International Autonomous Robot Racing Competition 2019 Rules

November 2018

1 Date

The International Autonomous Robot Racing Competition (IARRC 2019) will be held from 12th - 14th July 2019. The competition agenda is shown in the timeline chart below:

Date	Time	Event
11th July	All day	Registration
	19:00~21:00	Welcome meeting
12th July	9:00~12:00	Free-for-all practice Design Competition
	14:00~18:00	Design Competition Drag Race
13th July	9:00~12:00	Obstacles Avoidance Challenge & Urban Road Challenge
	14:00~18:00	
14th July	9:00~12:00	Circuit Race
	14:00~16:00	Sponsors Event
	16:00~17:00	Awards Ceremony

2 Competition Objectives

For the IARRC 2019 competition, the organizers would like to focus on not only the racing component but also the autonomy of the robots. There are four major challenges that every team will face:

1) Perception (lane tracking, localization and mapping)
2) Decision-making and path planning
3) Obstacles Avoidance
4) Vehicle dynamics and control

3 Team Eligibility and Registration

Teams can be comprised from high school, college, undergraduate and/or graduate students, and must be supervised by at least one faculty advisor from the institution. Interdisciplinary teams are encouraged (EE, ME, CS, etc.). Only the student component of each team will be eligible for any awards. Every faculty supervisor for each team are responsible to certify that all team members are registered students. For a student to be eligible to compete as a team member, they are required to have attended at least one semester of school as a registered student between **July 2018 – July 2019**.

Schools can enter more than one team, but each vehicle must have a separate team of students and a distinct design report. Each entry must be based on a separate chassis and different software and must be documented by a separate application form and design report, submitted in accordance with all deadlines.

All teams who wish to enter the competition must submit a team name and pay an early bird, non-refundable registration fee of **$200.00 CAD** before **March 31st, 2019, at 23:59 EST** or a regular non-refundable registration fee of **$400.00 CAD** before **April 30th, 2019, 23:59 EST**.

This year we set up the online payment and it can be paid through VISA, Mastercard, and American Express **credit card**. Here's the payment link:

https://university-of-waterloo.myshopify.com/products/iarrc-2019-registration-fee

Receipts will be issued as soon as the online payment are processed and email back to the team leader by email. The registration and intent to compete forms are available on the IARRC website at https://iarrc.org/registration/

4 Vehicle Requirements

The competition is designed for a semi-rugged outdoor mobile vehicle. All competing vehicles must satisfy the following requirements:

Length	The length of the Vehicle must be between **30 cm** and **140 cm**
Width	The width of the Vehicle must be between **20 cm** and **70 cm**
Weight	The vehicle must not exceed a maximum weight of **55kg**.
Propulsion	The vehicle must be propelled entirely by battery power. No liquid combustible fuel storage systems are allowed.
Mechanical E-Stop	A mechanical E-Stop must be present with a red button at a minimum height of **30 cm**. The mechanical E-Stop must completely disable the vehicle's drivetrain by cutting power to the motor(s).
Wireless E-Stop	The wireless E-Stop must operate over a minimum range of **50 feet**. The wireless E-Stop must stop the vehicle's motion within **5 seconds**.
Markings and Interference	The vehicle must not interfere with other vehicles' sensing or navigation abilities, cannot have any markings that could confuse other vehicles (**orange** cone or **white** lines), and cannot contain any RF interference devices. This requirement will be assessed by the judges at the time of qualification.
Autonomy	The vehicle must be able to drive in a straight line at a constant speed of **2 m/s** for **10 m** and come to a stop within **5 m**.
Maximum Speed	The vehicle must be hardware limited to operate up to **10 m/s** maximum.

4.1 Guideline for Batteries

Canada has a strict regulation for transporting batteries, please check the link to make sure that the total watt-hours of the batteries of your racing robot and other electronic devices do not violate the regulation. https://www.catsa-acsta.gc.ca/en/guidelines-batteries

Also, you are also responsible to fully check the regulations in your own country.

5 Safety Qualification

Each vehicle must pass the safety qualification in order to compete in any of the competition events. Only qualified vehicles will be eligible for awards in any of the competitions. The qualification process will require demonstrating all vehicle requirements to the judges and can be attempted as many times as desired while qualification is open. For the autonomy requirement, teams can mark the straight-line path using cones, walls or lines, which will be available on-site.

6 Online Resources

A Github repository(https://github.com/IARRC/2019Resources) has been built for sharing some CAD model like the courses and signs that teams can use for test.

7 Competition Course

7.1 Course Location

The outdoor course will be located on the University of Waterloo campus in the Q parking lot (approximate GPS coordinates 43°28'28.3"N 80°32'26.1"W). The course may contain slopes up to 10 degrees.

7.1.1 Bad Weather

All events will be held outdoors unless the course is considered too wet by the judges or there is heavy rain. The races will continue in light rain. Vehicles should be prepared to operate in light rain and traverse small puddles. In the event of heavy rain, races will be held indoors in the University of Waterloo E5 Student Design Center.

7.2 Course Material

The track surface may be asphalt (outdoors) or concrete (indoors due to rain).

7.3 Course Shape

See competition events details in Section 7.

7.4 Lanes Boundaries

All lanes boundaries in the course will be created using solid **white** duct tape with a width of around **2 inches**. If the track has two lanes, we will separate the track using dashed lines with same width as boundary. The length of the intervals and the dashed lines are **25 cm** long.

Existing road lane markings painted on the asphalt that are within the course boundaries and deemed significantly distracting will be covered with dark grey outdoor carpet.

7.5 Start/Finish Lines

The start and finish lines will be marked with **6 inches** thick solid **magenta** lines. The width of each line will be same to the distance of the boundaries.

7.6 Traffic Light

A traffic light signal will be used to signal the start of the four dynamic competition events, located in the outside of the right-side boundary, **2 m** away from the starting line facing towards the vehicle.

Fig. 6.1 Illustration for traffic light position

As Fig. 6.2 shows, the traffic light has two lights in a row with the red one on the top side and the green one on the bottom side. Each light has a diameter of **100 mm**.

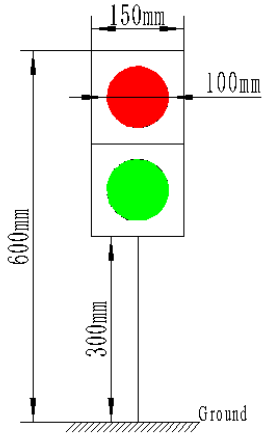


Fig. 6.2 Dimensions of the traffic light

As soon as the traffic light turns from red to green, the timer will begin counting time. As the same time, the vehicle should recognize the changes and automatically began the race. Once the robot passes the final line, the timer will stop counting.

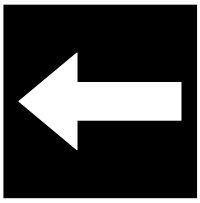
7.7 Obstacles

9-inch **orange** cones will be used as obstacles on the track of the Obstacles Avoidance Challenge event. It has a base of around 5.5x5.5 inches. You can purchase some similar cones to practice on Amazon (http://bit.ly/IARRCcones) or any other stores.

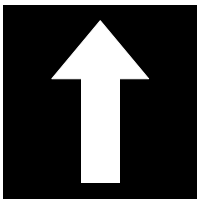
7.8 Traffic Signs

There will be three types of traffic signs in the Urban Road Challenge to signal vehicles to move forward, turn right and turn left. All signs are made in **20x20 cm** squares as shown in sections 6.8.1 to 6.8.3. Some of them will be placed at every intersection, similar to the placement of traffic lights. All signs will have a **black** background and a **white** arrow in the middle to indicate three different directions. You can download the vector file on our website and print it for practice.

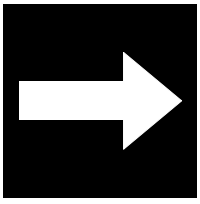
7.8.1 Sign for turn left



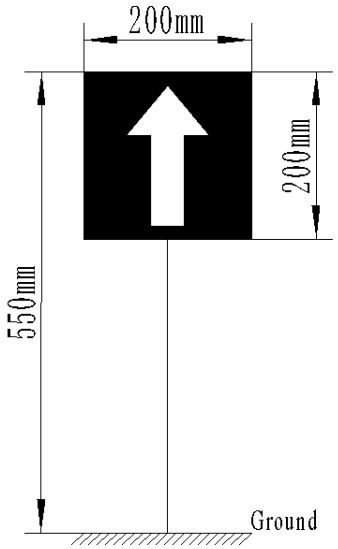
7.8.2 Sign for going forward



7.8.3 Sign for turn right



7.8.4 Dimension of traffic signs



8 Competition Events

This year, only one vehicle will be allowed to race on the track to provide fair scores and performance analysis about every robot. All vehicles are supposed to stop safely at the end of each race and to operate throughout the race without running off the course boundary.

During the welcome meeting, the team leaders will draw lots to determine the competition order. Before each event, the judge will call the team to prepare to start according to the order.

There will be four dynamic competition events this year: Drag Race, Circuit Race, Obstacles Avoidance Challenge and Urban Road Challenge. All vehicles will be scored based on time for all challenges. Two additional autonomy events will have extra requirements as stated in section 7.3, 7.4 and 8.8.

8.1 Drag Race

8.1.1 Course Boundary

The track will consist of a straight single lane with approximately **50 m** long and **1.5 m** wide (as shown in Figure 7.1 below). A brake zone will be created at the end of the drag race which is at least **6 m** long and ends with the obstacles with a minimal **20 cm** in height.

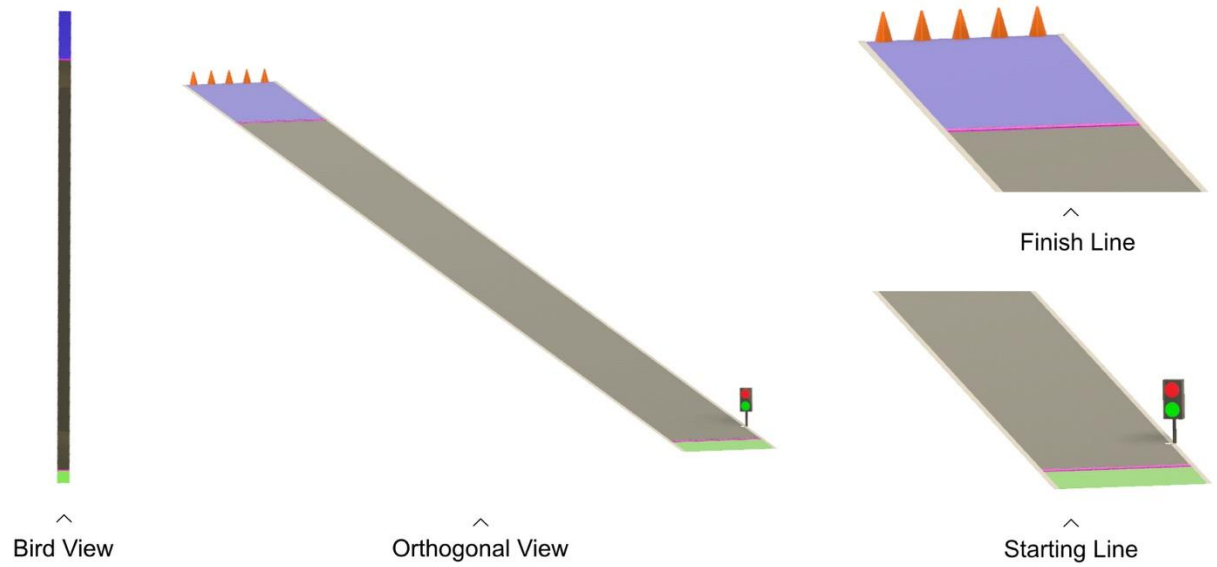


Fig. 7.1 Drag Race Course Boundary

8.1.2 Event Task

Before the event, every team will have **60 seconds** to prepare to start.

After the traffic light gives the start signal, a fully autonomous unmanned ground robotic vehicle must race on a straight track. Vehicle operation throughout the drag race all the way to a complete stop must be autonomous. Each vehicle is required to stay within its lane for the duration of the drag race and must come to a complete stop before the end of the brake zone (see driving rules above for penalties).

Every team will only have three chances, and the best score will be recorded.

The robots should finish the event in two minutes or less each time; otherwise, it will be regarded as Does Not Finish (DNF) and consume one “Time of Attempt”.

8.2 Circuit Race

8.2.1 Course Boundary

The lane will be around **2.0 m** wide and **70 m** long. The minimum radius of curvature for turning is **2 m**. It's a normal circuit track consisting of some curves and straight lines, but no intersections. The race will proceed in a clockwise fashion. The course layout will be similar to the 3D model as shown in *Fig. 7.2* below.

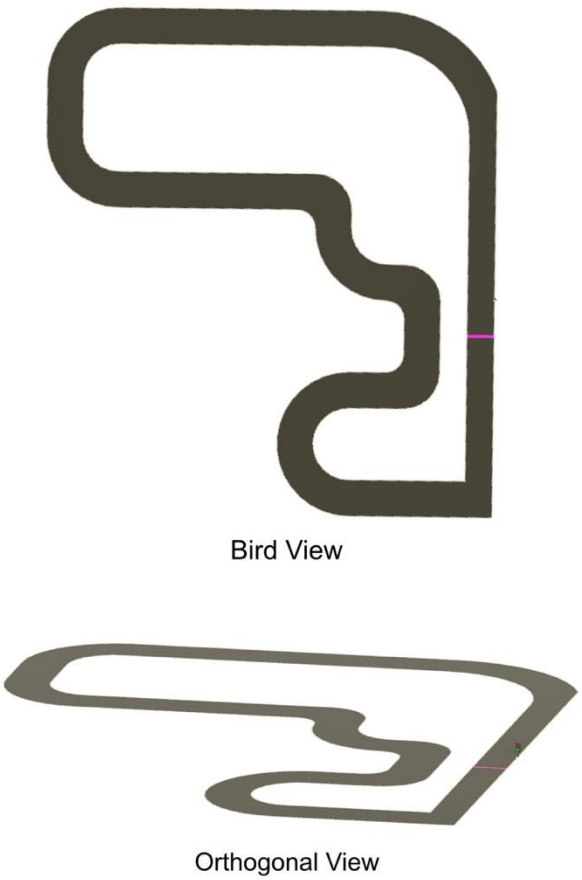


Fig. 7.2 Circuit Race Course Boundary

8.2.2 Event Task

Before the event, every team will have **60 seconds** to prepare to start.

After the traffic light gives a start signal, a fully autonomous unmanned ground robotic vehicle must race on the winding course and complete one lap. Each vehicle is required to stay within its lane for the duration of the drag race and must come to a complete stop after passing the finish line.

Every team will only have three chances, and the best score will be recorded.

Every team should finish in three minutes or less each time; otherwise, it will be regarded as DNF and consume one “Time of Attempt”.

8.3 Obstacles Avoidance Challenge

8.3.1 Course Boundary

The track will be same as the Circuit Race (please refer to *Fig. 7.2* shown in the previous section), and with additional static obstacles throughout the run. In most cases, the obstacle only has one cone and will be placed randomly in the middle, left-side or right-side of the track with intervals along the boundary between each other. For the most difficult scenario, there will be 5 cones in a row as shown in Fig. 7.3. We will give enough clearance even for the maximum allowable dimensions of the robots to pass. There will be around 15 obstacles in total.

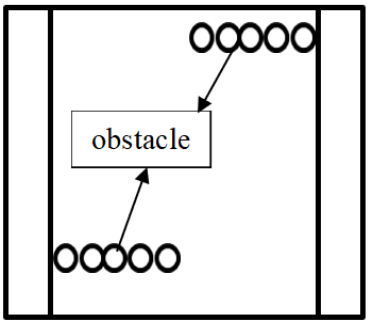


Fig.7.3 Illustration for obstacles

8.3.2 Event Task

Before the event, every team will have **60 seconds** to prepare to start.

After the traffic light gives the start signal, a fully autonomous unmanned ground robotic vehicle should try to avoid obstacles on the track as much as possible and reach the finish line. Even though this event will still count the score using time, it gives a large punishment coefficient in the case of failing to avoid obstacles.

Every team will only have three chances, and the best score will be recorded.

Every team should finish in three minutes or less each time; otherwise, it will be regarded as DNF and consume one “Time of Attempt”.

8.4 Urban Road Challenge

8.4.1 Course Boundary

The track consists of bidirectional single lanes with around **1 m** wide and **70 m** long for each lane (as shown in Fig. 7.4 below). Robots should keep running on the right lane of the track, even after turning. The robot will start on a straight track, then go into a grid field with a few intersections (like urban roads). By following some signs, you can find the way to the finish line. Traffic signs indicating a direction will be placed in front of each intersection, which means that there is only one way to go from the start to the finish line. There will be around 6 signs in total.

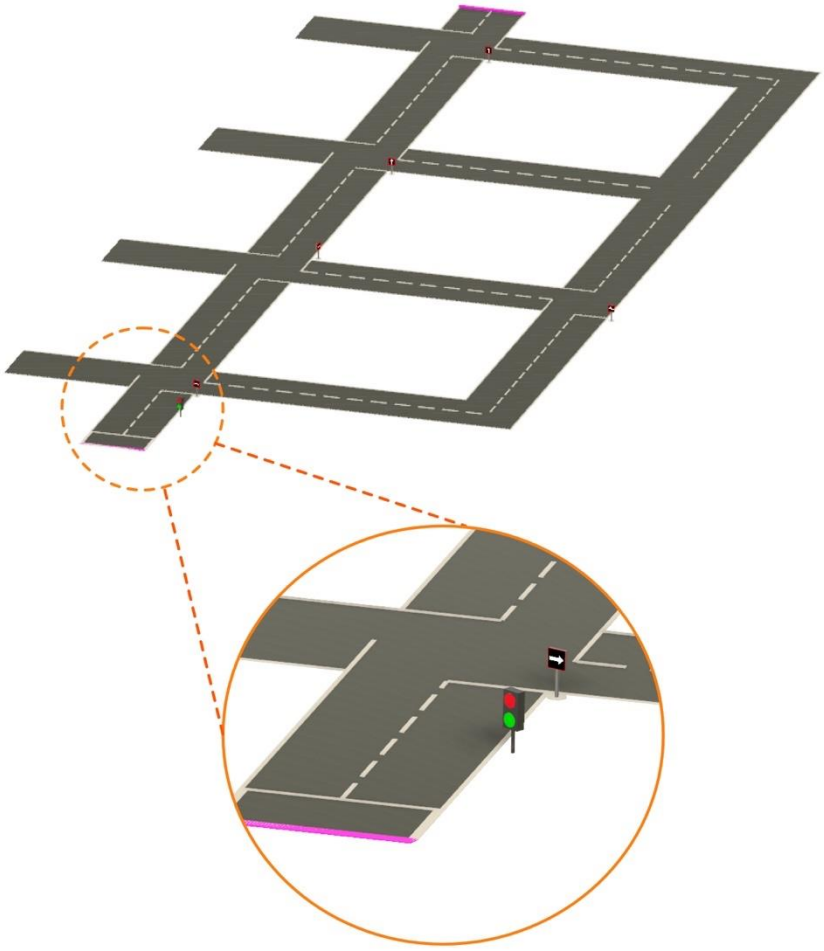


Fig.7.4 Illustration for the course of Urban Road Challenge

8.4.2 Event Task

Before the event, every team will have **60 seconds** to prepare to start.

After the traffic light gives a start signal, a fully autonomous unmanned ground robotic vehicle should follow the signs on the track as much as possible and reach the finish line. There are some intersections on the track, and you can find an optimal route to get the high score, which is determined by the traffic signs. All the robots should try to follow the signs to reach the final line. Once robots go to a different direction compared to the sign indication, it needs to stop and reset about **1 m** in the front of that sign.

Like driving scenarios in daily life, the robots are encouraged to keep moving on the right lane of the track all the time with **a bonus score**, but if fail to do that, it will not have any penalty. Considering the robot may have large minimum turning radii and can hardly stick on the right lane while turning right, it is allowed to get the bonus score by borrowing the adjacent left lane before or after turning left or right on the intersections. However, it should actively change back to the right lane after the turning action.

Every team will only have three chances, and the best score will be recorded.

Every team should finish in three minutes or less each time; otherwise, it will be regarded as DNF and consume one "Time of Attempt".

8.5 Design Competition

8.5.1 Written Report

The report should not exceed 8 letter-sized pages and use IEEE two-column conference format (http://www.ieee.org/conferences_events/conferences/publishing/templates.html). Each vehicle must have a distinct and complete report of its own. Participants are required to submit an electronic copy via e-mail by 5pm EST on July 5, 2019. For the teams who sign the Participant Submissions Release Consent, their electronic copy of the report will be posted on the competition's website in PDF format after completing the competition.

The report should present the conceptual design of the vehicle and its components. It's important to highlight any unique innovative aspects of the design and the intelligence aspects of the vehicle that address the 4 main challenges described above in the Competition Objectives.

Judges will score the written reports as follows:	**Maximum Points**
Effective innovation represented in the design	20
Completeness of solution to the competition objectives	20

Completeness of experimental results	20
Style (Language, Figures, Structure, Clarity)	20
Total	**80**

8.5.2 Oral Presentation

The technical talk should relate the highlights of the written report described above and include any updates of the design since the written report. The presentation must be made by one or more student members of the team to the judges and other interested members of the audience and should last no more than 10 minutes. After the presentation, judges and general audience may ask questions for up to 5 minutes. A Windows 10 laptop with Adobe Reader, PowerPoint, and a projector will be made available.

Judges will score the oral presentations as follows:	**Maximum Points**
Clear and understandable explanation of the innovations	20
Experimental results	20
Response to questions	20
Style	20
Total	**80**

8.5.3 Videos

Videos are expected to summarize the team's accomplishments, highlight innovative technologies and demonstrate the vehicle in action. The video length will be capped at 3 minutes, and are due on May 15th, 2019 11:59pm EST.

Judges will score the oral presentations as follows:	**Maximum Points**
Awesomeness of video (quality, editing, visual appeal)	10
Robot racing demonstrations	20

Explanations of technical innovations	10
Total	**40**

8.6 Summary on the four dynamic events

	Drag race	**Circuit race**	**Obstacles Avoidance Challenge**	**Urban Road Challenge**
# of lanes	1	1	1	2
Lane width (m)	1.5	2	2	1
Lane Length (m)	50	70	70	70
# of loops	-	1	1	1
Characteristics	Straight	Curvy	Curvy	Grid
# of vehicles at the same time	1	1	1	1
Time limit for any scores	2 min	3 min	3 min	3 min

9 Racing Rules

9.1 Traffic Light

The light will be red initially, then switch to green to signal the start of the race and remain green until the next race start. If the robots fail to automatically start after the light turned to green for **10 seconds,** it will be regarded as false start and each false start will result in a **1.2** multiplier penalty being applied to the final time.

9.2 Times of Attempts

For each challenge, every vehicle will be given three chances, and only the best score out of three attempts will be used.

9.3 Course Departure

The vehicles must remain within the course boundaries. If your racing vehicle failed to keep in the track, it will be considered as **DNF (Do Not Finish)** for that attempt. This rule will be applied to all challenges, since lane detection is critical for any autonomous vehicles.

9.4 Pit Stops

If a robot becomes disoriented or immobilized, the team or the judges must make an emergency pit-stop using wireless E-stop. The race will be considered as **DNF (Do Not Finish)** for that attempt.

9.5 Lack of Progress

Vehicles stopping on the course for over **30 seconds** without cause, failure to detect traffic light turning from red to green or driving in the wrong direction will be paused and taken out of the race. They will only be allowed back if they are deemed fit to continue by one of the judges. It will be considered as **DNF (Do Not Finish)** for that attempt.

9.6 Obstacles Collisions

During the Obstacles Avoidance Challenge event, if cones are knocked down or out, the team will face a punishment of **15** scores at each time, but the robot can keep going. If the robot fails to avoid obstacles for over **10** cones, it will be considered as **DNF (Do Not Finish)** for that attempt.

9.7 Urban Road Challenge

During the Urban Road Challenge event, if the vehicle fails to follow the instruction of the sign, it needs to stop and reset about **1 m** in the front of that sign and faces punishment of **25** scores at each time. If the robot fails to follow the sign more than **6 times**, it will be considered as **DNF (Do Not Finish)** for that attempt.

9.8 Scores

Each event has 200 points. For each competition, points will be awarded to each team, below is a breakdown of the points. For the Design Competition, the score will be given based on details in section 7.5.

Competition	**Maximum Points**
Drag Race	200
Circuit Race	200
Obstacles Avoidance Challenge	200
Urban Road Challenge	200
Design Competition	200
TOTAL	**1000**

For Drag Race and Circuit Race, the score will give as follow:

$$Score = \begin{cases} T_p * (150 * \frac{\frac{T_{max}}{T_{team}} - 1}{\frac{T_{max}}{T_{min}} - 1} + 50), if\ complete \\ 0, if\ incomplete \end{cases}$$

For Obstacles Avoidance Challenge, the score will be given as follow:

$$Score = \begin{cases} T_p * (50 * \frac{\frac{T_{max}}{T_{team}} - 1}{\frac{T_{max}}{T_{min}} - 1} + 150 - 15 * Penalties), if\ complete \\ T_p * (5 * N_{obs}), if\ incomplete \end{cases}$$

For Urban Road Challenge, the score will give as follow:

$$Score = \begin{cases} T_p * (50 * \frac{\frac{T_{max}}{T_{team}} - 1}{\frac{T_{max}}{T_{min}} - 1} + 150 - 25 * Penalties + Bonus), if\ complete \\ T_p * (15 * N_{signs}), if\ incomplete \end{cases}$$

T_p: the penalty coefficient for false start. It is 1.2 for false start and 1 for normal start.

T_{max}: is 150% of T_{min}

T_{min}: is the elapsed time of the fastest robot

T_{team}: best time that your team finishes the event

$Penalties$: number of hit obstacles or unfollowed signs

N_{obs}: number of obstacles that avoid successfully

N_{signs}: number of signs that follows

$Bonus$: 50 for keep moving on the right lane in the Urban Road Challenge.

The first term in all the equations is the performance score; if T_{team} exceeds 150% of T_{min}, this score is zero, but you can still get the completion score. You will get a non-negative score in Obstacles Avoidance Challenge and Urban Road Challenge, which means that the minimum score is zero.

10 Award

The Award trophies will be presented to the top three teams that perform the best overall in all five competitions. The champion team will receive a **$3000 CAD** prize, with **$2000 CAD** for the second-place team and **$1000 CAD** for the third-place team.

The awards may increase and awards for the top three of each event may also be possible as we get more sponsorships this year.

To receive any prizes, a team's robot *must* complete a full lap around the circuit course.

11 Disclaimer

The IARRC Committee and Officials will try to adhere to the above official competition details, rules and format as much as possible. However, it reserves the right to change or modify the

competition where deemed necessary for preserving fairness of the competition. Modifications, if any, will be announced as early as possible prior to the competition.