



NATIONAL ROBOTICS COMPETITION

# NRC COSPACE ROBOT CHALLENGE PRIMARY & SECONDARY CATEGORY (Autonomous Driving Challenge) SMART TRANSPORTATION



Version: 6 June 2024

Organised by:



**SP** Singapore Polytechnic

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## NRC 2024 PRIMARY & SECONDARY CATEGORY

### CHALLENGE BOOKLET CHANGE LOG

Version	Release Date	Description
1.0	6 May 2024	Official Challenge Booklet release
2.0	6 June 2024	Awards and Prizes

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# 1. General Information

## 1.1 National Robotics Competition (NRC) 2024

[National Robotics Competition \(NRC\)](#) has been an ongoing competition organised annually by Science Centre Singapore for the past 25 years with support from the Ministry of Education, various partners and sponsors. NRC has attracted more than 60,000 team members and 240,000 supporters to date. It is the only robotics competition in Singapore supported by the Ministry of Education.

NRC spurs students' interest and innovation in Science, Technology, Engineering and Mathematics (STEM). Students will be able to put their knowledge to practice and engage in hands-on STEM learning. With NRC as a stage for students to develop kinaesthetic learning and collaboration, it encourages students to develop problem-solving skills, entrepreneurial skills, creative thinking skills and team spirit among the team members. This is in line with Science Centre Singapore's mission "To promote interest, learning and creativity in science and technology, through imaginative and enjoyable experience and contribute to the nation's development of its human resource".

NRC 2024 tournaments comprise of:

- NRC Regular Category
- NRC Open Category
- NRC AI Maker Series
- NRC Preschool
  - Kubo Challenge
  - ARTec Challenge
- NRC Smorphi
- NRC CoSpace Robot Challenge
  - **Autonomous Driving Category**
  - Rescue Category

Registration for these category challenges will be via <https://forms.gle/V8wzHjY6gfrRBys29>. Competition registration opens **till 1<sup>st</sup> July 2024**.

*Note: Registration will be on a first come, first serve basis. If the category is full, your registration will be rejected and refunded*

## 1.2 Theme for NRC CoSpace Robot Challenge 2024

These are the official rules for NRC CoSpace Robot Challenge (Autonomous Driving Category) 2024. This rule book is released by the RoboCup Singapore CoSpace Technical Committee. English rules have priority over any translations.

The theme for NRC CoSpace Robot Challenge (Autonomous Driving Category) 2024 is **SMART TRANSPORTATION**.

In NRC CoSpace Robot Challenge – autonomous driving category, teams are required to complete 3 individual tasks commonly used in smart transportation, such as

- Navigation challenge
- Smart sensing challenge
- Path planning Challenge

The 3 tasks are designed to lead students on:

- How to use different type of sensors
- How to solve common problems in smart transportation, such as navigation and smart sensing.

There are two age groups.

- The primary age group is for students with little experience with robotics and coding. Novice teams are also welcome.
- Secondary age group is for students with foundation of robotics and coding, such as application using different sensors.

In 2024, a new exciting challenge using real robot (VRBOT-C6) will be introduced. In addition to the virtual competition, teams can join the CoSpace Real Robot Challenge. Awards will also be given to the winning teams of the real robot challenge. The NRC CoSpace Robot Challenge (Autonomous Driving Category) 2024 has two sub-divisions.

- Virtual Robot Challenge

It is compulsory for all teams to take part in the virtual robot Challenge.

- Real Robot Challenges (Optional)

Teams are encouraged to take part in the Real Robot Challenge using VRBOT-C6.

The NRC CoSpace Robot Challenge (Autonomous Driving Category) 2024 will present awards to the top 3 teams of the following categories:

- NRC CoSpace Real Robot Challenge
- NRC CoSpace Virtual Robot Challenge
- NRC CoSpace Robot Grand Challenge

The winner of grand challenge is evaluated based on the total score of real robot challenge and virtual robot challenge.

Assessment of the participants will be based on the RoboCup Singapore Education Framework, and students who demonstrate the required skills and competencies will be recognized with one of the following three grades: Pass, Merit or Distinction.

With the foundations built-up, students are able to complete the RoboCup Asia-Pacific (RCAP) CoSpace Autonomous Driving Challenge missions.

Contact us:

- Rule clarification: [cospace@robocupsg.org](mailto:cospace@robocupsg.org)
- Technical support: [support@CoSpaceRobot.org](mailto:support@CoSpaceRobot.org)

## 2. General Rules

### 2.1 NRC CoSpace Robot Challenge (Auto-Driving Category) Description

In NRC CoSpace Robot Challenge – Autonomous Driving Category, teams are required to program a virtual robot to complete 3 individual tasks commonly used in smart transportation, such as:

- Navigation challenge
- Smart sensing challenge
- Path planning challenge

### 2.2 Team

#### 2.2.1 Age Division

- Primary Age Group:
  - Teams comprising solely of students aged 8 to 12 years old, currently enrolled in primary school, are eligible to participate in the primary age group. If any team member is 13 years or above, the team will be categorised under the secondary age group.
- Secondary Age Group:
  - Teams with students aged 13 to 16 years old, and studying in secondary school can participate in secondary age group.

#### 2.2.2 Team Members

- A CoSpace Auto-Driving team should comprise 1 to 3 students, with each participant limited to registering for just one team.
- Every team must assign a captain, who holds the responsibility of communication with referees during the game.
- Each team member, including the captain, must carry out a technical role within the team, such as strategy planning or programming, which must be specified upon registration. Each member will need to explain his/her technical role and should be prepared to answer questions regarding the technical aspects of their involvement.

#### 2.2.3 Responsibility

The team members are responsible for:

- Verifying the latest version of the rules prior to the competition. If any rule clarification is needed, please contact the CoSpace Technical/Organizing Committee
- Checking updated information (schedules, meetings, announcements, etc.) during the event.

- Communications with CoSpace Technical/Organizing Committee for all CoSpace robot challenge related matters.

## 2.3 Referees

A referee is an official who manages the CoSpace robot challenge and makes sure that the challenge rules are followed. The referee receives and uploads the teams' virtual programs, as well as running the game.

## 2.4 Interruption of a Game

In principle, a game will not be stopped during the challenge unless the referee needs to discuss an issue/problem with the CoSpace Technical/Organizing Committee.

## 2.5 Conflict Resolution

### 2.5.1 Referee

- During the CoSpace Robot Challenge, the referee's decisions are final.
- At the conclusion of a game, the referee will ask the captain to sign the CoSpace Robot Challenge result sheet. Captains are given a maximum of 1 minute to review the result and sign. By signing it, the captain accepts the final result on behalf of the entire team. In case of further clarification, the team captain should write their comments on the result sheet and sign it.
- A violation of the rules may result in disqualification from the tournament or the round at the discretion of the referee, officials, organizing committee and general chairs.
- In case the team refuses to sign the scoresheet after the game, they should be advised to file a complaint following the procedure in Section 2.5.4 This should not interrupt the following games. The referee should follow the instruction given by the chief judge.

### 2.5.2 Rule Clarification

- It is the team's responsibility to verify on the official website the latest version of the rules prior to the competition. If any rule clarification is needed, please contact the CoSpace Technical/ Organizing Committee.
- If necessary, a rule clarification may be made by members of the CoSpace Technical/ Organizing Committee, even during a tournament.

### 2.5.3 Special Circumstances

- 2.5.3.1 Under special circumstances, such as the occurrence of unforeseen problems or malfunctions of the robot, rules may be modified by the Organizing Committee Chair in



conjunction with available Technical Committee and Organizing Committee members, if necessary, even during a tournament.

- 2.5.3.2 If any of the team captains/members/mentors do not show up to the team meetings to discuss the problems and the resulting rule modifications described in 2.5.3.1, it will be considered as an endorsement

#### 2.5.4 Complaint Procedure

- Rule issues are not to be discussed during the run. Referee decisions are binding for the CoSpace robot challenge. A team may protest by executing the following complaint procedure. The procedure is automatically invoked if a referee decides to abort the run for any reason.
- To initiate the complaint procedure, the team leader of the challenging team has to contact a member of the Technical Committee within 10 minutes of the end of the run. The member of the Technical Committee will then invoke a team leader conference in consultation with the Organizing Committee. The following parties will participate in this conference: the referees of the run, Organising Committee members, and the Technical Committee (counselling). The situation shall be resolved by unanimous consent or by vote of the Organising Committee members. The chief charge should inform the referee concern about the final decisions.
- All teams are reminded that while this is a competition, the league is also about cooperative research and evaluation, as such, complaints should be handled in a fair and forthcoming way.

## 2.6 Code of Conduct

### 2.6.1 Fair Play

- CoSpace coding challenge is built upon the foundation of fairness, respect, and friendship. Team members should be mindful of other people and their robots when moving around the tournament venue.
- Mentors (teachers, parents, chaperones, translators, and other adult team members) are not allowed in the student work area. They are not allowed to be involved in the programming of students' robots.

### 2.6.2 Behaviour

- Prior to the Challenge, team leaders and mentors are required to sign and acknowledge that they fully understand and are aware of the rules as well as Code of Conducts for the Challenge. All participants are responsible for their own actions.
- During challenge, participants are to follow the directions of the referee. Failure to do so will result in a WARNING (Yellow Card). Subsequent infractions will result in an automatic DISQUALIFICATION (Red Card) of the round. Disqualification as a result of deliberately distract the competition is FINAL and appeals will not be entertained in any form. The status of Yellow/Red Cards will be recorded.
- **WARNING (Yellow Card) procedure**

- A WARNING can be issued at the sole discretion of the lead referee; however, assistant referee will be consulted. If no objection is raised, WARNING will be issued.
- A WARNING will be issued for the following disruptive behaviours and activities including but not limited to:
  - a) Not following referee's instructions
  - b) Disturbing other participants and/or competition staffs (including referees).
  - c) Speaking loudly, shouting, using any kind of profanities or making sound that resembles profanity.
  - d) Sabotaging other teams' belongings or equipment.
  - e) Entering competition area when other teams are competing.
  - f) Entering other teams' area without explicit permission.
  - g) Engaging in disorderly conducts such as fighting, physical scuffles, running around competition and/or team area.
  - h) Harassing referee.
  - i) Mentor interference with referee decisions.
- **DISQUALIFICATION (Red Card) procedure**
  - A DISQUALIFICATION can be issued at the sole discretion of the lead referee; however, assistant referee will be consulted. If no objection is raised, DISQUALIFICATION will be issued.
  - An immediate DISQUALIFICATION can only be issued jointly by the lead and assistant referee. A DISQUALIFICATION will be issued for the following cases:
    - a) Teams have collected two consecutive WARNINGS during competition period. A competition period is defined as the start to end of duration of competition.
    - b) If one team copies a program from another team, both teams will be disqualified.
  - Once the RED CARD is issued, the team will be disqualified from the current run. If team receives 2 RED CARDS, it will be disqualified from the whole entire competition.
  - All immediate DISQUALIFICATION will be reviewed by the Chief Judge and the Organising Committee. Infractions that resulted in immediate DISQUALIFICATION will be reviewed and additional sanctions such as bans from future competitions will be considered.
- **Penalty**
  - The following are strictly prohibited:
    - a) During the game, using third-party software, self-written code, or any other tools to retrieve additional system information is strictly prohibited.
    - b) Any other behaviours that affect the normal operation of the RCAP CoSpace Auto-Driving Simulator, and direct or indirect control of the behaviours of the RCAP CoSpace Auto-Driving Simulator, such as the scaling of the simulation window is strictly prohibited.
  - A DISQUALIFICATION from the current match can be issued at the sole discretion of the CoSpace Chief Judge and CoSpace Technical Committee if teams offend the Penalty rules for the first time.
  - A DISQUALIFICATION from the entire competition can be issued at the sole discretion of the CoSpace Chief Judge and CoSpace Technical Committee for repeat offenders.

- **Sharing**
  - Teams are encouraged to share their codes and strategies with members after the competition.
  - Any developments may be published on the RCAP Academy Channel (<https://www.youtube.com/RCAPAcademy/>) or CoSpaceRobot.org after the event.
  - CoSpace coding challenge sharing and presentation furthers the mission of RoboCup as an educational initiative.
  
- **Spirit**
  - It is expected that all participants (students and mentors alike) will respect the RoboCup mission.
  - The referees and officials will act within the spirit of the event.
  - It is not whether you win or lose, but how much you learn that counts!

## 3. Fields

### 3.1 Real World

#### **REAL\_WORLD Dimension**

The dimensions of the REAL\_WORLD are 180cm x 240cm.

The floor may be either smooth or textured and may have steps and/or gaps of up to 3mm. It can also be printed on a canvas.

The real world will be placed so that the floor is level.

#### **REAL\_WORLD Layout**

The REAL\_WORLD may consist of any of black guidelines, obstacles, detour markers and mysterious tasks.

#### **Guidelines**

- The guideline can be black, white or any other distinct colours.
- The guideline (width: 1.8 - 2.2cm) may be made with standard electrical insulating tape or printed onto other materials.
- The guideline forms a path to guide REAL\_ROBOT in REAL\_WORLD.
- Straight sections of the black guideline may have gaps with at least 5cm of straight line before each gap. The length of a gap will be no more than 20cm.



Figure 1: Sample of black

#### **Ramps/Bridges**

There could be ramps/bridges to allow the robots to “climb” up to and down from different levels. Ramps will not exceed an incline of 25 degrees from the horizontal.

### Detour Markers

There are some colour markers to help robots make decisions at junctions. The marker can be of any colour.



Figure 2: Sample of detour markers

### Obstacles

The obstacles can be cylinders or cubes. The size, design and colour of obstacles can be varied.

### Tasks

There are 3 tasks on the REAL\_WORLD. Each task has a start, end point and several waypoints.

### Waypoints

The real robot must navigate through all waypoints in any order on the REAL\_WORLD. The real robot may be requested to perform special actions when passing the waypoints.

Typical REAL\_WORLD layout:

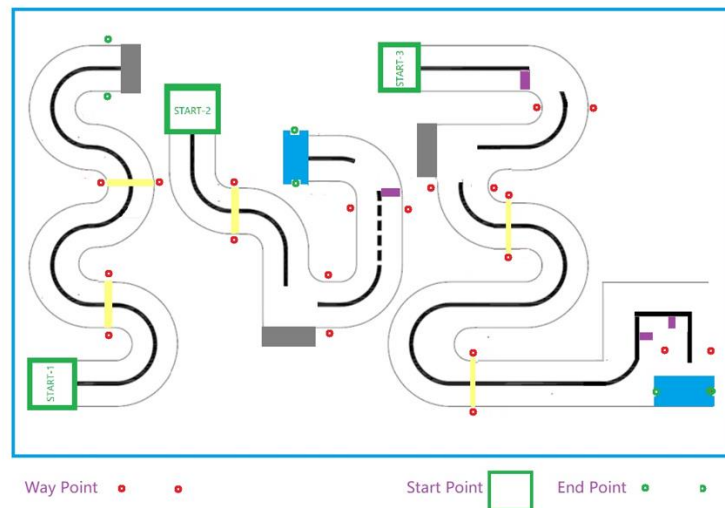


Figure 3: Real Field

## 3.2 Virtual World

The VIRTUAL\_WORLD may consist any of black/white guidelines, obstacles, gantries, waypoints, detour markers, and mysterious tasks.

### Black/White Guidelines

- There will be black line on light road or white guideline on dark road.

- The black/white guideline forms a path to guide the virtual robot.
- Straight sections of the black/white guideline may have gaps with at least 5 cm of straight line before each gap. The length of a gap will be no more than 20 cm.



Figure 4: Black / white guideline

### Obstacles

The virtual obstacles can be walls, buildings, cylinders, or cubes. The size, design and colour of obstacles can be varied.

### Detour Markers

There are some colour markers in virtual VIRTUAL\_WORLD to help robots to make decision at junctions. The marker can be of any colour.



Figure 5: Sample of detour markers

### Termination Markers

This is the terminal point of the Black/White guideline.



Figure 6: Termination

### Typical VIRTUAL\_WORLD layout



Figure 7: VIRTUAL\_WORLD Layout

## 4. Robot

### 4.1 Real Robot

#### Real Robot Configuration

Real robot VRBOT-C6 configuration is as follows:

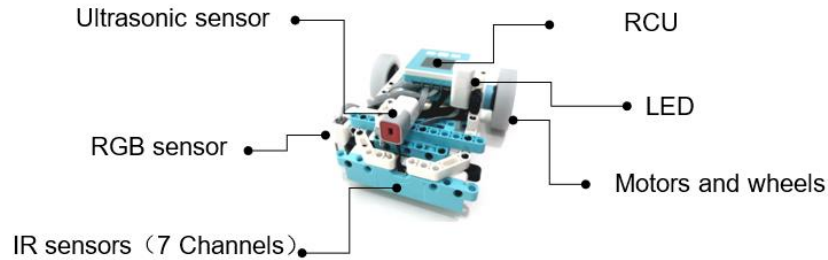


Figure 8: CoSpace Robot VRBOT-C6

VRBOT-C6 description can be found at <https://www.sang-nila.com/product/vrbot-c6/>

### Real Robot Control and Programming

- Teams can use GUI or Python built in the CoSpace Auto-Driving Simulator to program the VRBOT-C6.
- Real robot must be controlled autonomously. The use of a remote control, manual control, or passing information to the robot (by sensors, cables and wireless devices, etc) is not allowed.
- It is the team's responsibility to ensure the real robot is in good working condition to avoid any issues caused by the real robot during the real game. The robot should be fully charged.
- Teams are not allowed to change the motors, controllers, sensors, layout and structures of the assembled real robot in this challenge.
- It is encouraged to make the robot carry a small flag with a team name and team ID.

## 4.2 Virtual Robot

### VIRTUAL\_ROBOT Configuration

The VIRTUAL\_ROBOT configuration is as follows:

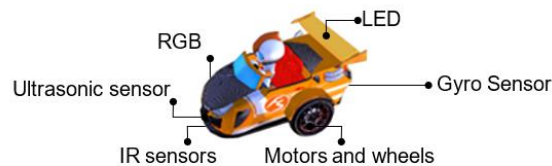


Figure 9: Virtual robot

### Robot Control

- Teams can use GUI, Python or C to program the VIRTUAL\_ROBOT to complete the task in VIRTUAL\_WORLD.
- ROBOT must be controlled autonomously. The use of a remote control, manual control, or passing information (by sensors, cables, wirelessly, etc.) to the robot is not allowed.

## 5. Challenges And Tasks

### 5.1 Challenges

The NRC CoSpace Robot Challenge (Autonomous Driving Category) 2024 has two sub-divisions.

- Virtual Robot Challenge
  - It is compulsory for all teams to take part in the Virtual Robot Challenge.
- Real Robot Challenge (Optional)
  - Teams are encouraged to take part in the Real Robot Challenge using [VRBOT-C6](#).

There will be 3 tasks for both Virtual Robot Challenge and Real Robot Challenge. All teams are required to complete these challenge tasks.

### 5.2 Tasks

#### Tasks for Primary Age Group

##### Task 1: Navigation Challenge

In this task, teams are required to program an autonomous car to avoid obstacles and track lines using infrared (IR) sensors and ultrasonic sensor in both real and virtual arenas respectively.



Figure 10: Navigation challenge

##### Task 2: Smart Sensing Challenge

In this task, teams are required to program an autonomous car to track lines, detect road markers and navigate in both real and virtual arenas using RGB colour sensor and IR sensors mounted on the car.

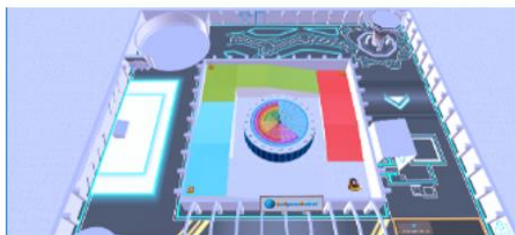


Figure 11: Smart sensing example

##### Task 3: Open Challenges

In this task, teams are required to program an autonomous car to complete open challenges using IR sensors, ultrasonic sensor, and RGB sensors.

## Tasks for Secondary Age Group

### Task 1: Navigation Challenge

In this task, teams are required to program an autonomous car to navigate in both real and virtual arenas using infrared (IR), ultrasonic, and RGB sensors mounted on the car.

### Task 2: Path Planning Challenge

In this task, teams are required to program an autonomous car to plan the best path using gyro sensor when traveling in both real and virtual arenas.



Figure 12: Path planning example

### Task 3: Open Challenges

In this task, teams are required to program an autonomous car to complete open challenges using all sensors mounted on the car.



Figure 13: Open challenge example

## 6. Gameplay, Judging and Scoring

### 6.1 Gameplay

#### Release of Task

The organising Committee will announce the tasks in the competition hall.

#### AI Submission

- The chief judge will announce the time for submission of the AI in the competition hall.
- Each team must submit an AI program for all 3 tasks which is created during the programming period to the chief judge. The code file name should follow the format announced by the chief judge in the competition hall.



**Virtual Run**

- 5 minutes before each run, team captains must report to the referee at their respective game stations.
- The referee or the team leader (following the referee's instruction) will reset the virtual robot and upload the virtual AI program.
- It is the team captain's responsibility to ensure that the correct program is uploaded.
- The referee or the team leader (following the referee's instruction) will run the game. After clicking the "PLAY" button, No one will be allowed to touch the PC until the game ends.
- Team captain must be present during the entire virtual run.
- Referee will complete all 3 tasks. Team captain is required to acknowledge the result by signing on the scoresheet.

**Real Run**

- Teams will be given 2 minutes for last-minute calibration and testing of the REAL\_ROBOT on the real field before the start of the real run.
- The team captain will upload the programs to the REAL\_ROBOT, place the REAL\_ROBOT at the "START" point of each task in REAL\_WORLD as instructed by the referee.
- The team captain will manually start the REAL\_ROBOT after the referee's command.
- REAL\_ROBOT is required to pass all way points in any order for each task.
- It is the team captain's responsibility to ensure that the correct program is uploaded.
- Team captains must be present during the full length of the real run.
- For each task, there will be maximum of 3 re-starts allowed. The number of the re-starts will not be considered as further penalty in any form.

## 6.2 Judging and Scoring

### Tasks and Weightages

- CoSpace Real Robot Challenge
  - Task 1: Navigation challenge – 20%
  - Task 2: Smart sensing challenge – 30%
  - Task 3: Open challenge – 50%
- CoSpace Virtual Robot Challenge
  - Task 1: Navigation challenge – 20%
  - Task 2: Smart sensing challenge – 30%
  - Task 3: Open challenge – 50%

### Judging

The completion criteria for each task are defined as follows: "The robot must start from the designated starting point of each respective task, navigate through a series of waypoints, and finally reach the endpoint."

In the CoSpace real robot challenge, only the number of waypoints successfully passed is taken into account when computing the result of this task, regardless of the time spent during the entire duration.

The score for each task is calculated using the following formula:

$$\text{Score of each task} = \frac{\text{Number of waypoints passed}}{\text{Total waypoints} + 1} \times \text{Weightage of the task} \times 100$$

In CoSpace virtual challenge, the same formula is adopted. The result will be computed by CoSpace Server at the end of each virtual task.

### Scoring

- CoSpace Real Robot Challenge
  - The score of each round of real robot challenge is determined by the accumulative scores of three tasks.
  - If the real robot challenge consists of a few rounds of games, the final score is the summation of each individual rounds.
  - In the event of a tie, the ranking of the real robot challenge is then determined by score of Task 3 followed by time taken for task 3.
- CoSpace Virtual Robot Challenge
  - The score of each round of virtual challenge is determined by the accumulative scores of three tasks.
  - If the virtual robot challenge consists of a few rounds of games, the final score is the summation of each individual rounds.
  - In the event of a tie, the ranking of the virtual robot challenge is then determined by score of Task 3 followed by time taken for task 3.
- CoSpace Robot Grand Challenge
  - The score of each round of grand challenge is determined by the accumulative scores of three real robot tasks and three virtual tasks.

- If the grand challenge consists of a few rounds of games, the final core is the summation of each individual rounds.
- In the event of a tie, the ranking of the grand challenge is then determined by score of virtual Task 3 followed by time taken for virtual task 3.

## 7. Awards and Prizes

The NRC CoSpace Robot Challenge (Autonomous Driving Category) 2024 will present awards to the top 3 teams of the following categories:

- CoSpace Real Robot Challenge
  - 1st Place: Medals for each participant
  - 2nd Place: Medals for each participant
  - 3rd Place: Medals for each participant
- CoSpace Virtual Robot Challenge
  - 1st Place: Medals for each participant
  - 2nd Place: Medals for each participant
  - 3rd Place: Medals for each participant
- CoSpace Robot Grand Challenge

The winner of grand challenge is evaluated based on the total score of Real Robot Challenge and Virtual Robot Challenge.

- 1st Place: \$300, Trophy for each team and Medals for each participant
- 2nd Place: Medals for each participant
- 3rd Place: Medals for each participant

All participants will also receive certificates of participation.

The organiser reserves the right to amend the prizes without prior notice.

RoboCup Singapore CoSpace Technical Committee.

## CONTACT US

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