National Instruments Autonomous Robotics Competition (NI ARC)

2017 Task and Rules Documentation

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Overview

Competition Background:

Approaching its 7th year, the NI Autonomous Robotics Competition (NI ARC) welcomes university teams from Australia, New Zealand and a team from Singapore to participate in this premier tertiary level international robotics competition.

With the theme of 'Autonomous Vehicles: Transportation Innovation', teams will be designing and building an autonomous robot over the course of 6 months. The competition will conclude in a live final event in Sydney wherein the autonomous robots will be performing certain tasks aligned with the team with the objective of acquiring more points than the competition.

Team robots will have to carry out various tasks within a certain time limit. Points will be awarded based on specific tasks executed and the time it takes to complete all the tasks.

Teams will be required to complete and submit 5 competition milestones in order to qualify for the live final event. The milestones are progressive and will demonstrate the robot's capability to perform the core tasks that will all be carried out at the live final event.

Theme:

This year's competition will incorporate next generation transportation. Students will experience using industry-leading hardware and software, and how to design an intelligent vehicle which can follow road rules and regulations, giving the students a practical means of understanding various facets of engineering, specifically robotics, with a strong focus on learning outcomes.

Student teams this year will be required to design an autonomous/driverless vehicle to transport a passenger around town. Using navigation, spatial awareness and strategy to achieve this task, the track will simulate traffic conditions and may include, other vehicles, pedestrians, speed restrictions etc. The task will be to pick up and transport passengers while abiding by the road rules.

Design Elements:

The Robot design is made up of three key parts; mechanical design and build, electronics and software design. Each component is just as important as the other, and therefore requires as much attention leading up to the live competition.

What NI recommends is to distribute the workload to each member equally, an example of a four-student teamwork distribution would be as follows:

Student 1 – Software design

Student 2 – Software design/components procurement

Student 3 – Mechanical design and build

Student 4 – Electronics design and build

However, the above is just an example and teams may have more or fewer members and distribute the workload as they see fit. Some core elements of each part may include; control using software, localisation of the robot, motor integration and actuation.

Generally, there are no restrictions on the size of the robot. However, the track will have certain parameters (e.g. gates and pick up zones) which the designers need to abide by.

Task Elements:

The competition is designed to test various common facets of robotics applications including:

- **Localisation** – Knowing the robot's position within a certain map is essential if the robot is required to move within the map. The competition is based on a relatively large track – 6m x 4m.
- **Obstacle Avoidance** – Avoiding obstacles is another key element of the design.
- **Path Planning** – Determine the best path to take to the objective. Keeping in mind blocked roads etc.
- **Task** – Complete a given objective.

The track will see the robots navigate through a simulated City and pickup and drop off passengers.

The competition final will consist of a group stage followed by 4 knockout rounds. During the group stages, all teams that top their groups will advance automatically to the next stage. The remaining spaces in the knockout rounds will be filled based on the points system from all remaining teams. Knockout rounds will then commence wherein the team that ends up with the most points after the round will progress to the next round.

As the rounds progress, the level of complexity increases in terms of the amount of obstacles involved, and the amount of points on offer. Points on offer, number of passengers, type of obstacles and point deductions are all included in the 'Competition Round' section.

Objectives of the Robot

1. **Navigating:** The Robot will begin from the Home area and make its way to the pickup areas. Once loaded with the cubes, the robot must make its way to the Drop-off through the City Grid (navigation). Bumps with any elements of the track will result in point deductions.

2. **Navigating, Path Planning and Obstacle Avoidance:** Some city streets may be blocked due to road work, so the robot must decide the best path to follow. The robot needs to then drop off the cubes at the Drop-off area. The robot must avoid any obstacles while doing so.

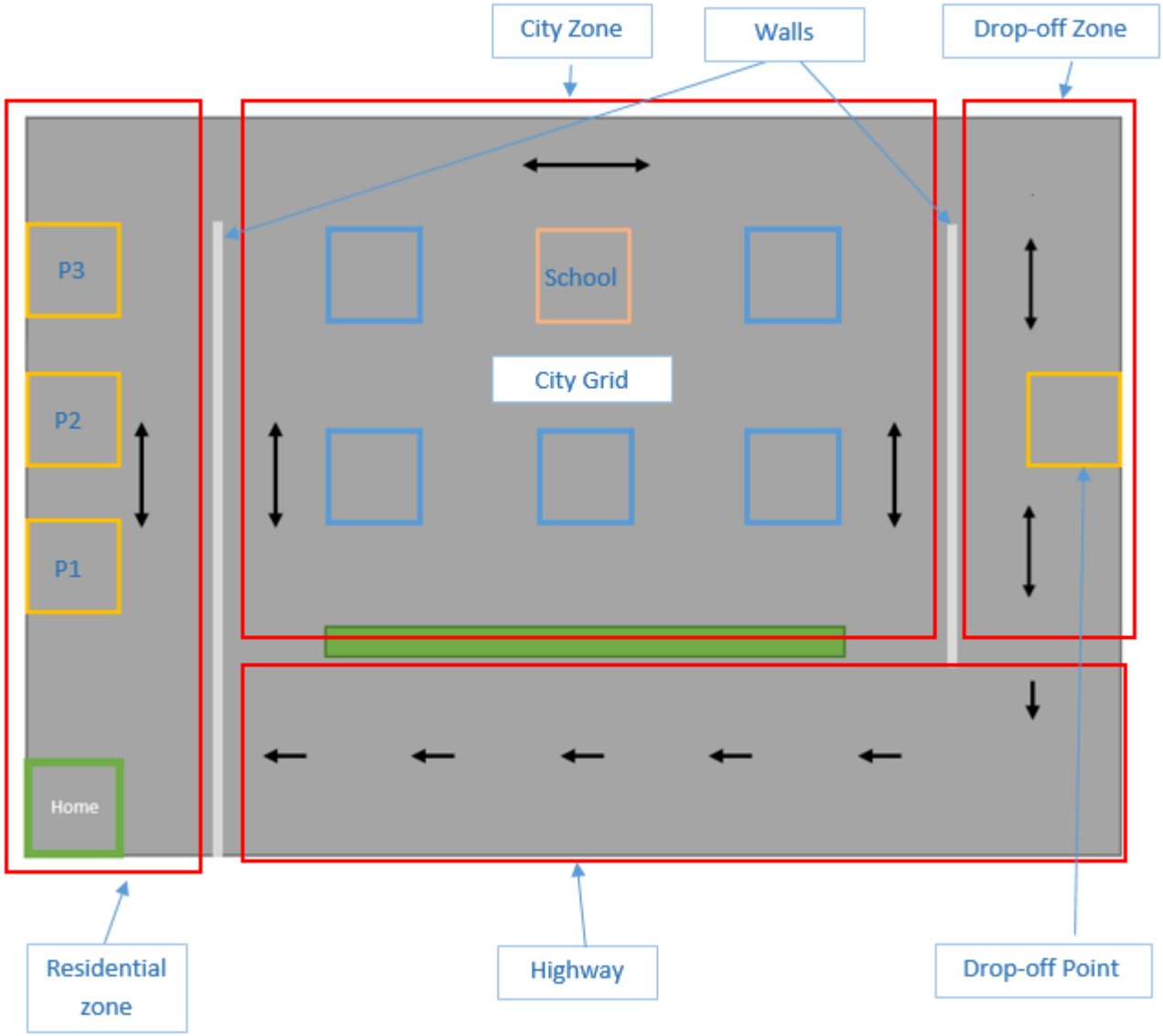
3. **Navigating, Path Planning and Obstacle Avoidance:** Once the cubes are dropped off, the robot must then make its way back Home. It can either take the route through the City Grid, otherwise, it can also take the Highway. However, the Highway will have a moving vehicle, which the robot must avoid. Also the highway is one way, therefore, moving backwards on the highway will result in point deductions.

4. **Communication with the server:** The robot can communicate with the server broadcasting information about traffic conditions.

Note: *Teams will be given specifications of the communication protocol of the server and data packet structure.*

The Track and Course Elements

The Track:



Passengers (Cubes):

The smart vehicle will be tasked to drive passengers from pickup to their destinations. The passengers will be represented by cubes and will be loaded/seated onto the robotic vehicle by a team member. Similarly, at the destination, the cubes will be unloaded by a team member.

Each successful drop-off will be awarded certain points. If the cubes are dropped at any point within the track aside from the Drop-off Point, the team will not be awarded any points for the dropped cube.

The cubes are:

- Made out of PU Foam Material (Stress cube) and cubic in shape
- Orange in colour with an NI design printed on 2 sides of the cube

The cubes are approximately 64 mm x 64 mm x 64 mm. Sample cubes will be sent to each NI ARC team for reference.

Home Area:

The Home area, where the robot will be starting from, has dimensions of 500 mm x 500 mm (refer to Figure 1). Teams must place their robot within the Home Area at the beginning of the round. The Home Area will be marked with green tape.

Figure 2: Home Area (eagle view)

Pickup Zone:

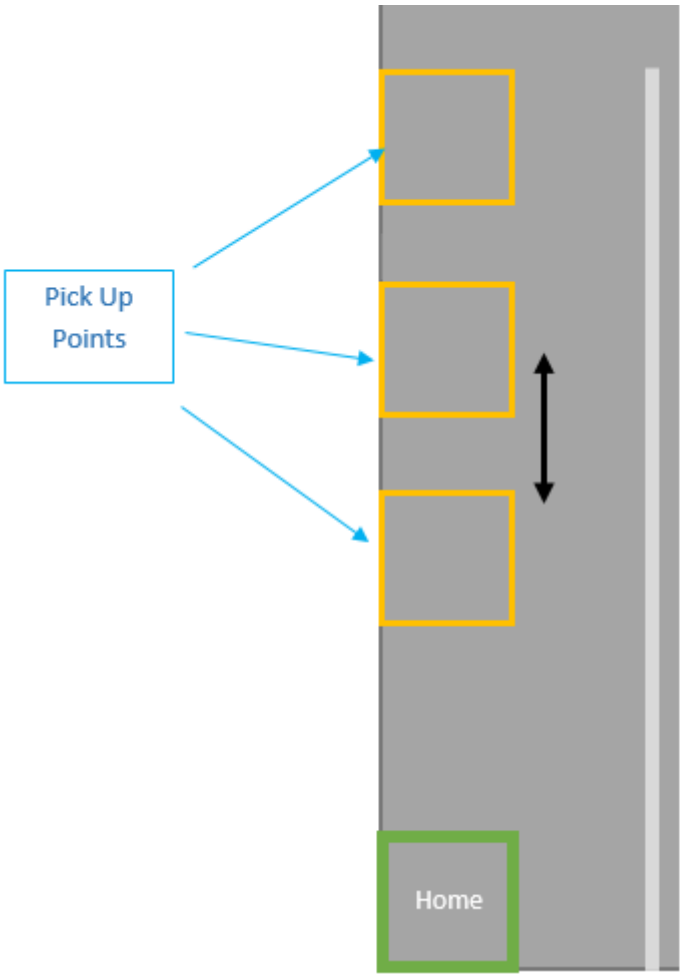


Figure 3: Passenger pickup (eagle view)

The Residential Zone is simulating houses in a neighbourhood, where generally passengers are picked up. The Pick Up points are placed near the Home area within the Residential Zone and are three in total. Each Pick Up point will be marked with yellow tape and will have a dimension of 500 mm x 500 mm.

The robot must be stationary while the cubes, representing passengers, are loaded. A team member must load the cubes on robot. If a cube is loaded while the robot is still in motion, then points will be deducted (refer to the point section for details).

City Grid:

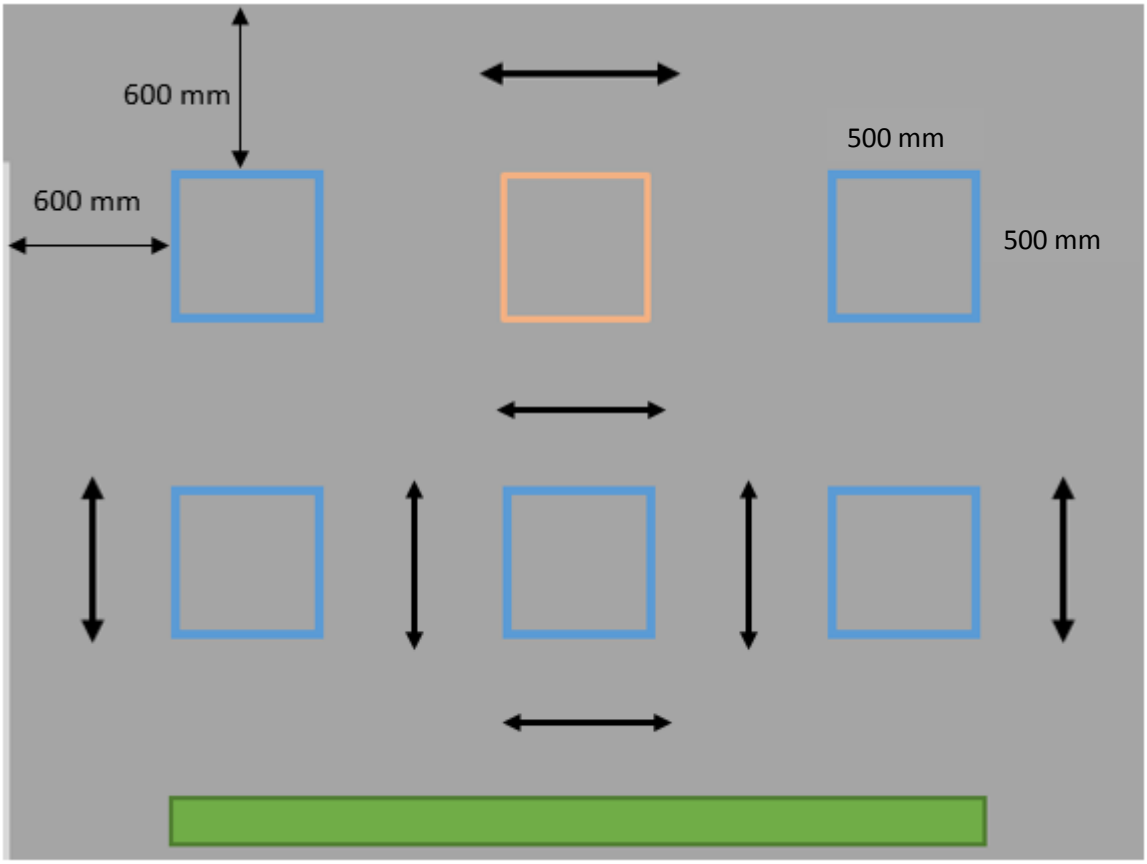


Figure 4: The City Grid (eagle view)

The City Zone is representing a city but in a much smaller scale, and the City Grid refers to the roads within the City Zone. The City Zone includes buildings, a school and a park. The buildings and school are marked blue and orange respectively (refer to Figure 4). They will be constructed using Glass Perspex. They are 500 mm x 500 mm and no more than 900 mm high. However, each building may vary in height between 500 mm to 900 mm.

Each road in the City grid are 600 mm wide and are two-way roads, therefore, the robots are permitted to travel both ways. The park will be made from artificial grass and may have items on it. The robot is not allowed to touch the grass.

School zone:

Within the City grid, there is also a school surrounded by roads. This is the School Zone, where robots need to slow down to a certain speed. The zone is shown in Figure 5.

The red marking will show where the speed limits are applied, therefore, the robot must slow down to a given speed when entering this grid.

An NI myRIO will be used along with sensors to detect speeds of vehicles entering the zones. The details of the speed limits and suggestions on how teams can measure speed will be available shortly and will be communicated to the teams via email.

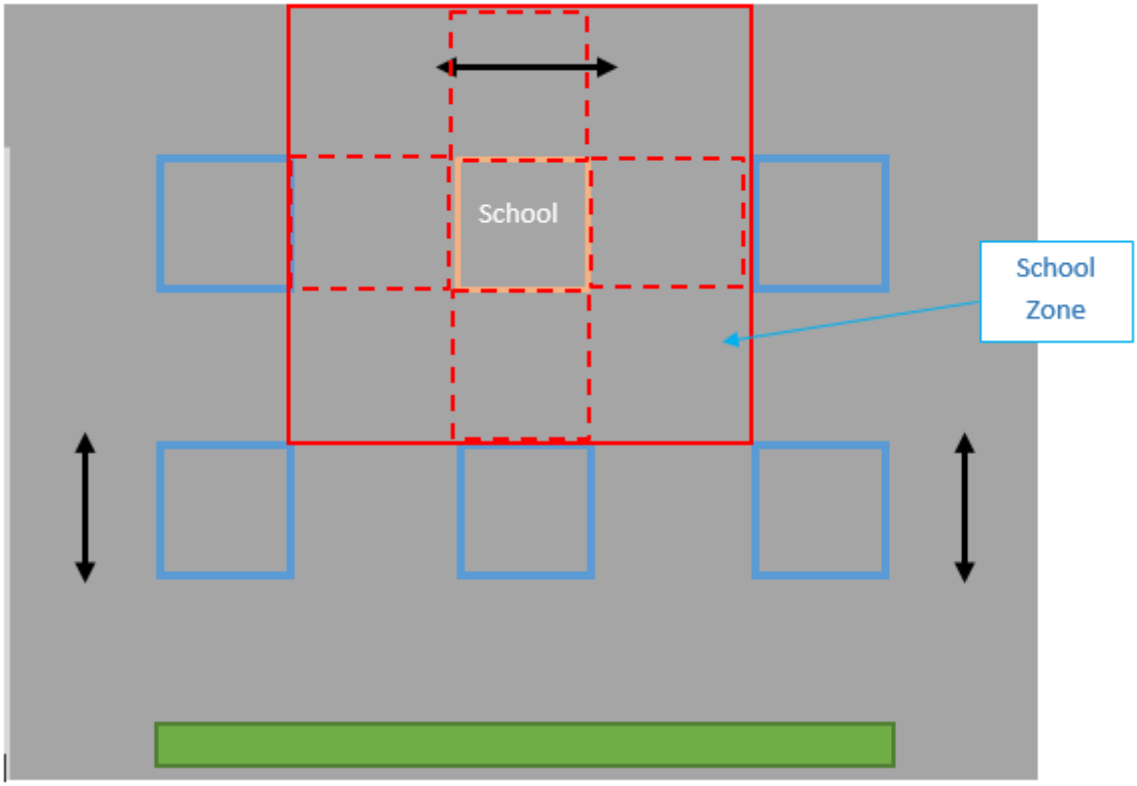


Figure 5: School Zone (eagle view)

Drop-off Zone and Drop Off Point:

The Drop-off Zone is a one-way road and has a Drop-off Point marked by yellow tape. The area of the Drop- off Point will be 500 mm x 500 mm. Refer to Figure 6.

These two conditions must be met before the cubes can be unloaded from the robot:

- The robot must be completely inside the drop off point.
- The robot must come to a complete stop.

If any part of the robot, whether touching the ground or not, is not completely inside the drop off point when unloading of cubes commence, points will be deducted.

On the line will be considered as inside the Drop-off point.

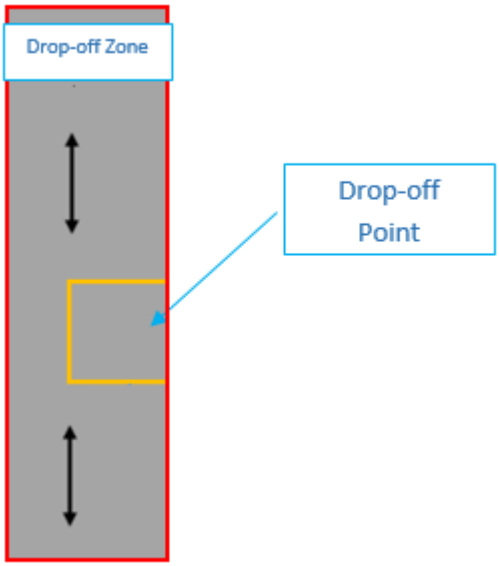


Figure 6: Drop-off Zone and Drop-Off Point (eagle view)

Highway:

The Highway is strictly a one-way road and the direction of traffic is from the Drop-off Zone towards the Residential Zone. If the robot moves in the opposite direction in anywhere in the Highway, there will be points deducted (refer to the point section for details).

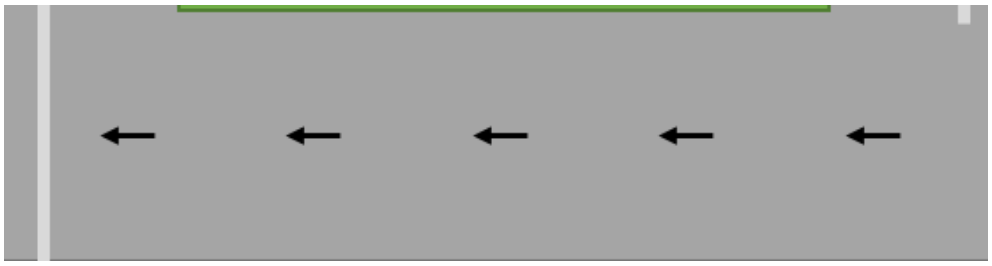


Figure 7: Highway (eagle view)

Walls, Openings, Flooring, Obstacles and The Park

Walls:

Walls are considered to be the boundaries of the entire track as well as the sections between zones. There will be walls separating the Residential Zone and the City Zone and the City Zone and Drop off Zone.

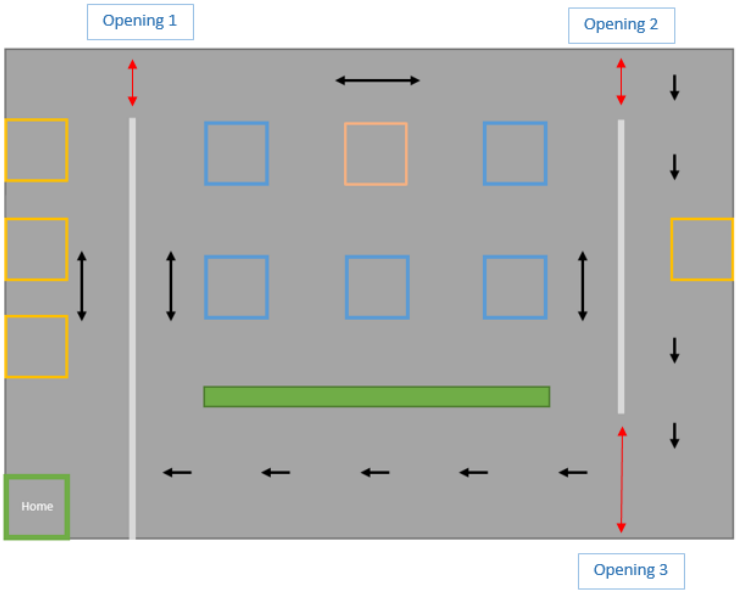
All the walls will use the same material with the same specifications.

The height of the walls will be 90 mm and will be made from timber. The width of the sections will be 90 mm.

Opening:

There will be three openings in the competition track and they are marked in red in the figure below.

Openings 1 and 2 will be 600 mm wide while Opening 3 will be 1000 mm.



Flooring:

The material for the flooring will be vinyl. A sample 1 m x 1 m competition track material will be sent to each NI ARC team.

Obstacles:

There will be two types of Obstacles - Dynamic obstacles and Static obstacles.

Static obstacles will be present in the Residential zone and will be 500 mm x 90 mm x 90 mm.

The Dynamic obstacle will be another robot and will be moving along the highway (more details to follow).

The Park:

The Park will be made from artificial grass and will be 2700 mm x 200 mm. The Park may also have various items on it.

If any part of the robot touches the grass, it will result in point deduction. (refer to the point section for details).

The City Grid:

The roads in the City Grid may also be blocked, due to road work. The number of blocked roads will depend on the round. Each street length will be considered as the length of the adjacent buildings.

The streets will be blocked with similar material as the walls (i.e. timber).

For reference, refer to Figure 8.

In addition, information about blocked roads will be broadcasted via Wi-Fi. Details of the broadcast, e.g. protocol, data packets etc. will be available to the teams soon.

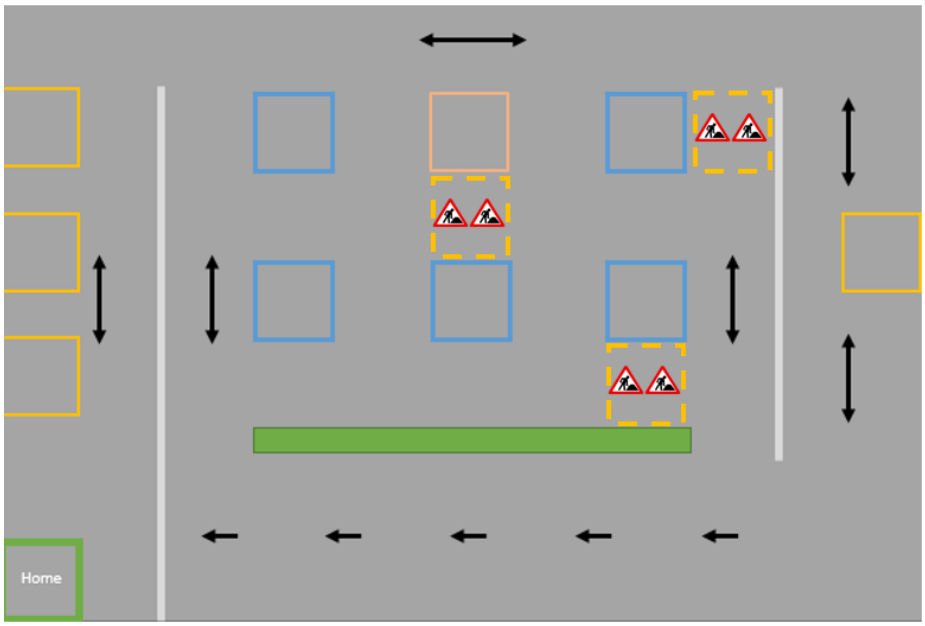


Figure 8: Blocked roads (eagle view)

Point System and Live Competition Structure

On the day of the live final, teams will be drawn randomly and placed in groups. The track will be duplicated for the purpose of two teams competing at the same time, and against each other. The coordinates and dimensions of known elements* in each track will be identical to the other track.

There will be a total of five rounds in the live competition. With each round progression, there will be added difficulty and tasks for additional points as added options.

**exact known coordinates will be given in next revision of the document*

First Round (Group Stage - Qualification)

In the first round, teams will be randomly assigned into groups. Each team will participate in three heats. For each heat, teams will have the objective of transporting 2 passengers. Points for each heat will be awarded based on the point system outlined below. Out of the three heats (or number of heats each team partakes in), only the highest scoring heat will be counted for each team (average scores will not be accumulated at any stage).

The highest scoring team from each group in the first round (group stage) will automatically advance to the round of 16.

All remaining teams (all teams excluding those that qualified for the quarter finals by placing first in their groups) will then be placed in order based on their highest score. The highest scoring teams from each group plus the highest scoring teams from the remaining teams will make up the 16 teams that will advance to the next round.

The equation for determining points is:

Total Points = [(150 sec - time taken) x multiplier] + points added - points deducted + bonus points
Where multiplier = 1

In the case of identical times for multiple teams, additional points will be counted according to **table 1**.

Round of 16

In this round, the top teams will face off against the bottom teams, after the 8 firsts-placed teams are put in order based on points, and the other 8 qualifiers are ordered by the same methodology.

First will play sixteenth, second will play fifteenth, and so on. This round is a knockout round, where you will compete against one opposing team only, with the team earning more points progressing to the next round.

Total Points = [(150 sec – time taken) x multiplier] + points added – points deducted + bonus points
Where multiplier = 1.5

Quarter-finals

This round is a knockout round, where you will compete against one opposing team only, with the team earning more points progressing to the next round. Refer to Table 1 for the point system. The equation for determining points is:

Total Points = [(150 sec – time taken) x multiplier] + points added – points deducted + bonus points
Where multiplier = 2

Semi-Finals

This round is a knockout round, where you will compete against one opposing team only, with the team earning the most points progressing to the next round. Refer to Table 1 for the point system. The equation for determining points is:

Total Points = [(150 sec – time taken) x multiplier] + points added – points deducted + bonus points
Where multiplier = 2.5

Final rounds (Championship Round and Battle for 3rd place)

The final rounds (Championship Round and Battle for 3rd place) will follow a best of 3 format where you will compete against one opposing team only. The team that gets to 2 wins first against the opposing team will win the round.

Total Points = [(150 sec – time taken) x multiplier] + points added – points deducted + bonus points
Where multiplier = 3

Name of Round	Round	Format	Time Limit (mins)	Min # of Passengers to drop off	# Roadblocks	NI Robot in Dynamic Obstacle Path
Qualifiers	1	Group Stages	2.5	2	Max 1	Stationary
Round of 16	2	Knockout	2.5	2	Max 2	Stationary
QTR-Finals	3	Knockout	2.5	3	Max 2	Moving slowly (one direction)
Semi-Finals	4	Knockout	2.5	3	Max 3	Moving slowly (one direction)
Battle for 3rd place	5	Best of 3	2.5	4	Max 4	Moving fast (one direction)
Championship Round	6	Best of 3	2.5	4	Max 4	Moving fast (one direction)

Table 1. Round Format

Name of Round	Points	Bonus	Point Deduction
Qualifiers	• Points for transporting each cube: 150 pts each *The robot must be completely inside the Drop-off Point and must come to a complete stop before a team member unloads the cube for points to be awarded.*	• Maintaining speed limit in the School Zone: 50pts • Finishing task without collision with any walls or without entering blocked roads, and following all road rules: 200pts • Successfully unload all cubes in the Drop Off Point and return back to the home area. (200 pts)	• Minimum 2 cubes (passengers) to be picked up and dropped in the drop off area • False starts: -20 pts. Time gained from the false start will be considered as time taken to complete the task. • Deduction for bumping into walls and/or entering blocked roads: -30 pts /Bump. • Any bumps or if the robot moves on the grass will result in points deduction: -50pts. • Dropping the cube (passenger) anywhere other than drop off point: -50pts • Points will be deducted if the robot is not completely inside the Drop off Point: -25 pts • Points will be deducted if robot doesn't come to a complete halt while loading and dropping off passengers: -30 pts • Collision with stationary NI Robot: -100 pts. • Deduction for violating one-way roads: -100 pts • Deduction for violating speed limit in school zone: -50 pts

Round of 16	• Points for transporting each cube: 150 pts each *The robot must be completely inside the Drop-off Point and must come to a complete stop before a team member unloads the cube for points to be awarded.*	• Maintaining speed limit in the School Zone: 50pts • Finishing task without collision with any walls or without entering blocked roads, and following all road rules: 200pts • Successfully unload all cubes in the Drop Off Point and return back to the home area. (200 pts)	• Minimum 2 cubes (passengers) to be picked up and dropped in the drop off area • False starts: -20 pts. Time gained from the false start will be considered as time taken to complete the task. • Deduction for bumping into walls and/or entering blocked roads: -30 pts /Bump. • Any bumps or if the robot moves on the grass will result in points deduction: -50pts. • Dropping the cube (passenger) anywhere other than drop off point: -50pts • Points will be deducted if the robot is not completely inside the Drop off Point: -25 pts • Points will be deducted if robot doesn't come to a complete halt while loading and dropping off passengers: -30 pts • Collision with stationary NI Robot: -100 pts. • Deduction for violating one-way roads: -100 pts • Deduction for violating speed limit in school zone: -50 pts
QTR-Finals	• Points for transporting each cube: 150 pts each *The robot must be completely inside the Drop-off Point and must come to a complete stop before a team member unloads the cube for points to be awarded.*	• Maintaining speed limit in the School Zone: 50pts • Finishing task without collision with any walls or without entering blocked roads, and following all road rules: 200pts • Successfully unload all cubes in the Drop Off Point and return back to the home area. (200 pts)	• Minimum 3 cubes (passengers) to be picked up and dropped in the drop off area • False starts: -20 pts. Time gained from the false start will be considered as time taken to complete the task. • Deduction for bumping into walls and/or entering blocked roads: -30 pts /Bump. • Any bumps or if the robot moves on the grass will result in points deduction: -50pts. • Dropping the cube (passenger) anywhere other than drop off point: -50pts • Points will be deducted if the robot is not completely inside the Drop off Point: -25 pts • Points will be deducted if robot doesn't come to a complete halt while loading and dropping off passengers: -30 pts • Collision with stationary NI Robot: -100 pts. • Deduction for violating one-way roads: -100 pts • Deduction for violating speed limit in school zone: -50 pts

Semi-Finals	• Points for transporting each cube: 150 pts each *The robot must be completely inside the Drop-off Point and must come to a complete stop before a team member unloads the cube for points to be awarded.*	• Maintaining speed limit in the School Zone: 50pts • Finishing task without collision with any walls or without entering blocked roads, and following all road rules: 200pts • Successfully unload all cubes in the Drop Off Point and return back to the home area. (200 pts)	• Minimum 3 cubes (passengers) to be picked up and dropped in the drop off area • False starts: -20 pts. Time gained from the false start will be considered as time taken to complete the task. • Deduction for bumping into walls and/or entering blocked roads: -30 pts /Bump. • Any bumps or if the robot moves on the grass will result in points deduction: -50pts. • Dropping the cube (passenger) anywhere other than drop off point: -50pts • Points will be deducted if the robot is not completely inside the drop off area: -25 pts • Points will be deducted if robot doesn't come to a complete halt while loading and dropping off passengers: -30 pts • Collision with stationary NI Robot: -100 pts. • Deduction for violating one-way roads: -100 pts • Deduction for violating speed limit in school zone: -50 pts
Battle for 3rd Place and the Championship Round	• Points for transporting each cube: 150 pts each *The robot must be completely inside the Drop-off Point and must come to a complete stop before a team member unloads the cube for points to be awarded.*	• Maintaining speed limit in the School Zone: 50pts • Finishing task without collision with any walls or without entering blocked roads, and following all road rules: 200pts • Successfully unload all cubes in the Drop Off Point and return back to the home area. (200 pts)	• Minimum 4 cubes (passengers) to be picked up and dropped in the drop off area • False starts: -20 pts. Time gained from the false start will be considered as time taken to complete the task. • Deduction for bumping into walls and/or entering blocked roads: -30 pts /Bump. • Any bumps or if the robot moves on the grass will result in points deduction: -50pts. • Dropping the cube (passenger) anywhere other than drop off area: -50pts • Points will be deducted if the robot is not completely inside the drop off area: -25 pts • Points will be deducted if robot doesn't come to a complete halt while loading and dropping off passengers: -30 pts • Collision with stationary NI Robot: -100 pts. • Deduction for violating one-way roads: -100 pts • Deduction for violating speed limit in school zone: -50 pts

Rules

1. The Robotic Vehicle:
   - Should be fully autonomous, self-powered and must move i.e. you cannot build a conveyor system etc.
   - Must use the NI myRIO provided.
   - Must have the majority of the code written and implemented using the LabVIEW software provided. Alternate programming languages can be used to program sensors and actuators if it is required, however, will not be supported.
   - Must not use any other Central Processing Unit (CPU) apart from the myRIO controller unless it is embedded inside a sensor or actuator for signal conditioning purposes. Image processing cameras with built in CPUs such as NI Smart Camera can be used to offload **Image processing**. Always consult with the NI ARC team before purchasing additional hardware.
   - Must have a switch (hardware) to trigger it to start performing the task and an emergency switch to stop it.
   - Must begin from the Home Area. Refer to map for details.
   - Should not bump into any walls or obstacles within the track.
   - Must not damage any component of the track, including the cubes. Disqualification may apply at the discretion of competition judges if the robot is deemed destructive to the competition arena and its elements.

2. Additional external circuitry for signal conditioning (i.e. amplification, filtering etc.) may be used.

3. While round is in progress, only NI staff is permitted in the competition arena. Only when the referee has called time can a representative of each team step in to collect the robot.

4. Interference and human interaction with the robot when a team's run has commenced is prohibited unless permission from the judges have been granted. Otherwise, the team will forfeit their run for the qualifiers, battle for third and championship round and an automatic loss in the round of 16, quarterfinals and semifinals.

5. Teams can appeal to call time if they want to stop their robot's run. Time can be called only if the judges agree that it will be harmful to the robot or the track to continue. **A penalty of 3 bumps (75pts) will be applied to the team's run when they call time.**

Contacts:

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Support: niarc.australia@ni.com
Web: australia.ni.com/ni-arc or nz.ni.com/ni-arc
Community: Facebook (facebook.com/niroboticscomp)

Useful Links:

myRIO: www.ni.com/myrio
LabVIEW: www.ni.com/labview
LabVIEW Robotics Module: www.ni.com/robotics
LabVIEW Core 1 and Core 2 Self-Paced Online Training: www.ni.com/training

Reference for Track Materials:

Obstacles and Wall material

https://www.bunnings.com.au/porta-90-x-90mm-1-2m-standard-and-better-pine-dar_p0021157

Perspex

https://www.bunnings.com.au/suntuf-900-x-600-x-5mm-clear-acrylic-sheet_p1010490

Green Tape (Home Zone)

https://floorsafe.com.au/anti-slip/cv16-tapes/cv12-floor-marking-tape/cv64-red/

Yellow Tape (Pick up and Drop-Off Point)

https://floorsafe.com.au/product/floor-marking-tape-50mm-yellow-rrp-13-20/

Appendix A. Milestone Reference