    - This scoring method balances the difficulty level across differing tests. If a test is so difficult that only one team attempts it, the team will receive 100 points. Conversely, to score well in an easier test that everyone can do, teams must be close to the best.
    - A team's total across all tests is then multiplied by their Updated TDP score when deciding on finals qualification.

- Autonomous robots get extra time (5 minutes) in each test method in which only autonomous operations are allowed. Robots that worked teleoperated during the mission get this extra time if they switch to autonomy.
    - In the interests of ensuring that double timeslots for autonomous operation are assigned to teams that are likely to use it, a team must have demonstrated to a member of the OC the autonomous features of their robot prior to the assignment of timeslots.

3.2 Finals

At the conclusion of the preliminaries, teams will be notified at a team leader meeting who has qualified for the finals and what factors went into this decision based on scoring as outlined in §3.1.7. Note that qualification into the finals is per robot, not per team. Only one robot per team may enter the finals.

Finals are distinct from preliminaries. Scoring consists of two parts. An arena score is gained by traversing obstacles and terrains. This represents the ability of a robot to get to where it needs to go to perform its task. This is multiplied by the sensor and dexterity score, gained by demonstrating proficiency in sensing and dexterity. This represents the ability of a robot to perform its task.

The arena is rearranged into a closed maze of test methods. Robots start anywhere in the maze and score one point for traversing each terrain or obstacle in each direction (for a maximum of 2 per terrain or obstacle). Following the announcement of the finals-qualified teams, members from each finals-qualified team will collaborate to design and build the arena from the lanes used in the preliminaries such that all competing finalists are satisfied with the layout. OC members will work with teams to ensure each teams opinion is equally considered. See Fig. 1 for a sample configuration. Note that in 2019, double-sized (60 cm) terrain bays will be included in the finals configuration.

3.2.1 Schedule

Until the end of the preliminaries, we won't know how many teams qualify for the finals so we won't be able to fix the number and duration of finals runs until then. In general, each team will have 2 or 3 runs, each run being around 15-20 minutes long with an extra 50-100% time for autonomous-only operation for teams that have demonstrated autonomy in the preliminaries. The 1st, 2nd and 3rd places are decided by the accumulated scores of finals runs only (not preliminaries).
OPEN FOR DISCUSSION: Who is doing autonomy? Is 50% or 100% more time fair? Discuss at http://list.oarkit.org.

The procedure for each arena round is as follows:

- Before your mission, move your robot and other equipment to one of the provided waiting tables.
- **10 Minute Setup and Multiplier phase:** The operator sets up and then performs any sensor and dexterity tests that they wish to achieve as high a score as possible for their sensor and dexterity. They finish when the 10 minutes is up.

OPEN FOR DISCUSSION: Is there a better way of scheduling the multiplier? Discuss at http://list.oarkit.org.

Run Phase: During the run phase, the robot starts at one end of any of the lanes in the arena and traverses through the arena from one lane to another. The robot scores one point for traversing each lane in each direction, for a maximum of two points per lane. (Subsequent traversals of the same lane, in the same direction, don't yield any additional points.) Teams should decide on their start point and proposed path through the maze carefully to best play to the strengths of their robot. The operator may draw and refer to a map of the arena during their run if they desire.

If a reset (as defined in "Preliminaries") occurs, the score is reset and the robot moved to one end of any lane nominated by the operator (it need not be the previous start point). As per the preliminaries, the best 'mini mission' is the one that counts.

- **Extra time for Autonomous Operation only**: Teams that demonstrate autonomous operations in the preliminaries (generally by scoring at least one point autonomously) can have extra time during the finals for autonomous-only operation. This is considered a separate 'mini mission' with an opportunity to choose a different start point and all lanes available to (re-)score but the resulting score is added to the best teleoperated ‘mini-mission’. Note that any switch to teleoperation is considered the same as a reset.

- **5 minutes to clear the arena**.

Note: If your robot has radio issues, a tether/cable to communicate with the robot is acceptable. In this instance you will be allowed a tether operator, however they are forbidden to communicate with the pilot during the run and must manipulate the tether without affecting the mobility of the robot. It is recommended that teams considering using tethers factor this into their input into the final arena design and into their planned route through the arena.

3.3 Environmental Conditions

3.3.1 The environmental conditions at a tournament will be different from the conditions at home practice fields. Teams must come prepared to adjust their robots to the conditions at the venue.

3.3.2 Lighting and magnetic conditions may vary in the field.

3.3.3 The field may be affected by magnetic fields and interference (e.g. generated by under floor wiring and metallic objects, interference from major competitors, mobile phones, etc). Teams should prepare their robots to handle such interference. Organizers and referees will do their best to minimize external magnetic interference (eg. by routing cables away from the terrains) but no guarantees are made as to if this will be possible.

3.3.4 The field may be affected by unexpected lighting interference (e.g. such as camera flash from spectators). Teams should prepare their robots to handle such interference. Organizers and referees will do their best to minimize external lighting interference.

3.3.5 The OC will try their best to fasten the walls onto the field floor so that the impact from contact should not affect the robot.

3.3.6 All measurements in the rules have a tolerance of ±5%.

4. Trophies and Certificates

For the RMRC, trophies and certificates will be awarded to teams based on a number of categories. These are:

4.1 RMRC Overall

The following trophies result from the amalgamated score of the arena rounds:

- First Place

The following certificates result from the amalgamated score of the arena rounds:

- Second Place
- Third Place

4.2 Best in class certificates

The team/robot with the highest score in a specific robot class wins the according Best in Class certificate.

- Only the runs in the preliminary rounds count for Best in Class.
- To win any Best in Class certificate, you need a positive, non-zero score in 80% of the available tests.
- It is possible that a team could win more than one Best in Class certificate.

A certificate will be awarded to the winner in each of the following categories:

- Best in Class Mobility
- Best in Class Dexterity
- Best in Class Sensing

Note that the Open Source Innovation award in previous years has been replaced by the Updated TDM multiplier.

5. Conflict Resolution

5.1 Referee and Referee Assistant

5.1.1 All decisions during runs are made by the referee or the referee assistant, who are in charge of the field, persons and objects surrounding them.

5.1.2 During runs, the decisions made by the referee and/or the referee assistant are final.
5.1.3 At conclusion of a run, the referee will ask the pilot and observer to sign the score sheet, as outlined in §3.1. A maximum of 1 minute will be given to review the score sheet and sign it. By signing the score sheet, the team members accept the final score on behalf of the entire team. In case further clarification is required, the pilot or observer should write their comments on the score sheet and sign it. These will be revisited prior to or at the following team leader meeting.

5.2 Rule Clarification

5.2.1 If any rule clarification is needed, this needs to be discussed at the initial team meeting on setup day, or addressed with a member of the Technical Committee as soon as possible.

5.2.2 If necessary, even during a run, a rule clarification may be made by members of the OC.

5.3 Special Circumstances

5.3.1 If special circumstances, such as unforeseen problems or capabilities of a robot occur, rules may be modified by the Technical Committee, even during a tournament for the purpose of ensuring that the competition remains as far as practically possible. Such rulings will be announced as soon as practical to those present and again at the next team leader meeting.

5.3.2 If any of the team captains/mentors do not show up to the team meetings to discuss the problems and the resulting rule modifications described at §5.3.1, it will be considered as an agreement.

6. Code of Conduct

6.1 Spirit

6.1.1 It is expected that all participants (students and mentors alike) will respect the aims and ideals of RoboCup as set out in our mission statement.

6.1.2 The volunteers, referees and officials will act within the spirit of the event to ensure the challenge is competitive, fair, educational and fun.

6.2 Fair Play

6.2.1 Robots that cause deliberate or repeated damage to the field will be disqualified.

6.2.2 Humans that cause deliberate interference with robots or other operators, or damage to the field, will be disqualified.

6.2.3 It is expected that the aim of all teams is to participate fairly.

6.3 Behavior

6.3.1 Each team is responsible for verifying the latest version of the rules on the RMRC website, plus any clarifications posted to the mailing list (and, when at the competition, discussed at intervening team leader meetings) prior to each competition day.
6.3.2 Participants should be mindful of other people and their robots when moving around the tournament venue.

6.3.3 Participants are not allowed to enter setup or competition areas of other leagues or other teams, unless explicitly invited to do so by team members.

Only the team leader and admin staff should communicate with the driver of a robot in preparation for and during a competition run. People should avoid communicating with or getting in the way of the team members of a team preparing for, or within, an active run. The penalty for an individual repeatedly disturbing teams under competition is being barred from the team area for 4 competition hours (a competition hour is defined as an hour where the run schedule applies). This will mean that a team member barred at the end of the day will continue to be barred the following morning until this time expires (even if this is the finals). No allowances will
be made even if the barred team member is the main driver, technical lead, programmer, etc. Separate penalties may apply for disruption during the finals and/or for teams with no more competition runs.

- Competing teams have priority over tables, arenas and associated thoroughfares.

- All team equipment and robots still physically present on competition tables, in arenas or associated areas at the start of a competition setup run will be impounded until the end of that run, regardless of if the team owning the equipment is present. It is a practicing or previously running team's responsibility to keep up to date with the schedule and, if there is a run about to start, be out of the area before the setup time of the next competition run. No allowances will be made if the team is running in another lane next, if their equipment is impounded they forfeit that run. This timing may be delayed for administrative purposes if something happens outside the team's control.

- The driver or team leader must sign the score sheet during the packup time of that run for the sheet to count and the score to appear on the scoreboard. Any dispute (by that team or any other individual) must be raised by the following team leader meeting. At the end of each team leader meeting, all signed sheets up to that point, and all scores on the scoreboard, will be considered finalised.

- All people in the team area must be wearing their own badge or be escorted by an admin staff member. In exceptional circumstances, a staff member may delegate a mentor to escort an unbadged person. Anyone found not wearing their own badge but would otherwise be allowed in the team area will be barred from the team area for 4 competition hours. Anyone found sharing their badge with someone else will also be barred from the team area for 4 competition hours. This is in addition to any official action that the RoboCup Federation may take.

- There must be a mentor in the team area whenever any student is in the team area. A mentor may offer to be temporarily responsible for the students of another team, this must be declared to the organisers and the students' original mentor must be contactable by phone.

6.3.4 Teams will be responsible for checking updated information (schedules, meetings, announcements, etc.) during the event. Updated information will be provided on notice boards in the venue and (if possible) on the RMRC website and/or the RoboCup or RoboCupJunior websites.

6.3.5 Participants who misbehave may be asked to leave the venue and risk being disqualified from the tournament.

6.3.6 These rules will be enforced at the discretion of the referees, officials, competition organizers and local law enforcement authorities.

6.3.7 Teams are expected to be present at the venue early on the setup day as important activities will occur. These activities include, but are not limited to registration and team leader meetings.

6.4 Mentors

6.4.1 Registered, badged mentors are allowed in the competition area. Mentors are encouraged to assist in the operation of the challenge, either as judges or in assisting the OC with tasks such as testing suite manufacture, scoring, etc.

6.4.2 Sufficient seating will be supplied for mentors to remain in a supervisory capacity in the student work area.

6.4.3 Mentors are permitted to build, repair or be involved in programming of their team's robots in a limited capacity, both before and during the challenge.

6.4.4 Mentor interference with robots or referee decisions will result in a warning in the first instance. If this recurs, the team will risk being disqualified.

6.4.5 Robots have to be mainly students' own work. Any robot that appears to be identical to another robot may be prompted for re-inspection.

6.5 Safety

- Teams must secure all cables that cross thoroughfares so that they are not a trip hazard, be it with tape (to be of a type approved by the ICC), carpet squares or the like so that they are not trip hazards. Equipment causing trip hazards that are not addressed within 1 minute of an admin staff member pointing it out to the team (or that is unattended) will be made safe or removed, at the discretion of the admin staff member, without further notice, regardless of if the equipment is associated with an upcoming or active run. If a run is active in the area (or about to start) and returning the equipment will interfere with a run, that equipment will be impounded until the end of that run.

- All equipment connected directly to power outlets must be tested and tagged to Australian standards. This is a non-negotiable requirement imposed by the ICC (convention centre management). Any team found using equipment that does not carry a valid Australian test tag will receive one warning. A second warning will result in the ENTIRE TEAM being barred from the team area for 4 competition hours. A third will result in complete disqualification of the team. This is in addition to any action that the RoboCup Federation, ICC or event organisers may take, should they become involved. Note that testing and tagging is a simple, cheap process and the local organisers will have procedures in place to facilitate this, details to be announced. See https://www.safework.nsw.gov.au/hazards-a-z/electrical-and-power/electrical-inspection-and-testing for more details about the legal requirements for testing and tagging.

- Teams must follow radio restrictions as outlined in the radio policy document. Note that this includes bluetooth keyboards and mice, serial radio modems, "Spektrum" style RC units and so-on. Teams found violating this policy will be given one warning. A second warning will result in the ENTIRE TEAM being barred from the team area for 4 competition hours. A third will result in complete disqualification of the team.

- All team members must wear closed toed shoes within the team area. First violation will result in a warning, subsequent violations will each result in the team member being barred from the team area for 4 hours.

- The ICC may impose other regulatory requirements on teams. These will be publicised on the mailing list at http://list.oarkit.org when we are made aware of them. Compliance with these regulations is required to gain access to the venue and compete.

- Teams must be familiar with the safety risks inherent in their robots, such as those relating to burns, fire and explosion risk. In particular, teams making use of lithium batteries must be familiar with their safe use, charging, storage and accident management. This includes being familiar with the appropriate procedure for addressing a lithium battery fire. The Admin Team will have buckets of sand, fire blankets and extinguishers for class A, B, C and D fires available. All members of the team should familiarise themselves with the location and safe, appropriate operation of this equipment.

- The Admin Team may at any time question team members on their familiarity with any relevant matter of safety, particularly if a dangerous or potentially dangerous situation is brought to their attention. The Admin Team has final say as to if a particular practice is considered too dangerous for the competition venue.

6.6 Ethics and Integrity

6.5.1 Fraud and misconduct are not condoned.

6.5.2 RoboCup reserves the right to revoke an award if fraudulent behavior can be proven after the award ceremony takes place.

6.5.3 If it is clear that a team member intentionally violates the code of conduct, the person will be banned from future participation in RoboCup competitions.

6.5.4 Teams that violate the code of conduct can be disqualified from the competition. It is also possible to disqualify a single team member from further participation in the competition.

6.5.5 In less severe cases of violations of the code of conduct, a team will be given a warning. In severe or repeated cases of violations of the code of conduct, a team can be disqualified immediately without a warning.