Rules and Regulations 2013

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1 Overview

1.1 Competition

The competition “Carolo Cup” provides student teams from universities the opportunity to develop and implement autonomous model vehicles. The challenge is to realize the best possible vehicle control in different scenarios inspired by a realistic environment. The annual competition allows presenting the student’s skills to a jury of experts from industry and academia, and to compete with other student teams.

1.2 Objective/”Background story”

The student team is hired by a fictitious car manufacturer to develop, produce, and demonstrate a possible cost-effective and energy-efficient concept of an autonomous vehicle by using a model vehicle on a scale of 1:10. In the competition, certain tasks must be performed as quickly and reliable as possible; furthermore, the concept must be explained in a presentation.

1.3 Evaluation

Each concept is compared and evaluated with the concepts from other participating teams. Therefore, different static and dynamic disciplines are used to compete for a total of 1,000 points.

The following points can be earned as maximum in the respective disciplines:

Static events:

S1	Presentation of the manufacturing and the energy balance	140 points
S2	Presentation of the technical solutions	210 points

Dynamic events:

D1	Parallel parking	200 points
D2	Passing course without obstacles	200 points
D3	Passing course with obstacles	250 points

Maximum possible total score: 1,000 points

1.4 Event

1.4.1 Organizer

Technische Universität Braunschweig, Germany, hosts the student competition “Carolo Cup”.

1.4.2 Event Date

The “Carolo Cup” is held annually in February prior to the Symposium “Automation, Assistance and Embedded Systems for Transport (AAET)”. Detailed dates and deadlines can be found at the official website or on official posters.

1.4.3 Venue
The exact venue can be found on official posters or at the official website.

1.4.4 Language
Until further notice, the event "Carolo Cup" is held in German. Presentations and the team communication (mail, phone calls etc.) can also be carried out in English.

1.5 Rules

1.5.1 Committee
The "Carolo Cup" Rules and Regulations Committee is the only responsible to change and interpret the rules.

1.5.2 Validity
For the competition only the rules are applicable, which are available on the official website for download. As soon as any new regulation is adopted, the old loses its validity.

1.5.3 Questions
Each participant is required to read, understand, and accept the rules. Should the study raises questions about the rules they must as soon as possible be clarified together with the rules committee.

1.5.4 Authority
The "Carolo Cup" rules committee reserves the right to adjust the rules and schedules at any time and in any way. All participants are required to cooperate with the officials and to follow their instructions.

2 Participation Requirements
At "Carolo Cup" competition may participate only students who meet the following requirements.

2.1 Student Status
Each individual participant must be enrolled at a university in a Bachelor-, Master- or equivalent programme at the time of the contest, or his/her university degree may not be older than 6 months. Identification must be presented during registration. The type of studies is not specified. Research assistants or doctoral students must neither actively participate in the concept and development phase nor actively participate in the competition.

2.2 Minimum age
Each individual participant must be at least 18 years old.

2.3 Number of teams per university
The number of teams per university is not limited.

2.4 Registration
Details on registration will be published early on the official web site.

2.4.1 Registration date
Registration is announced on the web site.

2.4.2 Registration fee
The registration fee for the “Carolo Cup” is 200 € per team. The registration fee is not refunded. Accommodation, meals, and travel expenses are not included.

2.5 Publication rights
By registering, each team and each participant accepts the publication and dissemination of image, video, and audio material unless a contradiction is received until the competition day. Herein, the team presentations are included.

3 Requirements and restrictions on the vehicle
Compliance with the following rules will be reviewed and evaluated during the competition and results in point deduction or disqualification of the team in case of non-compliance. All disciplines must be carried out with the same vehicle.

3.1 Vehicle drive
The teams are obliged to use an electric drive. The number of driven wheels is not regulated (torque-vectoring is permitted). Alternative drives (e.g. chain-drive) is not permitted.

3.2 Energy supply
The power supply must be realized with batteries. Batteries can be changed between the various disciplines.

3.3 Vehicle dimensions
The vehicles are based on four-wheeled models, on a scale of 1:10. They are allowed to have only two axles. The wheelbase has to be at least 200mm. The track width, which is measured from tire center to tire center, must be at least 160mm. The height of fixed superstructures above the roadway must not exceed 300mm (flexible antennas higher than that limit are not considered). The competition organizers evaluate the vehicle height during the vehicle inspection by driving in RC mode through a fixed gate with the following internal dimensions: height 300 mm and width 400mm.

3.4 Steering / Suspension
The vehicle should use a two-wheel steering of the front axle; an additional steering of the rear axle is possible. The rest of the chassis design is left to the team. The technical solution for the steering must be the Ackerman steering (http://en.wikipedia.org/wiki/Ackermann_steering_geometry).

3.5 Sensors
The choice of sensors is not restricted and can be decided by each team individually.

3.6 Data Transmission
Any transfer of data/signals to and from the vehicle during the entire duration of the dynamic disciplines except for the RC mode (see 3.8) is prohibited.

3.7 Covering

The vehicle's covering must be removable at anytime, so that the used components can be evaluated. The mounted or used components must ensure the protection degree IP 11 (EN 60529).

3.8 RC mode

In emergency situations, it must be possible to stop the vehicle with a wireless remote control. This may be required when the vehicle cannot continue the required task autonomously due to a driving error or other malfunctions.

3.8.1 Activation of the RC mode

The RC mode is turned on and off by remote control. The active RC mode must be signaled with a sufficiently bright and all around visible blue flashing LED/lamp at the highest point of the vehicle. The flashing frequency must be 1 Hz with a duty cycle of 50%.

The RC mode must not be used preventatively. Thus, for using the RC mode a clear misconduct of the vehicle must be preceded like leaving the track or a collision with an obstacle.

3.8.2 Driving functions in RC mode

By enabling the RC mode, the vehicle is stopped immediately. In RC mode, the vehicle can only be moved with a maximum speed of 0.3 m/s in forward and backward direction. The vehicle may be steered. Other functions are not allowed.

3.8.3 Transmitter frequencies

To prevent interference between vehicles of different teams, transmitter frequencies must be announced prior to the organizers of competition. Conflicting frequencies must be changed.

Furthermore, transmission frequencies in the 2.4 GHz range are already in use by wireless cameras, etc. and can therefore not be used for the RC mode.

3.9 Signal lights on the vehicle

Comparable to real traffic, turning maneuvers must be indicated with certain light signals.

3.9.1 Brake light

At the rear of the vehicle there must be three red lights clearly visible. They must be activated during braking.

3.9.2 Turn signal (blinker)

On each side of the front and the rear a yellow/orange light must be attached. They must be flashing during turning or parking on the corresponding side. The flashing frequency must be 1 Hz with a duty cycle of 50%.

3.9.3 RC-mode light

At the highest point of the vehicle, a blue light visible from all sides must be attached to signal the activated RC-mode in a flashing manner (see section 3.8).

3.10 Expertise in vehicle development

The concepts behind the vehicle have to be conceived and implemented by the students themselves without the direct assistance of professional engineers or other service providers.

The students are allowed to read up on their knowledge or discuss problems with professional engineers or other service providers. However, it is not allowed to use off-the-shelf solutions.

3.11 Safety Policy

During the entire event, the instructions of the organizers regarding safety issues must be followed. A failure to comply with the instructions or guidelines may be punished or result in an exclusion from the free training or the entire competition. In particular, it must be paid attention to avoid violations of other participants or damages to vehicles of other teams by negligence.

With respect to the vehicle sensors, specific requirements are derived:

All components used in the vehicle have to comply with common rules for safe use in the public. Thus, the use of certain active sensors may be restricted. For example, when using laser-based sensors, they must meet laser class 2 verifiably. In general, damage to third parties must be avoided by a proper installation and operation of the sensors. In case of uncertainty about the risks of certain sensors, the approval of their usage must be examined with the competition management prior to the event.

Violations of this policy result in the immediate disqualification from the competition. In no case, claims for compensations against the organizers are allowed.

3.12 Changes to the vehicle

During the dynamic events no hardware modifications are permitted on the vehicle-except for necessary repairs, which are supervised. The software must not be modified between the disciplines. The replacement or charge of batteries is permitted.

4 Static disciplines

In the static events, the teams present and defend their concepts on the first day of competition to jurors. The jurors evaluate each team individually with a grade between 1 (maximum points) and 5 (0 points). The judges are experts from industry and research. The maximum possible points are described in section 1.3

4.1 Presentation of the overall concept

Each team has the possibility to outline the overall concept of their vehicle including the hardware and software architecture. Furthermore, the team must describe how they managed energy-balance and manufacturing costs.

4.2 Presentation of technical solutions
Each team must explain their concept for the dynamic disciplines. The disciplines are: driving on the road, parking, obstacles/intersections. The presentation has to address perception and control.

4.3 Submission of presentations
All presentations must be submitted in digital format (ppt, pptx, or pdf) prior to the competition to the following email address: konzepte@carolo-cup.de. The total file size of the presentations must not exceed 10 MB. The submission deadline will be announced at the official website.

4.4 Sequence
Each team has 30 minutes for their presentation. After 30 minutes the jury stops the presentation. The presentation is followed by a 20 minutes discussion with the jurors to defend a team's concepts. The jury's scorecard will be published prior to the competition on the website.

5 Dynamic disciplines
In the dynamic events, the capabilities of the autonomous model vehicles are evaluated.

5.1 Course without obstacles

5.1.1 Scenario
This entrance scenario is easy regarding to its complexity: There is only one road. The road is a replica of a rural road, consisting of long straights, sharp curves, and intersections. The road is constantly 820mm wide and on the outer sides marked with solid lines. A dashed center lane marking divides the two outer lane markings. All lane markings are white and approximately 20mm wide. The center lane marking is interrupted every 200mm by a 200mm gap. The closest curve has an inner radius of 1,000mm. The entire course is located in a plane.

All three lines can be broken up to 1,000mm at any point. However, at most two lines at the same time are missing at any point of the course except at intersections. An exemplary scenario, which includes defects, is shown in appendix 6.5.

5.1.2 Sequence

5.1.2.1 Start
The goal in this discipline is to drive autonomously as many rounds as possible on a previously unknown course.

The vehicle starts on the road to a white 40mm wide start line by pressing a button on the vehicle. It runs autonomously and as fast as possible on the unknown circuit in the right driving lane.
The organizers will announce the starting order prior to the competition. A team must be ready to start within one minute after the end of the run of the previous

team. “ready” means that the vehicle is positioned at the specified starting position, and is ready to start (note: teams with vehicles that have a longer preparation time for a start are advised to follow the course of the competition and to prepare the vehicle in accordance with one or two teams earlier (booting the onboard computer, etc.)).

5.1.2.2 Attempts

The team spokesman for the respective teams can cancel a run within the first 30 seconds. The team may repeat the run once after all the other teams have completed their first runs. A cancellation will be punished according to Sec. 5.1.3.

5.1.2.3 RC mode

When the autonomous vehicle has left the course and is unable to return to the track on its own, the team is allowed to use the RC mode. This manual intervention leads to additional deductions (see Sec. 5.1.3).

5.1.3 Scoring

5.1.3.1 Time

Each team has 3 minutes for this discipline. The time measurement is started when the course marshals are ready and after 1 minute waiting time at the latest. When a vehicle is still not ready to start, the necessary additional time for preparation will be reduced from the available 3 minutes time frame.

5.1.3.2 Penalties

Violation	**Maximum allowed number of violations**	**Penalty**
Using RC mode	Infinite	5m
Erroneous usage of braking lights	3	5m
Cancellation and 2nd try	1	40m
Leaving the own lane with more than one wheel	Infinite	5m

5.1.3.3 Scoring

The longest driven distance reduced by penalties will earn full points for this discipline; the points for the other teams are distributed pro rata.

5.2 Parallel parking

5.2.1 Scenario

5.2.1.1 Road

Parallel to a straight road defined in Sec. 5.1 is a parking strip on the right hand side, which is 300mm wide. Within that parking strip, there are already parked vehicles imitated by white cartons, which may be fixed to the ground. The distance between the right white lane marking and the left side of such a carton is between 20mm and 200mm. The distances between the obstacles vary up to 400mm. The obstacles’ height is at least 100mm. The street and the parking strip are within one plane. Obstacles block the road right after the parking strip.

5.2.1.2 Parking spot

The parking spots are distributed in an arbitrary sequence with lengths of 550, 630, or 700mm and a width of 300mm (cf. Sec. 5.2.3.2 for penalties). The parking spot is bounded on the left side by the white lane marking of the road and on the right side with a solid white lane marking, which is also 20mm wide.

5.2.2 Sequence

While driving on the right lane, the vehicle shall find a parking spot on its right hand side and park in as fast as possible without colliding with other obstacles.

5.2.2.1 Start

The vehicle starts on the road at a white 40mm wide start line by pressing a button on the vehicle. Then it starts driving alongside the stationary obstacles searching for a sufficiently large parking spot. Once the parking spot is found, the parking process must be indicated by a flashing direction signal. Illuminating all direction indicators indicates the end of the parking process.

The regulations from Sec. 5.1.3.1 apply for waiting times.

5.2.2.2 Attempts

Each team must carry out three parking attempts. The teams start in the predefined order.

5.2.2.3 RC mode

The use of the RC mode is not allowed in this discipline.

5.2.3 Scoring

5.2.3.1 Time

The time that is necessary for the parking process is determined between passing the starting line until flashing of all direction indicators.

5.2.3.2 Penalties

Violation	**Penalty**
Distance to the obstacle in front or behind the vehicle < 10mm	Attempt invalid
Parking process lasts longer than 30s	Attempt invalid
The vehicle is not within the left and right solid lane after completion	Attempt invalid
Collision	5s
Direction signals are not used correctly	5s
Crossing of the outermost white lane	5s
Violation of the maximum allowed angular deviation of 5 degrees to the road	5s
Usage of 630mm parking spot	8s
Usage of 700mm parking spot	15s

5.2.3.3 Scoring

Each run is scored individually. The fastest team in each run will earn full points for this discipline; the points for the other teams are distributed pro rata. The final score is the average from all three runs.

5.3 Course with obstacles

This discipline extends discipline D1 (Sec. 5.1) by the following aspects.

5.3.1 Scenario (extension)

5.3.1.1 Stationary obstacles

Stationary obstacles are located in this run at several locations around the course in the own and the opposite lane and outside the course. All obstacles are made of white cartons with dimensions as in indicated in appendix 5.5. Furthermore, the cartons may be fixed to the ground. The minimum distance between obstacles is 1,000mm. The obstacles are not necessarily allocated uniquely to a specific lane.

5.3.1.2 Dynamic obstacles

Furthermore, there is at least one dynamic obstacle. This obstacle is similar to the static obstacles ("moving white box with the appropriate dimensions") and may appear in the own lane, the opposite lane, or at intersections.

It is moving with a maximum speed of 0.6 m/s on its lane. There are no situations in which the entire road is blocked by the dynamic obstacle.

5.3.1.3 Intersections with stop lines

The intersection is right-angled; its dimensions are defined in Sec. 5.6. The stop line is 40mm wide.

5.3.2 Procedure

5.3.2.1 Start (extension)

In the second run (cf. D3, Sec. 1.3), obstacles, intersections, and right-of-way-situations may occur.

The obstacles may require a lane change with the use of direction indicators. Overtaking must be completed within a maximum of 2m after passing the obstacle without collisions.

The vehicle must wait at least 2s in front of a 40mm wide stop line. The vehicle's front edge must be in front of the stop line but and must be not farther away than 15cm from the stop line. After waiting for at least 2s, the intersection can be passed normally.

Furthermore, the autonomous vehicle must stop at the stop line to check whether a dynamic obstacle is approaching from the right. The autonomous vehicle must give the right of way at intersections to the dynamic obstacle depending on the stop line arrangement (cf. Sec 5.3.1.3). When there is a right of way situation, the autonomous vehicle must wait until the dynamic obstacle has

cleared the intersection completely. In any case, any collision must be avoided with the dynamic obstacle.

On the open road the obstacle may be overtaken.

The regulations from Sec. 5.1.3.1 apply for waiting times.

5.3.2.2 Attempts

The team spokesman for the respective teams can cancel a run within the first 30 seconds. The team may repeat the run once after all the other teams have completed their first runs. A cancellation will be punished according to Sec. 5.1.3.

5.3.2.3 RC mode

When the autonomous vehicle has left the course and is unable to return to the track on its own after a collision, the team is allowed to use the RC mode. This manual intervention leads to additional deductions (cf. 5.1.3).

5.3.3 Scoring (extension)

5.3.3.1 Time

The time, which is needed to wait for the passing of dynamic obstacle, is added to the 3min.

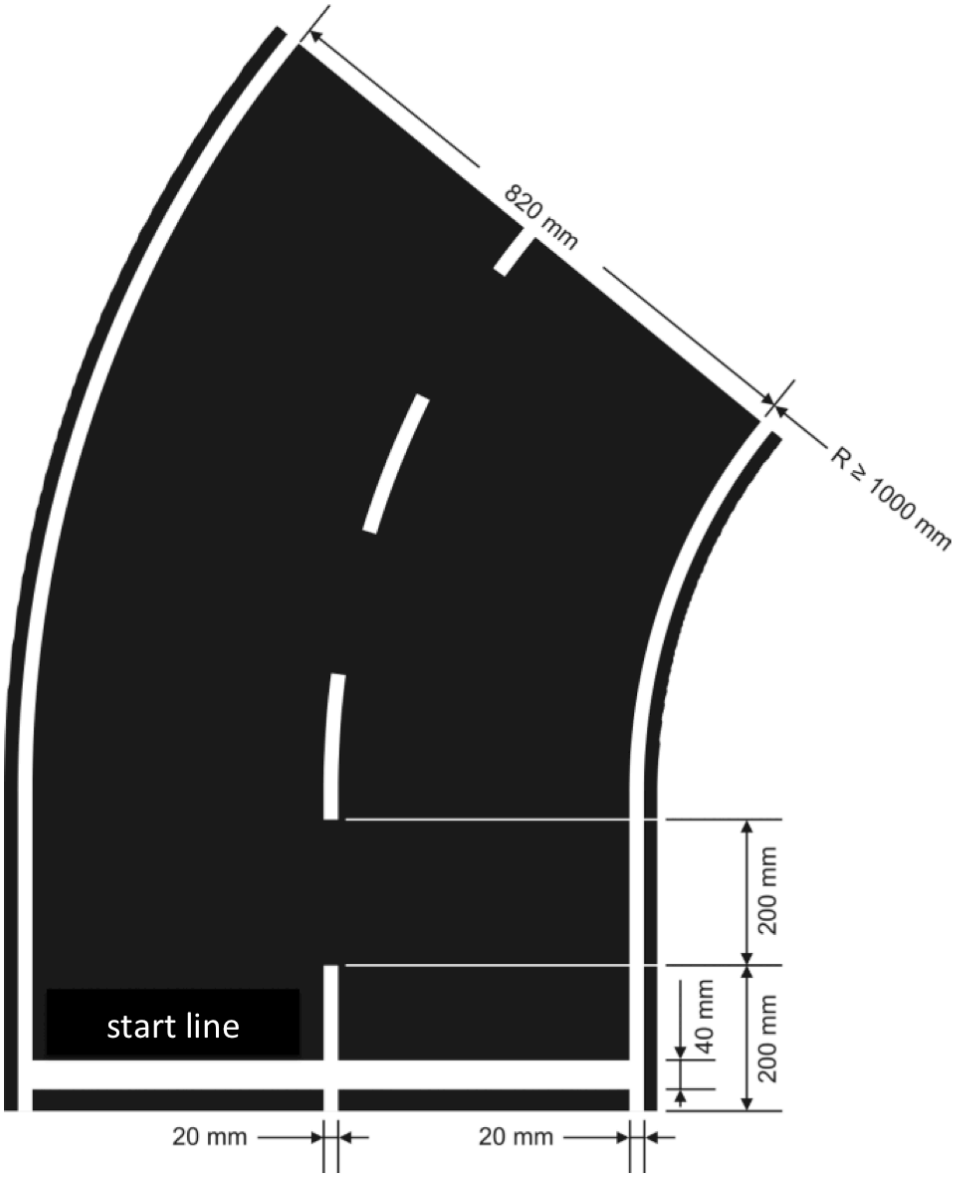
5.3.3.2 Penalties

Violation	**Maximum allowed number of violations**	**Penalty**
Stopping outside from intersections	Infinite	5m
Neglecting the stop line	Infinite	20m
Collision	Infinite	5m
Erroneous usage of direction lights	3	5m
Overtaking lasts too long	Infinite	5m

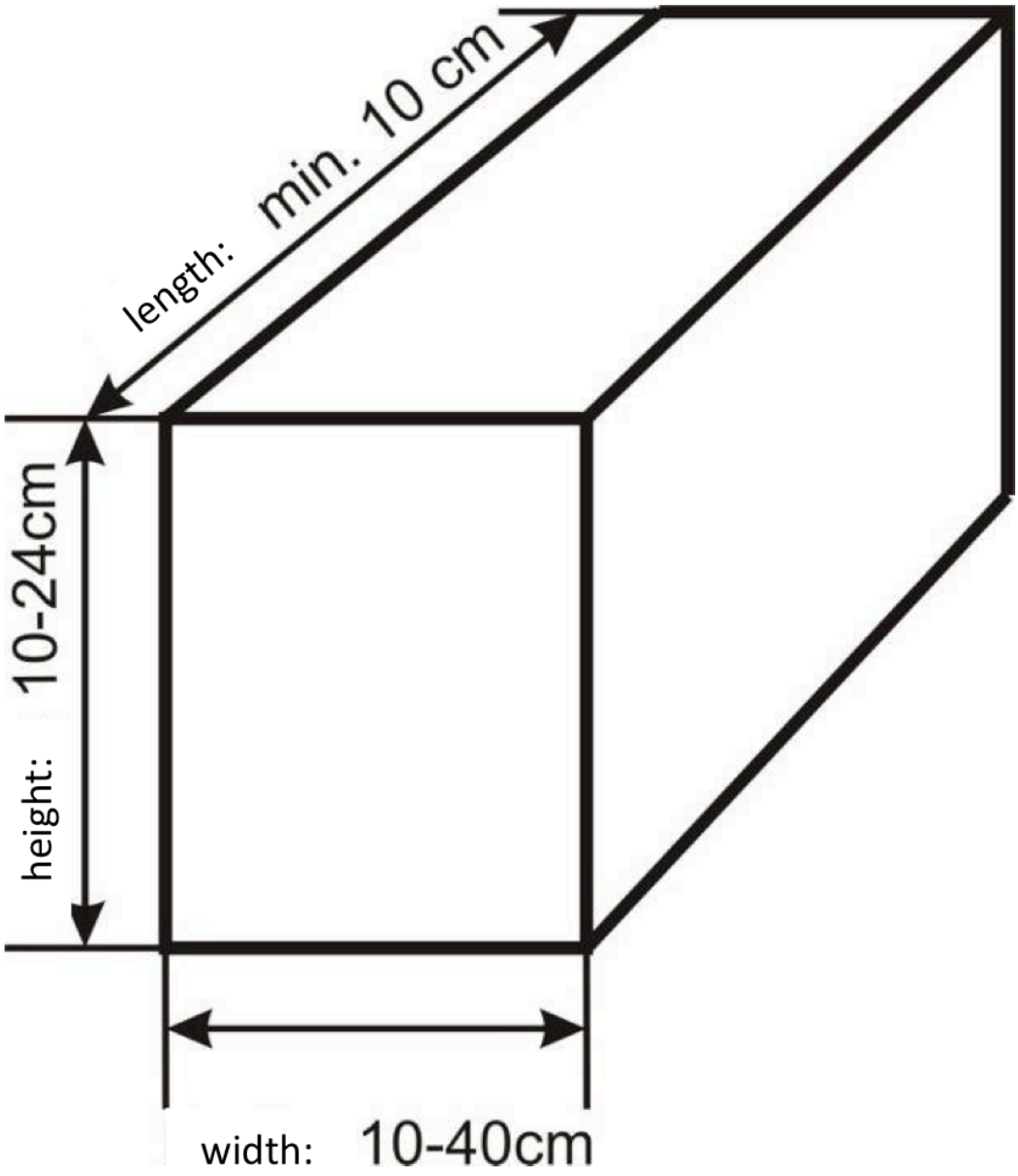
5.3.3.3 Scoring

The longest driven distance reduced by penalties will earn full points for this discipline; the points for the other teams are distributed pro rata.

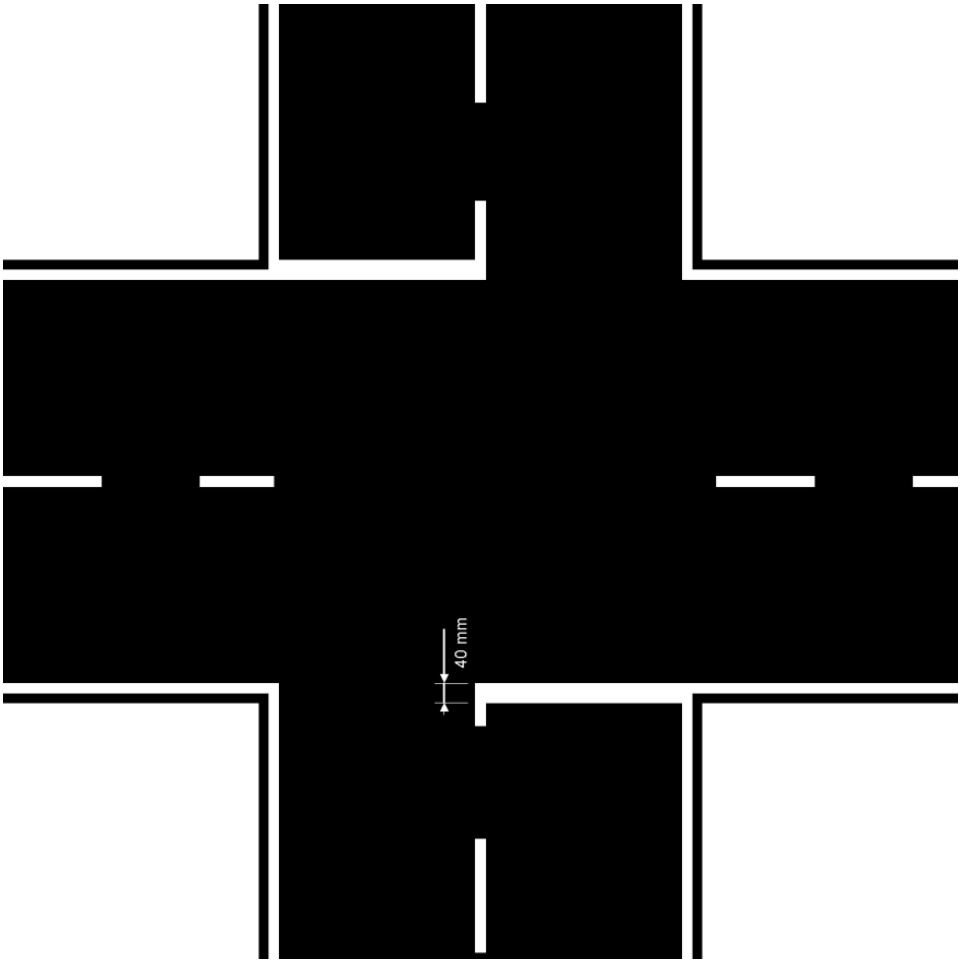
5.4 Road layout



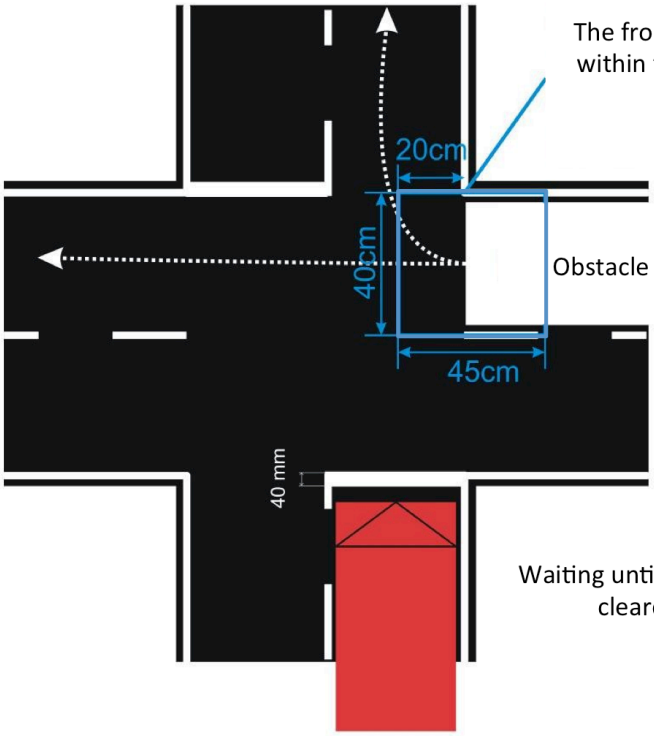
5.5 Dimensions of obstacles



5.6 Intersection

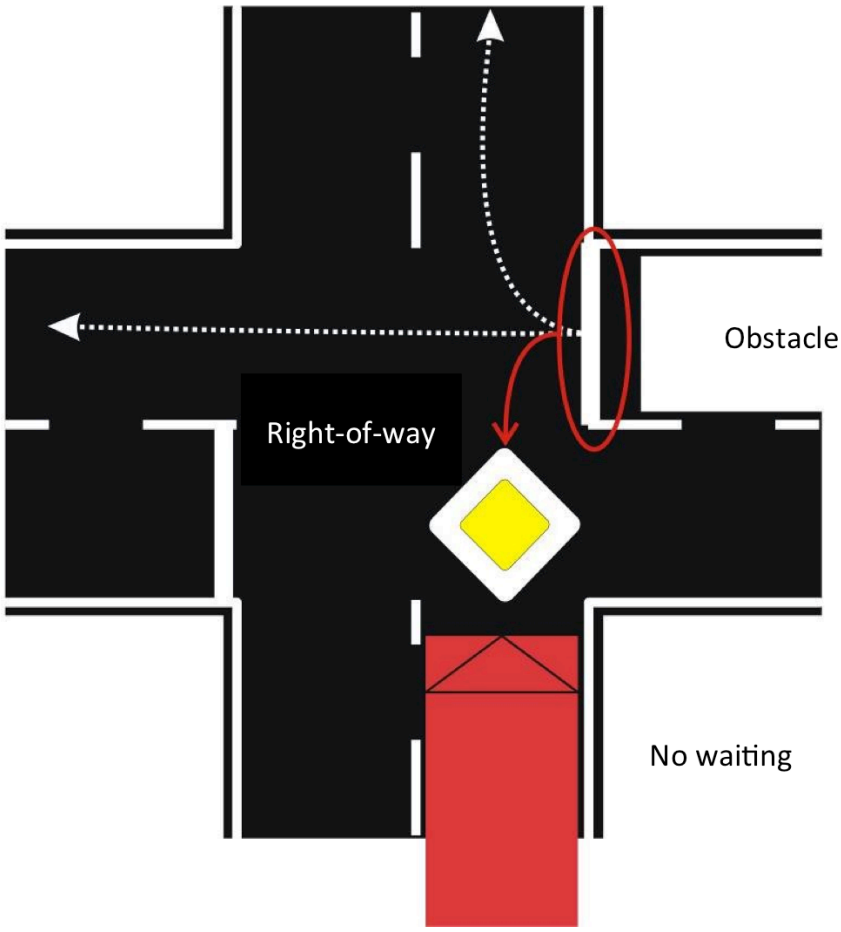


5.7 Dynamic obstacle at an intersection

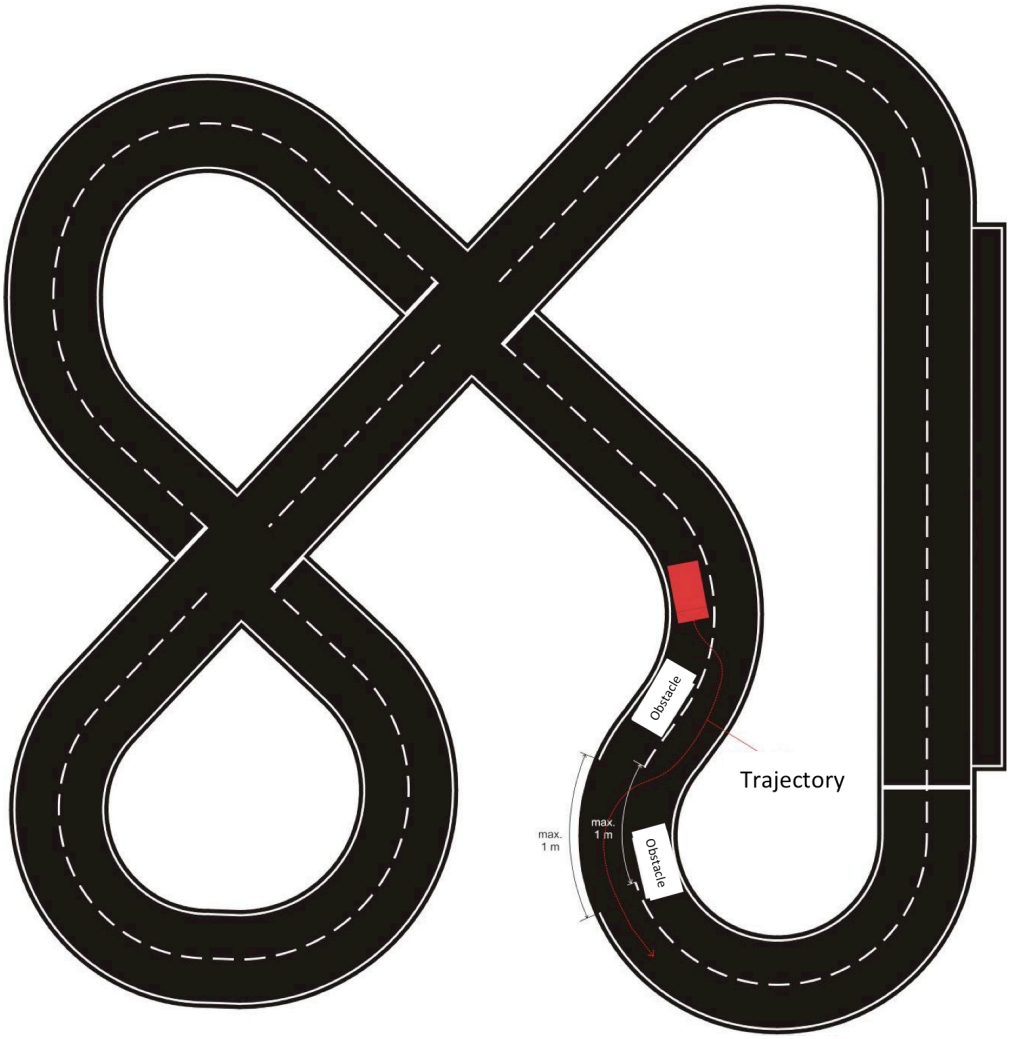


The front of the dynamic vehicle must be within the indicated area to determine a right-of-way-situation.

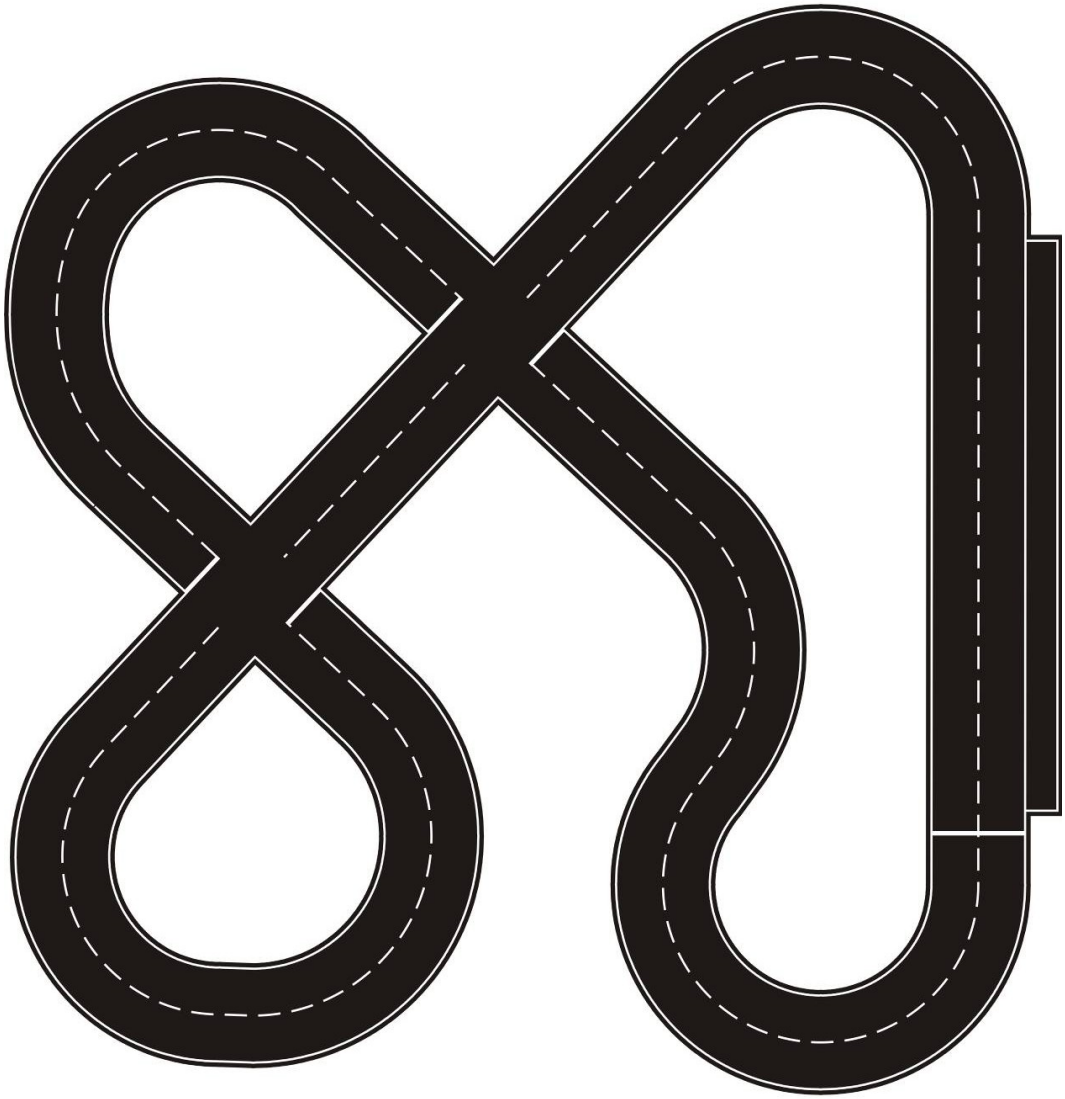
Waiting until the dynamic obstacle has cleared the intersection.



5.8 Example for a course with broken lane markings and obstacles



5.9 Example for a possible course (layout from the competition in 2009)



5.10 Possible parking strip layout