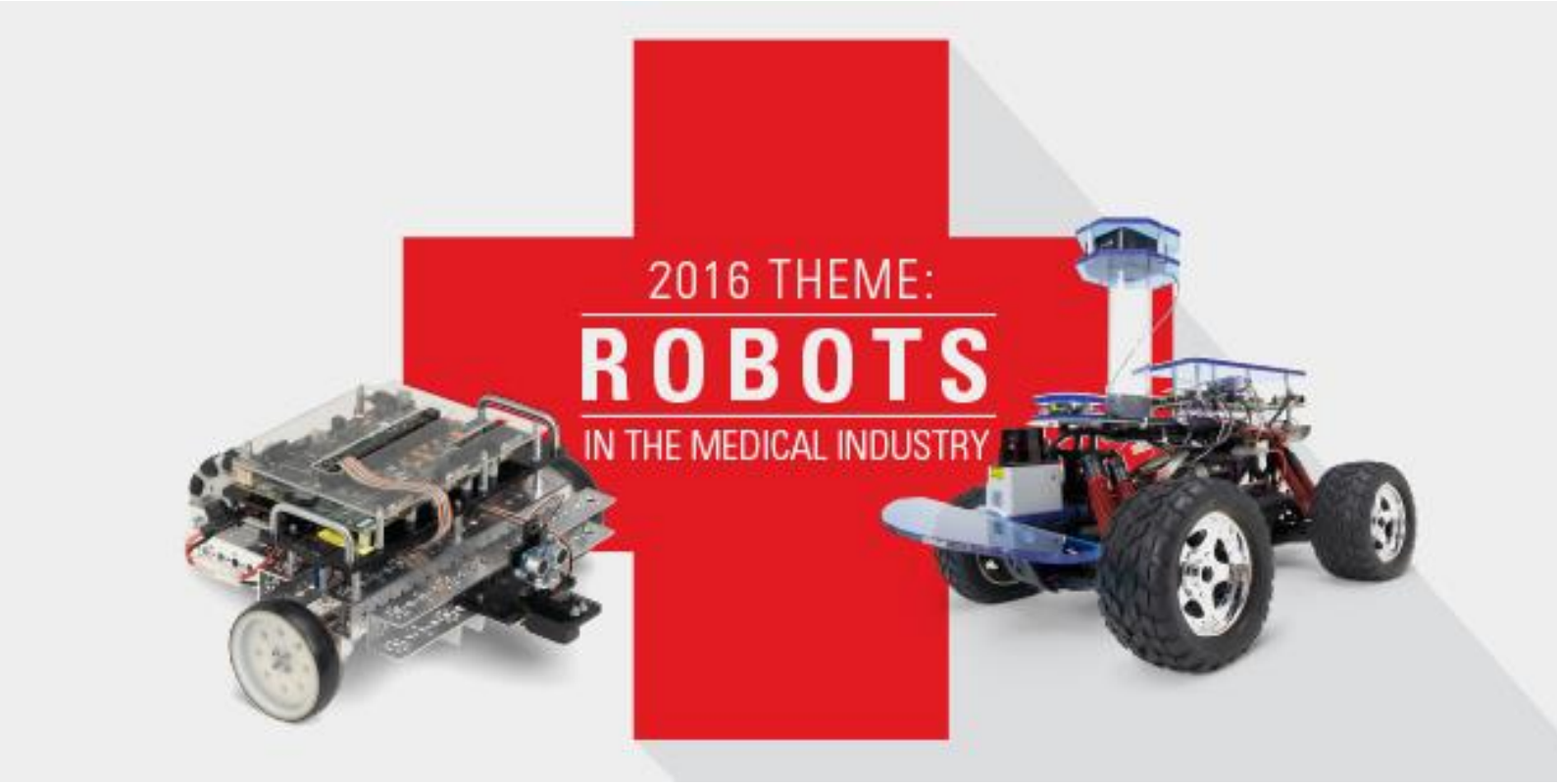
NATIONAL INSTRUMENTS

AUTONOMOUS ROBOTICS COMPETITION



NI ARC 2016

COMPETITION TASK AND RULES

Contents

Overview

Competition Background:

Now in its 6th year, the annual NI Autonomous Robotics Competition (NI ARC) welcomes teams from top universities and educational institutions around Australia and New Zealand to participate in this premier tertiary level international robotics competition.

Each team will be tasked to design and build an autonomous robot over the course of 6 months to perform certain tasks and compete against other university teams in the live final event.

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. Cash prizes are at stake with the winner, 2nd place and 3rd place taking home $2,500, $1,000, and $500 respectively. A $500 bonus prize will also be awarded to the team with the best robot design. Moreover, teams that successfully complete the competition task will get to keep the robotics development kit provided by NI consisting of the NI myRIO and LabVIEW Robotics Software.

This year, teams will be required to complete and submit 5 milestones aligned to the competition tasks over the course of several months. 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. To qualify for the live final event, teams must complete all 5 milestones.

Theme:

Technological advancements in the field of robotics have brought about a lot of benefits and improvements in the development and preservation of human life. Robots are now being incorporated into hospitals to assist doctors in performing surgeries, doing check-ups from a remote location, and also aiding hospital staff with functions such as delivery of supplies within the hospital just to name a few examples.

This year, team robots will have to perform tasks such as transporting medicine to different hospital rooms, avoiding both static and dynamic obstacles, all while optimising performance to maximise efficiency with the objective of earning the most amount of points.

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 work load to each member equally, example of a four student team work 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 less members and distribute the workload as they see fit. Some core elements of each part may include; control using software, localisation of robot, design and building of a pick and place mechanical system, 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. Especially where there may be people working in close proximity.
- **Object Handling** – The robot needs to be able to handle the Medicine units properly and transport them to the correct location.
- **Path Planning** – Determine the best path to take to the objective.
- **Task** – Complete a given objective.

The track will see the robots navigate through a simulated hospital environment and distribute medical supplies where they are required.

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 Medicines, 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 Starting area loaded with Medicine units. It will be engaged then will make its way between two walls and into the Main Area (navigation). Bumps with any elements of the track will result in point deductions.

2. **Navigating, Path Planning and Obstacle Avoidance:** The robot needs to then deliver the Medicine to either the Storage (awarding least amount of points per Medicine unit) or the Wards (awarding moderate points per Medicine unit). The robot must also avoid any static obstacles in this area.

3. **Object Handling:** The robot must carefully place the medicine unit/s on an elevated carrier within the spaces (Storage or Ward). If the Medicine rolls out of the elevated carrier, then points will not be awarded.

4. **Navigating, Path Planning and Obstacle Avoidance:** The robot can also make its way to the Emergency area and into the Operations (refer to Figure 1 for track overview) Theatre to deliver Medicine units (awarding most points per Medicine unit). However, this can only be done after the robot has delivered a number of Medicine units to the Ward.

   The robot must avoid moving into the Dynamic obstacles path and more importantly, it must not collide with the Dynamic obstacle. Points will be deducted if the robot enters the Dynamic obstacle path and a large amount of points will be deducted if there is a collision with the Dynamic obstacle.

   Note: T*he number of Priority Medicine for the Ward before the Operations Theatre is specified in the 'Competition Round' section of this document.*

   Note: T*he robot can deliver to any number of spaces (Storage, The Wards and Operations Theatre) or any combinations of spaces as long as it abides by points 2 and 4.*

5. **Communication with server:** The robot can communicate with the server to gain bonus points once the robot has delivered all the Medicine units and moving towards the Finish area.

   Note: *Teams will be given specifications of the communication protocol of the server. The teams will need to send a string message to the server to gain the bonus points. The application software to be used on the day of the competition as the server will be sent to the teams for testing.*

The Track and Course Elements

The Track:

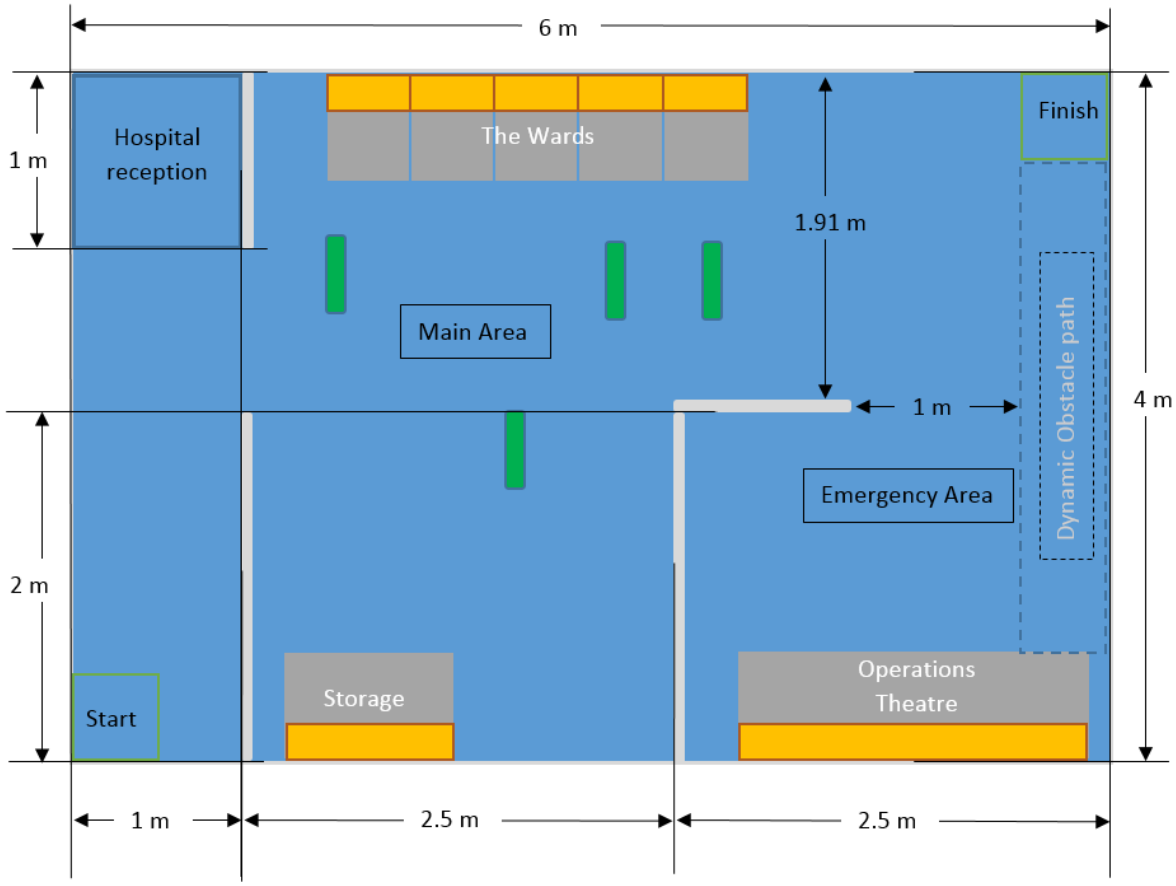


Figure 1: The Competition Track (eagle view)

Medicine Units:

The robots will be tasked to deliver Medicine to locations within the hospital, including, Storage, Wards for patients and Operations Theatre. It is vital that the robots take great care when it comes to handling the medicine. Medicine will be referred to as Medicine unit and each unit delivered will award teams with certain amount of points.

Circular cubes will represent the Medicine unit and will be:

- Made out of PU Foam Material (Stress ball)
- Cubic in shape
- White in colour with an NI design printed in 2 sides of the cube

Above is the picture of the Rounded Cube that will be used to represent the Medicine units in the competition. The Rounded Cubes are approximately 64 mm x 64 mm x 64 mm. Sample Rounded cubes will be sent to each NI ARC team for reference.

Starting Area:

The Starting 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 Starting Area with the Medicine units loaded before it begins its run. The Starting Area will be marked with green tape.

Figure 2: Start Area (eagle view)

Hospital Reception:

The Hospital Reception area is a general visitor's area and is restricted for the autonomous robot to enter. If the robot enters this area, point deductions will be applied.

This will be marked by dark green tape and will have walls on three sides (refer to Figure 1 and 3). The area of the Reception will be 1 m x 1 m.

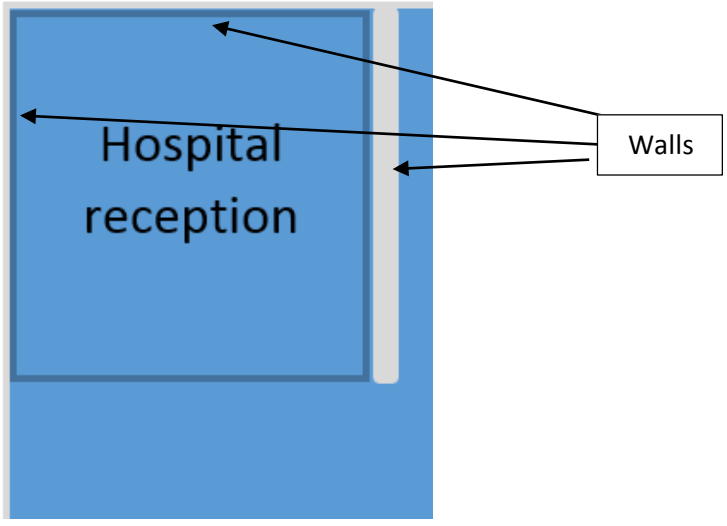


Figure 3: Hospital Reception (eagle view)

Main Area:

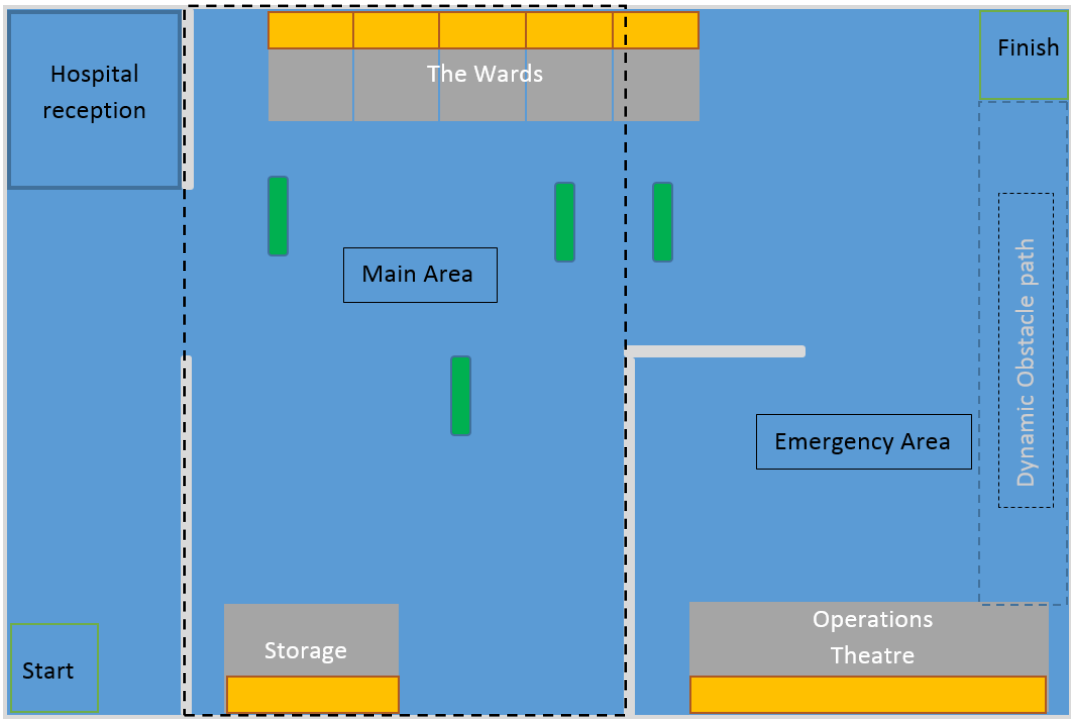


Figure 4: The Main Area (eagle view)

The Main area within the hospital (highlighted above), will host the 'Storage' and 'The Wards' spaces. In this area, static obstacles will also be present.

Storage:

The area of the space will be 1000 mm x 600 mm and the two sides plus the back wall will be made of Glass Perspex.

The Storage will have an elevated carrier within (refer to the 'Walls, Openings, Flooring, Obstacles and Elevated Carrier for dimensions) where the robot must place the Medicine units in order to gain the associated points. If the Medicine units roll away from the Elevated Carrier, then points will not be awarded. There is not limit on how many Medicine units that can be delivered to the Storage.

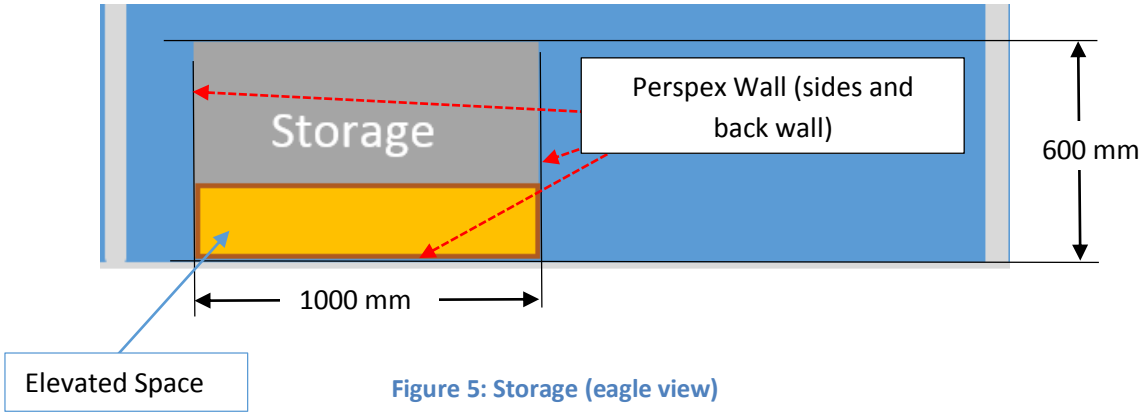


Figure 5: Storage (eagle view)

The Wards

There will be 5 wards tending to a patient in each. In the Wards, the robot can choose any or all of the 5 wards to deliver medicine units to for it to gain points. A **maximum** of **one** Medicine unit can be delivered to each Ward for all the rounds in the competition. Placing additional medicine units in each ward will not result in further points.

The Medicine units must be placed carefully on the elevated carrier within (refer to the 'Walls, Openings, Flooring, Obstacles and Elevated Carrier for dimensions). If the Medicine units do not stay on the elevated carrier, then points will not be awarded.

Each Ward is 500 mm x 600 mm and similar to the Storage will be built with Glass Perspex.

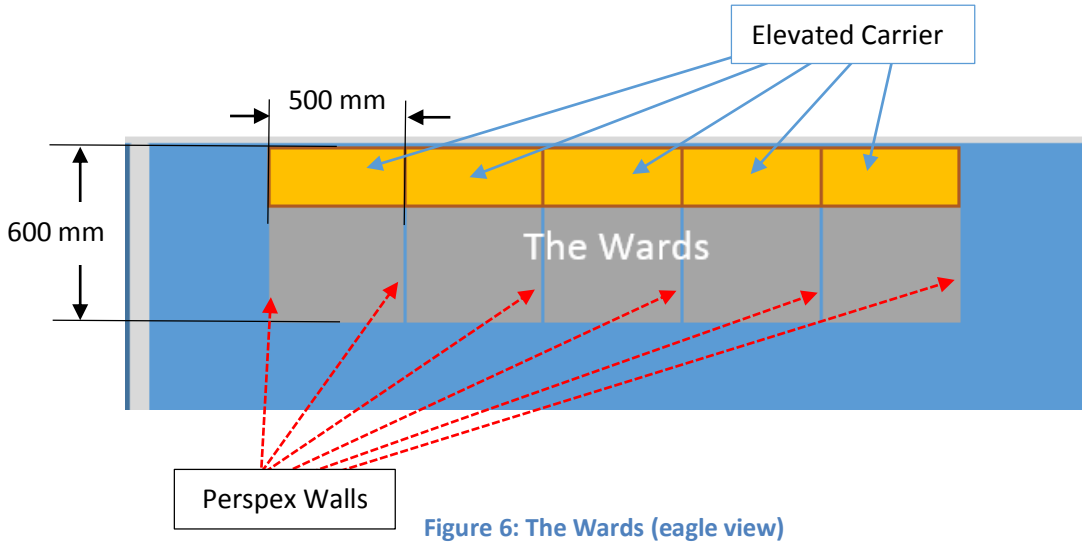


Figure 6: The Wards (eagle view)

Emergency Area:

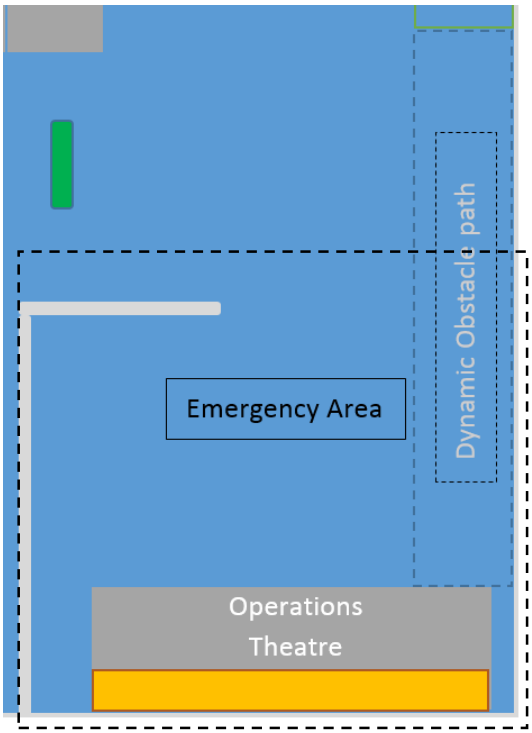


Figure 7: Emergency Area (eagle view)

The Emergency Area is slightly enclosed with walls and accommodates the Operations Theatre. Robots entering this area must take care so to avoid contact with the dynamic obstacle which is also functioning in this area.

Operations Theatre:

The Operations Theatre is 2000 mm x 600 mm. The delivery of the Medicine units to the Operations Theatre will be priority based, meaning a certain number of Medicine units must be first delivered to the Ward before they can be delivered to the Operations Theatre.

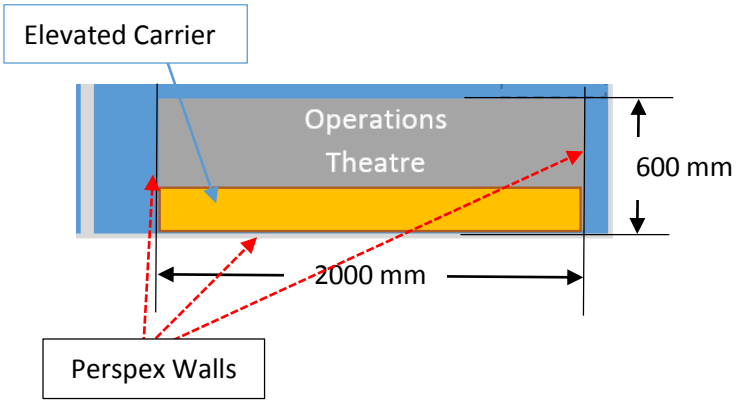


Figure 8: Operations Theatre (eagle view)

The number of prerequisite Medicine units to be delivered to the Ward before the Operations Theatre is specified in the Competition Round section of this document.

The Medicine units must be placed carefully on the elevated carrier (refer to the 'Walls, Openings, Flooring, Obstacles and Elevated Carrier for dimensions). If the Medicine units roll away from the elevated carrier, then points will not be awarded. It must stay in the elevated carrier until the robot's run is finished for the bonus points to be granted.

Finish Area

The Finish Area is where the robot will park once all tasks have been completed. It has dimensions of 500 mm x 500 mm and will be marked with white tape (refer to Figure 1).

The Robot must be completely positioned inside the Finishing Area for the referee to stop the clock. On the line will be considered inside the area.

Walls, Openings, Flooring, Obstacles and Elevated Carrier

Walls:

Walls are considered to be boundaries of the entire track, sections (The Main and Emergency areas) and rooms (specifically the Storage, the Wards and Operations Theatre). Both the inside wall, dividing the two sections of the track, and wall around the whole track will use the same material with same specifications.

Height of the walls will be 90 mm and made from timber. The width for the internal walls dividing the sections will be 90 mm.

Opening:

There are two openings in the track between sections. Both of which are 1 m wide (refer to figure 1).

Flooring:

The material for the flooring will be Vinyl. Sample of 1m x 1m track material will be sent to each NI ARC team.

Obstacles:

There will be two different types of obstacles; static and dynamic obstacles. Static obstacles include walls and static objects which will placed anywhere within the space depicted in the below diagram.

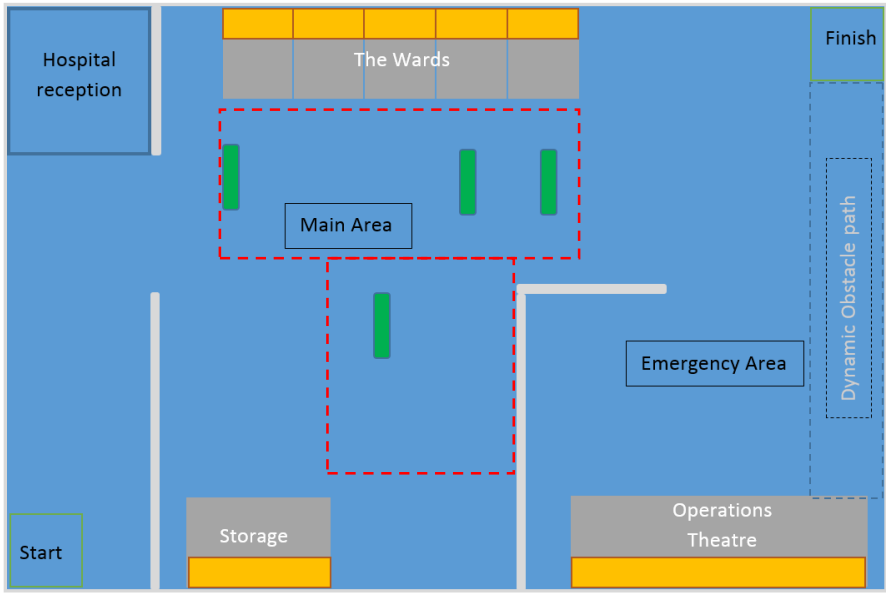


Figure 9: Static Obstacles (eagle view)

The static objects will be placed at least 1m away from the nearest wall, vicinities of the Storage and The Wards space, and other static objects.

The static objects may assume any configuration accordance with Figure 5, but will always be longitudinal in reference to Figure 9. The material which the obstacles will be made out of, will be timber. The dimensions are 500 mm x 90 mm x 90mm.

The Dynamic Obstacle will be an NI Robot and will either be moving or stationary according to Table 2 in the Competition Round section. However, the Dynamic Obstacle will be bound to the specified area depicted below (from the edge of the Finish area to the edge of the Operations Theatre).

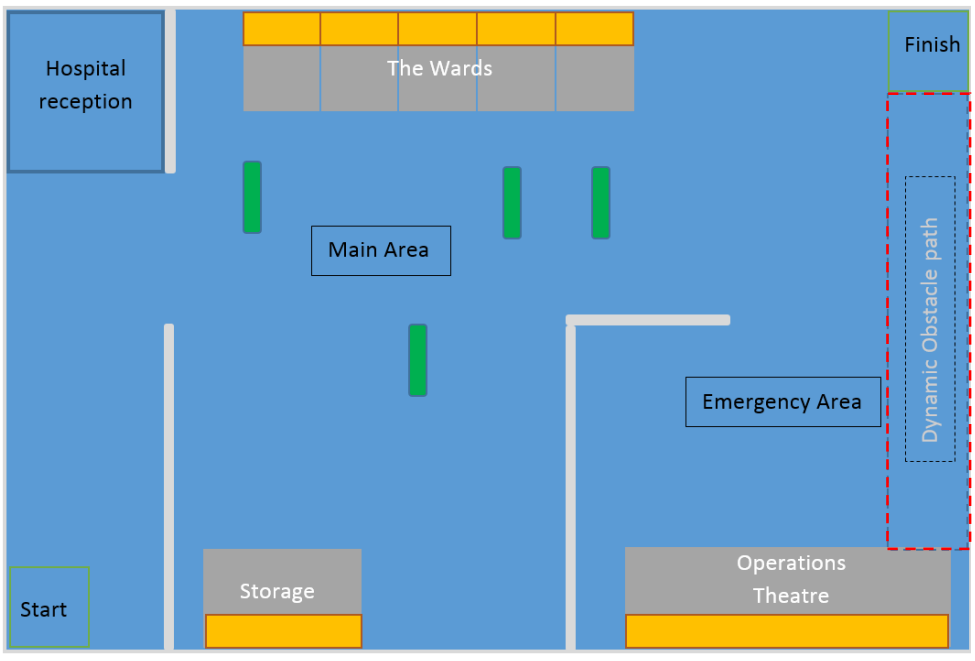


Figure 10: Dynamic Obstacles (eagle view)

Elevated Carrier:

The Elevated Carrier (in all locations) will be a timber piece with the dimension: 120 mm x 45 mm (width x height). The carrier will sit between each Perspex glass for the Ward, Operations Theatre and Storage.

Figure 11: Elevated Carriers

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 (exact known coordinates will be given in next revision of the document) elements in the track will be identical.

There are a total of five rounds in the live competition. With each round progression, there will be added difficulty and additional points up for grabs. The task however, will remain more or less the same.

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 delivering 2 medicine units. 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**.

All Rounds will be Knockout Rounds starting from the Round of 16.

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 tables below for 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 tables below for 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 round (Championship Round and 3rd place playoff)

This round is the final and knockout round, where you will compete against one opposing team only, with the team earning more points to be crowned the 2015 Champion. Refer to tables below for point system. The equation for determining points is:

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)	# of Medicine Units	Min # of units in wards before Operations Theatre Delivery	# Obstacles in the Main Area	NI Robot in Dynamic Obstacle Path
Qualifiers	1	Group Stages	2.5	2	1	Max 3	Stationary
Round of 16	2	Knockout	2.5	2	1	Max 3	Stationary
QTR-Finals	3	Knockout	2.5	3	2	Max 4	Moving slowly in one direction
Semi-Finals	4	Knockout	2.5	4	2	Max 5	Moving fast in one direction
Playoffs for 3rd place	5	Knockout	2.5	5	3	Max 7	Moving fast omnidirectional
Championship Round	5	Knockout	2.5	6	3	Max 7	Moving fast omnidirectional

Table 1. Round Format

Name of Round	Points (per Unit)	Bonus	Point Deduction
Qualifiers	• Points for delivering medicines to various places: Storage Area : 100pts Each Ward : 150pts *The Medicine must stay on the elevated carrier until the end of its run for the points to be awarded.*	• Delivering units in Operation Theatre: 300pts • Finishing task without collision with any obstacles: 200pts • Delivering all units before finish: 250pts • Wi-Fi messaging to server: 250pts	• Minimum 1 medicine unit is to be delivered to any one of the wards before going to operation theatre. Only one unit can be delivered to each ward, no points will be awarded for the second unit in a ward. • Deduction for bumping into walls and/or Obstacles: -25 pts /Bump. • False starts: -20 pts. Time gained from the false start will be considered as time taken to complete the task. • Getting close to the Dynamic Obstacle path (DOP): -30 pts. If any part of the robot (whether touching the ground or not) is on this Area line points will be deducted. • Collision with stationary NI Robot in DOP: -100 pts. • Getting into Hospital Reception will cause deduction in points (any part of the robot, whether touching the ground or not): -25pts.
Round of 16	• Points for delivering medicines to various places: Storage Area : 100pts Each Ward : 150pts *The Medicine must stay on the elevated carrier until the end of its run for the points to be awarded.*	• Delivering units in Operation Theatre: 300pts • Finishing task without collision with any obstacles: 200pts • WiFi messaging to server: 250pts	• Minimum 1 medicine unit is to be delivered to any one of the wards before going to operation theatre. Only one unit can be delivered to each ward, no points will be awarded for the second unit in a ward. • Deduction for bumping into walls and/or Obstacles: -25 pts /Bump. • False starts: -20 pts. Time gained from the false start will be considered as time taken to complete the task. • Getting close to the Dynamic Obstacle path (DOP): -30 pts. If any part of the robot (whether touching the ground or not) is on this Area line points will be deducted. • Collision with stationary NI Robot in DOP: -100 pts. • Getting into Hospital Reception will cause deduction in points (any part of the robot, whether touching the ground or not): -25pts.
QTR-Finals	• Points for delivering medicines to various places: Storage Area : 100pts Each Ward : 150pts *The Medicine must stay on the elevated carrier until the end of its run for the points to be awarded.*	• Delivering units in Operation Theatre: 300pts • Finishing task without collision with any obstacles: 200pts • WiFi messaging to server: 250pts	• Minimum 2 medicine unit is to be delivered to any one of the wards before going to operation theatre. Only one unit can be delivered to each ward, no points will be awarded for the second unit in a ward. • Deduction for bumping into walls and/or Obstacles: -25 pts /Bump. • False starts: -20 pts. Time gained from the false start will be considered as time taken to complete the task. • Getting close to the Dynamic Obstacle path (DOP): -30 pts. If any part of the robot

			(whether touching the ground or not) is on this Area line points will be deducted. • Collision with dynamic NI Robot in DOP: -150 pts. • Getting into Hospital Reception will cause deduction in points (any part of the robot, whether touching the ground or not): -25pts.
Semi-Finals	• Points for delivering medicines to various places: Storage Area : 100pts Each Ward : 150pts *The Medicine must stay on the elevated carrier until the end of its run for the points to be awarded.*	• Delivering units in Operation Theatre: 300pts • Finishing task without collision with any obstacles: 200pts • WiFi messaging to server: 250pts	• Minimum 2 medicine unit is to be delivered to any one of the wards before going to operation theatre. Only one unit can be delivered to each ward, no points will be awarded for the second unit in a ward. • Deduction for bumping into walls and/or Obstacles: -25 pts /Bump. • False starts: -20 pts. Time gained from the false start will be considered as time taken to complete the task. • Getting close to the Dynamic Obstacle path (DOP): -30 pts. If any part of the robot (whether touching the ground or not) is on this Area line points will be deducted. • Collision with dynamic NI Robot in DOP: -200 pts. • Getting into Hospital Reception will cause deduction in points (any part of the robot, whether touching the ground or not): -25pts.
Playoffs for 3rd Place and the Championship Round	• Points for delivering medicines to various places: Storage Area : 100pts Each Ward : 150pts *The Medicine must stay on the elevated carrier until the end of its run for the points to be awarded.*	• Delivering units in Operation Theatre: 300pts • Finishing task without collision with any obstacles: 200pts • WiFi messaging to server: 250pts	• Minimum 3 medicine unit is to be delivered to any one of the wards before going to operation theatre. Only one unit can be delivered to each ward, no points will be awarded for the second unit in a ward. • Deduction for bumping into walls and/or Obstacles: -25 pts /Bump. • False starts: -20 pts. Time gained from the false start will be considered as time taken to complete the task. • Getting close to the Dynamic Obstacle path (DOP): -30 pts. If any part of the robot (whether touching the ground or not) is on this Area line points will be deducted. • Collision with dynamic NI Robot in DOP: -200 pts. • Getting into Hospital Reception will cause deduction in points (any part of the robot, whether touching the ground or not): -25pts.

Table 2. Point System

Development Tools, Training and Support

Tools: Each team will be provided with an **NI myRIO** embedded hardware device, which features a dual-core ARM® Cortex™-A9 real-time processing and Xilinx FPGA customizable I/O , along with the **LabVIEW Graphical Development Environment** and associated Modules for Robotics Applications; the LabVIEW Real-Time, LabVIEW FPGA and LabVIEW Robotics Modules.

Training: Team members also have access to exclusive **LabVIEW Core 1 and LabVIEW Core 2 Self-Paced Online Training**, ensuring you build your skills and proficiency with our industry leading graphical development software. Once this training is completed, you will also receive live training to help you get started with the NI myRIO.

Support: Team members will also have access to technical support from designated NI engineers, along with mentoring, recommendations and many tips, tricks and reference resources throughout the duration of the competition.

Materials: Key track elements will be sent to each team for reference, such as 1m x 1m track flooring, objects to handle, etc. Where NI will source the items will also be made available so teams may replicate the track in house.

Contact Information

Free call: Australia: 1800 300 800 or New Zealand: 0800 553 322
Email: niarc.australia@ni.com
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

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 Starting 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 Medicine units. Disqualification may apply at the discretion of competition judges if the robot is deemed destructive to the competition arena and its elements.

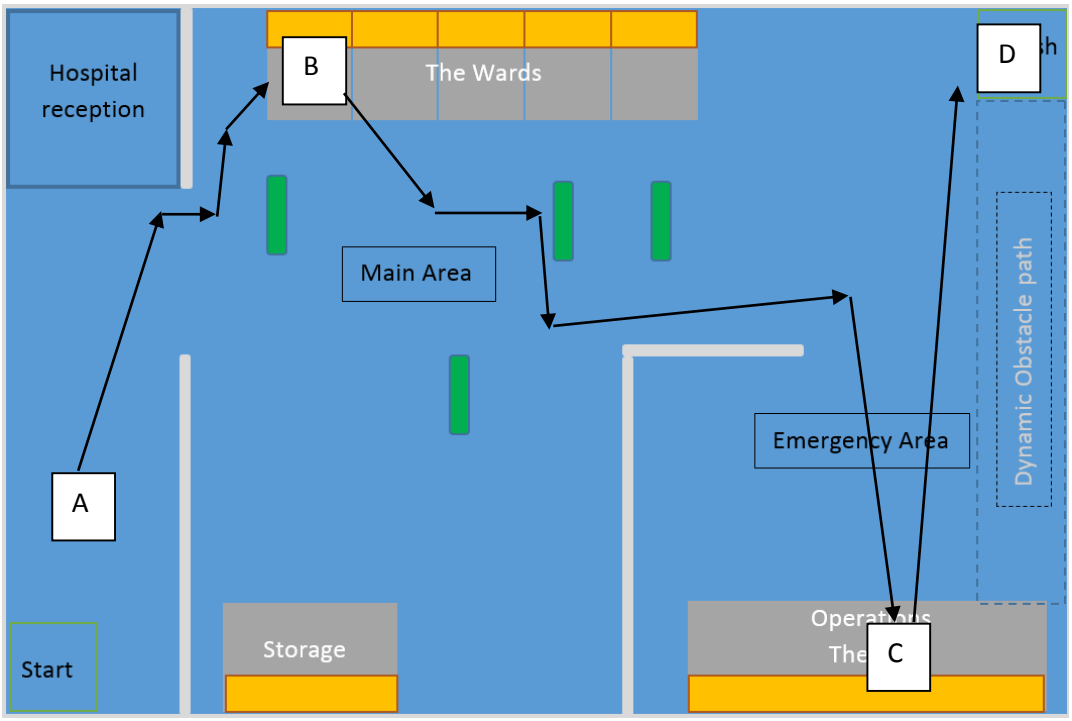
2. Additional external circuitry for signal conditioning (i.e. amplification, filtering etc.) may be used.

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.

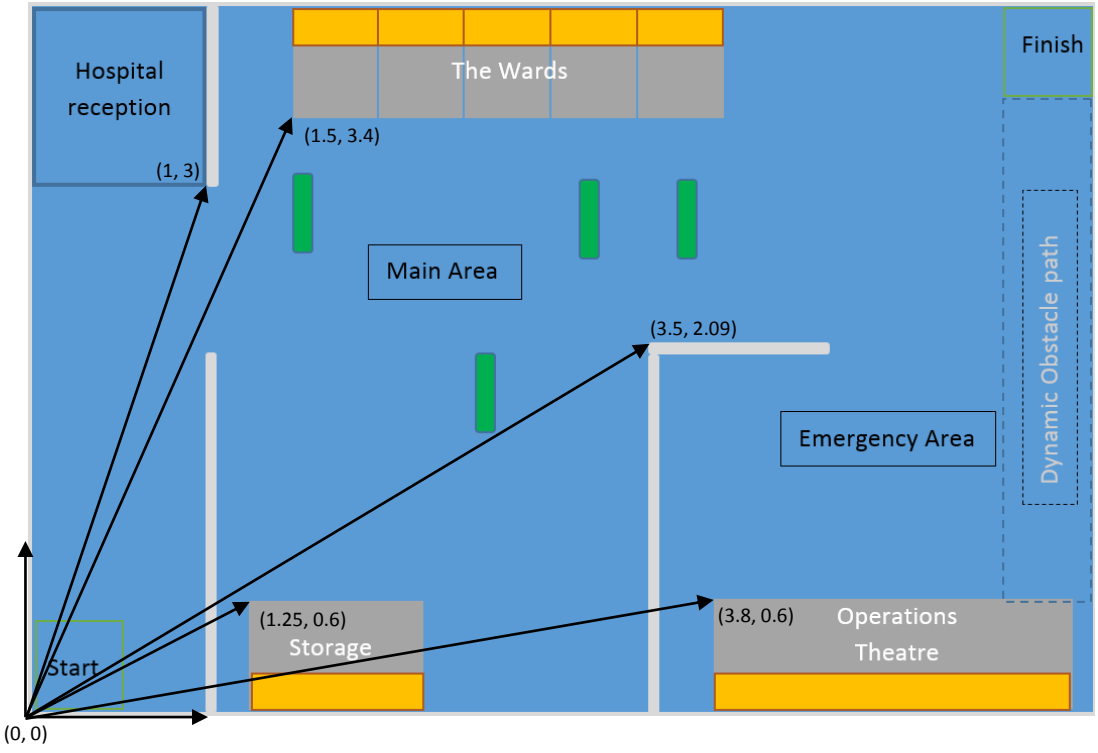
4. Interference and human interaction with the robot when a team's run has commenced is prohibited unless permission from the judges have been granted. Otherwise, the team will forfeit the round.

5. 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.**

Appendix A. Milestone Reference



Appendix B. Track Coordinates



**Note: all coordinates are in meters*