

ROBOTICA 2011
FESTIVAL NACIONAL DE ROBÓTICA

Competition

Rules and Technical Specifications

Autonomous Driving Competition

(January, the 6th, 2011)

Notes:

- Unless where explicitly indicated, all measurements provided in these rules have a precision of $\pm 5\%$.
- Text which is new for the 2011 edition is marked in bold. Text relating to the Rookie Class competition will not be marked in bold since this class is completely new for the 2011 edition.

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1. Introduction

The Autonomous Driving Competition is a competition for fully autonomous robots that takes place in a track with the shape of a traffic road, surrounded by two parallel side lines and including two lanes separated by a dashed mid line (see section 3 – Competition Area). The competition, starting in 2011, includes two independent classes designated "Rookie Class" and "Challenge Class". Each of these classes has its specific set of rules and particular competition organization, that also corresponds to different levels of challenge and difficulties to overcome.

2. Robot

Dimensions

The robot has to fit entirely into a rectangular parallelepiped box 60cm wide, 100cm long and 80cm high (these values have an accuracy of $\pm 1\%$).

Autonomy

The robot is a completely autonomous vehicle. All decisions are taken by the systems included in it and all of its energy sources must also be embedded there. **Competitors are not allowed to use any form of communications to externally interfere with the control of the robot. Simple telemetry can be used but its unidirectional nature (from robot to external system) must be demonstrated during technical verifications.**

Security

The robot must have adequate security mechanisms according to its power and mode of locomotion so that it can stop itself in situations that may pose any sort of danger to people or property. In particular, the robot must provide a connector by means of which the power to the motors can be disconnected through an externally controlled relay (dry contact). This connector is mandatory except in the situation noted below. The power switching device (see diagram) is provided to the team by the organization at the start of its race test and can be remotely actuated through a radio-frequency (RF) link. In turn, this RF device is exclusively handled by the referee, who will determine the circumstances under which the robot must be immobilized.

The power switching device is placed inside a box with 100x80x50 (mm), which must be attached to the robot through a 20x80 (mm) Velcro strip. An adequate space for this purpose must be provided in the contestant robot. The Velcro strip placed in the robot should be of the female type. **If the team can demonstrate that the maximum speed of the robot is low enough so that no danger to people or property can be produced, then it is the Jury competence to decide if the team can or can not be allowed to compete without the security device.**

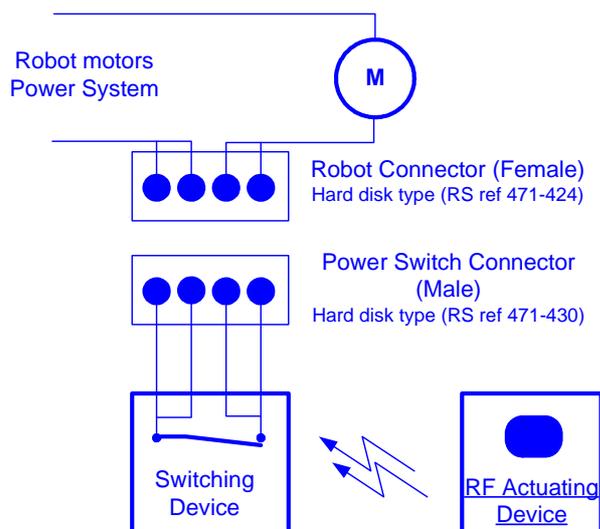


Figure 1 –Electrical schematic of the power switch device.

3. Competition Area

3.1 Track

Dimensions

The competition track is placed within an area of (11 x 16.4) m, has the format of a traffic road and is surrounded by two parallel side lines. A representative view of this route is shown in Figure 2. The radii of curvature of the inner and outer curved paths are 1.55m and 3.1m respectively. The straight leg is 10m long. The distance between lines, measured between their inside limit, is 150cm. The lines themselves are 5cm wide. At the centre of the runway there is a dashed line that divides the track into two equal side bands. The white sections of this dashed line are 5cm wide by 20cm long and are evenly spaced by 15cm.

All data regarding the key measures of the track, zebra crossing and parking areas is shown in Figure 3.

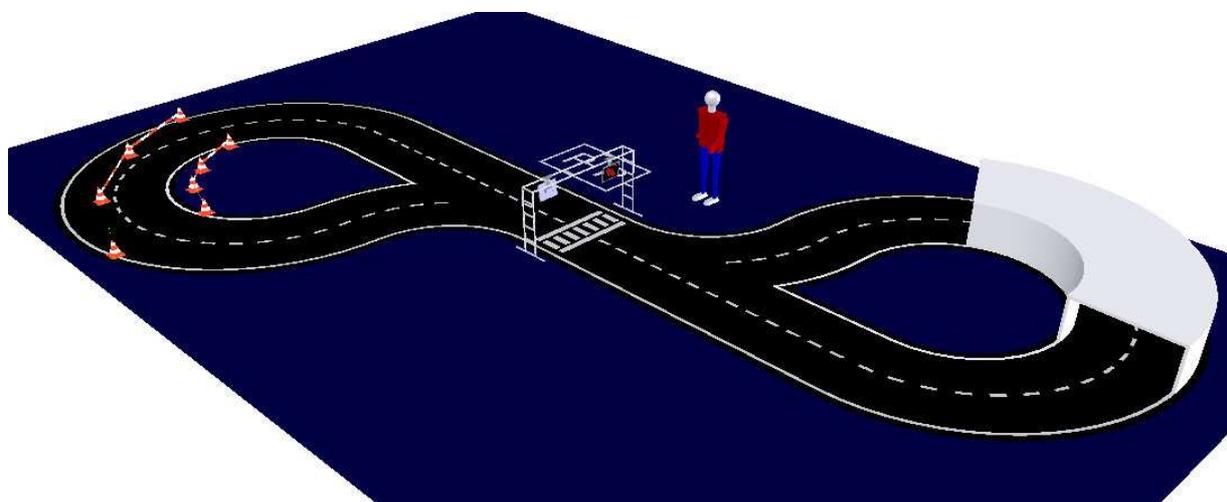


Figure 2 – Track overview

Colors

The track floor is black and infrared absorbing. The side lines are white and are infrared reflective. The area outside the track, but adjacent to the external lines, forms a band at least 20cm wide, and uses the same color of the track floor.

Zebra Crossing

A walking zebra crossing is placed roughly at the centre of the straight leg, and at the junction of the two circular sections, as represented in Figure 4. The “zebra” area consists of seven white stripes with a size of 10x30cm, and spaced 10cm from each other. This area is placed 10cm away from the track outside delimiting lines. The zebra crossing is limited on both sides by two white lines with 10x130cm (centered on the runway). All traces of this zebra crossing are infrared reflective.

Starting and arrival zones

An area immediately prior to the zebra crossing, but intercepting its first cross line, is assumed to be the departure / arrival zone, when considering the direction of movement of the robot. This is set in accordance with the rules further explained in the "competition" chapter.

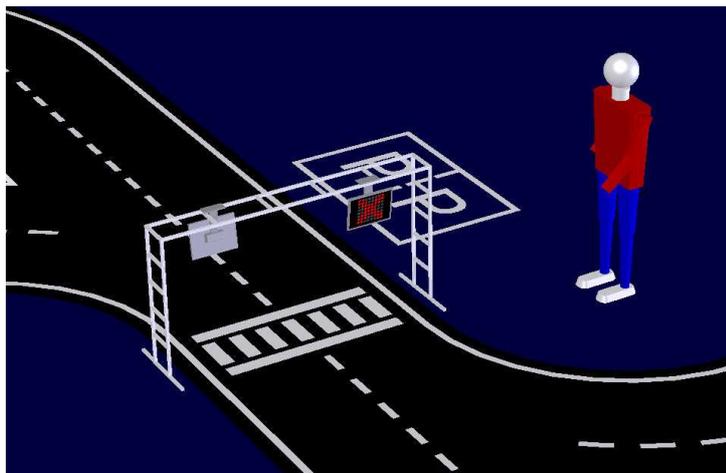


Figure 4 –Zebra crossing, parking area and start / arrival zone

Parking area (**Challenge Class only**)

A car parking area is located right after the zebra crossing and on its right side when considering the robots starting direction. It consists of two contiguous rectangles where the letter "P" is inscribed. The distance between the park side closest to the track and the track external line (B distance in Figure 3) will be 20 cm \pm 50%. The maximum distance between the zebra crossing and the start of the park (A distance in Figure 3) may vary between 50 cm and 200 cm. Other measurements can be found in Figure 3.

3.2 Tunnel (Challenge Class only)

Dimensions

The tunnel will be placed on the track in one of its circular sectors and will cover an angle of about 90 degrees. Its interior dimensions are approximately 150cm wide by 100cm in height. Its average length is about 3.6 m. The vertical edges of entry and/or exit of the tunnel will have a minimum width of 5cm to facilitate its recognition.

Color and materials

Both the tunnel entry/exit vertical edges and its interior walls will be white to reflect infrared light. The roof can be built of any material, not necessarily white and not necessarily flat.

3.3 Working Zone (Challenge Class only)

Description

The working zone reflects a detour from the original route of the track. This working zone has a length and form previously unknown to the teams, and its actual placing is revealed by the organization only after all robots are placed in closed park. The working zone can be coincident either with a curve zone or with a straight leg of the original pathway. This working zone path always starts on the outside lines of the track, extends away from the original route either to its outside or inside, and then returns to the original path. An example of a working zone is provided in Figure 5.

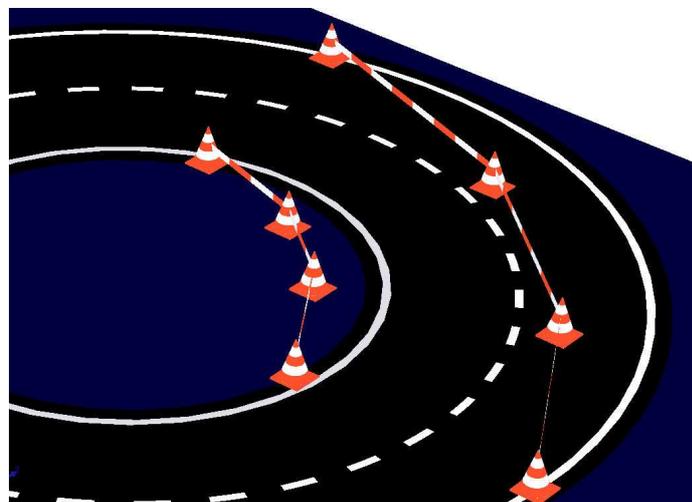


Figure 5 – Working zone example

Color and materials

The working zone is delimited on its entry and exit by two pairs of orange and white cones (adapted from those used in work performed on actual roads), placed on the track outside lines. The working zone path will be bounded on the left and right by a sequence of cones similar to those cited above and spaced approximately 1m from each other. Each pair of consecutive cones is connected by a 5cm wide ribbon, placed upright and alternately colored red and white (the colors are approximate - the tape is similar to the commercial version used to delimit undergoing work on public roads). The down side of this tape will be about 10cm above the ground (see Figure 7).

3.4 Obstacles (Challenge Class only)

Description

In the second and third rounds of the **Challenge Class**, an obstacle will be placed on the track. Robots are expected to detect and avoid this obstacle by moving around it (see more on “competition” chapter). In the third round an obstacle will also be placed within the parking area. The obstacle is a rectangular parallelepiped box with a 60cm square base and a minimum height of 20cm. The obstacle will be green colored. A placement example of this obstacle can be seen in Figure 6.

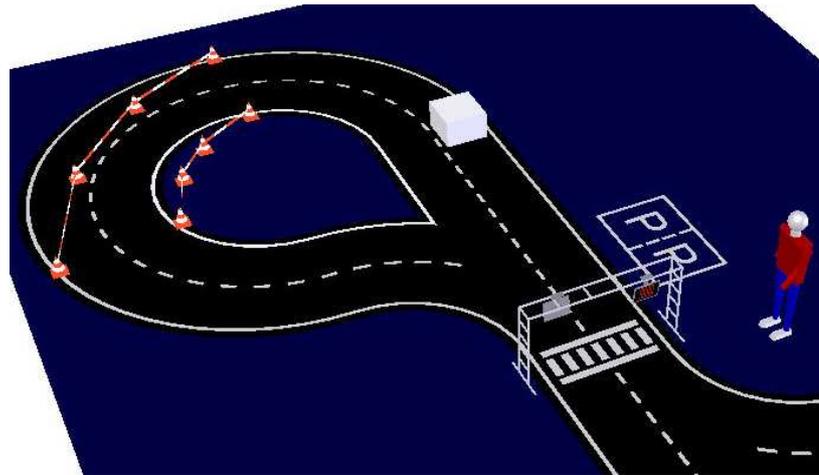


Figure 6 –Obstacle placing example

The obstacle position on the track can vary between trials for the same robot, and is the jury responsibility to determine this obstacle location. The obstacle will never be placed inside the tunnel, on the zebra crossing, or inside a working zone route.

3.5 Signaling Panels

Description

Two 17" TFT panels will be mounted right above the zebra crossing, in the inverted position, and vertically aligned with each one of the half parts of the track.

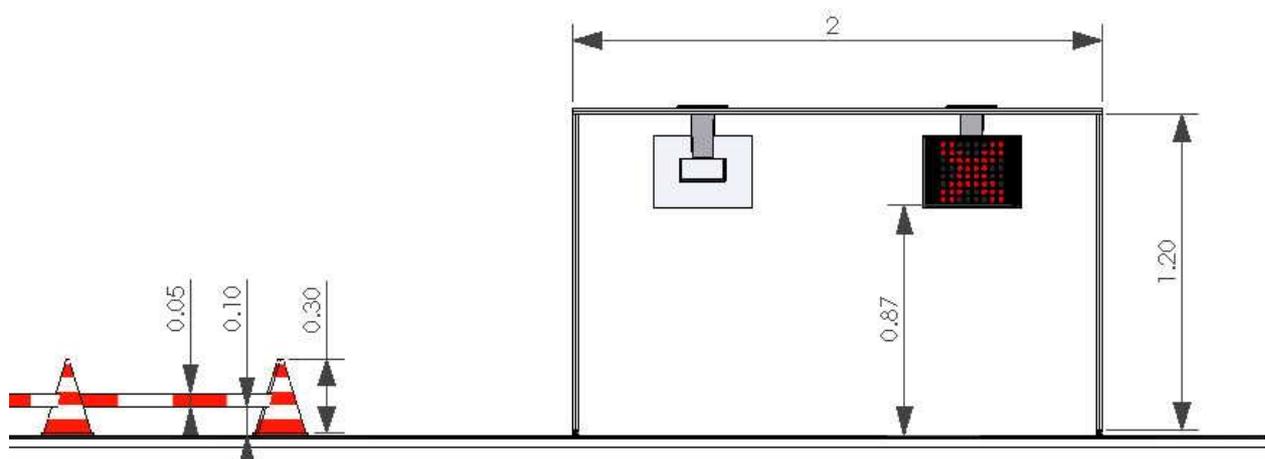


Figure 7 –Signaling panels and working zone cones - dimensions

Indicating signals characteristics

The indicating signals presented on the TFT panels are generated from an image with 1024x768 pixels. The symbols themselves occupy a square area with 600x600 pixels (the files for each of the images used can be found on the FNR 2008 site). The colors used for the signals, are respectively the red, green and yellow over a black background.

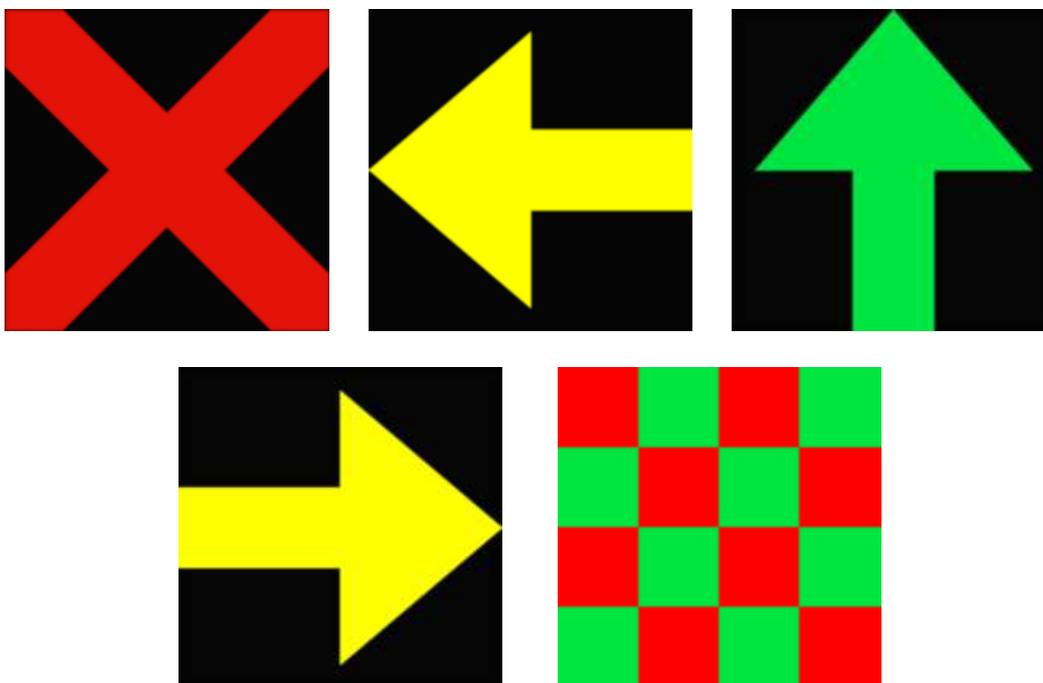


Figure 8 – Signaling panel drawings. In the checkers flag, colours are presented in an alternate succession

Signaling and its associated function

The aim of the signaling panels is to conduct the robots trials, giving them orders to:

- 1- Stop
- 2- Follow straight ahead
- 3- Follow to the left
- 4- End the trial
- 5- Follow to Parking area

Correspondence between each of these functions and the information presented in the signaling panels is:

Function	Action	Signal
1	Stop	A red colored "X"
2	Follow straight ahead	A green colored vertical arrow
3	Follow to the left	A left pointing yellow horizontal arrow
4	End of trial	Red and green checkers flag (each alternating form lasts for 0.25 s)
5	Follow to parking area	A right pointing yellow horizontal arrow

The actual images of the five symbols presented in these panels can be observed in reduced scale in Figure 8. **In the Rookie Class, only the "Stop" and the "Follow straight ahead" signals will be used.**

Positioning

A signaling panel will be available for each direction of the course. The panel shall present itself to the robot on the right side of the track, considering the direction of its movement. The base of the panels will be 87 cm above the ground ($\pm 2\%$) and its angle regarding the vertical plane will be of 25° (see Figure 7). The signaling panels will be mounted on an aluminum structure adequate for this purpose. Given the high placement of these panels and depending on the site lighting conditions a set of opaque devices may be placed, in order to minimize the effects resulting from the impact of direct light.

3.6 Traffic Signs (Challenge Class only)

Description

Six different traffic signs will be available for the competition. Their dimensions are limited by a bounding square of 305x305mm (equivalent to a 17" diagonal) standing on a post at 87cm from the ground. This is equivalent, in terms of size and height, to the TFTs of the signaling panels. The base of the sign (305mmx200mm) will be placed 10cm away from the side line (Figure 9). Both the base and the post are painted white.

The signs present themselves to the robot on the right side of the track, considering the robot direction of movement. The backside of the signs will be painted in black.



Figure 9 – Example of a traffic sign placed on the side of the track.

Types of traffic signs

Two of the traffic signs will be warning signs (triangular shape), two will be mandatory signs (round shape), and the other two will be information or services signs (square shape). The selected traffic signs for the 2011 competition are the ones shown in Figure 10. Signs are marked with number 1 or 2. This number will be used to identify a specific sign within each pair of the same type.

Signaling lights

All robots **of the Challenge Class** should be equipped with three leds, of colors GREEN, RED and BLUE (alternatively a single three color led can be used). These leds are intended to show that the robot has detected and identified a traffic sign. The red led must be used to identify a warning sign, the blue led to identify a mandatory sign and the green led to identify an information sign. These leds must be turned ON once, for 1 second, to identify traffic signal 1, and twice (1 second ON, 1 second OFF, and 1 second ON again) to identify traffic signal 2. Identification display, by means of the leds, must start when the robot is within a runway zone called validation area, which starts 1.5 meters before the traffic sign and ends 1.5 meters after this same sign. Leds must be bright enough to be clearly visible from a 5 meter distance. The use of the three leds is only mandatory for the robots that intend to detect and identify the traffic signs (see more on “competition” chapter).



Figure 10 – The six traffic signs selected for the 2011 edition.

3.7 Continuous central line (**Challenge Class only – see note at the end**)

The runway may present a continuous central line overlaid on the dashed central line. This line is, at least, two meters long, and will not coincide with other obstacles in the runway (such as tunnel, green obstacles or working zone). Its limits are always at least two meters apart from the dashed line segment ends (cross zone or zebra crossing). See Figure 11 for an example.

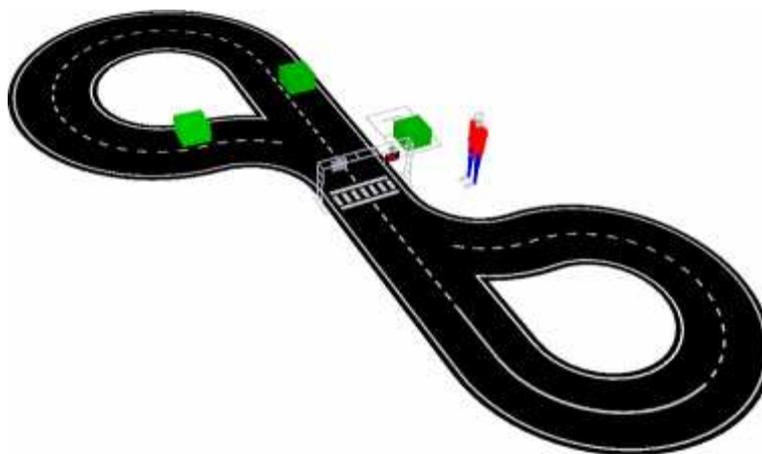


Figure 11 –Example of a possible location for the continuous central line.

Continuous central lines will only be used in the first and second rounds. Robots are expected to detect these lines and keep all their points of contact on the floor on either side of this line for all of its length. As with the outside lines, a robot can have one or more of its floor contact points over the line, as long as these points don't completely cross to the other side (see more on “competition” chapter).

NOTE: For the Rookie Class, the continuous central line may also be present, but has no direct implications in this class competition.

Reserved lane

A mandatory sign (number 2) will be associated with the continuous central line, and will be placed outside the right lane, marking this lane as reserved for public transportation. This sign will be placed around 1 meter before the beginning of the continuous line – in both directions (see Figure 12). Robots able to validly detect this sign should avoid the reserved lane, and use only the one not associated with the sign. This obligation ends with the ending of the continuous line.

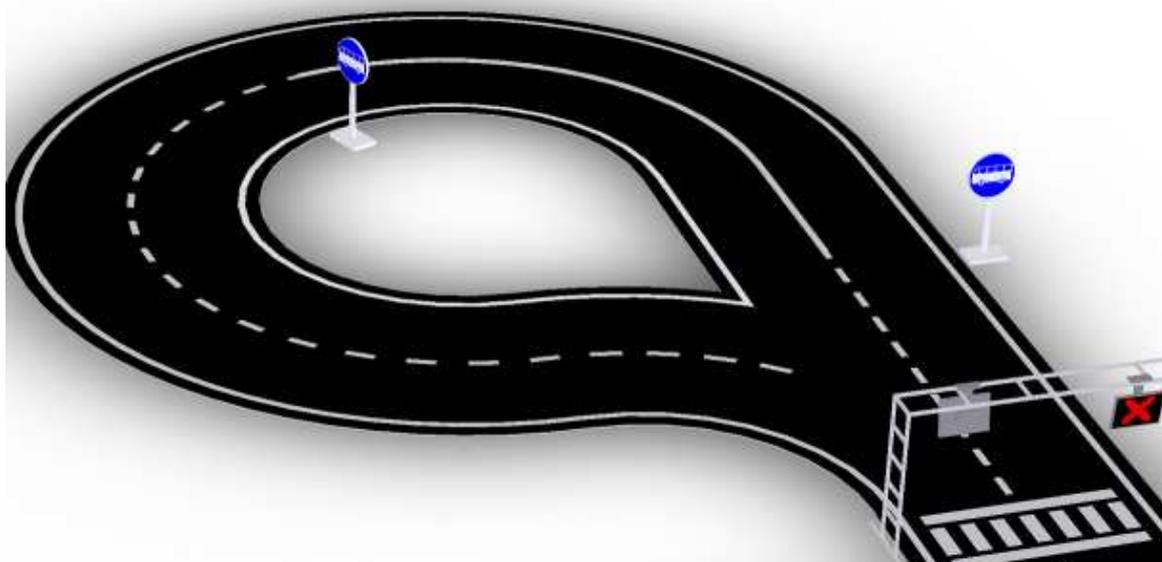


Figure 12 –The continuous central line with the mandatory sign marking one lane as reserved.

4. Competition – Rookie Class

4.1 Overall picture

Objective

The aim of the competition is to complete a double lap around the track, starting from the area of departure/arrival and reaching the same area in the shortest possible time and with the least possible penalties.

Organization

The competition is organized in a set of two rounds held on two consecutive days.

First round

The first round is essentially a pure speed test. In this round, the signaling panels are only used to trigger the robot departure, by changing from the "Stop" sign to the "Follow straight ahead" sign. Each team will assign one of its members to manually start the robot. The robot can only be started once the "Follow straight ahead" sign is shown in the signaling panels. A set of traffic signs are placed outside of the track according to the above rules. The solo objective of these signs is to act as outside obstacles. The number and location of the traffic signs is not known in advance.

The robots have to complete 2 laps on the runway circuit, and then immobilize themselves at the arrival area. During this test, each team has the right to carry out a number of timed attempts, limited either to a maximum of four attempts or to the maximum duration of the race test - ten minutes. At the end of each race test, only the attempt with better classification will be taken into account.

Second round

The second round will be disputed only by the eight top teams, considering the classification obtained in the first round of the previous day. This second round will be disputed as a play off competition, with two teams competing simultaneously against each other in pursuit mode. In this round, the robot must always keep itself within the right lane of the track.

Four trials will be disputed:

- In the first trial, teams will compete according to classification obtained in the previous day with the following arrangement: 1st against 8th, 2nd against 7th, 3rd against 6th and 4th against 5th.
- In the second trial, the four qualified teams will compete in two groups of two, according to a draw taken by the jury right after the end of trial one.
- In the third trial, the two teams that did not qualify in the previous trial will dispute the third and fourth final classification positions.
- In the last trial the first and second places of the final classification will be disputed by the two remaining qualified teams.

As in the first round, a set of traffic signs are placed outside of the track in previously unknown positions.

In the second round each eliminating trial will be disputed in a series of attempts. The first team that wins two attempts also wins the trial. In each attempt the winning team will be obtained by one of the following outcomes:

- The team with the best result considering total time plus penalties to complete the two laps;
- The remaining competing team, in the case one of the competitors incur in a penalty that dictates that its attempt is early terminated. In such a case, the attempt is immediately terminated and the win will be awarded to the remaining team.
- The team that comes near to its opponent team less that 10cm before the end of the two laps.

If all the necessary attempts can not be held within the trial time limit, it is the responsibility of the jury to decide which of the two teams is responsible for the situation. That team will be eliminated regardless of the results of the concluded attempts.

Closed park

Just before each of the two rounds, the robots must be subject to a technical verification by the jury, after which they are placed in a closed park for all the duration of the round. Non-compliance with these procedures will determine that the robot will not be allowed to compete in this round. Robots must return to the closed park, and stay there until the end of the round, just after each of their race tests. During the closed park period teams are not allowed to perform maintenance operations on their robots except those regarding battery handling.

Technical verification

Technical verification is aimed to observe and verify the compatibility of all mechanical, electrical, electronic, dimensional and security aspects of the robot in regard to these rules. It will be performed just before the robots are placed in closed park at the beginning of each round. Technical verification is the sole and exclusive responsibility of the jury.

Race test sorting

The order by which each team participates in the first round will be determined and announced by the organization before this round, after all robots are in closed park and with the express consent of the jury.

Maintenance and technical assistance

During, and only during the course of its race test, the team will be allowed to make changes and technical assistance to its robot, provided they do not collide with the requirements laid down in these regulations. Verification of adequacy of the robots to these same regulations can be decided by the jury at any time. If a robot performs a race test in irregular conditions it will be excluded from competition.

Time limits and number of attempts

The time limit for each race test in the first round is 10 minutes, with a maximum of 4 attempts. This period of time starts when the team is called to show up in the track. If the time limit expires during a team attempt, this attempt is immediately terminated, in which case the competent classification rules apply.

In the second round, the same 10 minutes apply to both teams competing in the play off for the maximum of three attempts.

Classification

The classification of each robot in the first round is obtained by adding its chrono attempt time to the penalty time it has been awarded. The attempts time is the exact time measured between each departure and arrival. The classification after this round, from first to last, will be obtained by increasing order of classification times. This classification will be used to select the eight teams that participate in the second round.

- NOTE: if the total number of teams actually participating in the first round is less than eight, then only the four top teams will be selected for the second round, which will then be reduced to three trials. In this case, and in the first trial, teams will compete according to classification obtained in the previous day with the following arrangement: 1st against 4th and 2nd against 3rd.

Start

At the start for each attempt the frontal part of the robot must overlap the outside line of the zebra crossing, as shown in Figure 13, so that no point of the projection of the robot on the ground plane is beyond that line.

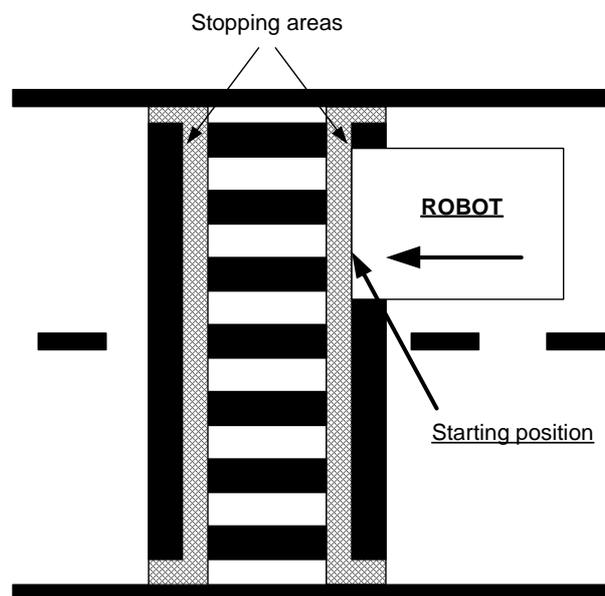


Figure 13 –Starting position and stopping areas.

The robot will be put in its starting position by one, and only one, of the team elements, who handles the procedure to start the attempt. Once the robot has been set in motion, the same element should move away from inside the perimeter of the track.

In both rounds the departure is given by the signaling panel that, from the "Stop" ('X') signal, will change to the "Follow straight ahead" signal. The stopwatch is synchronously fired with this signal change.

In the first round, all robots start from the starting position in the same direction – in the opposite side of the parking area and towards it.

Arrival

In the first round, the attempt ends when the robot enters the stopping zone for the 4th consecutive time, after completing two laps on the track, and immobilizes itself. The clock stops simultaneously with robot immobilization in that area. The robot must stop at the vicinity of the zebra crossing, and in such a way that at least part of the vertical projection of the robot on the track intersects the stopping area as shown in Figure 14. No point of that projection may, however, overlap the zebra area of the crossing.

Early end of an attempt

If, during an attempt, all points of contact of the robot with the ground go outside any of the external outlines of the track, the attempt is stopped by the referee using the wireless device to cut the power to the robot engines (see chapter on security).

Four other situations will also result in the early end of the robot attempt:

- If any of the robot points of contact with the ground keeps outside any of the external outlines of the track for more than two meters.
- If any of the robot points of contact with the ground goes outside any of the external outlines of the track for more than four times during the attempt.
- If the robot touches any of the traffic signs or the signaling panel structure more than three times during the attempt.
- If the robot crushes against any of the traffic signs or the signaling panel structure in such a way that it produces a significant change in these accessories position.

Except for periods of time between attempts, no team members may remain within the perimeter of the track or less than 50 cm away from it. Violation of this rule will determine the immediate interruption and cancellation of the undergoing attempt.

Race test Interruption and overtime

The referee may decide to interrupt the race test whenever consulting the jury may be needed or whenever configuration of track accessories, e.g. traffic signs, must be restored to its original position. To do so, the referee should require a temporary suspension of time counting. As soon as conditions permit, the referee should request the time counting to be resumed. (Warning: do not confuse the counting of the race test time with the timing of attempts - see paragraph 6: timing). Reinstatement of accessory configuration will be provided by a support team, appointed for that purpose by the organization.

Moreover, whenever there is clear evidence that the race test was delayed due to exceptional circumstances not directly attributable to the team(s), the referee, after consulting the jury, may grant a time extension period equivalent to those delays.

4.2 Penalties

Collisions with track accessories

Collisions against any accessories in the area of competition, including the signaling panels support and the traffic signs, provided they do not significantly alter their disposition, imply a penalty of 11sec. A collision causing a clear change in the accessories positioning determines the early termination of the current attempt of the robot (with the corresponding penalty) with an additional penalty of 19sec, as well as the interruption of the attempt for

appropriate track reconfiguration. For the purposes of this rule, and when referring to an obstacle position change, a clear change of position is only taken into account when the intersection between its base of support and the area that was occupied before the collision is null. Any collision that does not determine the interruption of the attempt will be solved by the referee, who will reposition the obstacle to its original position.

Going outside the track

If one of the robot points of contact with the ground gets completely out of any of the track outside lines, the robot will suffer a penalty of 7sec for each time that happens. If the described situation occurs more than four times during an attempt, or if any of the robot points of contact with the ground remains outside the track for more than two meters, then the present attempt is terminated with a penalty of 21sec.

If all the contact points of the robot with the ground get beyond the track outside lines, then the present attempt is terminated with a penalty of 23sec.

Detaining outside the stopping zone

In the first round, if the robot, while detaining its movement at the end of its attempt, does not stop within the stopping area, a 9sec penalty will be awarded.

Attempt early termination

If a particular attempt is early terminated, the attempt time for classification purposes shall be obtained as follows:

$(\frac{1}{4} \text{ of the race test time limit}) \times [4 - (\text{number of full half laps travelled})] + (\text{penalties incurred}).$

Penalty summary

The following table presents a summary of the different types of infraction, related effects and awarded penalties.

Infraction	Related effect	Penalty (sec)
Small collision with track accessories		11
Collision with track accessories altering geometry	Attempt termination	19
Going outside of the track (partial)		7
Going outside of the track more than 4 times	Attempt termination	21
Going outside for longer than 2 meters	Attempt termination	21
Going outside of the track (full)	Attempt termination	23
Stopping outside the stopping area		9

5. Competition - **Challenge Class**

5.1 Overall picture

Objective

The aim of the competition is to complete a double lap around the track, starting from the area of departure/arrival and reaching the same area in the shortest possible time and with the least possible penalties.

Organization

The competition is organized in a set of three rounds held on consecutive days. Each round includes a race test for each team. During this test, each team has the right to carry out a number of timed trials, limited either to a maximum of four trials or to the maximum duration of the race test. At the end of each race test, only the trial with better classification will be taken into account.

First round

The first round is essentially a pure speed test. In this round, the signaling panels are only used to trigger the robot departure, by changing from the "Stop" sign to the "Follow straight ahead" sign. In this round no tunnel, working zone or obstacle will be placed on the track. However, the continuous central line and a set of traffic signs will be used in this round. The number and location of the traffic signs is not known in advance. The robots have to complete 2 laps on the runway circuit, and then immobilize themselves at the arrival area. Once the robot has passed over the zebra crossing for the third time the signaling panel will present the stop sign again.

Second round

During the second round the signaling panels will be in full operation and an obstacle will be present on the track. No tunnel or working zone will be used in this round. Along the two laps to be completed in each trial the robot must obey the indications provided by the signaling panels. The continuous central line and a set of traffic signs will also be used in this round. Again, the number and location of the traffic signs is not known in advance

Third round

The third and final round will use the signaling panels, the tunnel, the traffic signs and the working zone. No continuous central line will be used in this round. One of the two places of parking area will also be occupied by an obstacle. The jury can decide which of the two places of the parking area is free for each of the team trials. In this round and in the previous ones, the jury also decides, after all the robots are in closed park, which are the possible locations of the track for the obstacle and/or the traffic signs to be placed on. These locations may not interfere simultaneously with both sides of the track.

Parking

In the second and third rounds, and after completing each trial, the robot must perform a parking maneuver in response to the corresponding signal presented by the signaling panel.

The robot is said to be parked when, having stopped inside the park, more than 50% of the area of its projection on the ground is within the parking area outlines. The robot is said to be properly parked when it is parked and the projection of its outer contour on the ground does not intercept the outlines of the parking area. In the third round, the parking maneuver will only be considered correct if this maneuver does not interfere with the location of the obstacle previously placed in one of the two locations available (Figure 14).

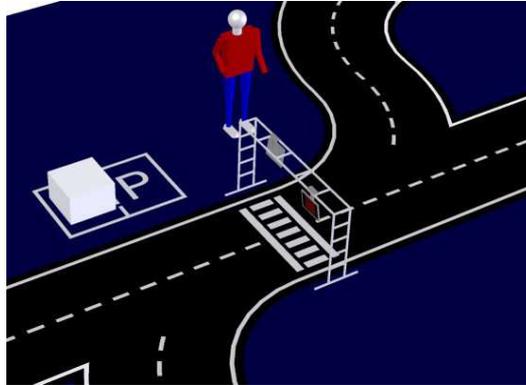


Figure 14 –Obstacle on the parking area during the third round.

Closed park

Just before each round, the robots must be subject to a technical verification by the jury, after which they are placed in a closed park for all the duration of the round. Non-compliance with these procedures will determine that the robot will not be allowed to compete in this round. After their race test the robots will return to the closed park, and stay there until the end of the round. During the closed park period teams are not allowed to perform maintenance operations on their robots except those regarding battery handling.

Technical verification

Technical verification is aimed to observe and verify the compatibility of all mechanical, electrical, electronic, dimensional and security aspects of the robot in regard to these rules. It will be performed just before the robots are placed in closed park at the beginning of each round. Technical verification is the sole and exclusive responsibility of the jury.

Race test sorting

The order by which each team participates in a given round will be determined and announced by the organization before each round, after all robots are in closed park and with the express consent of the jury.

Maintenance and technical assistance

During, and only during the course of their race test, the team will be allowed to make changes and technical assistance to its robot, provided they do not collide with the requirements laid down in these regulations. Verification of adequacy of the robots to these same regulations can be decided by the jury at any time. If a robot performs a race test in irregular conditions it will be excluded from competition.

Time limits and number of trials

The time limit for each race test is 10 minutes, with a maximum of 4 trials. This period of time starts when the team is called to show up in the track. If the time limit expires during

a team trial, this trial is immediately terminated, in which case the competent classification rules apply.

Demonstrations

After completing its race test participation (with a maximum of 4 trials) any team can use up to 3 minutes of its remaining time to make a demonstration of their choice. This demonstration may not extend itself beyond the 10 minutes allocated to the team. The demonstration will be exhibitional and will not be used for classification purposes.

Classification

The classification of each robot is obtained by adding its chrono trial time to the penalty time and bonus time it has been awarded. The trial time is the exact time measured between each departure and arrival. In the second and third rounds, the time required for the parking maneuver is not accounted for in the determination of the trial time.

The partial classification after each round, from first to last, will be obtained by increasing order of classification times.

After each round, the robot classification time will be added to those of the previous rounds, and will determine, after the third round, the aggregate time used to obtain the final classification.

Start

At the start for each trial the frontal part of the robot must overlap the outside line of the zebra crossing, as shown in Figure 15, so that no point of the projection of the robot on the ground plane is beyond that line.

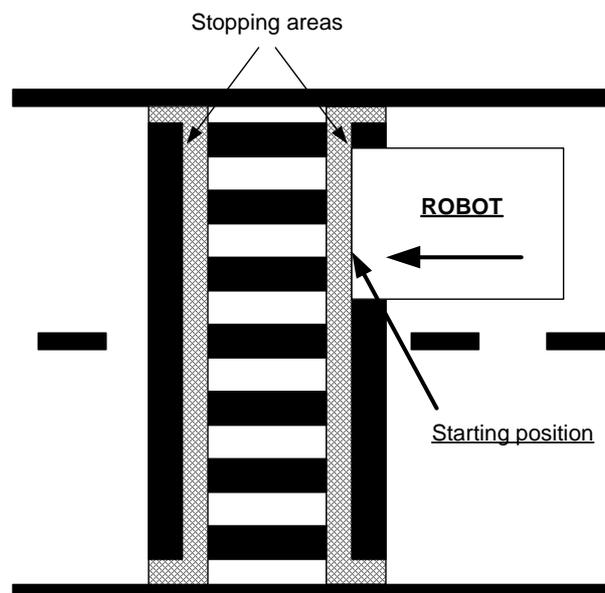


Figure 15 –Starting position and stopping areas.

The robot will be put in its starting position by one, and only one, of the team elements, who handles the procedure to prepare the robot for the trial. The same element should move away from inside the perimeter of the track while allowing the timekeeper to start

the trial. If the team wants to manually trigger the departure of the robot, it can do so, but this option implies a penalty (see the relevant section).

In all three rounds the departure is given by the signaling panel that, from the "Stop" (red 'X') signal, will change to either the "Follow straight ahead" or "Follow to the left" signal. The stopwatch is synchronously fired with this signal change.

The robots start from the starting position in all rounds, and always in the same direction – in the opposite side of the parking area and towards it.

Arrival and intermediate stopping

In the second and third round, whenever the signaling panel indicates the "Stop" function, the robot must stop at the vicinity of the zebra crossing, and in such a way that at least part of the vertical projection of the robot on the track intersects the stopping area as shown in Figure 15. No point of that projection may, however, overlap the zebra area of the crossing.

The trial ends when the robot enters the stopping zone for the 4th consecutive time, after completing two laps on the track, and immobilizes itself. The clock stops simultaneously with robot immobilization in that area. In the second and third rounds, the signaling panels indicate the "Stop" function (with the red and green checkers flag) when a robot ends its trial. Once the robot has stopped, and after a period of time between one and six seconds (randomly generated), the signaling panel will show the right pointing yellow arrow, indicating that the robot must follow to the parking area. Only then should the robot resume its march, performing its parking maneuver in a maximum time of 30 seconds. The disregard for this sign and parking outside the allowed time limit will be penalized independently.

During the first round the parking area will not be used.

Signaling panels operation

During each trial, the signaling panel controller ensures the random change between the available states (go forward or turn left). In two out of three times that the robot approaches the signaling panels during its trial (without counting departure and arrival), the controller generates the "Stop" signal (red 'X') for a time that can vary between 1 and 9 seconds, randomly selected, and then goes into one of the other two states. The sum of the two times corresponding to the presentation of the "Stop" signal will always be 10 seconds. This lapse of time is measured right from the moment when the robot stops at the stopping area.

Early end of a trial

If, during a trial, all points of contact of the robot with the ground go outside any external outline of the track, the trial is stopped by the referee using the wireless device to cut the power to the robot engines (see chapter on security). Except for periods of time between trials, no team members may remain within the perimeter of the track or less than 50 cm away from it. Violation of this rule will determine the immediate interruption and cancellation of the undergoing trial.

Race test Interruption and overtime

The referee may decide to interrupt the race test whenever consulting the jury may be needed or whenever configuration of track accessories, e.g. tunnel, obstacles, traffic signs or accessories of the working zone must be restored to its original position. To do so, the

referee should require a temporary suspension of time counting. As soon as conditions permit, the referee should request the time counting to be resumed. (Warning: do not confuse the counting of the race test time with the timing of trials - see paragraph 5: timing). Reinstatement of accessory configuration will be provided by a support team, appointed for that purpose by the organization.

Moreover, whenever there is clear evidence that the race test was delayed due to exceptional circumstances not directly attributable to the team, the referee, after consulting the jury, may grant a time extension period equivalent to those delays.

5.2 Penalties

Collisions with track accessories

Collisions against any accessories in the area of competition, including the tunnel, the signaling panels support, the accessories of the working zone, the traffic signs and the obstacle, provided they do not significantly alter their disposal, imply a penalty of 11sec. To this end, the cones and tape of the working zone are assumed to be a single accessory. A collision causing a clear change in the accessories positioning determines the early termination of the current trial of the robot (with the corresponding penalty) with an additional penalty of 19sec, as well as the interruption of the trial for appropriate track reconfiguration. For the purposes of this rule, and when referring to an obstacle position change, a clear change of position is only taken into account when the intersection between its base of support and the area that was occupied before the collision is null. Any collision with the obstacle that does not determine the interruption of the trial will be solved by the referee, who will reposition the obstacle in its original position.

Going outside the track

If one of the robot points of contact with the ground gets completely out of any of the track outside lines, the robot will suffer a penalty of 7sec for each time this happens. However, if all the contact points of the robot with the ground get beyond the track outside lines, then the present trial is terminated with a penalty of 23sec. For this purpose, during the third round, and when in the presence of the working zone, the tape that connects the cone pins is assumed to be the outside line of the track.

Wrong direction

Every time the robot does not comply with the direction pointed out by the signaling panels, a penalty of 25sec will be applied. This penalty can be given up to four times per trial, corresponding to the four times that the robot will have to interpret the signaling panel to decide which direction to take.

Non stopping at the stop sign

Whenever the robot does not respect the "Stop" sign (red 'X') a penalty of 90sec is applied. This penalty may be given up to three times per trial, and will also be applied if the robot, having detained itself at the stop sign, resumes its march before the signal changes.

Detaining outside the stopping zone

If the robot, while detaining its movement at the stop sign, does not stop within the stopping area, a 9sec penalty will be awarded. This can be done up to three times per trial.

Parking at the parking area

If the robot, after stopping at the end of its trial, resumes its march before the appearance of the parking signal (right pointing yellow arrow), it incurs in an additional penalty of 19sec. This penalty is cumulative with the "Detaining outside the stopping zone".

If the robot does not perform the parking maneuver in a maximum time of 30sec measured since the appearance of the parking sign, it suffers a penalty of 23sec. It is considered that the robot did not carry out the parking maneuver when, having stopped at the end of its trial, it does not resume the march after 2sec measured from the appearance of the parking sign.

If the robot, having parked within the valid time limit, does not perform this maneuver correctly (that is, it is not properly parked), it suffers a penalty of 7sec. Each of these penalties may be awarded only once per trial.

Manual trigger of a trial

Whenever a team takes the option of starting its robot trial manually, a penalty of 30sec is added to this trial.

Trial early termination

If a particular trial is early terminated, the trial time for classification purposes shall be obtained as follows:

$(\frac{1}{4} \text{ of the race test time limit}) \times [4 - (\text{number of full half laps travelled})] + (\text{penalties incurred}).$

Penalty summary

The following table presents a summary of the different types of infraction, related effects and awarded penalties.

Infraction	Related effect	Penalty (sec)
Small collision with track accessories		11
Collision with track accessories altering geometry	Trial termination	19
Going outside of the track (partial)		7
Going outside of the track (full)	Trial termination	23
Wrong direction at the signalling panels		25
Non stopping at the stop sign		90
Early departure at the stop sign		90
Stopping outside the stopping area		9
Early parking manoeuvre		19
No parking manoeuvre, performed in more than 30sec or delayed for more than 2 sec.		23
Irregular parking manoeuvre (out of bounds or interfering with the parking obstacle)		7
Manual triggering of the trials		30

5.3 Bonus

Detecting traffic signs

The correct detection and identification of traffic signs, as well as the compliance with the reserved lane in the continuous central line area, are not mandatory. Robots that are able to correctly perform these tasks are awarded a bonus in the form a time amount which is subtracted from the robot overall time (chrono time + penalties). These bonuses are awarded according to the following rules:

1. Whenever a robot, using its colored leds, correctly identifies a traffic sign and its type within the validation area, a bonus of 3 seconds is awarded.
2. If the robot also correctly identifies the sign number (1 or 2), an extra 2 second bonus is awarded.
3. Respecting the reserved lane, by using the opposite one, awards a bonus of 10 seconds. This last bonus is only valid if the robot, besides using the non reserved lane, did also correctly identify the associated mandatory traffic signal. The reserved lane bonus does not add up with bonus 1 and 2.

If during one of the full laps, a traffic sign is signaled while the robot is outside its validation area, the bonuses awarded during that lap will be cancelled.

Not crossing the continuous central line

If, while travelling near the continuous central line, none of the robot points of contact with the ground crosses completely over this line, the robot will be awarded a bonus of 5sec. This bonus is only awarded if the robot has correctly identified the associated mandatory traffic signal.

Bonus summary

The following table presents a summary of the different types of bonus.

Action	Bonus (sec)
1 - Identifying a traffic sign and its type	3
2 - Identifying the sign number	2
3 - Respecting the reserved lane (*)	10
4 - Not crossing the continuous central line (**)	5
(*) - Does not add up to 1 and/or 2 but requires 1 and 2 to be achieved (**)- Requires 3 to be achieved	

6. Jury, Referee and time keeping

Jury

The jury is the maximum authority in the interpretation and application of the herein defined rules or in every deliberation regarding issues that may be missing from them. Its mission is to verify the compliance of the robots with these rules during technical verifications, and support the referee, during the competition, in their audit and enforcement.

Through its authority, the jury ensures justice in the application of rules and regulations. Decisions of the jury board are final. Appeal from jury decisions is not possible.

The Jury is appointed by the Organizing Committee.

Referee

The referee ensures the correct application of the competition rules and gives permission, if necessary, for team members to enter the track area during the race tests. The referee may also stop the race test whenever necessary to dialog and consult the jury.

Regarding any issues that may be missing in these rules the referee must, in all cases, consult the jury.

The referee is appointed by the Organizing Committee.

Time keeping

Timing keeping is provided by an automatic integrated control system which also controls the signaling panels. This system includes two independent clocks: a time totalizer, responsible for measuring the time of the race test, and a time counter responsible for measuring the time of each trial.