Technische Universität Braunschweig

Carolo-Cup

Carolo-Basic-Cup@Home Regulations 2021

January 20, 2021

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Website: www.carolo-cup.de

Technische Universität Braunschweig

Contents

Legend:

- Due to the "@Home" format of this year's Carolo-Cup this document has changed fundamentally. Only some changes of the regulation compared to the **last year's** version are marked in **red**. New or deleted paragraphs might not be marked.

Technische Universität Braunschweig

1 Overview

1.1 Objectives

The student competition “Carolo-Cup” provides a platform for student teams to get involved with the conceptualization and implementation of automated model vehicles. The challenge is to realize the best performing vehicle guidance system for different scenarios, which have been derived from requirements arising from a realistic environment.

In the annual competition, participating students have the opportunity to present their know-how in front of judges from industry and academia while competing with teams from other universities.

The “Carolo-Basic-Cup” includes a reduced set of new scenarios and requirements and can be compared to the “Basic Class” of previous Cups. It particularly aims at new and smaller teams, lowering the threshold for successful participation. Prizes and scoring are separated from the main competition.

1.2 Tasks

The student team is put in charge of developing, producing, and demonstrating a cost- and energy-efficient 1:10 concept for an automated vehicle by a fictional OEM. **In the “@Home” format, teams will prepare a video of their vehicle mastering a predetermined set of scenarios.** In addition, the developed concept must be presented and explained.

1.3 Scoring

Each concept and its realization will be assessed in comparison to the results of the other participating teams. For this, the teams compete in different static and dynamic events, while being awarded at most **400 points**. Points will only be awarded after successful registration and participation in both, the static events and the video competition.

The maximum amount of points is distributed to the different events as follows:

Static Events:	
S1: Presentation and Overall Concept	150 Points
S2: Technical Approaches	150 Points
Dynamic Events:	
Video competition first place	100 Points
Video competition second place	50 Points
Video competition third place	25 Points
Maximum Score:	400 Points

1.4 Competition

1.4.1 Organization

The student competition "Carolo-Cup" is organized and presented by the Technische Universität Carolo-Wilhelmina in Braunschweig.

1.4.2 Awards and Prizes

Teams that participate in the static events and submit a video according to the competition assignment of the "Carolo-Basic-Cup" will be recognized with a cash award of 500 €.

1.4.3 Dates

The "Carolo-Cup" annually takes place in February. In 2021, the virtual presentations will be performed in January. The videos will be submitted and evaluated in February. (Due) dates will be published on the website.

1.4.4 Venue

The Carolo-Cup@Home is a virtual event.

1.4.5 Language

The official "Carolo-Cup" language is English. Communication with the teams (emails, phone calls, etc.) are also possible to be conducted in German.

1.5 Regulations

1.5.1 Commission

Rules and obligations of the “Carolo-Cup” can only be modified by the “Carolo-Cup Regulations Commission”. In cases of uncertainty or discrepancy the commission is responsible for official statements.

1.5.2 Validity of Regulations

Only the regulations which have been published on the official website are valid for the competition. Old Regulations are invalidated, as soon as a new version of the regulations is published. Updates of the regulations will additionally be announced to registered teams.

1.5.3 Questions

Every participant is obliged to thoroughly read, understand, and accept the regulations. In case of questions, the commission is to be consulted. Questions can directly be posed to the commission, contact information is published on the official “Carolo-Cup” website.

1.5.4 Authority

The commission can change the schedule or the regulations of the event at any time. All participants are obliged to cooperate with the commission and follow their instructions.

1.5.5 Limit of participating teams

The commission reserves the right to limit the number of participating teams if this becomes necessary due to organizational reasons. In case of such a limit additional qualifying tasks may be requested from the teams.

2 Prerequisites for Attending

Only students fulfilling the following conditions are allowed to participate in the “Carolo-Cup” competition.

2.1 Status of Enrollment

Every participant must either be currently enrolled in a Bachelor’s, Master’s or a comparable degree program or the respective degree must not have been obtained more than six months before the competition. A corresponding registration number / certificate of enrollment has to be presented with the registration for the competition. There is no restriction concerning the subject of study. Research staff and PhD students may not participate actively in conceptualization or development of the vehicle. They may not participate actively in the competition (cf. Section 3.11).

2.2 Minimum Age

Participants must be over 18 years of age at the start of the competition.

2.3 Number of Teams per Institution

The number of teams per Institution is not limited. However, the development of the vehicles must be strictly separated. Software and hardware architectures of the respective teams must differ significantly.

2.4 Registration

Details concerning the registration will be published on the website.

2.4.1 Date of Registration

Due dates for registration can be found on the website.

2.4.2 Admission Fee

An admission fee of 100 € per team is issued for the "Carolo-Cup@Home". The admission fee covers organizational expenses and is not refundable.

2.4.3 Registration Form

Details on the registration process will be published on the website. The registration is only complete if the student enrollment status is confirmed for all team members. A respective document provided by the commission must be filled and sent until the end of the registration period. The registration will be revoked in case of falsely filled information.

2.4.4 Competition Assignment

Teams are free to choose whether to participate in the "Carolo-Basic-Cup" or in the "Carolo-Master-Cup" during registration. Apart from this, the following exceptions apply:

1. Teams that came in on third to first rank in the previous "Carolo-Master-Cup" have to participate in the "Carolo-Master-Cup".
2. The winner of the previous "Carolo-Basic-Cup" has to participate in the "Carolo-Master-Cup".

Exceptions from these regulations need to be discussed with the commission. Additionally, there will be a due date for final assignment to one of the competitions, announced to all registered teams.

2.5 Publication Rights

By registering, every team and every participant declare their agreement with the publication of image, video and audio recordings. This also includes **videos submitted for the video competition and** recordings of team presentations. This agreement might be revoked until the day of the competition.

3 Vehicle Requirements and Limitations

The observance of the following regulations will be monitored during the competition. Violating these regulations will lead to a deduction of points or exclusion from the competition. The same vehicle must be used for all events.

3.1 Drivetrain

The vehicle must be equipped with (an) electric motor(s). The number of driven wheels is not limited (torque vectoring is allowed). Other motors (e.g. combustion engines) are not permitted.

3.2 Energy Supply

Energy must be supplied in the form of batteries. Changing the batteries between single events is allowed.

3.3 Physical Dimensions

The vehicles must be based on four-wheeled 1:10 scale chassis. Only two axles are permitted. The wheel base must measure at least 200 mm. The track width (measured from the center of the wheels) must measure at least 160 mm. The vehicle, including possible extensions and bodywork, must not be wider than 300 mm. The height of fixed installations must not exceed a height of 300 mm above the track surface. Flexible antennae are allowed. Apart from this, the design of the chassis is subject to the team's creativity, as long as it adheres the maximum physical dimensions.

3.4 Steering / Tires

At least one axle must be steerable. Teams are expected to use cushion or foam rubber tires. The use of traction additives or studded tires is not allowed.

3.5 Sensor Setup

The sensor setup can be arbitrarily chosen by the teams. Laser sensors are allowed only up to class 2 devices.

3.6 Data Transmission

No data or signals must be transferred from the vehicle to the outside world during the dynamic events, except for those signals necessary for the remote control (cf. Section 3.8).

3.7 Bodywork

The teams must be able to quickly disassemble the vehicles' bodywork, so that the inner parts of the vehicle can be inspected at any times. The bodywork must conform to IP 10 (EN 60529).

3.8 RC-Mode

In emergency situations, the vehicle must be stoppable and maneuverable using a remote control. This can become necessary due to faults or errors in the data processing or due to other problems so that the vehicle cannot continue to execute its automated driving task.

3.8.1 Activating RC-Mode

RC-mode is activated by the remote control. An active RC-mode must be signaled by utilizing a sufficiently bright, flashing, blue light, which is visible from any position on the track. The light must be fixed at the highest point of the vehicle. The light must flash with a frequency of 1 Hz, showing a duty cycle of 50 %, beginning with the status "on" when activating RC-mode. RC-mode must only be activated after a clear misbehavior of the vehicle. This means e.g. completely leaving the designated course of the track.

3.8.2 Driving in RC-Mode

Activation of RC-mode must instantly bring the vehicle to a complete halt, without further steering maneuvers. The vehicle must be in standstill for at least 1 s before it may be controlled with the remote control. During the events, the vehicle must not drive faster than 0.3 m/s forward and backward when RC-mode is engaged. Additional functionality is not allowed in RC-mode.

3.9 Handling of the Vehicle

The vehicle must provide two distinctive buttons (e.g. push-buttons, touchscreen buttons, etc.), which start the different modes for the dynamic events. The buttons must be uniquely identifiable and easily reachable in order to allow non-team members (e.g. Judges, Referees) to start the vehicle.

3.10 Lights

As in real traffic, lights shall signal different driving maneuvers.

3.10.1 Braking Lights

Three clearly visible and differentiable braking lights must be installed at the rear of the vehicle. Active braking must be signaled.

3.10.2 Direction Indicators

Each corner of the vehicle must be equipped with a yellow / orange light. The respective lights at the correct side must be flashed at a frequency of maximal 2 Hz (50 % duty-cycle, initial state "on") when overtaking, turning, or parking.

3.10.3 RC-Mode-Indicator

A clearly visible blue light is to be installed at the highest point of the vehicle, which flashes to signal the activation of RC-mode (cf. Section 3.8).

3.11 Development Know-How

The basic concepts of the vehicle must be conceptualized and implemented by the students themselves. They must not accept the direct help of professional engineers or suppliers. The students are encouraged to do research and/or discuss their problems with professional engineers or suppliers. Ready-made solutions may never be included in the vehicle. This particularly concerns the use of predesigned algorithms which may be part of a hardware platform and serve the purpose of providing a fully functional system for perception, behavior generation, or control for automated vehicles or robots. The final decision on acceptable components is taken by the commission. The teams are encouraged to contact the commission early in case of doubts or questions about a particular component. In case of violating these guidelines or intentional fraud, the commission has the right to exclude the respective team from the competition.

3.12 Safety Regulations

Each individual is required at all times to take care that no other participants are injured or other vehicles are damaged due to careless behavior.

As far as the sensor setup is concerned, special requirements and restrictions arise. All components within the vehicles must adhere to established guidelines for safe public usage. Particularly the usage of active sensors can be limited by this rule. The teams must make sure that no third parties are subject to possible injury due to installation or handling of the sensors.

3.13 Modification of the Vehicle

Teams are encouraged to refrain from making significant changes to the hardware or software of the vehicles within the video competition.

4 Static Events

During the static events, the teams must present and defend their concepts in front of a jury. Each key aspect of the presentation is rated with an individual score between 10 (maximum score) and 0 (no points). The judges are experts from industry and academia.

The maximum attainable score is described in Section 1.3.

4.1 Overall Concept Presentation

Each team has the possibility to explain the overall concept behind their vehicle, independent from the required functionality for the dynamic events. The overall concept specifically covers the software and hardware architecture of the vehicle. Additionally, each team shall present how energy and cost efficiency have been considered during the design phase. Sponsored hardware has to be included in the cost estimation at retail price. Purchase prices must be assessed for self-made items. Wrong assumptions will be reflected in the overall score.

4.2 Presentation of Technical Approaches

Each team must present their strategy for mastering the challenges of the dynamic events. The main challenges are: Lane detection and lateral control, parking, handling of obstacles and intersections. The aspects of perception and control must be described for each major function.

4.3 Presentation of Project Management Processes

The teams shall explain how obtained knowledge and know-how is preserved for future team generations (knowledge management). **This year, the challenges of the pandemic situation and solutions found shall also play a significant role in the presentation. The teams should address what protective measures have been taken in their facility and under which hygiene concept they operate.**

4.4 Deliverables: Presentations

All presentations must be digitally available (ppt, pptx or pdf) and sent to ***carolocup-konzepte@ifr.ing.tu-bs.de*** by **January 25, 2021 at 8:00 CET**. The files must not exceed a file size of 10 MB. The due date for presentation files will be announced on the

website. Late submission of presentations will be penalized with a loss of 100 points in the static events result. The teams will be asked to prepare slides to introduce their team during the dynamic events. Details will be announced prior to the competition.

4.5 Agenda

Presentations will be performed in a virtual environment in front of the jury, interested representatives of other teams, and guests of the event. There is a time budget of 20 min for the actual presentation. After this budget, the presentation will be interrupted by the jury, followed by a panel discussion of about 10 min. The evaluation sheet for the static events will be made known to the teams prior to the competition. The length of the presentation is subject to change in case of a large number of participating teams. In this case the teams will be informed sufficiently early.

5 Dynamic Events

During the dynamic events, the actual performance of the automated model vehicles will be challenged in **a video competition inspired by** two different disciplines (Free Drive and Parking, Obstacle Evasion Course).

"Carolo-Master-Cup" videos will be evaluated separate from the "Carolo-Basic-Cup" videos, due to the additional elements of the "Carolo-Master-Cup".

The circuits for dynamic events of the "Carolo-Basic-Cup" correspond to a rural road scenario. Parking maneuvers are performed in a distinctive parking zone following the starting line during the "Free Drive" discipline.

5.1 Referees

A jury consisting of experts from industry and academia will evaluate the submitted videos. The three highest ranked videos will be awarded with points as described in Section 1.3.

5.2 Free Drive (w/o Obstacles) and Parking

Some of the challenges encountered for the video competition originate from a round course without obstacles that includes a parking lot. The vehicle drives in the right lane.

5.2.1 Scenario

The complexity of this scenario is limited. It consists of a road with two parallel lanes - one for each driving direction. This scenario shall imitate a rural road environment, consisting of long straight sections, tight turns, intersections and also containing a parking lot. All markings are white and approx. 18 mm to 20 mm wide, if not specified differently. The starting line (a checkered line of approx. 50 mm) marks the beginning of the track, which is the parking zone (cf. Section A.1.1).

5.2.1.1 Parking Lot

Following the starting line, there are parking areas containing spots for parking in parallel and perpendicular orientation to the track within the next 10 m. The parking zone is a straight part of the track with a dashed center line without missing lane markings. Additional elements (intersections, missing lane markings, etc.) are not present. Both areas for parking are located in this zone.

Parallel Parking Within the parking zone there is a parallel parking area next to the right lane. White cardboard boxes represent other vehicles. The boxes can be fixed to the ground. There is a space of 20 mm to 200 mm between the right lane marking and the side of the obstacle which faces the track. The obstacles measure at least 100 mm in height and length. The parking area and the track are located in the same ground plane.

There will be multiple parking spots of different size in the parallel parking area next to the track. The left and right hand limits of the parking spots are defined by the right lane marking and an additional solid white line (also 18 mm to 20 mm wide). Front and rear limits are defined by white cardboard boxes (cf. Section A.1.1.1). Approaching from the starting line, the parking spots will be growing in length. The final and largest spot will be at least 700 mm in length. Nevertheless, small distances of under 400 mm might be present between obstacles anywhere inside the parallel parking area .

Perpendicular Parking An additional type of parking area within the parking zone consists of several parking spots with a perpendicular orientation to the track. This area is located on the left hand side of the track and may also be used for parking. All spots have the same size, as shown in Section A.1.1.2. The parking spots are separated and limited to the front as well as to the rear by 18 mm to 20 mm wide white markings. Parking spots can be blocked by obstacles. A parking spot is considered to be blocked, if the vehicle cannot be placed completely inside the spot. There is always at least one free parking spot. Obstacles possess the same dimensions as in the parallel parking area and can be placed at a distance of 20 mm to 100 mm from the solid left lane marking. For parking, the vehicle must be positioned inside one marked spot that is not blocked. Vehicles may move forward or backward into the parking space. The left lane of the track may only be crossed during the actual parking maneuver. When searching for a parking spot, the vehicle must continue to use the right lane.

5.2.1.2 Lanewidth

Each lane has a width of 350 mm to 450 mm, measured from the inside of the respective markings. The left and right markings do not show lateral misalignments.

5.2.1.3 Lane markings

Both lanes are separated by a dashed center line. The center line is interrupted every 200 mm for another 200 mm. This shape continues until reaching an intersection or the starting line, so that the center line might stop with a gap at these points.

The left and right track boundaries are given by solid white lines.

Neighboring sections of the track are space at least 50 mm apart, measured from the outer edges of the markings. The minimal distance of the track to the end of the course area is 300 mm. The sharpest turn has an inner radius of 1000 mm.

All of the lane markings can be missing at arbitrary locations for a maximum of 1000 mm. Except for intersections, no more than two markings are missing at the same time. An example scenario is depicted in Section A.3 in the appendix.

In this event, no obstacles are located on the track. Possible stop lines and regulations concerning the right of way are to be ignored.

5.2.1.4 Artifacts

The design of the area outside of the road is not defined. Artifacts in the form of objects or remainders of lane markings might be located outside of the road area. The minimal distance between artifacts and valid lane markings is 100 mm.

5.3 Obstacle Evasion Course

Addtional challenges encountered for the video competition originate from the "Obstacle Evasion Course" with additional elements which need to be considered during the driving task. Static and dynamic obstacles are added to the rural road scenario. All definitions concerning the course of the road maintain validity. There will be at least 1000 mm track length between obstacles.

5.3.1 Static Obstacles

During this event, a number of static obstacles will be placed in the right lane, in the left lane and outside of the track. The body of each obstacle consists of white cardboard with dimensions as specified in the appendix (Section A.2.1). Obstacles can be fixed on the ground. The obstacles are not always placed exactly in a specific lane, however under no circumstance can both lanes be blocked. In this sense, static obstacles outside the track are no artifacts in the sense of Section 5.2.1.4. Thus, the described minimum distance to lane markings for artifacts does not apply.

Obstacles may force the vehicle to change lanes. Lane changes must be indicated using the turn indicators. Passing maneuvers must be executed without touching an obstacle. They must be completed after a maximum distance of 2 m after having passed the obstacle.

5.3.2 Dynamic Obstacles

Apart from static obstacles, at least one dynamic obstacle is present on the track. Its shape resembles the static obstacles ("driving white cardboard box") and it can be encountered in both lanes and in combination with other track elements, as long as this is not explicitly excluded. It moves at a speed of 0.6 m/s. Dynamic obstacles do not execute lane changes and do not perform any passing maneuver.

Dynamic obstacles can stop temporarily and potentially block the right lane. It may be passed, but not in intersections. Passing maneuvers in intersections are penalized. A dynamic obstacle will never block both lanes in combination with a static obstacle. Thus, allowed passing maneuvers can always be executed without encountering an obstacle on the left lane. The passing maneuver is subject to the same regulations as when passing a static obstacle.

5.3.3 Intersections

Sections of the track can be part of intersections with other parts of the track. The respective lanes meet at angles between 70° and 90°. An intersection possesses three to four entries or exits respectively. Design and layout of the intersections are shown in the appendix (Section A.1.2). Left and right lane boundaries of intersecting lanes can be connected through a rounded transition with a radius of about 100 mm. Intersections must be crossed driving straight.

Entries to intersections can display stop lines. These lines are 36 mm to 40 mm wide and cross one lane completely. Entries without a stop line are not marked separately.

If a stop line is located in the own lane, the vehicle must stop for at least 3 s. The front of the vehicle must be located in front of the stop line, however the distance must not be greater than 150 mm. The right of way of a dynamic obstacle must be respected at an intersection, if the dynamic obstacle is located within the defined area (cf. Section A.1.2.1). If the vehicle does not possess the right of way, it must wait until the dynamic obstacle has completely crossed the intersection. Only one dynamic obstacle at a time can be present at an intersection.

A Appendix

If not indicated differently, dimensions and angles specified in the figures have a tolerance of ±5 %. Unless otherwise noted, all dimensions are in millimeters (mm).

Dimensions and angles defined in the previous chapters may not be repeated in the figures.


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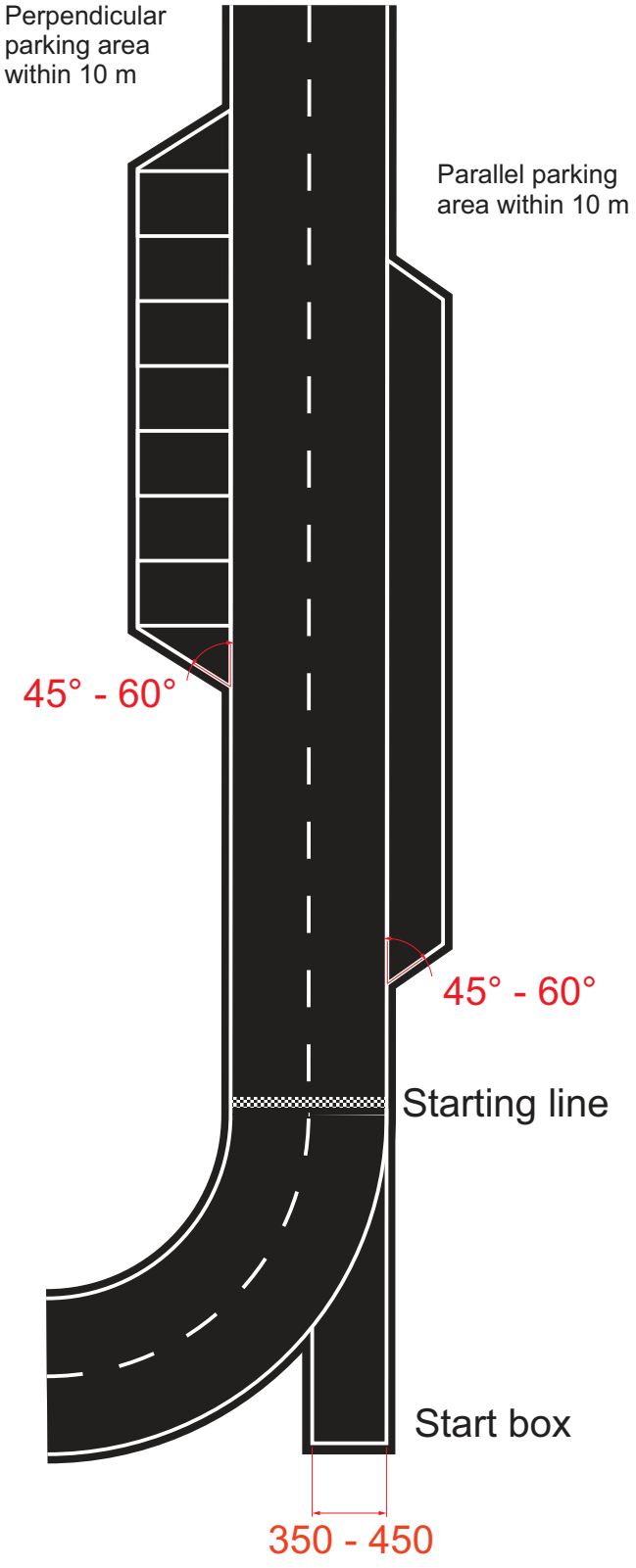
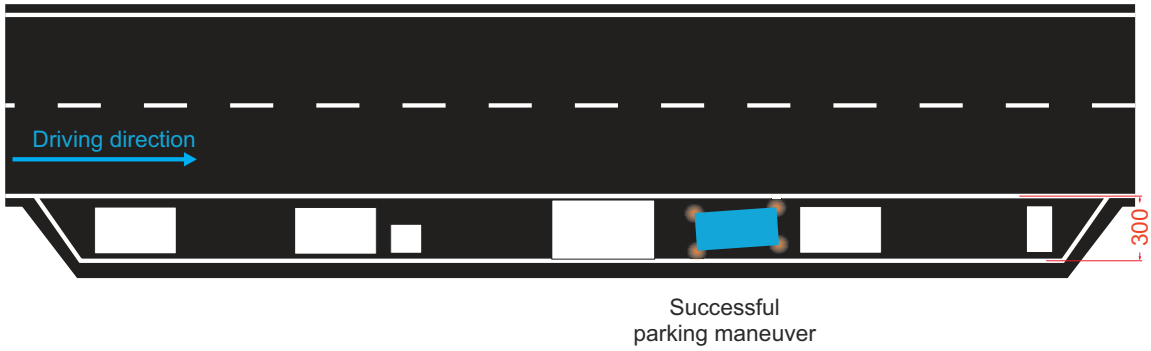
A.1 Road Description

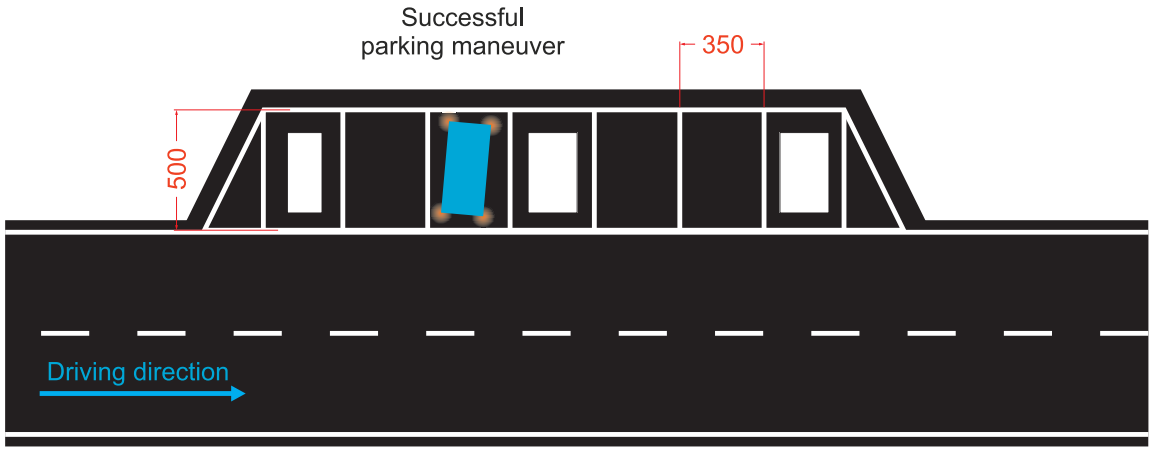
A.1.1 Parking Lot



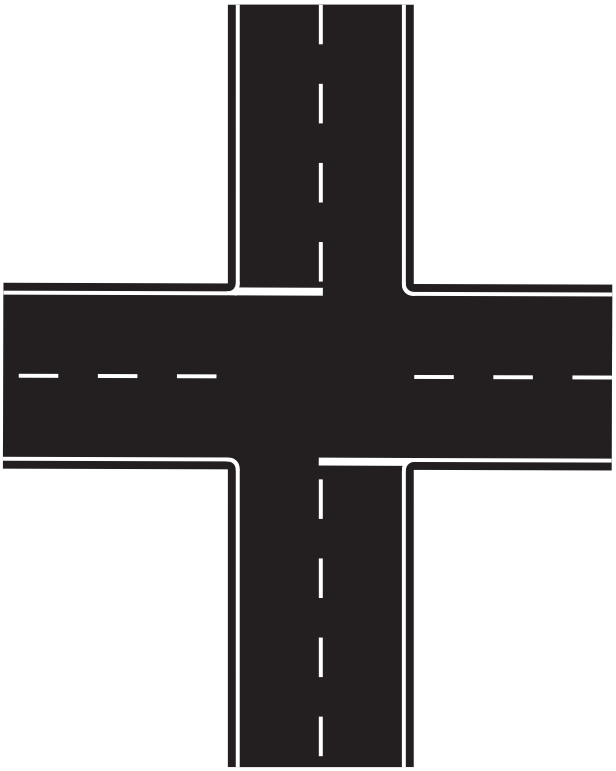
A.1.1.1 Parallel Parking



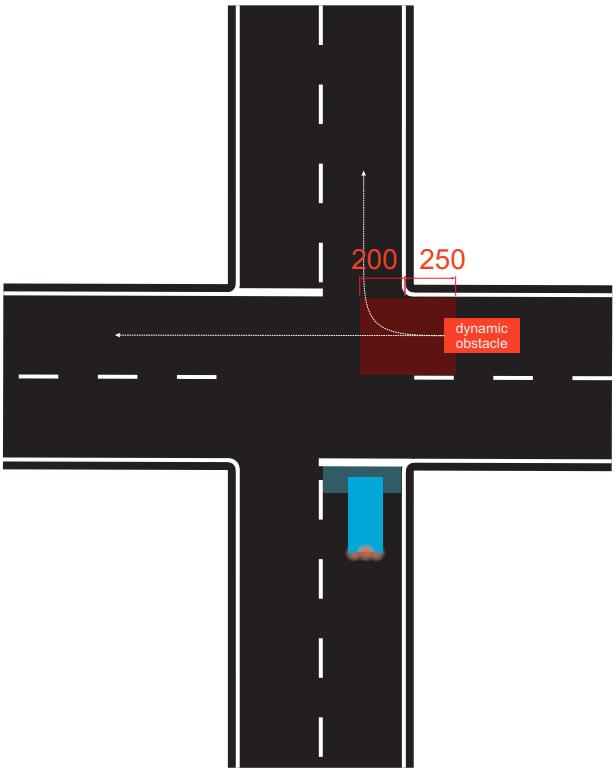
A.1.1.2 Perpendicular Parking



A.1.2 Intersections

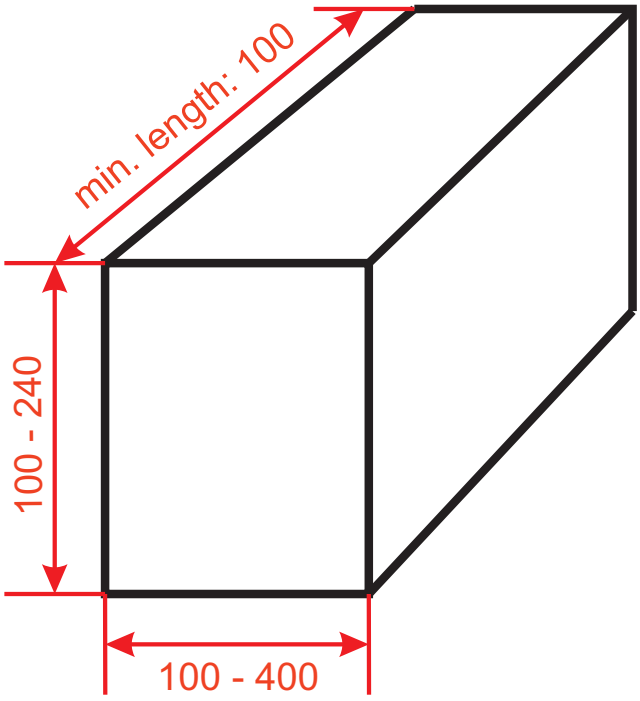


A.1.2.1 Dynamic Obstacles at Intersections - Give-Way Condition



A.2 Dimensions of Obstacles

A.2.1 Static and Dynamic Obstacles on the Track



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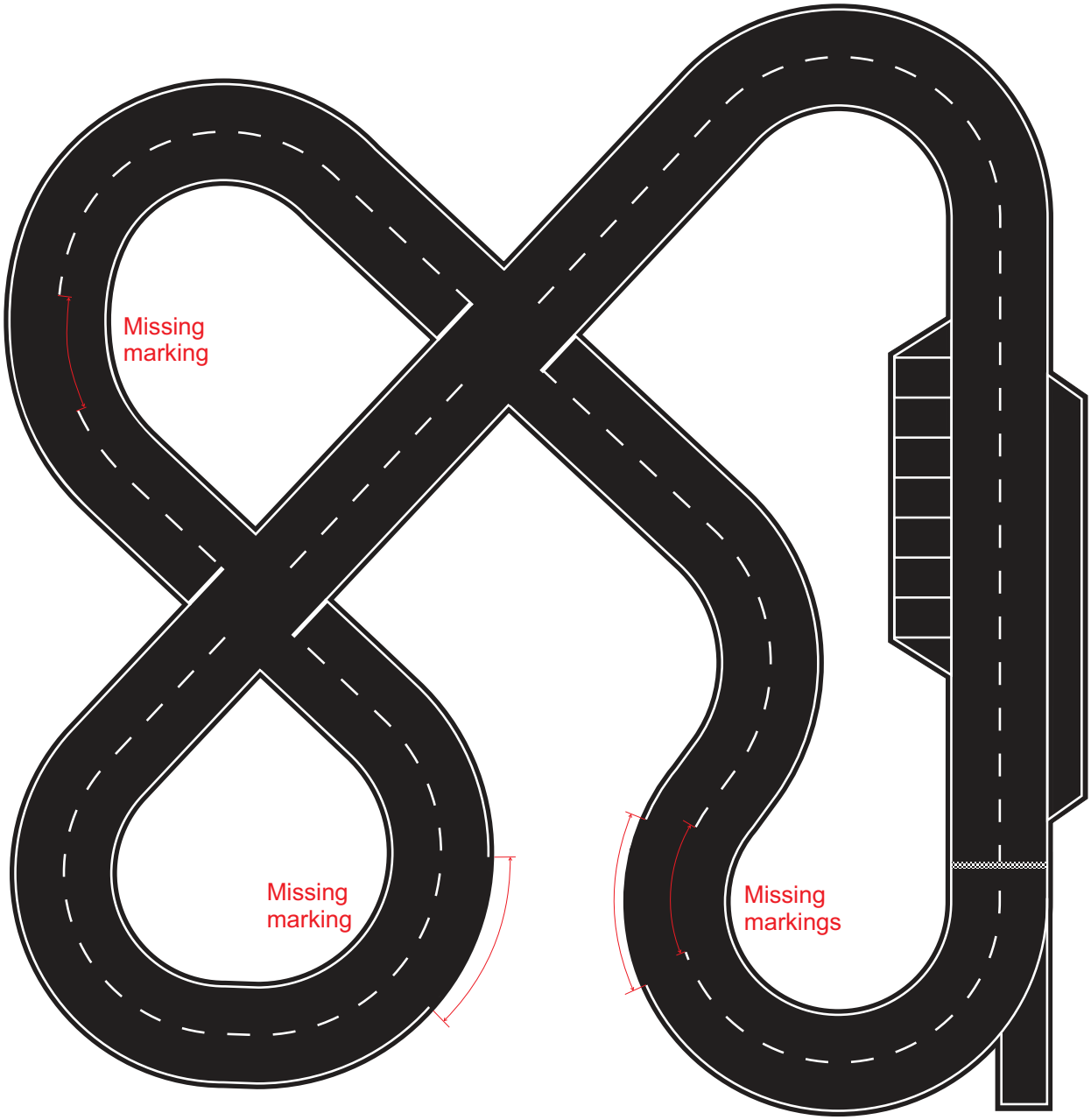
A.3 Example Circuit



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A.4 Markings of the Start Box Gate