

# RoboCup Standard Platform League (NAO) Rule Book

RoboCup Technical Committee

(2022 rules, as of 2022-05-16)

Questions or comments on these rules should be mailed to  
`rc-spl-tc@lists.robocup.org`.

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# 1 Setup of the Environment

## 1.1 Field Construction

The standard soccer field consists of 8 mm artificial turf mounted on a flat wooden base with a total area of length 10.4 m and width 7.4 m. Care should be taken to ensure the field is as flat and level as possible. Additionally, the wooden base should be well-supported and should not give when humans stand or walk on it.

Figure 1 shows the dimensions of a standard soccer field. A more detailed technical drawing is provided in Appendix D to this document. Note that the penalty cross is a cross and there is a dash at center field. White field lines can be made of the same 8 mm artificial turf, but in white (i. e., made of white artificial turf), spray-painted or taped. Regardless of the solution, the field lines must be durable throughout the competition.

Figure 2 and Figure 3 depict the construction and placement of the goals. A support structure for the net shall be made with small black, white, or gray bars or cylinders. The support structure shall be constructed exactly as shown in Figure 3.

## 1.2 Field Colors

The colors of the soccer field are as follow:

- The field (artificial turf) itself is green (color is not specified, but it should not be too dark).
- The lines on the field are white, whether they are taped, spray painted or made from white artificial turf.
- Goals (see Figure 3). The posts and top crossbar of both goals are white. The net and the support structure for the net are white, gray, or black.

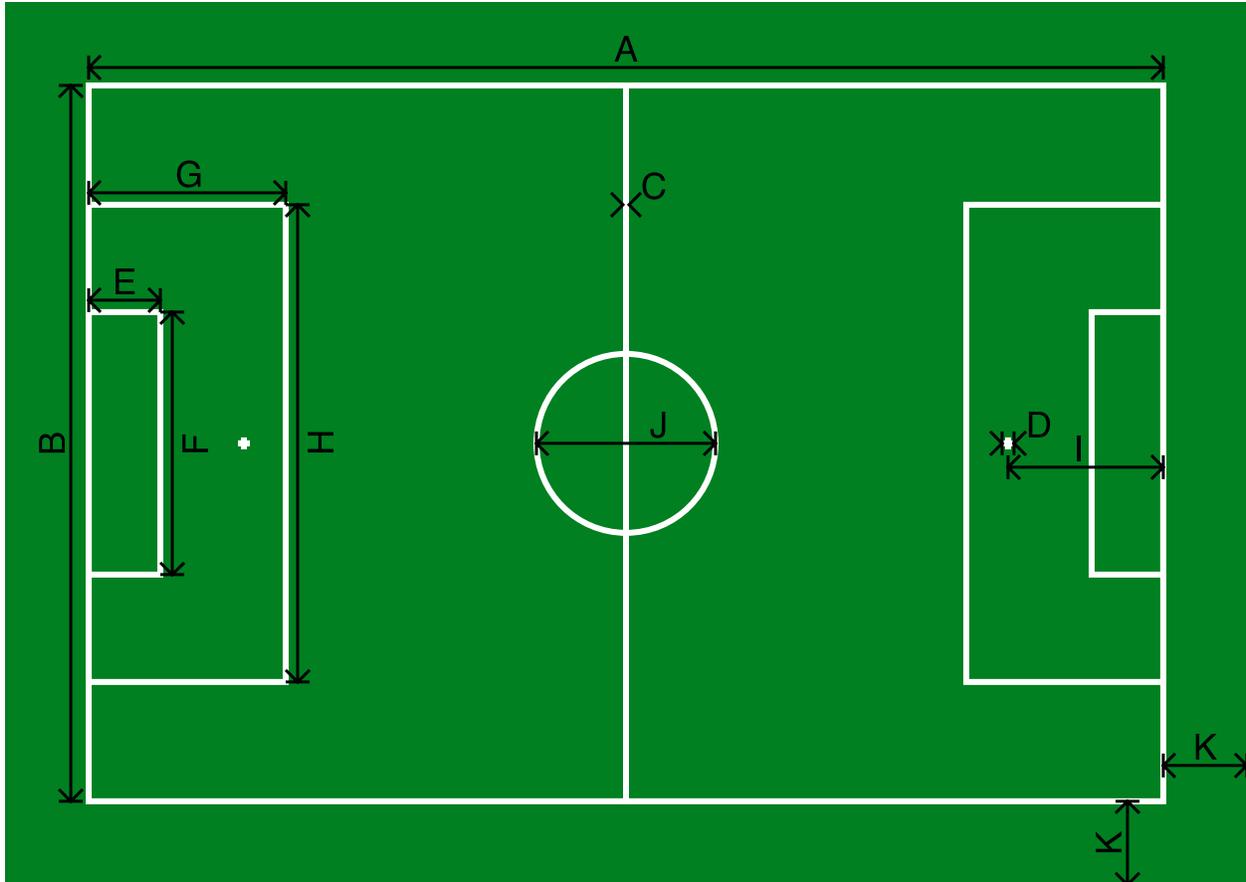
## 1.3 Lighting Conditions

The lighting conditions depend on the actual venue. SPL fields should be placed near or under windows where possible. Whether window lighting is used, ceiling lights should be provided as necessary to ensure that most of the field is never darker than 300 Lux (400 Lux preferred).

Lighting is not required to be even and hotspots may occur on the field. The lighting design (comprising both natural and artificial light sources) shall aim to limit the ratio between the brightest and darkest patches on the field to less than 10:1. In general, lighting irregularities, including changes that occur during the competition, are acceptable and will not be cause for delay. Such irregularities may include sun streaming through windows, light bulbs turning off, light bulbs being replaced, etc.

## 1.4 Venue Setup

Fields may be located close to one another. Barriers will not necessarily be constructed between adjacent fields to block the robots from seeing other fields, goals, or balls. However, barriers will be constructed to block sight between any fields that are not located at least three meters apart. Hence, for each side of a field that is adjacent to another field, either barriers will separate the fields or at least 3 m will be between the carpet of adjacent fields.



ID	Description	Length (in mm)	ID	Description	Length (in mm)
A	Field length	9000	G	Penalty area length	1650
B	Field width	6000	H	Penalty area width	4000
C	Line width	50	I	Penalty cross distance	1300
D	Penalty cross size	100	J	Center circle diameter	1500
E	Goal area length	600	K	Border strip width	700
F	Goal area width	2200			

Figure 1: Schematic diagram of the soccer field (not to scale) and corresponding dimensions in mm. Note that measurements on this diagram are made to the center of lines.

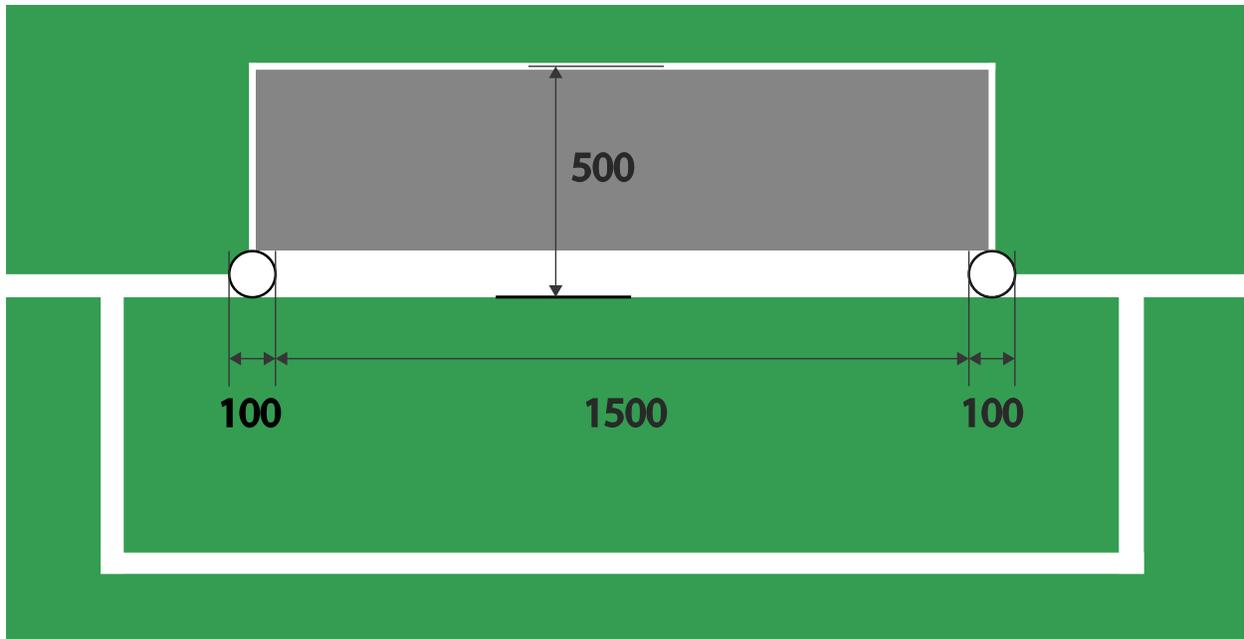
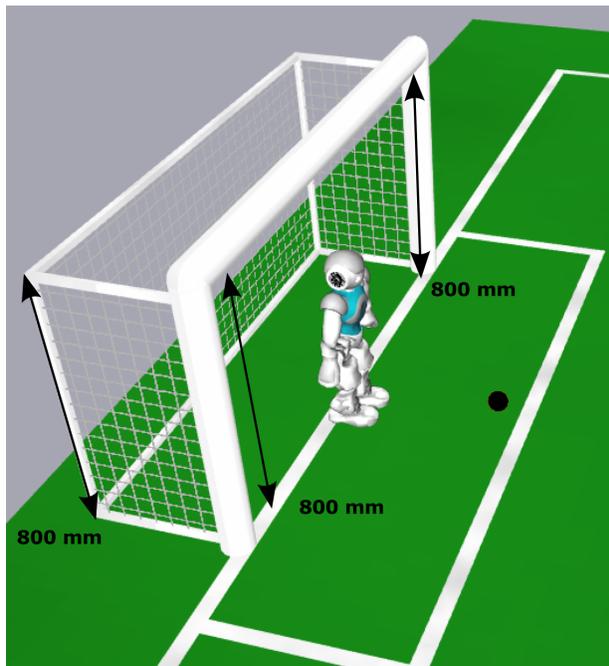


Figure 2: Dimensions of the goal (in mm), viewed from above, and its placement on the field.



The goalposts and crossbar are made from 3 white cylinders with a diameter of 100 mm. The net:

- has a height of 800 mm
- is of white, gray or black color
- is tightly supported via the support structure, in a way to minimize interference with the goalkeeper
- has a weave with holes smaller than the ball diameter.

Figure 3: Appearance and dimensions of the goals.



Figure 4: A NAO and an official ball.

## 1.5 Ball

The official ball is a soft foam ball with a black and white soccer ball print (see Figure 4). They are 100 mm in diameter and weight 44 g. These balls are available by writing to [info@sportpaint.de](mailto:info@sportpaint.de) (in German or English) and asking to order the "pu schaumstoffball 10cm 100ss". Each ball costs €2.86 plus shipping, where shipping cost depends on the destination.

## 1.6 Definition of Inside and Outside

A line is always part of a region of the field. This means, that *inside/outside*  $\langle region \rangle$  refers to the green area as well as the surrounding line. Specifically:

- The field boundary lines are part of the field
- The penalty area lines (and the end field line inside of the goal) are part of the penalty area
- The center circle lines are part of the center circle

The only *exception* to this rule is the center field line, which does not form part of any half. That is, a robot is *outside* a half of the field if it is touching the center line.

## 1.7 Streaming setup

There are multiple use cases for a streaming setup:

- Stream all videos to RoboCup SPL Youtube channel to store them there
- Allow team members from remote to watch their robot's match
- Evaluate team's performance measures online from videos recording (Part of Technical Challenge 2022)

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## 2 Robot Players

A match is played by two teams, each consisting of not more than **5** players. At most one player may be designated as *goalkeeper*, the others are all *field players*.

### 2.1 Hardware

All teams must use black, gray, red, blue, or orange plated NAO humanoid robots manufactured by SoftBank Robotics.

Absolutely no modifications or additions to the robot hardware are allowed. No additional hardware is permitted including off-board sensing or processing systems. Additional sensors besides those originally installed on the robots are likewise not allowed. The only exceptions are:

- Setting the passive wrist joints to a fixed position either with glue or a transparent or white duct tape.
- Protecting the fingers with white finger protectors provided by the manufacturer or with transparent or white duct tape.
- Placing white duct tape over the battery case and screw (under the robot jersey) to keep the battery case in place and prevent the battery becoming disconnected.
- A memory stick may remain in the head during operation. Only ordinary USB flash memory keys that sit flush or recessed to the head casing may be utilized. Other USB dongles or devices, as well as memory sticks that are not flush or recessed, are not permitted.

A computer with two monitors (one for GC and one for TCM) will be provided by the event organizers for the purpose of sending GameController messages to the robots and observing if no robot violates the rules for wireless network usage. Additionally, there should be at least one monitor mirroring the second screen of the GC PC showing the GameState Visualizer.

### 2.2 Goalkeeper

The goalkeeper is allowed to touch the ball with its arms/hands only while it is within its own goal area. It always has the jersey number “1”.

### 2.3 Field Players

Each of the four field players has a jersey number from the set {2, 3, 4, 5, 6}. However, by default, the number “6” should only be used for a substitute that enters the game later.

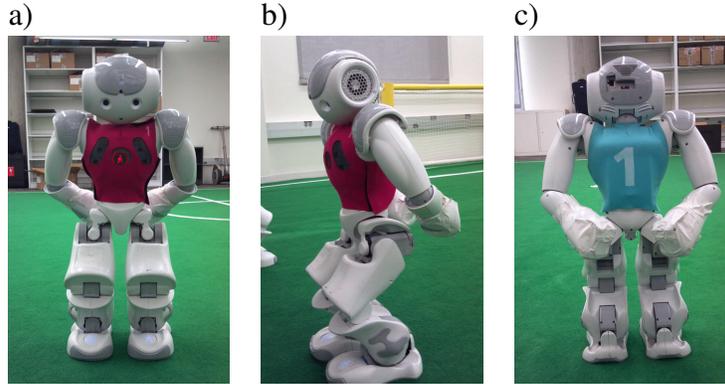


Figure 5: Team markers. a) Front view. b) Side view. c) Back view.

## 2.4 Team Markers

Robots use colored jersey shirts as team markers. Each jersey shirt has a player number (1-6) printed on it. The team markers are worn as shown in Figure 5.

Teams may use any jersey that was approved for a RoboCup SPL competition in the last 4 years without needing to approve it in 2022 again.

Teams may design and manufacture their own jerseys in any color (multi and many color jerseys are acceptable), but must follow these guidelines:

- Jerseys should be the **tank top** style used at RoboCup 2013/2014 and should cover approximately the same areas of the robot as shown in Figure 5. The torso LED must be clearly visible. Jerseys may include the sonar panel used in the 2013/2014 jerseys, although this is not required. Jerseys may not cover the shoulders of the robots.
- Jerseys must have a primary color that comprises at least 70 % of the jersey.
- Jerseys should not contain distractors, such as large pictures of SPL balls or white stripes on green jerseys.
- All players on a team must wear identical jerseys, including the goalkeeper.
- A team must wear the jerseys that it starts a game in for the entire game.
- Jersey material must be non-reflecting, non-shiny, and non-textured. Material that is glittery is also not appropriate.
- Jerseys should be numbered 1-6 on both sides. The numbers must be large and **easily** recognized by humans.
- Teams must have two sets of jerseys that are significantly different in terms of their primary color.

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- Designs must be submitted to `rc-spl-tc@lists.robocup.org` for approval by 2022-05-01. If the team has jersey prototypes, they should submit close-up images of a robot wearing the jersey – these images should be taken from front, back, and side angles. If the team has no prototypes, then designs depicting the expected jersey should be submitted. If submissions show separated front and back halves of jerseys then the team must specify which halves are matched to form home and away jerseys. All images and designs should be submitted in pdf or jpg format.

Each team must designate a “home” color and an “away” color when asked about one month before RoboCup. Teams must wear their ‘home’ jerseys when they are “home” (the first team listed on the schedule). Teams will wear their “home” jersey when they are “away” (the second team listed on the schedule) as well, unless either the head referee or the GameController program believes the jerseys of two competing teams are too similar. In this case, the “away” team will then wear their “away” jersey.

Some teams wish to include additional information or logos on their robots. The following are allowable:

- Attaching player numbers to the heads and/or legs of the robots. These numbers should be black with a white background, and should correspond to the number on the robot’s jersey.
- Adding sponsor or team logos to the upper legs of the robots (see Figure 6). A box drawn around the non-white area of these logos must not cover more than a  $25\text{ cm}^2$  area. At most one logo may be attached per leg - if you wish to attach more than one logo per leg, email the Technical Committee at least two weeks before the competition. Depending on the size and design of the logos, this may be allowable.
- Adding small black and white stickers to the torso of the robots stating the name of the robot, the name of the team, or similar information. These stickers must be small and mostly white.

## 2.5 Communications

The robots must play without human control. Communication is only allowed among robots on the field and between the robots and the GameController.

### 2.5.1 Non-Wireless Communications

In general there are no restrictions on communication between robots in play on the field using visual signalling (e. g. gestures) or the robot’s built-in microphones, speakers, and infrared transceivers. However, communication that causes excessive discomfort to an audience, affects the safety of an audience, or violates normal playing rules is not permitted.

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## 2.5.2 Wireless Communications

The only wireless hardware allowed to be used by the teams are the wireless network cards built into the NAOs, and the access points provided by the event organizers. All other wireless hardware must be deactivated. A team may be disqualified if one of the team members violates this rule.

Each team will get a range of IP addresses that can be used both for their robots and their computers. The network configuration (e. g. IP addresses, channels, SSIDs, and required encryption) of the fields will be announced at the competition site.

Wireless robot-to-robot communication among the robot players is allowed, as long as it uses the access points provided by the event organizers (using the so-called ad-hoc mode is prohibited), messages are sent via UDP broadcast, and the SPL standard message format is used. The SPL standard message format is specified in the header *SPLStandardMessage.h* that is distributed with the latest GameController release at <https://github.com/RoboCup-SPL/GameController>.

Each team will be assigned a range of IP-addresses that can be used for robot-to-robot communication. Each team will also be allocated a single UDP port for network broadcasts. Specifically, a team's port will be 10000 plus that team's GameController number. All robot-to-robot communication during matches must be sent via UDP broadcast. Unicast communication between robots is prohibited.

The amount of data transmitted by a team in a single game is limited. The limit is measured as the total number of UDP packets sent by any robots of a team. A team may not exceed 1200 packets per game. For each minute of irregular extra time (see Section 3.12), the limit is increased by 60 packets. However, this does not apply to a team that has already exceeded its limit before. The GameController tracks the number of messages that have already been sent and includes counters for packets remaining per team in `RoboCupGameControlData`.

If a team exceeds their limit the game is scored with 0 goals for the offending team. Robot-to-robot communication that violates the SPL rules result in a game scored with 0 goals for the offending team (even when discovered after the game was finished). Measurement of the limits starts with the ready state and ends with the finished state. Limits do not apply during penalty kick shoot-out. If a knock-out game results in a draw and both teams exceeded their message limit, the team last exceeding their limit wins the game.

The limit of allowed packets will be lowered in future competitions to encourage smart event-based communication.

In addition to robot-to-robot communication, robots may send:

- Additional status update packets that are sent to the GameController.
- Team specific debug information may be sent to an external computer owned by the team. A robot may send debug information at most once every 2 s in a single UDP packet.

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These additional packets do not count towards the team's data limit and may not be used for robot-to-robot communication. They must be sent as unicast and may not be sent as broadcast.

Teams and their robots must not listen into another team's communication.

Robots are not allowed to be connected to access points of fields that are currently running official games of other teams. Robots may only communicate on fields that are not running an official game or fields which they are playing on.

The GameController will use UDP to connect to the robots. The source distribution of the GameController provides the header file *RoboCupGameControlData.h* that defines all messages sent by the GameController to the robots. They correspond to the *robot states* described in Section 3.2.

Robots send status updates (defined in *RoboCupGameControlData.h*) to the GameController. These return packets must be addressed directly to the GameController PC (i. e. not broadcast) and sent on the GameController return UDP port specified by the symbol `GAMECONTROLLER_RETURN_PORT` in *RoboCupGameControlData.h*.

The use of remote processing/sensing is prohibited.



Figure 6: Example Sponsor/Team Logo placement on legs.

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## 3 Game Process

### 3.1 Structure of the Game

A game consists of three parts, the first half, a half-time break, and the second half. Each half is 10 min counted from the initial kick-off. The half-time break is 10 min, and during this time both teams may change robots, change programs, or do anything else that can be done within the time allotted.

The head referee signals the commencement of each half with a single whistle blow (that is, the Initial kick-off, see Section 3.4). The head referee signals the end of the first half with two short whistle blows, and the end of the second half with two short plus one long whistle blow. The head referee should make *all* of these whistle sounds from the T-junction of the half-way line.

The teams/robots will change the goal defended during the half-time break.

### 3.2 Robot States

Robots can be in *eight* different *primary* states (see Figure 7). Wireless connection must be available, so these states will be set by the GameController. Teams must implement code to receive and correctly respond to wireless GameController packets, and also give a visual indication of the game state.

**The usage of the button interface as a replacement for any GameController commands/transitions is not allowed in the main competition!**

Should, on both teams, at least two robots have problems with the wireless network or GameController connection the head referee should issue a referee timeout (see Section 3.11). If fewer robots do not respond to the GameController then they are, at the beginning, not included in the game (via a ‘Request for Pick-up’, see Section 3.9), and the game starts without the offending robot.

**Unstiff.** It helps to facilitate a consistent and safe handling of the robots for remote competition. During any state, if all head buttons are pressed at least one second, the robot should move to a safe seated/crouched position and `unstiffen` all joints. So while in the `unstiff` state the robot is not allowed to move in any fashion! After booting, the robots are in their `unstiff` state. Pressing the chest button once while in the `unstiffen` state, permits the robot to stiffen its joints and return to the `initial` state, or a state as indicated by GameController.

**Initial.** The robots are not allowed to be moving in any fashion besides initially standing up. Shortly pressing the chest button will switch the robot to the `penalized` state.

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**Ready.** In this state, the robots walk to their legal positions for Kick-Off (see Section 3.5) or a Penalty Kick (see Section 3.7.1)). They remain in this state, until the head referee decides that there is no significant progress, up to a maximum of 45 s for a Kick-off and 30 for a Penalty Kick. The GameController can activate sub-states for kick-off and penalty kicks. This state is not available if only the button interface is implemented.

**Set.** In this state, the robots stop and wait for Kick-Off (see Section 3.5) or a Penalty Kick (see Section 3.7.1)). Illegally positioned robots are penalized and placed on the side of the field. Robots are allowed to move their heads or get up if fallen before the game (re)starts, but they are not otherwise allowed to move their legs or locomote in any fashion. If a robot cannot get up, fallen robot is called (see Section 4.6). The penalty time counter is frozen during this state. Note that all penalized robots are left in place (on the side of the field, or in-place for motion in set) and must wait to get unpenalized. The GameController can activate sub-states for kick-off and penalty kicks. This state is not available if only the button interface is implemented.

**Playing.** In the playing state, the robots are playing soccer. Shortly pressing the chest button will switch the robot to the penalized state. During the playing state, the GameController can activate the sub-states for free kicks (see Section 3.7).

**Penalized.** A robot is in this state when it has been penalized. It is not allowed to move in any fashion, this includes stopping the head turning. Shortly pressing the chest button will switch the robot back to the playing state.

**Finished.** This state is reached when a half is finished. The robots then have to sit down.

**Calibration.** This state denotes the robot is acting with automatic calibration. This state may only be entered from *initial* by first pressing the front head button concluded by the chest button, for at least one second by the referees.

The referee will announce the start of the playing state with a single whistle blow. The GameController playing signal will be delayed by 15 seconds. This delay applies to both kick-off and penalty shots. Robots that begin moving their legs or move in any fashion during set (i. e. before the referee blows the whistle) will be penalized *in place* on the field via the “Motion in Set” (see Section 4.5) GameController signal until the GameController transmits the playing signal. A robot will be moved back to its original position if it has moved significantly before becoming penalized. Note that responding to a whistle on another field will result in this penalty.

The current game state should be displayed on the LED in the torso. The colors corresponding to the game states are:

- *Unstiff*: Blue-Blinking
- *Initial*: Off
- *Ready*: Blue

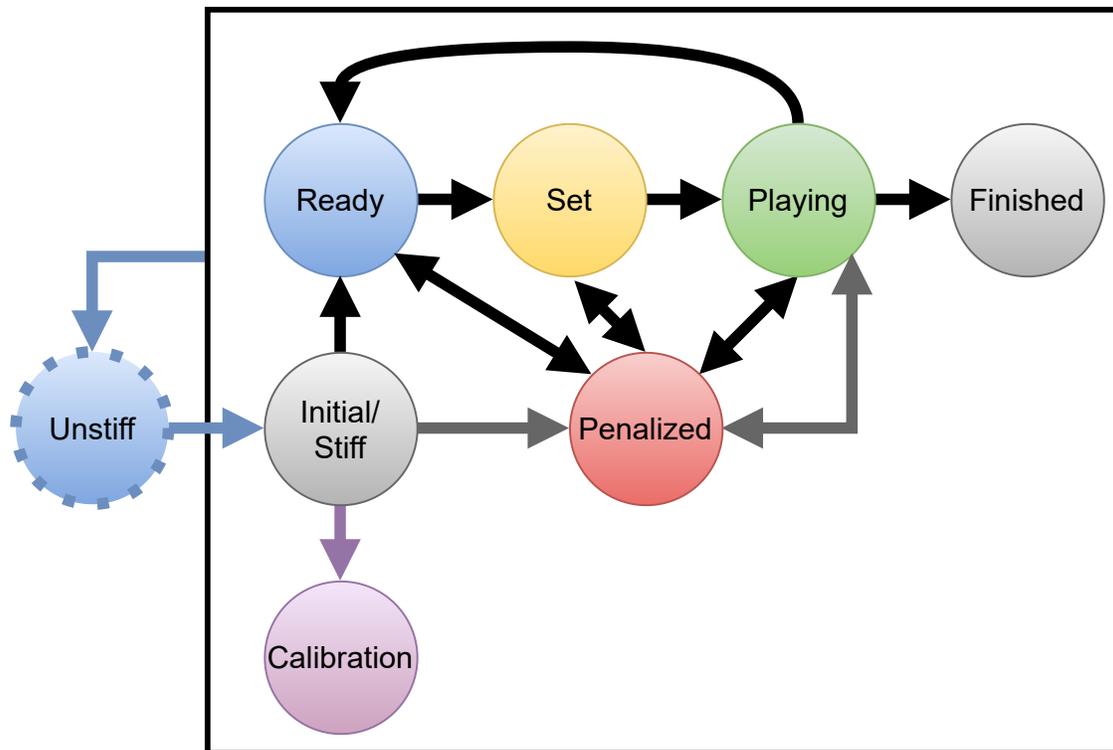


Figure 7: Diagram of the robot states.

**Chest button** transitions are shown as gray arrows. However, any transition possible should be sent by the GameController.

**GameController** transitions are shown as black arrows.

Calibration transitions are shown as purple arrows which mean pressing the **front head button + the chest button**.

From any state it can be transitioned to the `unstiff` state, shown as a blue arrow, via pressing all **three head buttons**. Pressing the **chest button** in the `unstiff` state allows a transition to the `initial` state, or a state as indicated by the GameController.

- Set: Yellow
- Playing: Green
- Penalized: Red
- Finished: Off
- Calibration: Purple

The current GameController requires robots to know both their team number and their robot number within the team. It is each team's responsibility to make sure this is correctly configured. It is recommended that the robot indicates its number within the team on boot up so that this can be easily checked at the start of the game.

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## 3.3 Goal

A goal, including own goal, is achieved when the entire ball (not only the center of the ball) goes over the goal-side edge of the goal line, i. e. the ball is completely inside the goal<sup>1</sup>.

The head referee signals a goal by a single whistle blow, followed by the call “Goal <color>”. The head referee should point with one arm towards the center of the field. To assist robots listening for whistles, the referee should blow the whistle from on the carpet at the end of the fields where the goal was scored.

The GameController signal (to the robots) of a goal being scored, will be delayed by 15 s.

### 3.3.1 Invalid Goal

A goal is invalid (that is, it can never be awarded) in the following circumstances:

1. When an Indirect Kick is required but has not occurred (see Section 3.3.2).
2. When the last contact of the ball was with an attacking robot that played the ball with the arms/hands as defined in Section 4.11. However, an own goal may be scored by any defending robot playing with arms/hands.
3. When a team scores on themselves and there are no opponent robots on the field that are active (a definition of *active* is given in Section 4.6).

In these cases a goal is not scored (that is, the goal is ruled invalid), and the game will proceed with a Goal Kick (see Section 3.7). The head referee should also advise why the goal is invalid, such as by calling “Not indirect”, “Played with hands” or “No own goal”.

### 3.3.2 Indirect Kick

The attacking team may only score a goal via indirect kick from any restart into *playing* from a Free kick except for a Penalty kick. This rule applies also for the defending team in case of unexecuted Kick-off and the ball is free.

- A robot may not score a goal from a direct kick, including via deflections.
- The ball must be deliberately played-at a second time (by either another robot, or the same robot) before a goal may be scored. A deliberate play at the ball includes successfully kicking the ball, dribbling the ball (and subsequently leaving possession of the ball), or the goalkeeper playing at the ball with its hands.

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<sup>1</sup>The goal line is part of the field.

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- If a robot plays the ball to itself, this means that the ball must leave a circular area of at least 0.75 m around the robot before the ball is played a second time and to be considered as an indirect kick.
  - Note that an own-goal may always be scored without requiring an indirect kick.

**Example 1:** Player 2 (of the red team) kicks the ball to Player 3, who then kicks the ball into the goal. This is a successful indirect kick, and the goal counts.

**Example 2:** Player 2 (of the red team) kicks the ball at the goal, and it is deflected of the side of the foot of a blue-team robot into the goal. This is *not* an indirect kick, and the goal does not count.

**Example 3:** Player 2 (of the red team) kicks the ball “upfield”. A blue-team robot kicks the ball a short distance, after which Player 2 kicks the ball again into the goal. This is a successful indirect kick, and the goal counts.

**Example 4:** Player 2 (of the red team), walks up to and dribbles the ball. To be an indirect kick, Player 2 must then stop, and visibly back-away from the ball, before approaching to dribble a *second* time. The robot then scores. This is a successful indirect kick.

**Example 5:** Players of the red team fail to execute a Kick off. After the ball is free the defending team kicks the ball directly into the goal. This is *not* an indirect kick, and the goal does not count.

### 3.4 Initial Kick-off

The first kick-off at the start of each half or after a timeout is an initial kick-off. Robots have to be ready next to the field at latest 2 min before an initial kick-off. All robots must be in the *unstiff* state.

Latest 1 min before the game starts all robots must be placed on the sidelines facing the other sideline in their own half by their team (if present in person at the competition site) or their responsible referee according to Figure 8. If a team places robots themselves for initial kick-off, it is allowed for the team to vary the spacing and orientation of the robot positions along legal positions on their half’s sidelines (see also Section 1.6).

Robots are brought into the *initial* state after they are placed. Once the robots receive the *ready* signal from the GameController, they proceed as described in Section 3.5.

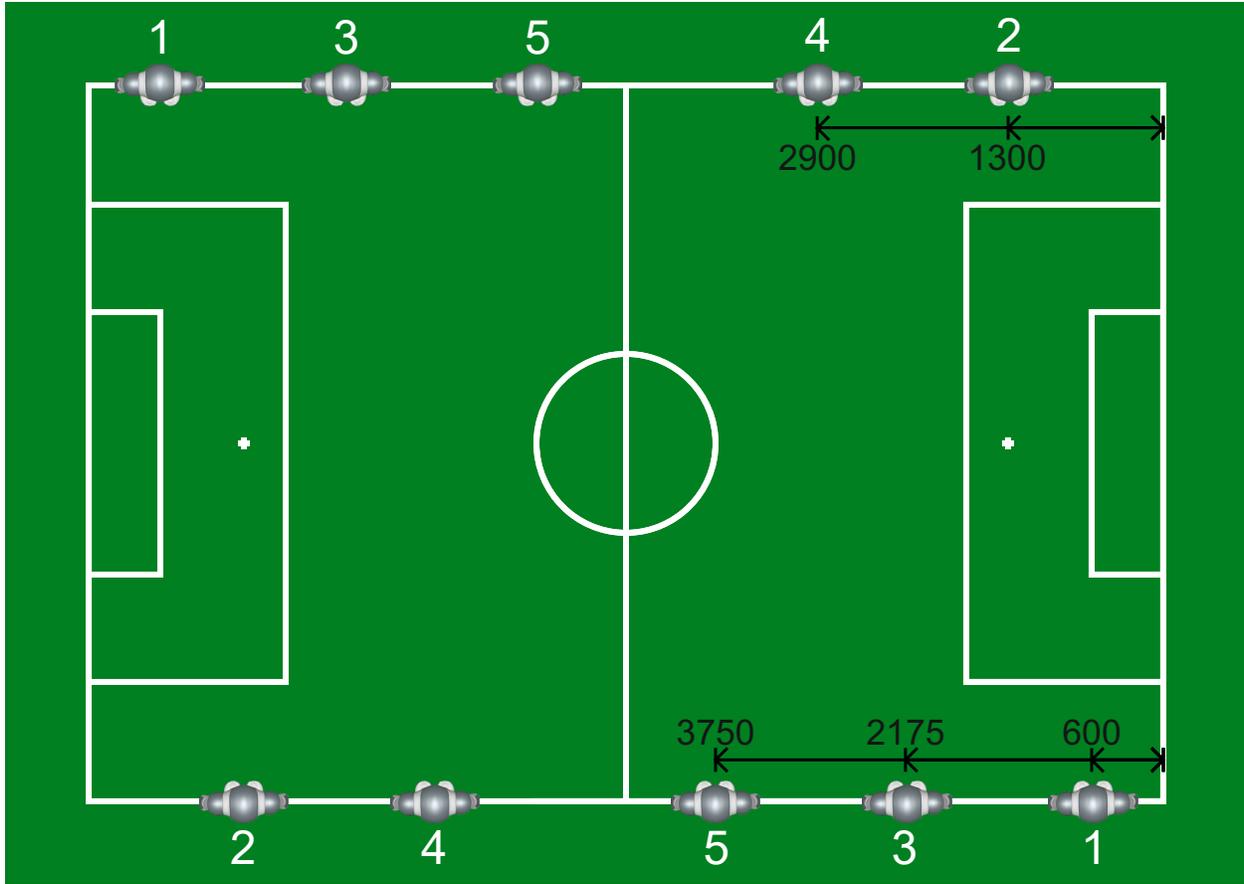


Figure 8: Positions, player numbers and distances from the center of the goal line for the initial kick-off of the robots.

### 3.5 Kick-off

For kick-off, the robots listening wirelessly to the GameController, run through three states: *ready*, *set*, and *playing*. It is to a team's responsibility to have their robots listening to the GameController!

In the *Ready* state, the robots must walk to a legal kick-off positions for their team.

When reaching the *Set* state, the kick-off team can be positioned anywhere within their own half and the center circle. Only one robot of the kick-off team is allowed to stay within the whole center circle. All robots in the center circle, except the closest to the center point of the center circle, get penalized by "Illegal Positioning" (see Section 4.4). If the kick-off team has a robot positioned in the opponent's half of the center circle, only this robot, called kick-off player, is allowed to execute the kick-off. If a different robot of the kick-off team is executing the kick-off, this robot gets penalized with "Illegal Positioning" and a moved ball gets moved back.

When reaching the *Set* state, the defending team can be positioned within their own half, except for inside the center circle including its line.

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Beginning with *Set* no player is allowed to touch the halfway line except for the kick-off player within the center circle (see Section 4.4). Robots are allowed to be positioned inside the area of their own goal. Both teams are also subject to restrictions on the penalty area (see Section 4.4). The limitations on kick-off positions end for both teams as soon as the ball is free. The green carpet border, except for the area of the goal, is not part of either teams own half. All robots that do not reach legal positions or enter illegal positions before the ball is free will be penalized with the “Illegal Position” penalty (see Section 4.4).

In the *Set* state, the robots must not move (see Section 3.2). A referee places the ball on the center point of the center circle. If the ball is moved by one of the robots during *Set*, it is moved back by one of the referees.

**There is no manual placement of any robot.**

The head referee signals the kick-off by a single whistle blow, followed by the call “Playing”. The head referee must signal this from the T-junction of the half-way line.

After the head referee has signaled the kick-off, the robot’s state is switched to *playing* by the GameController. The defensive team must stay outside the center circle until the ball is in play. The ball is in play once it is touched by the attacking team or once 10 s have elapsed in the playing state. Before the ball is in play, robots are not allowed to leave their own halves. Otherwise, a robot will be penalized with the “Illegal Position” penalty (see Section 4.4).

The GameController and head referee will indicate this by the call “Ball Free”. If a defensive player enters the center circle before the ball is in play, the “Illegal Position” penalty is applied (see Section 4.4).

Note a goal may not be scored from within the center circle on kick-off (see Section 3.3.1), and that indirect kick rules apply (see Section 3.3.2).

### **3.6 Kick-in**

A ball is considered to have left the field when there is no part of the ball over the outside of the boundary line (i. e. the line itself is in). If the ball leaves the field it will be replaced on the field by an assistant referee. Balls are deemed to be out based on the team that last touched the ball, irrespective of who actually kicked the ball.

If the ball goes over a sideline then the assistant referee will replace the ball back on the point of that sideline where it went out. A free kick (see Section 3.7) is awarded to the team that did *not* last touch the ball by the referee calling “Kick-in <color>”.

If the ball goes over an end-line then the assistant referee will replace the ball back on the field, depending on which team last touched the ball.

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- If the ball was last touched by the defensive team, a *Corner Kick* (see Section 3.7) is awarded to the attacking team. The referee calls “Corner Kick <color>” and the ball is placed on the corner on the same side of the field that the ball was kicked-out.
  - If the ball was last touched by the offensive team, a *Goal Kick* (see Section 3.7) is awarded to the defensive team. The referee calls “Goal Kick <color>”, and the ball is placed on the corner of the goal area on the same side of the field that the ball was kicked-out. That is, the corner inside the field, not the t-junction where the goal area meets the goal line.

In these examples, “red half of the field” refers to the half the red team is defending.

**Example 1:** The red goalkeeper kicks the ball out the end of the field to the right of the goal. The referee calls “Corner Kick blue”, the ball is placed on the corner to the right of the goal and a free kick is started.

**Example 2:** A blue robot kicks the ball out the end of the field to the right of the goal the red team is defending. The referee calls “Goal Kick red” and the ball is placed on the right corner of the goal area.

**Example 3:** A blue robot at midfield kicks the ball over the left sideline 2 m into the red half of the field. The referee calls “Kick-in red” and the ball is replaced on the left sideline where it went out.

**Example 4:** A blue robot kicks the ball but the ball touches a red robot at midfield before leaving the field near the center line. The ball is regarded as out by red, the referee calls “Kick-in blue” and the ball is replaced on the kick-in line where it went out.

### 3.7 Free Kick

A Free Kick is initiated:

- When the ball goes over the sidelines, termed *Kick-in*.
- When the ball goes over the end-lines initiated by the defensive team, termed *Corner Kick*.
- In place of an end-line Kick-in initiated by the offensive team, also termed a *Goal Kick*.
- A pushing penalty (see Section 4.10) awarded near the ball, termed a *Pushing Free Kick*.
- A pushing penalty (see Section 4.10) awarded near the ball against the defending team within their own penalty area, termed a *Penalty Kick*.

The head referee will announce a Free Kick, calling one of:

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1. For a *Kick-in/Goal Kick/Corner Kick*: “Kick-in/Goal Kick/Corner Kick <team>” for the team that did not last touch the ball.
  2. For a *Pushing Free Kick*: “Foul <offending color><offending number>” for the pushing robot.
  3. For a *Penalty Kick*: “Penalty Kick <offending color><offending number>” for the pushing robot.

The GameController will then activate the sub-state for the respective free kick. Note that in the case of the Pushing Free Kick the sub-state is activated automatically through the “Foul”. The team who is awarded the Free Kick (termed the attacking team) has 30 s to complete the kick. For a “Penalty Kick”, the game instead proceeds as described in Section 3.7.1.

When necessary, the referee may need to place the ball. For a Pushing Free Kick, the ball will be left in place, and only repositioned in accordance with the pushing rules (see Section 4.10). If the ball left the field, the ball will be positioned as described in Section 3.6.

During the Free Kick, only the attacking team may approach within 0.75 m to the ball. All robots of the defensive team must immediately move away from the ball. Defensive robots that violate these restrictions are penalized with the “Illegal Positioning” penalty (see Section 4.4) which results in a standard removal penalty (see Section 4.2). Additional penalties against any further robots during the free kick, including Pushing, do not result in an additional Free Kick, but still use the appropriate removal penalty.

A Free Kick is deemed completed and play returns to normal if:

- The attacking team touches the ball, except for a robot getting up which is exempt from this rule.
- The 30 s time period expires (or the game time expires).

The head referee will announce a Free Kick is completed, by “Ball Free”, and the GameController resumes the game state *playing*. Note that the sub-state will be automatically left after the 30 s time period expires.

### **3.7.1 Penalty Kick Procedure**

When the GameController activates the Penalty Kick, the game changes to the *Ready* state with *free kick* sub-state active.

This denotes that the robots are given time to set up and prepare for the penalty kick. Similar to kick-off, the game clock is *paused* during finals games only. The referees should pick up the ball.

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Robots have 30 s to get into position for the Penalty Kick. At the end of 30 s, the game changes to the *Set* state with *free kick* sub-state active. Similar to a kick-off, during the *Set* state the robots are waiting for the Penalty Kick to commence. Standard penalties apply. Additionally, only the goalkeeper robot from the defending team may be within the penalty area. The goalkeeper robot must either be touching the goal line or stay outside its own penalty area. If the goalkeeper positioned itself inside the goal area but ahead of the goal line it is placed back by the referee during *Set* state, so the center of its feet touches the center of the goal line. The placement should happen perpendicular to the goal line without rotating the robot. If this manual placement would lead to a position the robot collides with a goal post, it is placed inside or outside the goal post on the goal line, depending on which position is closer. Only one robot from the attacking team may be within the penalty area, and it may not block the penalty spot. Blocking the penalty spot is considered to be an illegal position. All robots that do not reach legal positions will be penalized with the “Illegal Positioning” penalty (see Section 4.4).

The referee should also place the ball on the penalty spot during *Set*. The referee signals the Penalty Kick commences by blowing the whistle once, and calling “Playing”. The game switches to the *free kick* sub-state of the *Playing* game state, and the game clock is resumed. (Note that the GameContoller signal is delayed by 15 s when switching from *Set* to *free kick* sub-state). The attacking team has 30 s to complete the Penalty Kick.

During the Penalty Kick:

1. The defensive goalkeeper robot must always be in contact with the goal line if it is inside the penalty area, and must remain on its feet. The goalkeeper is only permitted to “dive”, and be off it’s feet after the attacking robot has touched the ball.
2. The attacking robot may move freely.
3. All robots must be within the field-of-play. That is, robots may not be outside the field lines, but within the field border.
4. No other robots may enter the penalty area (see Section 4.4).
5. Additional penalties against any further robots, including Pushing, do not result in an additional Free Kick, but still use the appropriate removal penalty.

The attacking robot (taking the penalty kick) may only score a goal if it touches the ball once. Once the attacking robot has touched the ball, it may not score a goal until another robot (from either team) touches the ball. If this robot “scores”, it results in a Goal kick (see Section 3.3.1).

The Penalty Kick is deemed completed if:

- The attacking team touches the ball, even if the robot has fallen.
- The 30 s time period expires (or the game time expires).

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The head referee will announce a Free Kick is completed, by “Ball Free”, and the GameController resumes the game state *playing*. Note that the sub-state will be automatically left (returning to the *playing* state) after the 30 s time period expires.

Note that the restrictions on the attacking robot still apply after the penalty kick is complete.

## 3.8 Game Stuck

In the event of no substantial change in the game state for 30 s, this is considered a game stuck. “Substantial change” can consist of a robot seeing and moving towards the ball OR robots exploring the field (presumably in an attempt to find the ball).

The main referee has two options how to solve the game stuck and to reestablish the chance of progress in the game. The intention of the game stuck rule is to achieve progress with as little intervention as possible, i. e. the *Local Game Stuck* rule will be preferred, but only if there is a chance that its application will result in progress in the game.

### 3.8.1 Local Game Stuck

If one robot is preventing the game from proceeding — perhaps by circling the ball repeatedly without kicking the ball — it is recommended to improve progress by removing this one robot. The head referee calls “Local Game Stuck <robot>” for this robot, which is penalized (see Section 4.7).

### 3.8.2 Global Game Stuck

If no robots have made progress towards the ball or began to explore the field in 30 s Global Game Stuck should be called on the team whose robot is *not* nearest the ball. The referee calls “Global Game Stuck <color>”.

Once the referee calls Global Game Stuck, players enter the Ready state, and a new kick-off is awarded to the team that was closer to the ball when the Global Game Stuck was called. A global game stuck can only be called if at least one robot has touched the ball since the previous kick-off.

## 3.9 Request for Pick-up

Either team may request that one of their players be picked up (called “Request for Pick-up”). In the Playing or Ready state, players may only be picked up for hardware failures. In all other states, players may be picked up for any reason.

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Every change (hardware or software) is allowed during a request for pick-up. In particular, it is permitted to change batteries, fix mechanical problems, reboot the robots, and change configuration files. It is also allowed to replace a broken robot by a substitute robot. It is discouraged to change the robot's control program, **but not forbidden**.

Any strategic "Request for Pick-up" is not allowed. That is, gaining an advantage by removing the robot from the game. In this case, the head referee will indicate when the robot is no longer affecting play and can be removed from the field by an assistant referee.

To prevent mistakes and confusion during games, only team captains (see Section 5.4) should make a "Request for Pick-up", and only one designated person per team shall accept the robot from the referee, and hand it back after fixing the problem. The returning robot may be returned following the normal replacement procedure once at least 45 s have elapsed since the robot was removed from play. Note that this penalty does not follow the standard removal procedure, and hence does not count towards the incremental penalty count. If the picked-up robot was penalized, the penalty time of the robot counts down with the game clock throughout the pick-up.

The robot should be returned to the assistant referees in the *penalized* state. Note here, that the returning robot or the substitute robot will have to wait out any remaining penalty time of the picked up robot after the team handed their robot back to the assistant referees.

### 3.10 Request for Timeout

Each team can call a **maximum of 1 timeout per game** with a total time of no more than **5 minutes**. During this time, both teams may change robots, change programs, or anything else that can be done within the time allotted. During normal game time, a team may call a timeout at any stoppage of play (after a goal, stuck game, before a half, etc.). Alternatively, a team may call a timeout before a penalty shootout if they have not used their timeout yet (see Section 3.15).

The timeout ends when the team that called the timeout says they are finished, at which time they must be ready to play. The other team must be ready to play at the time the timeout runs out, or **2 minutes** after a prematurely called end of the timeout, whichever is earlier. If the other team is not ready to play in time, it has to call a timeout of its own.

The clock stops during timeouts, even during the preliminaries, and is reset to the time when the current stoppage of play began.

After the completion of the timeout, the game resumes with a kick-off for the team which did not call the timeout.

If a team is not ready to play at the assigned time for a game, the referee will call the timeout for that team. After the expiration of such a timeout, if the team is still not ready to play then the referee shall start the game with only one team on the field. The team that was not ready can return its robots to the field as per the rules for "Request for Pick-up". If both teams are not ready, the referee will call timeouts for both teams. This "double timeout" expires after 10 minutes.

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### **3.11 Referee Timeout**

The head official may call a timeout at any stoppage of play if he or she deems it necessary. A referee timeout should only be called in dire circumstances — one example might be when the power to the wireless router is down or no robot listens to the GameController. However, when and whether to call a referee timeout is left up to the head referee.

Referees may call multiple timeouts during a game if needed. Teams may do anything during these timeouts, but they must be ready to play **2 minutes** after the referee ends a timeout. The referee should end the timeout once he or she believes the circumstance for which the timeout was called has been resolved. In cases where the circumstance for which the timeout was called is not resolved within 10 minutes, the chair of the technical committee should be consulted regarding when/if play should continue.

The team who would have kicked off if the timeout had not been called shall kick-off when the game resumes.

### **3.12 Extra Time**

The head official may decide to add time to the clock if a substantial delay (such as an enormous wireless delay) causes excessive game time to be lost. The decision to add time to the clock should be made immediately after the incident. The person working the GameController should execute this addition of time using the GameController interface.

### **3.13 Mercy Rule**

A game will conclude once the game score shows a goal difference of 10. Ending the game is mandatory once a goal difference of 10 is reached.

### **3.14 Rules for Forfeiting**

Teams who do not make a good faith effort to participate in a scheduled game are considered to forfeit the game.

If a team notifies the technical committee that they wish to forfeit less than two hours before their scheduled game time, simply fails to show up for their game, or decides during their game that they wish to forfeit, then the opposing team will play the match against an empty field. However, any own goals will not be scored. Hence, after an opponent forfeits, the team playing against an empty field cannot do worse than they were doing at the time the opponent decided to forfeit. Teams

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may choose to forfeit at any stoppage of play. However, once a forfeit is announced, they may not reverse this decision.

If a team notifies the technical committee that they wish to forfeit at least two hours before their scheduled game time, the following procedure will be followed.

- If a team chooses to forfeit a match in the round robin games the other team plays the match against an empty field. However, any own goals will not be scored.
- If a team chooses to forfeit in a knock-out game it gets replaced by the next best qualified team, i. e. the team it kicked out or left behind in the round robins.

Note that there are a few unlikely cases that are not covered by these rules. If a situation is not covered by these rules, the technical committee and the organizing committee will work together to make a decision.

Any forfeit will result in a qualification penalty being recorded (see Appendix A.6) but the circumstances of the forfeit will affect the severity of the offense and the impact on future qualification.

### **3.15 Penalty Kick Shoot-out**

A penalty kick shoot-out is used to determine the outcome of a tied game when an outcome is required (for example, when team progression is tied on all tie-break factors, during the promotion round, intermediate round, quarterfinals, semifinals, third place or final). There will be a no break between the end of the game and the start of the penalty kicks. As well as no change of robot's code is allowed!

All penalty shots are taken against the same goal<sup>2</sup>. At all stages of the competition, the penalty kick shoot-out will consist of three penalty kicks per team. The first (left) team in the GameController will have the striker robot for the first penalty kick. A team that has scored the most goals at the conclusion of these will be declared the winner. A winner can also be declared before the conclusion of the penalty shoot-out if a team can no longer win. If the two teams remain tied after three penalty kicks, then a sudden death shoot-out will follow until a definite winner is found.

The penalty kick shoot-out starts immediately without changing any code after the second half ended. No timeouts may be called during the penalty shootout. However, a team may request a timeout before the penalty shootout starts if they have a timeout remaining for this game. During timeout code changes are allowed.

Before the penalty shootout begins, each team must hand over to referees up to 6 prepared robots that may participate in the penalty shootout. No robots may be added once the penalty shootout

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<sup>2</sup>Which goal to take for the shoot-out is decided by in accordance with the teams, or otherwise by a coin toss.

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starts. Robots that will not participate in the shootout must not be on the wireless network and must stay outside of the field. All participating robots must be wearing the correct jersey for their player (1-6) and no duplicate numbers are permitted. Before each penalty kick, both teams must select the robot to participate (as goalkeeper or striker) in the penalty kick. The team leader communicates the selection to the head referee by privately handing the referee a card with their chosen number. After both teams have selected their player, the GameController operator selects the requested striker and goalkeeper robots from the opposing teams and the GameController communicates that all non-selected robots are substitutes and should remain inactive.

### 3.15.1 Penalty Kick

A penalty kick is carried out with one striker robot and one opposing goalkeeper. The penalty kick commences with the *set* game state activated. The striker (attacking) robot will be indicated by the GameController, by a suitable flag.

Referees place the ball, the striker, and goalkeeper robots. The ball is placed on the penalty spot closest to the goal being defended. The striker robot is positioned on the edge of the penalty area, facing the ball and the goal. The goalkeeper is placed with its feet on the goal line and in the center of the goal. Neither robot is permitted to locomote (move their legs) during the *set* state. Movement of the robot's head and arms is allowed.

**The usage of a button interface is not permitted.**

The head referee commences the penalty kick by blowing the whistle *once*, and calling "Playing". The GameController activates the penalty kick, switching to the *playing* game state. Note, the playing signal is delayed (see Section 3.2).

The striker robot is only allowed to contact the ball once. The time limit for the striker is 30 s after the penalty kick starts. A penalty shot is over when the ball has come to a full stop after the first contact by the striker robot. A goal is awarded to the attacking team if a goal has been scored (i. e. the ball has completely crossed the goal line). Otherwise, the score is unchanged.

The goalkeeper robot must always be in contact with the goal line and must remain on its feet until the striker robot touches the ball. The goalkeeper is only permitted to "dive", and be off its feet after the attacking robot has touched the ball. If the goalkeeper violates these rules, then a goal will be awarded to the attacking team.

All rules such as "Ball Holding", "Pushing" and others are applied during the penalty kick. A goalkeeper will not be penalized for inactivity during a penalty kick, provided its stiffness is on. Other penalties are applied as usual.

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### 3.15.2 Sudden Death Shoot-Out

Teams take one additional penalty kick each, and the game decision will be made as follows:

1. If only one team scores a goal, that team wins.
2. If both teams score a goal, the sudden death shoot-out is repeated.
3. If neither team score a goal, then a shot blocked by the goalkeeper beats a shot blocked by the goalpost which beats a wide shot. For example, if the shot of one team gets stopped by the goalkeeper and the other executes a wide shot, the first team wins. If both shots fall in the same category, e. g. wide, the shoot-out is repeated.
4. If after 3 sudden death penalty shots there is still no winner, the referee will toss a coin to decide the game.

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## 4 Forbidden Actions and Penalties

The following actions are forbidden. In general, when a penalty applies, the robot shall be replaced, not the ball.

### 4.1 Penalty Procedure

When a robot commits an infraction, the head referee shall call out the **infraction** committed, the **primary jersey color** of the robot, and the **jersey number** of the robot. The penalty for the infraction will be applied immediately by an assistant referee. The assistant referees should perform the actual movement of the robots for the penalty so that the head referee can continue focusing on the game. The operator of the GameController will send the appropriate signal to the robots indicating the infraction committed.

For penalties that are timed, the penalty time is considered to be over at the end of each half.

### 4.2 Standard Removal Penalty

Unless otherwise stated, all infractions result in the removal of the infringing robot from the field of play for a particular amount of time, after which it will be returned to the field of play. This process is called the *standard removal penalty*.

When the head referee indicates an infraction has been committed that results in the standard removal penalty, the assistant referee closest to the robot will remove the robot immediately from the field of play. The robot should be removed in such a way as to minimize the movement of the other robots and the ball. If the ball is inadvertently moved when removing the robot, the ball should be replaced to the position it was in when the robot was removed.

The GameController will send the appropriate penalty signal to the robot indicating the infraction committed. After a penalty is signaled to the robot, it is not allowed to move in any fashion. The removed robot will be placed outside the field facing away from the field of play.

The initial duration of the standard-removal-penalty-time is 45 s. Unless otherwise specified, the penalty time increases by 10 s each time a team commits any infraction.

During the *set* state the penalty time counter will not decrease.

The GameController will keep track of the time of the penalty. The operator of the GameController will signal the assistant referees when the penalty is 10 s from being over, so that one of them can place the robot in the half of the field which this robot's team is defending on the sideline that is farther from the ball. The robot should be placed close to the position where the penalty point projects on the sideline. This is illustrated in Figure 9.

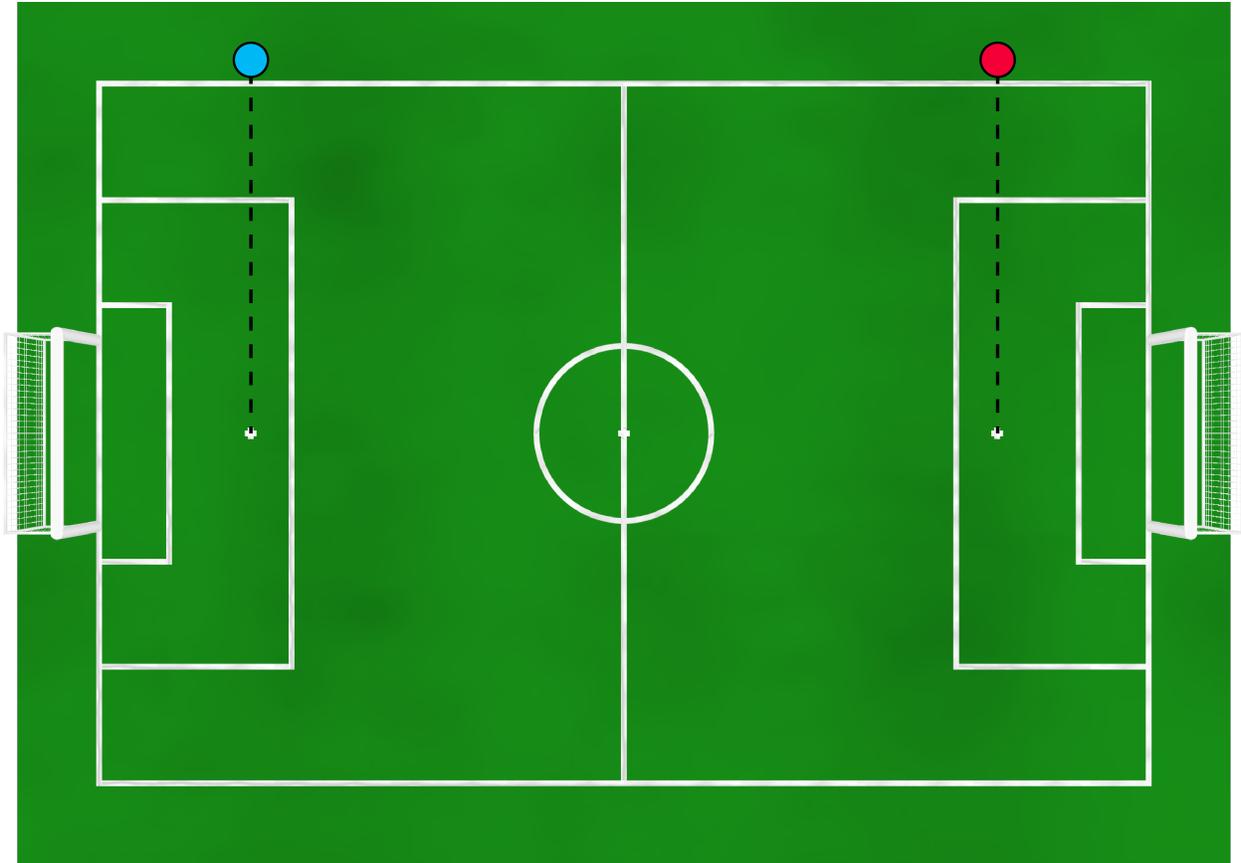


Figure 9: For robots coming back from a standard removal penalty, re-entry points are inline with the penalty spot in their own half, on the sideline on the side away from the ball.

If there is another robot already in this position, the robot should be replaced at a nearby location along the sideline. When finding a nearby location, locations away from the ball should be preferred, but they **must** still be in the robot's own half, so that the symmetry of the field can be resolved by the robot's localization system.

With approximately 5 s left before the penalty ends, the robot should be turned to face towards the opposite sideline.

When the robot is on the field again, the operator of the GameController will send the *playing* signal to it.

### 4.3 Forbidden Actions

The following actions are forbidden, but not treated as penalties. Each forbidden action specifies the actions to be taken by the referees.

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### 4.3.1 Manual Interaction by Team Members

Manual interaction with the robots, either directly or via some communications mechanism, is not permitted. Team members can only touch one of their robots when an assistant referee hands it over to them after a “Request for Pick-up”.

### 4.3.2 Locomotion Type

Robots have to clearly demonstrate bipedal walking similar to human walking. The head referee decides whether a robot’s locomotion is appropriate. Robots using inappropriate locomotion types will be removed via “Request for Pick-up” until they are able to show appropriate locomotion.

### 4.3.3 Damage to the Field

A robot that damages the field, or poses a threat to spectator safety, will be removed from the field for the remainder of the game.

## 4.4 Illegal Positioning

A robot penalized under illegal position has the “Illegal Position” penalty applied. Illegally positioned robots are subject to the standard removal penalty (see Section 4.2). The head referee will call “Illegal Position <robot>”. Referees may interchange “Illegal Position” with “Illegal Defender” or “Illegal Attacker” to help with clarity.

Illegal positions are described below.

For simplicity, Illegal Positioning penalties during the *Set* state (for kick-off or a penalty kick) do not count towards the incremental penalty count.

Refer to Section 1.6 for the definition of *inside/outside* of a region of the field.

### 4.4.1 Before and during Kick-off

If a robot violates the positioning restrictions made in Section 3.5 at the time the Set state starts, it will be penalized and removed for 15 s. If a robot enters the areas of the other team before the ball in *play*, it will be penalized and removed according to the standard removal penalty.

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#### 4.4.2 Penalty Area, at all times

During the **whole** game only *three* players (including goalkeeper) from the *same* team can be the *same* penalty area at the same time. This means a total of 6 robots may in the same penalty area at the same time.

A robot is within the penalty area if any part of its body is touching the ground inside the penalty area or touching one of its lines. The penalty is applied when any additional players (whether field player or goalkeeper) enter the area. Note that if a player is pushed into the penalty area by an opponent, this robot will not be subject to removal, unless it fails to exit the area within 5 s (or 5 s after getting up if the pushing led to falling).

If an illegal defender kicks an own goal, the goal is scored for the opponent. If there is any doubt about whether a goal should count (e. g. the illegal defender infraction is called, but the robot scores the own goal immediately afterwards, before it is removed) then the decision shall be against the infringing robot.

#### 4.4.3 Defender Encroachment during Free-kick

If a robot of the offending team does enter or not attempt to leave the circular area with 0.75 m diameter around the ball after a Free Kick (see Section 3.7) was called, “Illegal Position” is called. Note that the referee should not look for exact distances and rather penalize only those robots who clearly violate this rule. As a guideline, the robots of the offending team should clear the ball within 10 s.

#### 4.4.4 Penalty Area, during Penalty Kick

If a robot that enters the relevant penalty area during a penalty kick, except for the goalkeeper (defending team) and one robot of the attacking team, “Illegal Position” is called.

### 4.5 Motion in Set

Robots may not exit the Set state until either the referee’s whistle is detected or a GameController Playing signal has been received. The head referee will call “Motion in Set <robot>”. The offending robot is penalized *in-place* on the field. They will then be unable to move until they receive the GameController Playing signal. Motion in Set penalties do not follow the standard removal procedure, and hence do not count towards the incremental penalty count.

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## 4.6 Fallen or Inactive Robots

A fallen robot which is unable to autonomously stand up within 2 attempts, or 3 if disturbed externally during the first stand-up attempt, will be penalized and removed for 45 s. In both cases, the head referee will call “Fallen Robot <robot>”. The goalkeeper, inside its own goal area, is the only robot permitted to ‘dive’ (that is deliberately falling in a way that might cause its torso, arms, or hands) to intercept the ball. In all other cases, the robot remain upright – that is, supported by its feet.

A robot that has ceased activity for 10 s or has turned off will be removed and penalized for 45 s. The head referee will call “Inactive Robot <robot>”. A robot is active if it performs at least one of the following:

1. The robot walks in any direction, or turns.
2. The robot searches for the ball, or is looking at the ball.

Fallen/Inactive Robot penalties do not follow the standard removal procedure, and hence do not count towards the incremental penalty count.

**Note:** The intention of this rule is not to penalize robots simply for being stationary – provided they are not ‘asleep’ and have not ‘crashed’.

## 4.7 Local Game Stuck

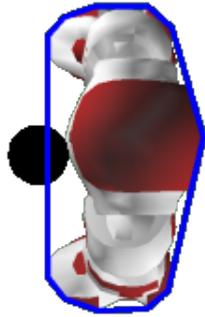
When Local Game Stuck is called, the nearest robot to the ball will be penalized and removed for 45 s. Local Game Stuck penalties do not follow the standard removal procedure, and hence do not count towards the incremental penalty count.

## 4.8 Ball Holding

The goalkeeper is allowed to hold the ball for up to 10 s as long as it has one foot inside in its own penalty area. In all other cases (except those noted in Section 4.8.1), robots are allowed to hold the ball for up to 3 s. Holding the ball for longer than this is not allowed. The head referee will call “Ball Holding <robot>”, and the robot removed under the standard removal penalty. The ball should be removed from the possession of the robot and placed where the penalty occurred. If the robot that held the ball has moved the ball before the robot can be removed, the ball shall be replaced where the penalty occurred. This applies to accidental goals.

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a)



b)



Figure 10: Examples for “Ball Holding”. The black circle is the ball, the blue polygon visualizes the convex hull of the robot’s projection onto the ground and the red area shows the occupied portion of the ball. Situations a) is legal, whereas b) violates the rule.

**Example.** A robot holds the ball, and before the referees can remove the robot, it shoots the ball into the goal. The goal will not be counted, and the ball will be replaced where the penalty occurred,

A robot must leave enough open space around the ball. The occupation of the ball is judged using the convex hull of the projection of the robot’s body onto the ground. “Enough open space” means that at least the half of the ball is not covered by the convex hull. It is not important whether the robot actually touches the ball.

Intentional continual holding is prohibited even if each individual holding time does not continue for up to the time limit. In general, robots should release the ball for approximately as long as they were holding it to reset the clock. Without a sufficient release, the continual holding is regarded as a continuous hold from the very beginning and the holding rule is strictly applied.

#### 4.8.1 Exceptions to the Ball Holding Rules

The following define situations where ball holding does not apply:

1. Ball holding may not occur when the ball becomes stuck between a robot’s legs. In such a situation, the head referee should call ‘clear ball’ and an assistant referee should remove the ball and place the ball approximately where it was before it became stuck.
2. Ball holding may not occur when a robot falls on a ball. The robot will either get up and hence free the ball, or the robot should be removed under the Fallen Robot rule.

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## 4.9 Player Stance

In order to intercept kicked balls the robots are allowed to go into a wide stance as long as it comes back to a normal stance within 5 s. Staying in a wide stance for longer than 5 s will result in the standard removal penalty.

## 4.10 Player Pushing

*Pushing* is a direct or indirect forceful contact with any other opponent robot, i. e., enough to destabilize it, and is not allowed. In the following, exceptions to this rule are specified in more detail. The head referee will call “Pushing <robot>”.

If the ball moves significantly as the result of pushing, then it should be replaced to where it was at the time of the infraction.

A **Pushing Free Kick**, see Section 3.7, is awarded against the robot penalized for pushing

1. if the robot are in an approximately 0.5 m radius around the ball and
2. if the pushed robot was **not** inside the penalty area of the pushing robot.

A **Penalty Kick**, see Section 3.7.1, is awarded against the robot penalized for pushing

1. if the robot are in an approximately 0.5 m radius around the ball and
2. if the pushed robot was inside the penalty area of the pushing robot.

The following exceptions define situations where pushing does not apply:

- Pushing may occur **only** between players of different teams.
- A stationary robot cannot be penalized for pushing, including a robot that is kicking, provided that the ball was close enough where a kick could have succeeded at the start of the kick motion.
- A robot currently getting up cannot be penalized for pushing.
- The goalkeeper cannot be penalized for pushing while looking at or chasing the ball in its own goal area.
- Front to front contact between robots with the ball between them does not constitute pushing.

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- Any robot proceeding to the ball whose side (i. e. arm, shoulder etc.) makes contact with another robot cannot be called for pushing, even if the second robot is not proceeding to the ball.
  - A robot pushed by another robot cannot simultaneously be called for pushing itself. Only the robot, who initially pushed the other robot, will be called for pushing.

#### **4.11 Playing with Arms/Hands**

Playing with arms/hands occurs when a field player (including a defender) or a goalkeeper outside its own goal area moves its arms/hands to touch the ball (except during a fall or get-up). A robot playing with arms/hands will be subject to the standard removal penalty and the ball will be replaced at the point where it contacted the arms/hands of the offending robot. If an own goal is scored as a result, the goal should count and the player should not be penalized.

Accidental playing with arms/hands when a robot falls or executes a get-up routine will not be penalized. If the ball goes out of play in this case, normal kick-in rules will apply (see Section 3.6). However, goals (except for own goals) resulting from a ball contact with the arms/hands during a fall or get-up do not count and result in a Goal Kick (see Section 3.7) as if the ball went over the goal line next to the goal.

#### **4.12 Leaving the Field**

A robot that intends to leave the 7.4 m × 10.4 m carpeted area will be subject to the standard removal penalty (see Section 4.2). The head referee will call “Leaving the Field <robot>”.

Additionally, a robot will also be subject to the standard removal penalty, when:

- The robot walks into the goal posts or goal net for more than 5 s, this includes robots that are stuck on the goal posts and unable to free themselves.
- The robot’s finger become entangled in the net (without any time constraint).

#### **4.13 Jamming**

During a match, any robot shall never jam the communication and the sensor systems of the opponents:

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**Wireless communication.** Each robot is only allowed to send a limited number of UDP messages that have to comply with a predefined format (see Section 2.5.2). If a robot uses a different protocol or sends too much data in a game, penalties will apply. If a team violates this rule in multiple games, disqualification from the tournament (including all technical challenges and side competitions) as well as an entry in the penalty list will be the consequence. Except for the wireless cards and the access points provided by the organizers of the competition, nobody close to the field is allowed using 2.4 GHz or 5 GHz radio equipment (including cellular phones and/or Bluetooth devices).

**Whistle interference.** Both the teams and the audience shall avoid intentionally confusing the robots by producing similar sounds to the game whistle.

**Acoustic communication.** If acoustic communication is used by both teams, they shall negotiate before the match how they can reduce interference. If only one team uses acoustic communication, the robots of the other team shall avoid producing any sound. In addition, both the teams and the audience shall avoid intentionally confusing the robots by producing similar sounds to those used for communication.

**Infrared communication.** If infrared communication is used by both teams, they shall negotiate before the match how they can reduce interference (if at all). Both the teams and the audience shall avoid confusing the robots by producing similar infrared signals to those used for communication.

**Visual perception.** The use of flashlights is not allowed during the games. However, flash photography from the audience is allowable as long as the head referee believes the purpose of the flash is not to jam any of the robots.

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## 5 Judgment

The referees are the only persons permitted on the carpeted area (i. e. the field and the border area).

### 5.1 Head Referee

The head referee is in charge of the game. Any decision of the head referee is valid. The head referee's decision is final and can not be changed afterwards, even by video proof. There is no discussion about decisions during the game, neither between the assistant referees and the head referee, nor between the audience or the teams and the head referee.

The head referee announces decisions by a clear loud call, and (as required) whistle sound. The whistle, or where there is no whistle the first verbal word of the referees calls, defines the point in time at which the decision is made. The referees should make efforts to use consistent and clear calls, and it is preferable for referees to use the calls as specified in these rules<sup>3</sup> The intention of specifying the referee calls is for clarity and consistency across games.

Where a whistle is required, the head referee first whistles and then announces the reason for the whistle. The head referee may choose to use any normal sports whistle. Each whistle sound should be short and not too loud as to interfere with other fields and simultaneous games. The head referee must *only* sound the whistle in circumstances described in these rules. There are three circumstances when the whistle is sounded, Kick-off (see Section 3.5), a goal (see Section 3.3), and ending a half of gameplay (see Section 3.1).

The head referee should avoid handling the ball (except for placing a ball for kick-off), and avoid handling the robots. Their duty is to monitor and adjudicate the game. The head referee should only handle robots and the ball if absolutely necessary to expedite gameplay or removal of penalized robots, where the assistant referees are otherwise occupied or too far away.

### 5.2 Assistant Referees

The two assistant referees handle the robots and the ball. They start the robots if the wireless is not working, they move the robots, if manual placement is requested, they take the robots out when they are penalized, and they put the robots in again. If a team requests to pick up a robot, an assistant referee will pick it up and give it to one of the team members once the head referee approves. An assistant referee will also put the robot back on the field. An assistant referee will also replace the ball when it goes off the field or becomes stuck between a players feet.

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<sup>3</sup>The calls specified in these rules are detailed in English. With the agreement of the teams, the referees may use suitable calls in any language. The exception to this are technical challenge(s) that depends on the calls as specified.

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The assistant referees can *indicate* violations against the rules committed by robots to the head referee, so that the head referee can decide whether to penalize a certain robot or not. Assistant referees should only enter the field to execute a decision made by the main referee. They should not prevent robots from falling during the game.

### 5.3 GameController Operator

The operator of the GameController sits at a PC outside the playing area. As with the head referee, the operator should make efforts to use consistent and clear calls. They will signal any change in the game state to the robots via the wireless as they are announced by the head referee. Note that for both kick-offs and goals, the moment of whistling is determining, not the verbal announcement of the head referee. The operator will also inform the assistant referees when a timed penalty is over and a robot has to be placed back on the field. They should announce when the ball is in play on kick-off by stating “Ball Free”, if the 10 s time period has elapsed in the playing state. They are also responsible for keeping the time of each half (i. e., they stop the clock after a goal or game stuck, and continues it at the kick-off<sup>4</sup>). They should count aloud the remaining seconds in a half once the time remaining is 5 s or less. Finally, they should repeat the calls of the head referee to make sure it was heard correctly.

### 5.4 Referee — Team communication

Both teams send a representative called team captain to the field 5 min before their match starts. This time should be used for welcome each other and discuss match related topics.

During the match only the team captains are allowed to communicate with the head referee. Only the team captains and two more people per team are allowed to stay next to the game controller tables. The rest of the team locates themselves around the other sides of the field if they want to watch the match. This allows the referees easier communication with the team and the game controller operator gets less disturbed.

After the match the teams thank the referees for their duty.

During all phases of the match teams and referees are communicating with respect to each other.

### 5.5 Referees During the Match

The head referee and the assistant referees should wear clothing and socks *of black or dark blue color* (blue jeans are acceptable) and avoid reserved colors for the ball, the goals, and player markings in their clothing. They may enter the field in particular situations, e. g., to remove a robot when applying a penalty. They should avoid interfering with the robots as much as possible.

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<sup>4</sup>The clock may not be stopped during the preliminaries.

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## 5.6 A Remark on Artificial Landmarks

The head referee may decide at any point before or during a game to relocate any objects around the field, or direct persons to another position around the field.

The intent of using same-colored goals is to remove artificial landmarks. Robots should be able to localize with the SPL field and its “normal” surroundings. Introducing new team-specific artificial landmarks is against the spirit and intention of the league’s progress. The application of this rule needs to be well considered and should be reserved for situations which seem constructed by one team or another, but will ultimately be the head referee’s decision alone.

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## A The Official RoboCup Competition Rules

This section contains rules that are not directly relevant for games and that may not apply at local opens. However, these rules will be upheld at the yearly international RoboCup competition.

### A.1 Qualification Procedure and Code Usage

The qualification procedure as well as the corresponding deadlines will be announced by the Technical Committee before qualification applications are accepted.

The RoboCup Standard Platform League offers unique possibilities to use code from other teams. In spirit of the RoboCup every team is generally allowed to use code from other teams to push the league further with their own research. This use must be cited. However, every participant of RoboCup *has a duty* to contribute to the league.

To qualify, every team must make at least *novel contribution* within their soccer software. A team must have made at least one contribution within the last 3 years. Contributions outside of this period are no longer considered sufficiently novel and a team must make at least one *new* contribution. It is also *mandatory* for a team to use their novel contribution in all competition games. A novel contribution is:

- Research publishable contribution to a *game critical module*
- Complete replacement of a *game critical module*, with original software. This may not necessarily be research publishable, but must be of equivalent scale and quality to research publishable work.

It is not a novel contribution to replace a module with code copied from another source, or to simply train a machine-learning model released by another team using new data.

As of the 2022 competition, the following are recognized as game critical modules: Ball detection, Robot detection, Robot vision (not otherwise listed), Localization, Walk/Kick engine, Dynamic stabilization, Behavior Architecture, & Distribution computation, Whistle detection.

As of the 2022 competition, the following are *not* recognized as sufficiently game critical (even if the ability to play soccer depends on these): Hand-written Soccer Behaviors, Natural Language detection, & Robot and GC Communication.

In their qualification application, teams may petition the technical committee to recognize other novel contributions not listed here. Additionally, a team that has participated at RoboCup for at least 3 years consecutively may petition the technical committee to recognize contributions to

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non-game critical modules, such as developing infrastructure for the league<sup>5</sup>. A team may also petition for the technical committee to reconsider the list of game critical and non-game critical modules. Successful petitions will be public ally announced to the league for transparency.

If a team that is otherwise eligible for qualification cannot provide sufficient evidence of the required contributions by the deadline for applications, then that team may be qualified for RoboCup *on probation*. In this case, the team must provide evidence of the required contributions to become *fully* qualified by the registration deadline of the RoboCup event. If no suitable evidence is provided, the team's probationary qualification will lapse.

Every applicant must also bring a poster containing the team's contribution, focused on the current year, to the RoboCup event to share their contributions with the other teams.

Failure to meet any of these requirements will result in a qualification penalty for subsequent years.

## A.2 Game Structure

The clock stops during stoppages of play (such as ready and set state after goals) from the quarter-finals onward. In round robin pool play, a game can finish in a draw as no penalty shoot-out will follow. In the promotion round, intermediate round, quarter finals, semi finals, 3rd place or final, a game that ends in a draw will be followed by a penalty shoot-out (see Section 3.15).

## A.3 Competition mode

Depending on the number of participating teams, the OC and TC create a competition table. The following modes can be selected:

- Group games, with or without intermediate rounds, with concluding knock-out phase
- Double elimination system
- Swiss tournament system
- Swiss tournament system with concluding knock-out phase.

All teams participating in the competition are initially ranked using the Glicko system<sup>6</sup> based on all available results from previous official RoboCup tournaments. (New teams will be ranked equally below all previously competing teams. Teams that participated previously but did not participate in the previous year will be ranked above new teams but below teams that competed in the previous year.)

The OC will announce two weeks before a competition:

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<sup>5</sup>However, the technical committee should balance whether a team is continuing to use their own software in games.

<sup>6</sup><http://www.glicko.net/glicko/glicko.pdf>

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- Competition mode and which competition rules will be applied
  - Initial ranking of participating teams
  - How to determine the overall winner and the ranking of the technical challenges
  - Pre-qualification rules.

## A.4 Referee Selection and Requirements

During pool play, the games will be refereed by members of teams from a different pool.

Each team has to referee a number of games. A schedule will be released specifying the games for which each team is required to provide two referees. Referees should report to the appropriate field at least ten minutes before the game is scheduled to start.

If a team fails to provide two referees for a game in which they are scheduled to provide referees, it will be noted by the organizing committee and recorded as a **qualification penalty** (Appendix A.6).

For each of the games, a team will be required either to provide the head referee and the operator of the GameController, or the two assistant referees. The two teams assigned to referee a game shall decide among themselves which roles each team will fulfill. Note, however, that the head referee and the GameController should always be from the same team.

A team may swap their scheduled refereeing duties with another team, but the team listed on the referee schedule will be held accountable if referees fail to appear for a game they are scheduled to referee.

The requirement to referee may be an extreme hardship for extremely small teams. If a team believes providing two referees for games will be an extreme hardship, they must send an email explaining their situation to the Organizing Committee and Technical Committee at least two weeks before the first set up day of the competition. The Organizing and Technical Committees will then consider the request and attempt to find an acceptable solution.

Referees must have good knowledge of the rules as applied in the tournament, and the operator of the GameController must be experienced in using that software. Referees and the GameController should be selected among the more senior members of a team, and preferably have prior experience with games in the RoboCup Standard Platform league.

In each game, each of the teams playing shall be able to veto one and only one eligible referee with no reason required. The veto must be delivered before the start of the ready phase or during a stoppage of play.

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## A.5 Subsequent Year Pre-Qualification Procedure

Up to 11 teams may become pre-qualified for the subsequent year's team competition by fulfilling one of the following criteria:

- Reaching the given pre-qualification criteria.
- Being the team with the best overall result in the technical challenges that is not pre-qualified by other means, and finishing at worst 5th in the technical challenges.

However, pre-qualified teams must do all the following in order to remain pre-qualified:

- Post in a publicly available location a team research report describing their work for the 2019 competition
- Publicly release code from that year's codebase, either in the form of a complete release (perhaps without behavior) or limited libraries. This release must be documented and coded in a way where it can be used by others.
- Submit a shortened application as required by the call for participation for the subsequent year's competition.

## A.6 Qualification Penalties

There are a number of offenses which lead to qualification penalties being recorded against a team. These are as follows:

- Withdrawing from RoboCup after the final commitment deadline
- Failing to referee when assigned (Appendix A.4)
- Forfeiting a game (Section 3.14)

A team cannot be pre-qualified for RoboCup in the year following a qualification penalty. Furthermore, a qualification penalty is considered by the Technical Committee when reviewing applications and will negatively affect the assessment of a team's application. Multiple penalties accumulate and will result in an even more negative assessment of a team's application. Qualification penalties are considered for a period of three years following the offense.

Whenever a qualification penalty is recorded, all relevant details including any possible mitigating circumstances are also recorded and these will also inform the assessment of a team's application.

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## A.7 Disqualification during Competition

A team may be disqualified during the RoboCup competition for:

- A serious violation of the terms of a team's qualification
- Gaining a Qualification Penalty during the course of the competition (see Appendix A.6)
- A serious breach of ethics, or serious behavior unbecoming of participants of RoboCup.

**Example.** A team promises to use their novel contribution in RoboCup games, but fails to do so. Alternatively, a team deliberately misleads the technical committee about the novelty of their work and/or their contribution to the league, such that they are deemed to have copied another team.

A team can *only* be disqualified by a decision of the *Board of Trustees of the RoboCup Federation*. The RoboCup Soccer SPL executive must petition the board in writing at their soonest possible availability. The executive must simultaneously inform the relevant team of the petition in writing.

A disqualified team automatically forfeits all games (see Section 3.14). For practicality, the disqualification should not apply *retroactively*. However, by majority vote of the team leaders, provisions for retroactive disqualification may be made in the fairness of the affected teams.

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## B Technical Challenges

### B.1 7 vs. 7

This competition extends the ideas from the mixed team competition, and 1 vs. 1 remote challenge from RoboCup 2021 to a standardized 7 vs. 7 on-site competition. Another goal is to enforce more collaborative game play. This challenge will only be executed if at least four teams participate.

#### B.1.1 Condition for participation

- A 7 vs. 7 team can be build from a single team but also from multiple teams.
- Teams need at least four own robots to play with.
- Teams have to provide three tested robots (**only V6 version**) to a robot pool.
- The pool robots have to be calibrated in limited time.

#### B.1.2 Rules

This challenge bases on all rules from the 5 vs. 5 competition (Sections 1 to 5). The following list contains extended and changed rules for this challenge in order to ensure, among other things, the safety of pool robots:

**Players** In total each team consists of 7 players without a substitution robot. The 7 robots consist of 4 own and 3 pool robots. Whereby the pool robots are only V6s. Each jersey shirt has therefore now player numbers between 1 and 7 printed on it (see Section 2.4). Also the new positions of the initial kick-off (see Section 3.4) for 7 robots can be seen in Figure 11. Blue and red jerseys with numbers from 1 to 7 are provided by the OC/TC. If a team decides to play with own jerseys, they have to provide an additional one with number 7 of the same shape.

**Wireless network** The available wireless network package budget defined in Section 2.5.2 will be increase by 40 % both for the initial budget and for the budget for playing time extensions.

**Referees** All referees are allowed to prevent robots from crashing to the ground by catching them beforehand and then laying them down gently. Additionally, the head referee decides whether a robot excessively damages itself and should remove it from the field via a forced “Request for Pick-up”, see Section 3.9.

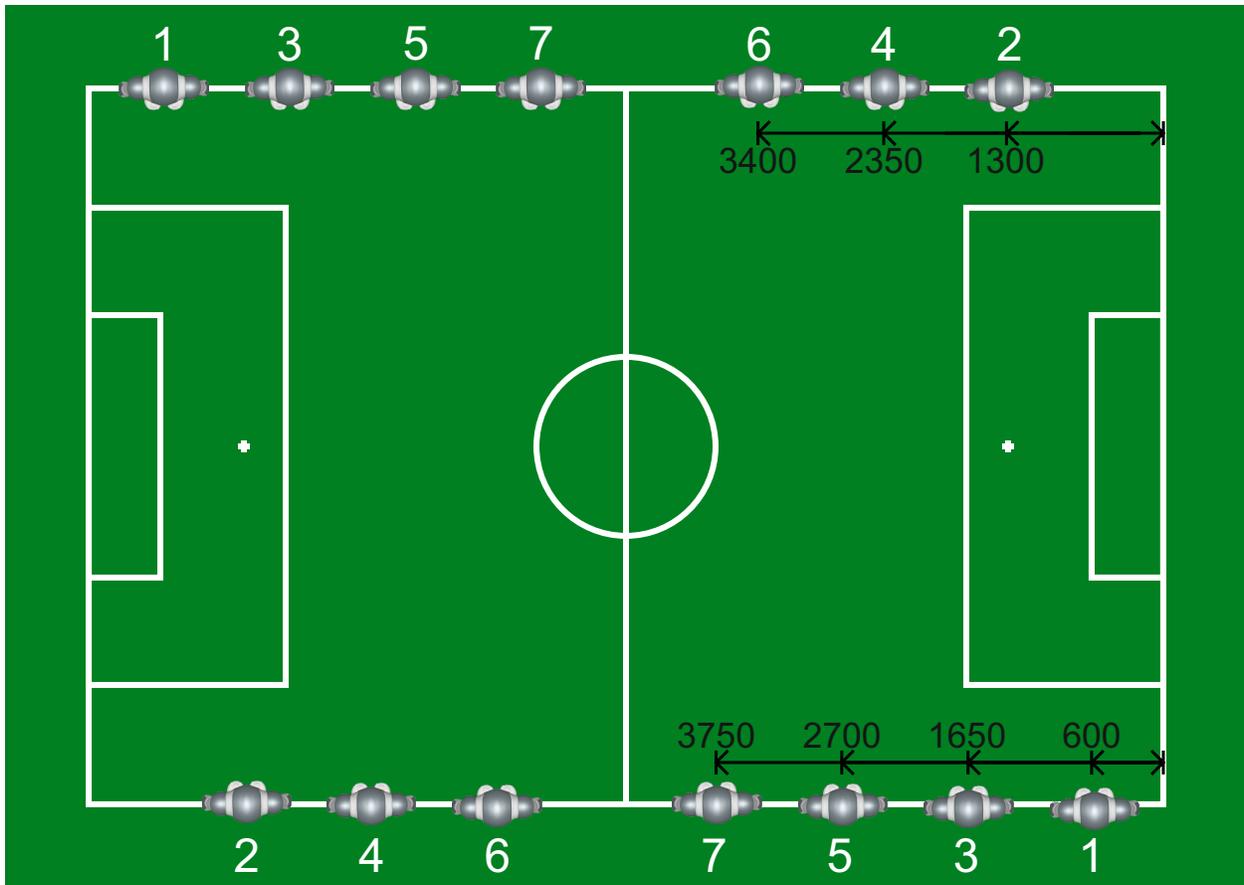


Figure 11: Positions, player numbers and distances from the center of the goal line for the initial kick-off of the 7 vs. 7 robots.

**Robot Pool** Each team has to contribute at least 3 robots to the robot pool, see Appendix B.1.1. If a team cannot provide enough own robots and there are still functional robots in the robot pool, then this team can get more than the 3 robots from the pool to restock up to 7 robots. However, the final decision is still up to the head referee.

The robot pool exists only virtually, so that there is no central location where all pool robots are stored. Each team is also allowed to use their own pool robots when they are not in use. However, each pool robot gets a unique ID and in order to be able to recognize the pool robots visually, a sticker is attached to the outer sides of the upper arms and on the back of the head.

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## Robot usage

All teams using a robot from the robot pool have to take care of the robot and try to prevent any damage from the robot. A safe operation of the robots is paramount. Referees should act to prevent damage to robots, and be proactive in enforcing rules designed to minimize damage. Teams should endeavor to install bug-free and conservative software. This challenge features elements of speed and competitive game play, there are strict consequences for damaging robots, and we hope no team will be prevented from competing due to these reasons. All teams are encouraged to implement features in their code to prevent falling or when falling to fall less destructive. We ask all teams to exchange ideas on that in our *RC-SPL Discord*.

**Robot pool disqualification** All teams using robots from the robot pool are encouraged to implement robot protection features to prevent abnormal amount of damage and falling. The teams providing robots trust in the teams using their robots that all robots are operated with care.

If a team providing a pool robot used in a game thinks that their robot has not been operated with affordable care, this team is allowed to request an “Investigation” by the head referee after the game.

All team captains of the robots used by the team under investigation, the captain of the team under investigation and the head referee meet for the investigation directly after the game. The head referee is leading the investigation. The team which requested the investigation presents their arguments why they think their robot was not used with care. Then all other teams can add arguments or express their view. Finally, the team under investigation can give their arguments. When all arguments have been exchanged, the following options are available:

1. The requesting team revokes their request. No further direct consequences for the team been under investigation. But the team is asked to improve their usage to prevent any future investigations.
2. The team under investigation agrees with the arguments of the requesting team: The team under investigation now gets a penalty card for robot pool usage.
3. The team under investigation disagrees with the arguments of the requesting team: Each team providing robots decides in secret if it wants to vote for a penalty card. Each team providing robots gives their decision to the head referee in secret. The head referee makes the decision public to the team under investigation. If the majority of the teams is for a penalty card, the team under investigation gets a penalty card for robot pool usage.

A team receiving their first penalty card has to improve their code for the pool robots until the next game to prevent future damages. They have to announce their modifications to the teams providing next their pool robots. These teams are allowed to request a pick-up of their robot during the game, if they think that their robot has not been handled carefully. They should give the team,

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the opportunity to change code, to solve the problem. If after a change, the problem is not solved, they are allowed to pick the robot up again for the remainder of the game. With this pick up they have to request an “Investigation”. If a team with a first penalty card, does not receive a penalty card in the following game, the card get removed. If a team receives a second penalty card, it is not allowed to use a pool robot in their next game. After their next game, one penalty card is removed. If a team receives a second penalty card for the second time, they are disqualified from the robot pool for the remainder of the competition.

**USB logging** For logging for remote teams, robots should work with both ext3 or ext4 formatted USB sticks. The USB stick should provide at least 8 GB of free space.

**Robot Pool Evaluation** In order to guarantee that the pool robots are functional, and all parts are working within their limits each team has to provide a proof of functionality one hour before a specific pool robot is planned for a game. Also, the team has to ensure that this robot had at least a cooldown period of 15 min and is charged to at least 80 %. A common robot evaluation image will be provided by the community with a standardized setup procedure (custom image) and with automatic calibration. Afterwards the robot should walk towards a ball and shoot it. If this evaluation is completed without any problems within 2 min and the robot falls down less than 2 times, the evaluation is to be rated as functional. Otherwise, this robot is considered to be non-functional for the time being. Every team can propose such an image up to the 2022-06-01, as well as additional tests which should be included in such an evaluation image. A manual how to use the custom image should also be included.

**Hardware Related Penalties** Since teams are partially playing with robots from other teams, there is a maximum of two hardware related penalties for each robot in the first half and one more in the second half. Hardware related penalties are:

- fallen robot or inactive robot, see Section 4.6
- request for pick-up in the playing or ready state – either by the team or forced by the head referee, see Section 3.9 and Appendix B.1.2.

These penalties are counted by the GameController operator and after that a robot with additional hardware related penalties is excluded for the rest of the game (they are transitioned into the unstuffed state by the assistant referees, see Section 3.2)!

**Own Pushing** In addition to the normal pushing rules, see Section 4.10, pushing may now occur between any robots, i.e., also between teammates.

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**Limited Diving** Pool robots are not allowed to dive for the ball on purpose, see Section 4.6, except for penalty kicks! In case of violation, the infringing robot will be taken out according to the forced “Request for Pick-up” rule, see Appendix B.1.2, and therefore counts as a hardware related penalty, see Appendix B.1.2. However, this restriction does not apply to the team’s own robots.

**Match Phases** Each match consists out of the following phases:

**Robot check** Each team marks and checks its robots sent to the robot pool as described in Appendix B.1.2 and reports its availability (1.5 h before a match starts).

**Setup** One hour before the match starts, the teams receive their randomly selected robots. They have now time for set-up and calibration. For calibration only one half of the field is available for a team. The area within the center circle is not allowed to be entered by the robots until the match starts.

**Game** During a match additional rules apply for the pool robots. Referees are asked to try to save the robots’ hardware by catching them before they crash onto the ground.

**After game** Teams have time of 15 min to return the pool robots to the pool.

**Mode** The mode will be determined after teams have registered. At least 4 teams should register, before the challenge will be executed. The selected mode (e.g., group phase, double elimination, Swiss system tournament) will be determined after teams have registered.

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## B.2 Visual Referee Challenge

### B.2.1 Challenge Goal

In the current SPL rules, the only time that a robot is required to listen directly to the human referees is for the kick-off and goal whistle. Otherwise, all human referee decisions are communicated to the robots via electronic GameController messages. In moving towards the 2050 RoboCup goal, robots will need to directly interpret referee calls and signals (such as whistles, spoken calls and hand signals), rather than receive information from an external electronic source.

This technical challenge tests a robot’s ability to identify three categories of hand signals:

1. Static hand signals with one hand.
2. Static hand signals with two hands.
3. Dynamic (motion) hand signals with one or two hands.

The intent of this challenge is to choose a *subset* of potential referee calls in SPL games and test ability of a robot to recognize different types of hand signals in preparation for adoption in RoboCup games, rather than compile a complete set of all referee signals.

### B.2.2 Challenge setup

One robot of the challenged team is placed in the center of the center circle facing the head referee, standing upright (stiffened) with both hands by its side. The robot should be running in the challenge mode at the start of the challenge. The team is free to choose how the software is started.

The head referee must stand on the T-junction of the center field line, opposite to the GC. The referee must wear a “black-and-white” striped referee jersey (if available otherwise fully black clothes) and must wear red gloves. The purpose of this clothing is to clearly distinguish the referee and their hands from background people.

The description of this challenge and hand-signals are described based on the viewpoint of the head referee. In these descriptions from the perspective of the head referee the “red team” is defined as playing from left-to-right, and the “blue team” as playing from right-to-left. The use of colors for identifying teams is used to give equivalence to the head referee calls during SPL games see Figure 12.

This challenge has *five* rounds. The referee should choose 2 one-hand static signals, 2 two-hand static signals, and 1 dynamic signal. Within each type, the referee randomly chooses a hand-signal and direction. The same hand-signal may be chosen twice (with different directions). The referee should decide before the execution of the challenge starts on each runs signals and direction pair

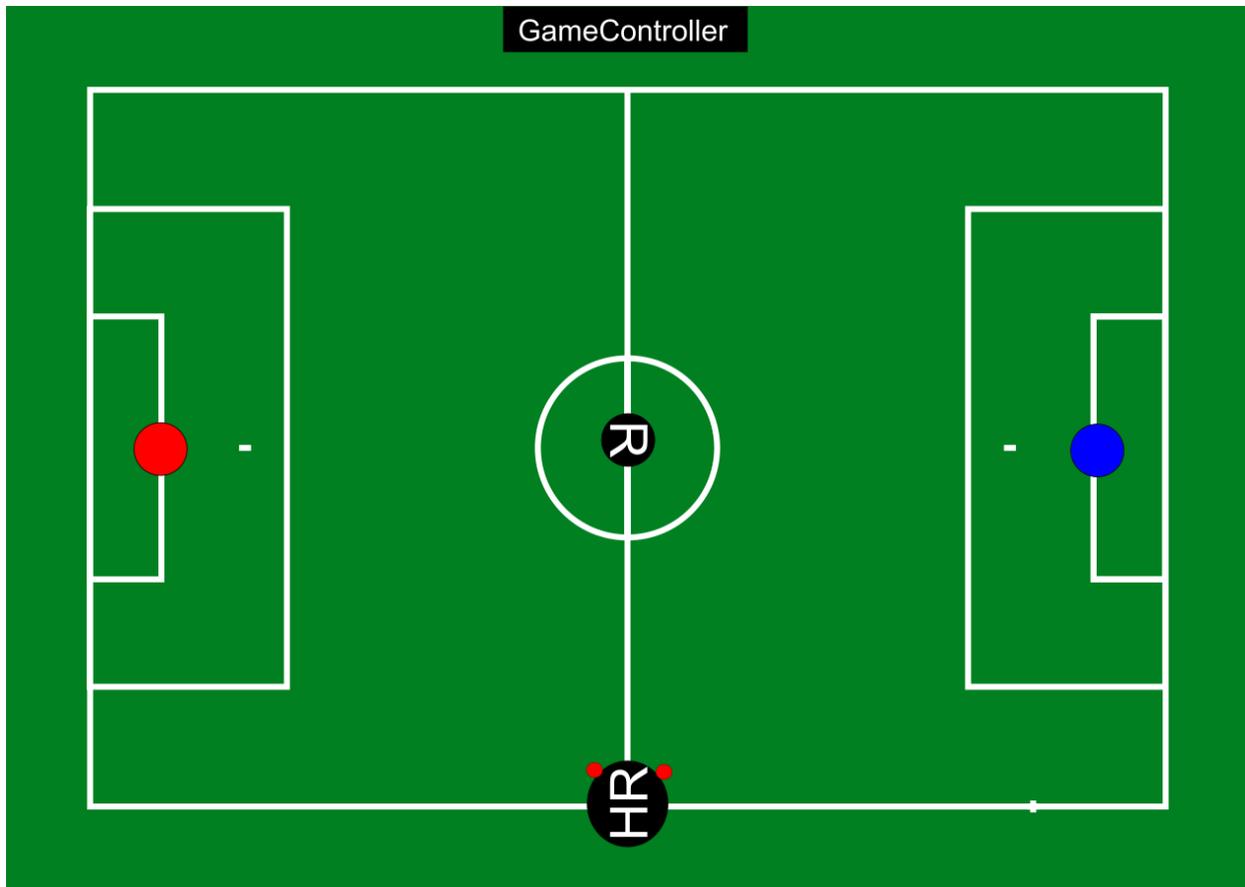


Figure 12: Positions of red, blue team's sides, challenged robot and head referee.

and note them down. An assistant supports the referee by showing the signal and direction, taking the timing and is also listening to the answer of the robot.

Each run works as follows:

1. The referee selects a hand-signal (and direction where applicable).
2. The referee blows the whistle once. The referee may not use one hand to hold (and blow) the whistle. The referee may instead leave the whistle held in their mouth without their hands.
3. 1 s after blowing the whistle, the referee indicates the hand-signal for 10 s.
4. During that time or within an additional 10 s, the robot must indicate the hand-signal that it has identified by:
  - (a) Using its arm(s) to *mirror* the referee's signal. That is, if the referee gives a signal for a decision for the "red team" using their left arm, the robot should *mirror* this signal using the robot's *right arm*, as the robot is facing the referee.

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- (b) Providing an audio phrase the referee’s decision, e.g., “Goal Red Team”. The exact wording is up to the team, but should clearly identify the referee’s signal.
  - (c) The robot’s gesture and voice output should be repeated until its front head button gets pressed for at least 1 s to indicate that the next round will start, and the robot moves back into its initial position. This should give the referee time to understand the robot’s answer clearly.
5. The length of time taken for the robot to indicate its interpretation from the referee blowing the whistle is measured (rounded-up to the nearest second).
  6. If the robot cannot identify the signal, it should remain motionless and provide no audio output.
  7. While not providing a hand-signal or using the whistle, the head referee must keep both hands flat and motionless by their side.

### B.2.3 Available Hand-Signals

Each hand-signal for the challenge is **described from the perspective of the head referee and pictured from the perspective of the robot**. Note that for the purpose of clarity, these do not necessarily correspond to human soccer hand-signals.

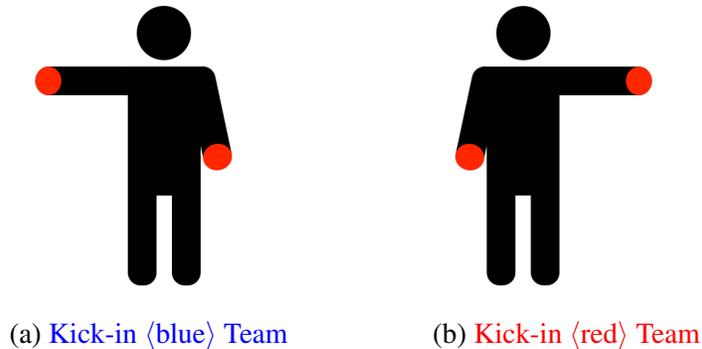


Figure 13: **Kick-in <color> Team**. One-handed signal. One arm, extended horizontally in the direction of the half of the field corresponding to the team that receives the Kick-in Free Kick. That is, right arm extended for the “Blue team”, and left arm extended for the “Red team”. The non-signal hand is flat and motionless by the side of the body.



(a) Goal Kick ⟨blue⟩ Team



(b) Goal Kick ⟨red⟩ Team

Figure 14: **Goal Kick** ⟨color⟩ **Team**. One-handed signal. One arm, extended 45-degree *up* in the direction of the end of the field where the goal kick will occur. That is, right arm extended for the “Blue team”, and left arm extended for the “Red team”. The non-signal hand is flat and motionless by the side of the body.

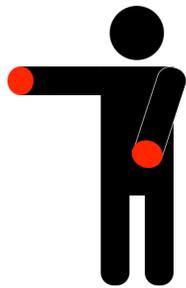


(a) Corner Kick ⟨blue⟩ Team  
(on the half of the red team)

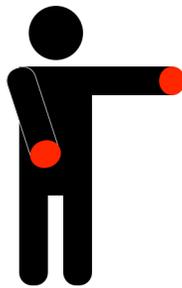


(b) Corner Kick ⟨red⟩ Team (on the  
half of the blue team)

Figure 15: **Corner Kick** ⟨color⟩ **Team**. One-handed signal. One arm, extended 45-degree *down* in the direction of the team executing the corner kick. That is, right arm extended for the “Blue team” executing the corner kick on the “Red team’s” side, and left arm extended for the “Red team” executing the corner kick on the “Blue team’s” side. The non-signal hand is flat and motionless by the side of the body.



(a) Goal  $\langle$ blue $\rangle$  Team

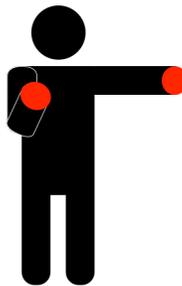


(b) Goal  $\langle$ red $\rangle$  Team

Figure 16: **Goal  $\langle$ color $\rangle$  Team.** Two-handed signal. One arm, extended pointing at the center circle. Other arm, extended horizontally in the direction of the half of the field corresponding to the team that scored the goal. That is, right arm extended for the “Blue team”, and left arm extended for the “Red team”.



(a) Pushing Free-kick  $\langle$ blue $\rangle$  Team because a red robot has pushed.



(b) Pushing Free-kick  $\langle$ red $\rangle$  Team because a blue robot has pushed.

Figure 17: **Pushing Free-kick  $\langle$ color $\rangle$  Team.** Two-handed signal. One arm, vertical with bent elbow and palm facing in the direction of the extended arm. Other arm, extended horizontally in the direction of the half of the field corresponding to the team that is *executing* the Free-kick. That is, left arm extended for the “Red team”, and right arm extended for the “Blue team”.

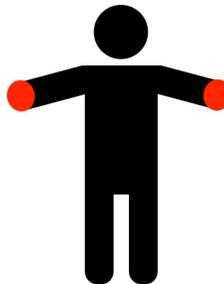
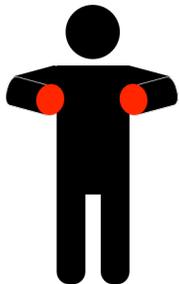


Figure 18: **Full-Time.** Dynamic two-handed signal. Both arms slowly move symmetrically inward and outwards on a horizontal plane, bending at the elbows. Note, for the purpose of this challenge, the whistle associated with this signal should be a *single* blow, unlike in normal SPL games.

---

#### **B.2.4 Challenge evaluation**

A team scores 1 point for every hand-signal that is correctly identified. A team scores an additional 1 point for correctly identifying the team corresponding to the signal (where appropriate: For a correct recognized *Full-Time* signal without announcing a team, the team gets also 1 point for the team color). A team loses 1 point for incorrectly identifying a hand-signal (note a team may have a negative final score). The total time for the robot to identify each hand-signal is summed (If a robot fails to identify a hand-signal the time for the hand-signal is 10 s. If a robot incorrectly identifies a hand-signal, the time is how long the robot took to provide the incorrect identification).

Teams are ranked by their total points. In the event of tie-breaks, the team with the fastest total time to identify all hand-signals is ranked higher. The team with the highest total points, and lowest total time (for tie-breaks), wins the challenge.

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## B.3 Dynamic Ball handling Challenge

This challenge extends the idea of RoboCup 2021's Passing Challenge. The purpose of this challenge is to enhance skills in ball passing and handling, and in robot's movement estimation.

### B.3.1 Challenge Goal

Score a goal as the attacking team after a double pass without letting the defending players touch the ball. To allow a fast attack, robots are given the ball in a way that allows the robots to pass the ball towards the next target without walking backwards or turning.

### B.3.2 Challenge Setup

This challenge uses a standard SPL field, with GameController and 3 attacking robots provided by the challenged team and three defending robots operating a provided common image (see Appendix B.3.6) from another team. If more than one image exists, then multiple images will be provided and for each run a new one will be randomly selected.

Attacking teams have to have their robots ready 40 min before the challenge starts. Attacking robots are not allowed to be modified afterwards (except a robot breaks, but even then the code should remain the same except for some necessary parameters). Attacking robots are stored switched off at a designated place until the challenge starts. A randomly selected common defender image is assigned to each team. They have to set up the image for their defending robots. In the remaining time the defending robots have to be flashed and calibrated. Teams have to practice setting up defending robots.

Since the challenge has three runs for each team, each team will be teamed with another team for a run. Following from this each run is divided into two phases. Executed after each other. For the first phase of a run the first mentioned team brings their three attacking robots and the other team provides the defending team. During the second phase teams switch their robots respectively.

After the first and second run, attacking robots must be switched off and stored at the designated place.

The robots are placed by the referees with some randomness to left or right facing the opponent's half as follows:

**Attacker:** 1st: goal area front line (Player No 1); 2nd: next to center line left of center circle (Player No 2); 3rd: next to center line right of center circle (Player No 3).

---

**Defender:** 1st: within center circle (Player No 3); 2nd: front line penalty area (Player No 2); 3rd: goalkeeper in the middle between the two goal posts (Player No 1). Defending robots are limited to a maximum speed of  $20 \text{ cm s}^{-1}$ .

**Ball:** On penalty spot of the attacking team's side

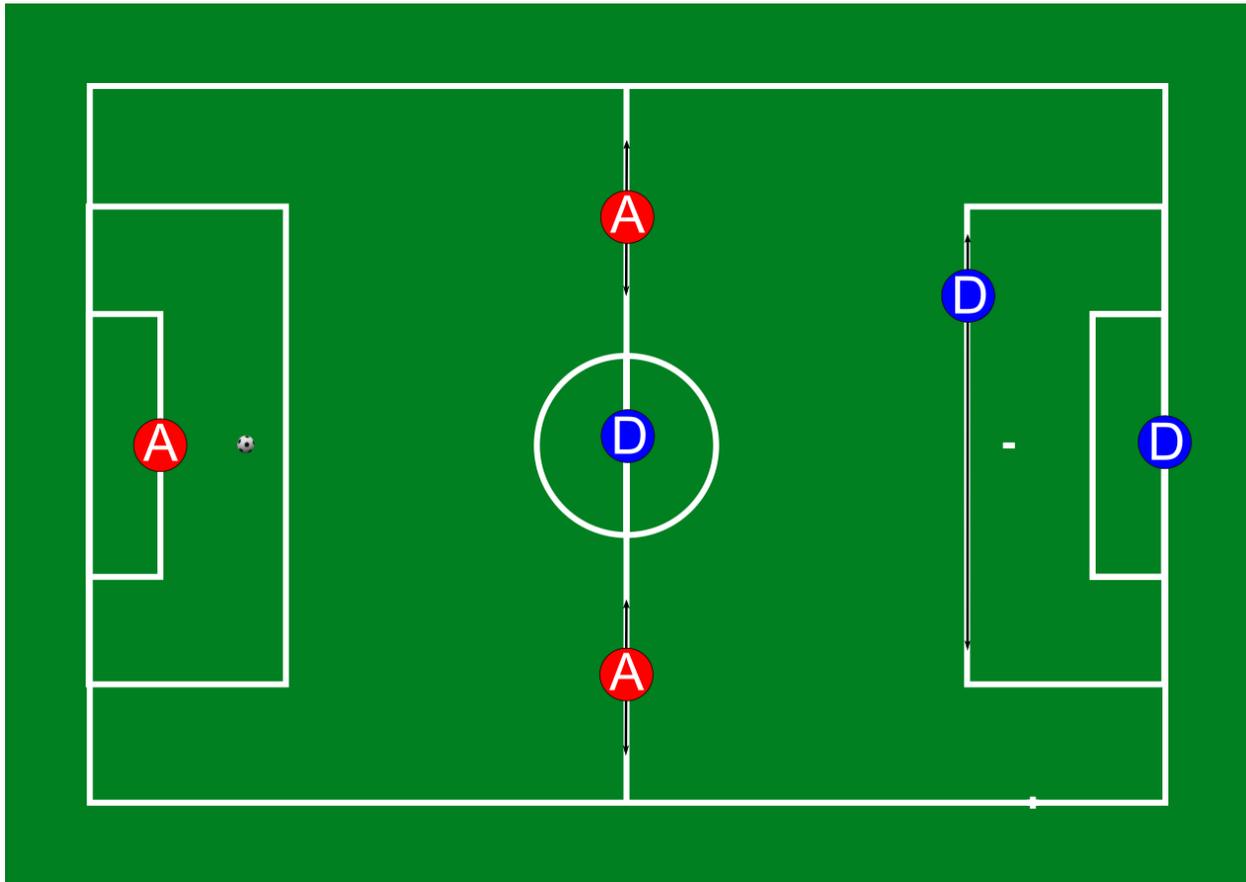


Figure 19: Possible positions of the **attacking (red)** and **defending (blue)** robots at the beginning of the challenge. All robots are facing their opponent's half.

Each team has three runs during this challenge.

### B.3.3 GameController

All robots have to communicate with the GameController. There is a special mode in the GameController for this challenge.

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### B.3.4 Challenge Execution

In `Initial` the robots get placed at their randomized starting positions, see Figure 19. The `GameController` switches from `Ready` directly into `Set`. The ball gets placed, and the head referee starts the run with one whistle blow, like at kick-off. If a robot does not listen to the whistle, it will receive the `Playing` signal from the `GameController` after a delay.

In `Playing` the following happens: The 1st attacker passes the ball towards the 2nd or 3rd attacker while he is under attack by the 1st defender. After the 2nd or 3rd attacker received the ball, and the ball is in the defender's half, it gets attacked by the 2nd defender. Next, the 2nd or 3rd attacker passes towards another robot, which tries to score a goal. The 1st defender does not walk back in its own half and the goalkeeper remains on the goal line and is not allowed to dive. The objective of the defending team is to intercept the passes, see stopping criteria.

All robots are allowed to move and dribble.

A pass counts as a **(semi-)valid** pass:

1. The ball has been kicked by a robot who has a minimum distance to the receiving robot of 2.5 m
2. and one of the following happens:
  - (a) The ball stops in a circle with radius 1.0 m around the receiver, but not within the arc defined in the next point (**semi-valid** pass: half the penalty of an invalid pass, i.e. 20 s).
  - (b) The ball stops in an 180° arc with radius 1.0 m around the receiver facing the next target either next receiver or opponent's goal, so the receiving robot does not have to move backwards to pass or to shoot a goal (see Figure 20).
  - (c) The ball is without stoppage played in the direction of the next target either next receiver or opponent's goal. Target direction is defined as a 90° cone towards the next target.
  - (d) The ball gets intentionally deflected by the receiving robot in the direction of the next target either next receiver or opponent's goal. Target direction is defined as a 90° cone towards the next target.

All rules from the normal gameplay still apply. Only the standard removal penalty time gets extended to 240 s. If a defender pushes an attacking robot, the attacking team gets a time bonus of 15 s.

### B.3.5 Challenge Scoring

In each phase of a run the `GameController` measures the execution time from initial whistle until the run is stopped by one of the following criteria:

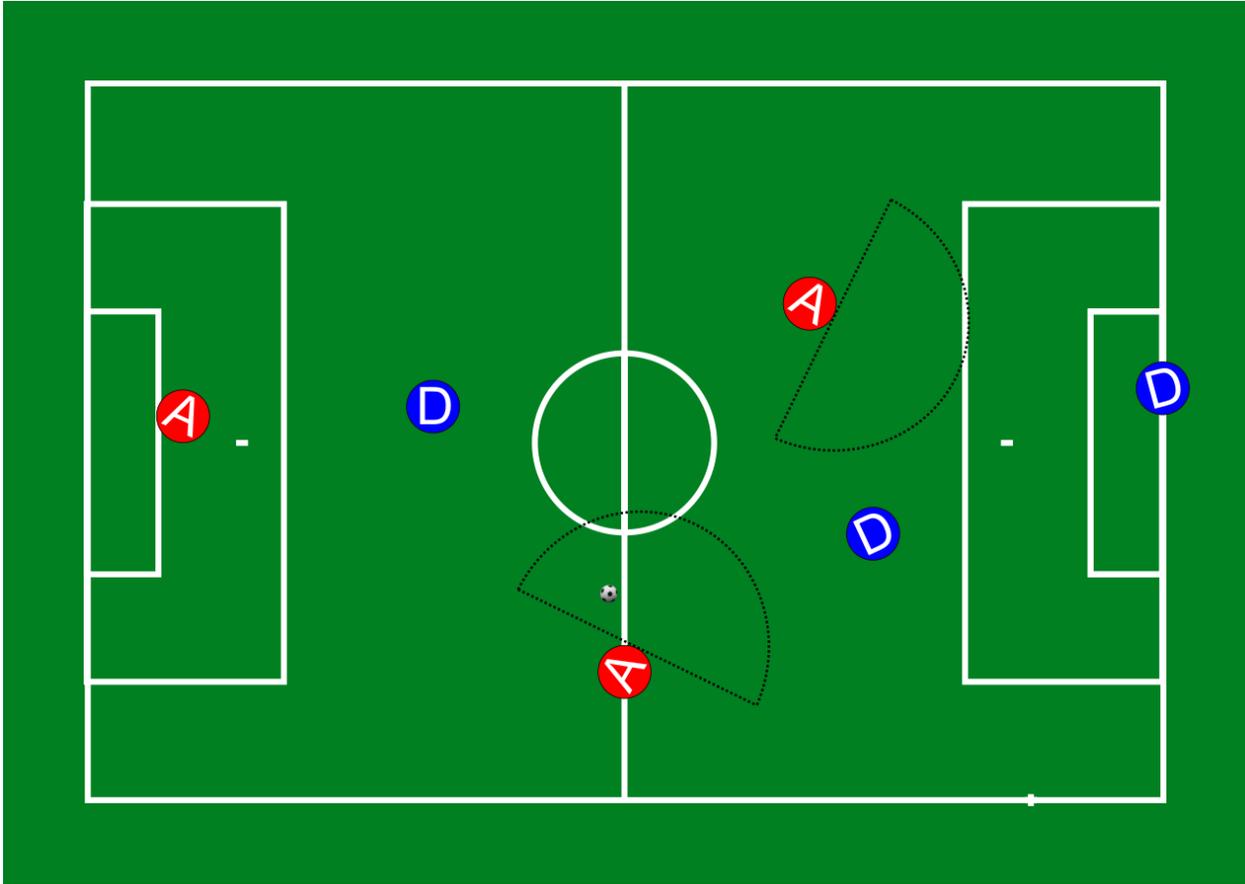


Figure 20: Possible challenge situation with **attacking robots** already oriented towards their targets. The arcs for a valid pass are indicated with dashed line style.

- A defender touches the ball.
- An attacking robot leaves the field.
- Ball leaves the field outside the defending goal area.
- An attacker pushes.
- A run exceeds 4 min execution time.
- A goal is scored after at least two passes out of this list have been executed:
  - valid pass,
  - semi-valid pass,
  - substantial pass attempt: Ball covers a distance more than approx. 2.0 m.
- Attacking team is not communicating with the GameController.

---

In the case that a goal gets scored before two passes (see list above) were executed, or the ball leaves the field within the defending goal area, the ball gets placed on the closest goal kick spot.

The score for the attacking team in a run will be calculated based on the following rules:

1. The time measured counts.
2. If an attacking robot has been pushed by a defender, subtract 15 s.
3. If a goal has been scored after two passes, subtract 30 s.
4. For each invalid pass, add 40 s.
5. For each semi-valid pass, add 20 s.
6. If the ball got touched by the 1st or 2nd defender, execution time will be 240 s.
7. If the ball leaves the field outside the defending goal area, execution time will be 240 s.
8. If an attacking robot has pushed, execution time will be 240 s.
9. If a team is not communicating with the GameContoller, execution time will be 240 s.

The final score is the mean time out of three runs.

### **B.3.6 Challenge image**

A common image will be provided by the community with the standardized setup procedure and with automatic calibration. Every team can propose such an image until 2022-03-15. The image will be tested until 2022-03-31 if they match the requirements and afterwards published if not the team gets feedback and has the opportunity to hand in a revised image.

1. One image applying to the standard button interface, using autonomous calibration and receives it player number through a text file on USB-stick.
2. Existence of documentation on how to flash, how to operate a robot, how to handle issues.
3. Does it apply to the rules?
4. Does it operate robustly?
5. Does it attack according to the rules?

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## B.4 Open Research Challenge — Video analysis / statistics

In order to evaluate the progress of the league, regardless of the annual rule changes, we need statistics similar to human soccer. Therefore, only GameController/TeamCom statistics are not sufficient for this. That's why there is an Open Research Challenge, as already known from the year 2019 (and previously until RoboCup 2014), which will focus on the generation of statistics from external video data from a go-pro type camera viewpoint.

### B.4.1 Challenge Goal

For this Open Research Challenge two major goals exist. The more short-term goal is to calculate extrinsic camera parameters (camera matrix) from the camera feed and to locate/track all moving objects (ball, robots) on the field. In addition to this, the more long-term goal involves the creation of game statistics based on the located objects and positions from the short-term goal. Here, the following statistics, among others, might be of interest, such as time under control, shots on goal (successful/unsuccessful), passes and so on. Since this is an open challenge, the decision of what to show (short-term, long-term, parts of it) is, within the scope of the goals aforementioned here, entirely up to the teams. In addition, the execution time for this challenge is also not relevant for the time being whether you process it online or offline to the video stream.

### B.4.2 Condition for participation

- In order to compete in this Challenge, teams must notify the TC (`rc-spl-tc@lists.robocup.org`) of their interest in participating by 2021-12-31, at the latest.
- Subsequently, all participating teams will receive a pre-processed video from the RoboCup2019 (i.e. a sequence of images) and have to label it according to the enclosed instructions. Annotating must be completed by 2022-02-01 in order to form a shared ground truth data set. The exact details are given to the teams together with the to be labeled data set.
- The annotations should be saved and uploaded as a single file per image sequence (so only one file per participating team) in the CSV format where the columns must be as follows:

filename	label	x <sub>min</sub>	y <sub>min</sub>	x <sub>max</sub>	y <sub>max</sub>	jersey color	jersey number
test.jpg	0	0	0	1919	1079	0	100
test.jpg	1	300	300	400	400	-1	-1
...	...	...	...	...	...	...	...

Thus this CSV file would look like that:

```
test.jpg,0,0,0,1919,1079,0,100
test.jpg,1,300,300,400,400,-1,-1
```

- 
- With this shared ground truth data set, teams can then implement their own approach/ideas. Also any failures in the annotations can be corrected by the community/teams since the data will be shared on the SPL Github<sup>7</sup>.
  - The teams have to create a poster (A3 or A2 size) for the RoboCup 2022 showing their results and prepare a short 3 minutes oral presentation which additionally explains and shows the idea and results of this approach. If there is a GameState monitor on site, it can be used for a presentation. However, this depends on the location and the teams should be prepared to give their presentation only with their poster if necessary.
  - All teams are requested to publish the code for their approach to enable a fast progress of the league in this area. However, only the top 3 ranked teams are required to publish their code with instructions within one month after the RoboCup 2022.

### **B.4.3 Scoring**

The winner will be decided by a vote among the SPL teams using the Borda count mechanism ([http://en.wikipedia.org/wiki/Borda\\_count](http://en.wikipedia.org/wiki/Borda_count)). Each participating SPL team will vote for their top 5 teams in order (excluding themselves).

Teams are encouraged to evaluate the performance based on the following criteria:

- Achievement of the long/short-term goal,
- execution time (and hardware requirements),
- metrics (accuracy/precision/recall),
- technical strength and
- novelty.

At a time decided by the designated referee, within one hour of the last demonstration if not otherwise specified, the captain of each team will submit the team's rankings by filling out an online form. Any points awarded by a team to itself will be disregarded. The points awarded by the teams will be summed and thus form the score of this challenge which is then converted according to the formula described in the beginning of this section.

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<sup>7</sup><https://github.com/RoboCup-SPL>

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## B.4.4 Labelling

This section gives a brief overview of the labelling task.

Input data (given):

- The assigned, pre-processed, go-pro videos/sequences from a game of the RC2019. These are not whole halftimes but only an excerpt of 5000 frames (at 30FPS this means about 2:42 min of continuous playing time).
- Additionally the GameController data, TeamCom logs and the intrinsic parameters of the go-pro are given.

Output data (to be annotated):

- Labelling of all robots participating in the game and the (main) ball: These objects should be labeled using bounding boxes, characterized by the top-left and bottom-right corner. Special attention should be paid to the bottom edge as this will be used to determine the position of the object.
- In addition, the robots must be labeled with their jersey color (as number based on the GC assignment<sup>8</sup>) and jersey number. However if the jersey number is not identifiable an ID starting with the number 100 and upwards should be used instead to clearly identify this robot in the sequence.  
*Note:* It could happen that you can't identify a robot and therefore give it an unique ID  $\geq 100$  and later you see its player number. Then this robot should also get its jersey number retroactively for all previous frames instead of the ID  $\geq 100$ .

The calculation of the extrinsic camera parameters (camera matrix) is optional.

Also not everything is fixed yet so that the TC is happy to accept suggestions at `rc-spl-tc@lists.robocup.org`.

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<sup>8</sup><https://github.com/RoboCup-SPL/GameController/blob/RoboCup2021/include/RoboCupGameControlData.h#L15>

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## C Changes From 2019

This is a brief non-normative list of rule changes from 2019 to 2022.

- Increased penalty area size and replaced old penalty area with goal area (Figure 1)
  - Moved goal kick position to corner of goal area (Section 3.6)
  - Moved striker position in penalty shoot-out to edge of penalty area (Section 3.15.1)
  - Removed exception for goalkeeper approaching the ball in a free kick (Sections 3.7 and 4.4)
  - Goalkeeper pushing (Section 4.10), diving (Section 4.6), and playing with hands (Section 4.11) is still only allowed in its own *goal area*
- Limited number of team messages per team per game (Section 2.5.2)
- Dysfunctional wireless results in referee timeout, button interface cannot be used (Section 3.2)
- Added robot states *Unstiff* and *Calibration* (Section 3.2)
- Robots have to sit down in *Finished* (Section 3.2)
- Added Invalid Goal / Indirect Kick Rule (replacing and extending kick-off shot penalty) (Sections 3.3.1 and 3.3.2)
- Added Penalty Kick as consequence for a foul by a player in its penalty area (Section 3.7.1)
- Specified all referee calls and whistle signals and locations
  - GC signal is delayed by 15 s after a goal (Section 3.3) and in penalty kick shoot-out (Section 3.15.1)
  - Whistle interference is jamming (Section 4.13)
- Changed kick-off rules
  - Standard poses for initial kick-offs (Section 3.4)
  - Kick-off taker may be in opponent half's part of center circle (Section 3.5)
  - Legal kick-off area may not be left before ball is in play (Section 3.5)
- Removed manual placement (Section 3.5)
- No break before penalty shoot-out (and therefore no software changes) unless a timeout is taken (Section 3.15)
- Penalty goalkeeper must always be in contact with the goal line and may not dive before striker touched the ball (Section 3.15.1)

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- Illegal Positioning penalty supersedes and extends Illegal Defender (Section 4.4)
    - Limited number of players per team per penalty area to 3, applies to both penalty areas
  - Fallen Robot is defined in terms of number of get-up attempts instead of time (Section 4.6)
  - Leaving the Field includes walking into the goalposts (Section 4.12)
  - Changed qualification procedure and code usage rules (Appendix A.1)
  - Added possibility of disqualification during competition (Appendix A.7)

# D Field Technical Drawings

