Rules of the RoboCup Small Size League

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References to the male gender in the rules with respect to referees, team members, officials, etc. are for simplification and apply to both males and females.

1. League Overview

1.1. Committees

The Small Size League (like every other league of the RoboCup) is run by close cooperation of three different committees (executive committee, technical committee and organizing committee), all with a different set of responsibilities. The members of the respective committees can be found on the official RoboCup Small Size League website (https://ssl.robocup.org).

In practice, there is no strict separation between the technical and the organizing committee. Members of both committees often work together on the joint set of tasks.

Additionally, the members of the local organizing committee organize the RoboCup event for all leagues.

1.1.1. Executive Committee

Executive committee members are responsible for the long term goals of the Small Size League and thus have also contact to other leagues as well as to the RoboCup federation. The executive committee presents the Small Size League and its achievements to the RoboCup federation every year and gets feedback to organize the league. Executive committee members are elected by the board of trustees of the RoboCup federation. They serve 3-year terms.

1.1.2. Technical Committee

The technical committee of the Small Size League is responsible for the technical aspects of the RoboCup, such as maintaining the rules and the shared software. All members are elected by the team leaders of the teams which have participated in the previous competition.

1.1.3. Organizing Committee

The organizing committee of the Small Size League is responsible for preparing and organizing the competition. This mainly includes making the schedule, performing the qualification process, and running the competition. The committee members are selected by the executive committee of the league and the RoboCup trustees.

1.1.4. Local Organizing Committee

The local organizing committee is responsible for planning and executing the event itself in accordance with the needs of the different leagues. This includes setting up the team areas (fields, network, tables, whiteboard, screens, etc.), creating a schedule for the event and implementing a safety and security concept.

1.2. Divisions

The Small Size League is divided into two divisions with separate tournaments, namely division A and division B. Division A is aimed at advanced teams whereas new and/or less competitive teams can play in division B. Each team will only play in one of those two divisions.

When submitting the qualification material, the team also chooses a preferred division including a short rationale. The members of the organizing committee will have the final word. Information about the qualification process can be found on the official RoboCup Small Size League website (https://ssl.robocup.org).

A summary of differences between the two divisions can be found in the Appendix.

Divisions allow for more radical advancements in the Small Size League without drastically raising the entry barrier for new teams. Additionally, they also considerably increase the amount of matches between teams of similar skill.

2. Playing Environment

2.1. Field Setup

2.1.1. Dimensions

The field of play must be rectangular and of the following size:

- Division A: 13.4 meters times 10.4 meters with a playing area of 12 meters times 9 meters
- Division B: 10.4 meters times 7.4 meters with a playing area of 9 meters times 6 meters

The exact field dimensions and the field markings at the venue may vary by up to ±10% in each linear dimension.

The two figures below show the dimensions of the field, the goals and special field areas, measured in millimeters between the line centers. Figure 1 shows the dimensions for division A and figure 2 for division B.

The numbers in the figures below show the distances in millimeters between the line centers.

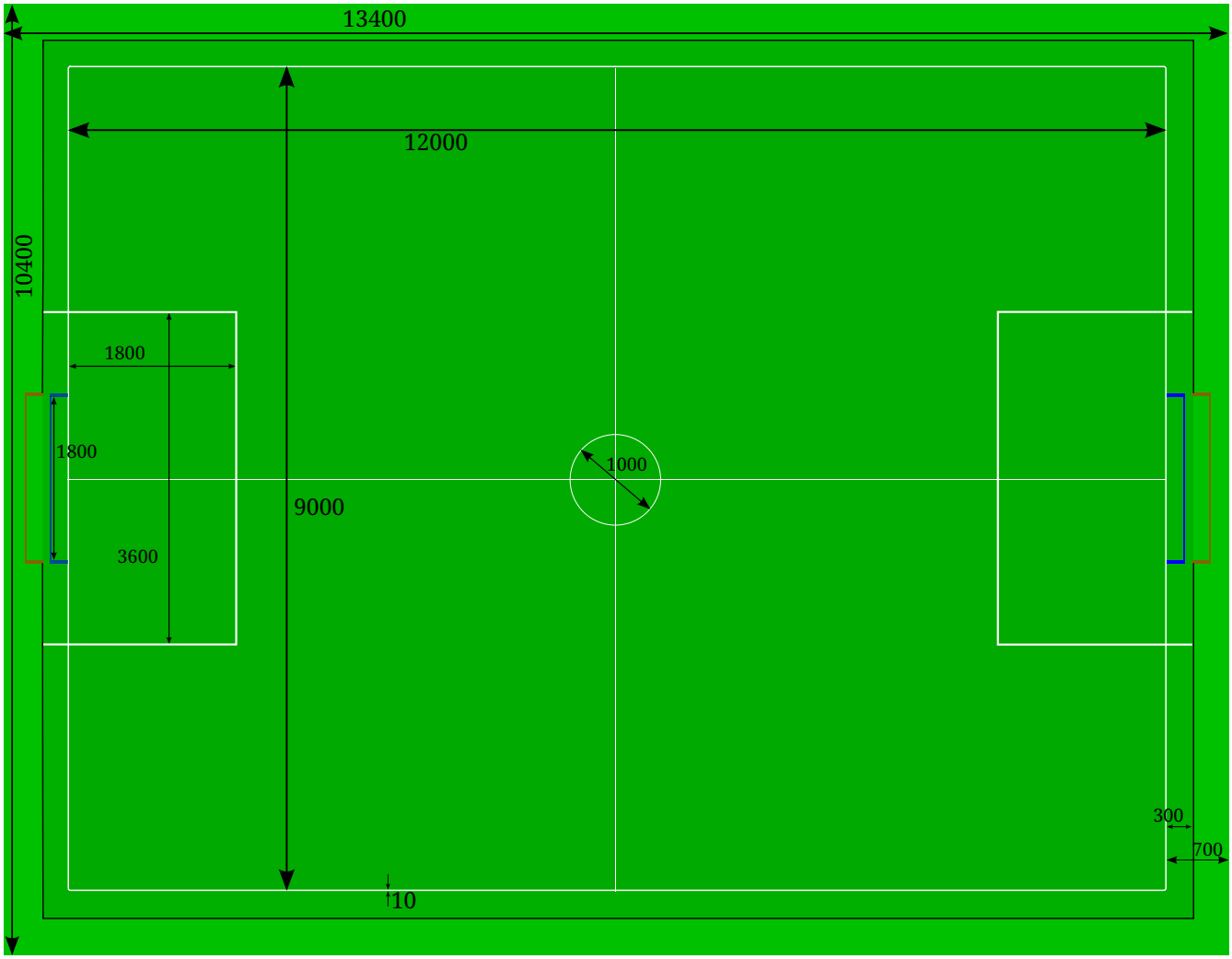


Figure 1. Field dimensions and markings for division A

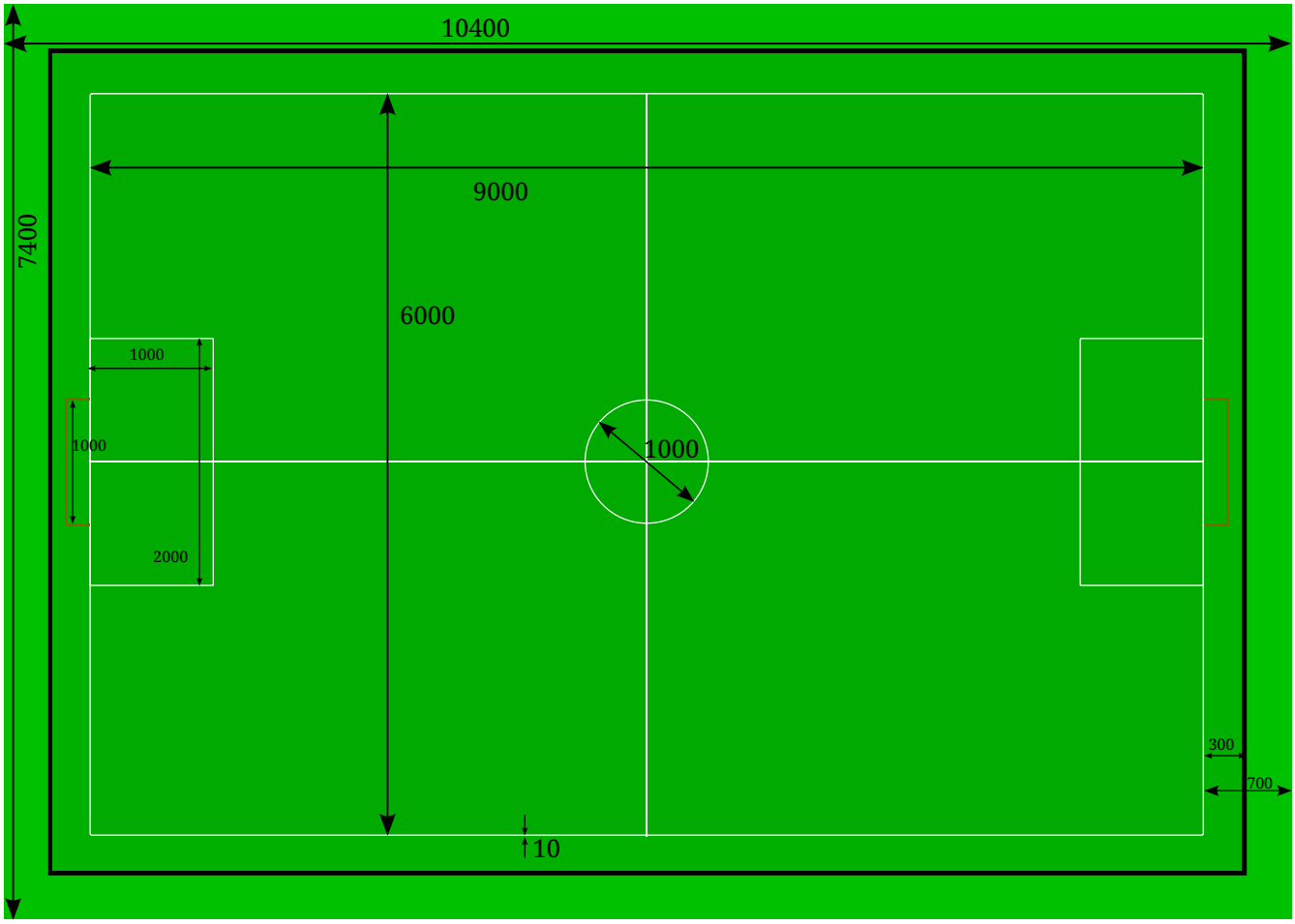


Figure 2. Field dimensions and markings for division B

2.1.2. Field Surface

The playing surface is green felt mat or carpet. The floor under the carpet is level, flat, and hard.

The field surface will continue for 0.7 meters beyond the field lines on all sides. The outer 0.4 meters of this runoff area, separated from the robot area by a 0.1 meters tall black wall, is used as a designated walking area for the referee and the assistant referee. The remaining 0.3 meters are the field margins.

2.1.3. Field Markings

The field of play is marked with lines. All lines are 0.01 meters wide and white (paint, spray, white carpet or strong tape). Lines belong to the areas of which they are boundaries. Distances between lines are measured from their centers. Distances from a robot are measured from its nearest side to the respective measurement point, with an assumed radius of 0.09 m.

Field Lines

The playing area is defined by four field lines. The two longer field lines are called touch lines. The two shorter field lines are called goal lines.

Halfway Line

The field of play is divided into two halves by a halfway line that runs along the width of the field

and through the center of the field. The halfway line is parallel to the goal lines.

Goal-to-Goal Line

The goal-to-goal line runs along the length of the field, passing through the center of the goals and the field. The goal-to-goal line is parallel to the touch lines.

This line is used to provide adequate features for the geometry calibration of the vision software and for optional local localisation of robots.

Center Circle

The center circle is located at the center of the field with a diameter of 1 meter. The center is at the crossing of the halfway line and the goal-to-goal line.

Defense Area

A defense area is defined as a rectangle touching the goal lines centrally in front of both goals. The size of the defense area is 3.6 meters times 1.8 meters for division A and 2 meters times 1 meter for division B, as shown in figures 1 and 2 respectively.

Penalty Mark

The penalty mark defines the point from which a team executes a penalty kick against the opponent goal. It is located on the goal-to-goal line and 8 meters (division A) or 6 meters (division B) away from the opponent's goal center.

2.1.4. Goals

Goals must be placed on the center of each goal line and anchored securely to the field surface. They consist of two 0.16 meters high vertical side walls joined at the back by a 0.16 meters high vertical rear wall. The inner face of the goal has to be covered with an energy absorbing material such as foam to help absorb ball impacts and lessen the speed of deflections. The inner goal walls are white, the outer goal walls, edges, and tops are black.

The distance between the side walls is 1.8 meters for division A and 1 meter for division B, and the goal is 0.18 meters deep. The goal walls are 0.02 meters thick and touch the goal line, but do not overlap or encroach on the field lines or the field. Figure 3 and figure 4 show these details for division A and division B respectively.

The numbers in the figures below show the distances in millimeters.

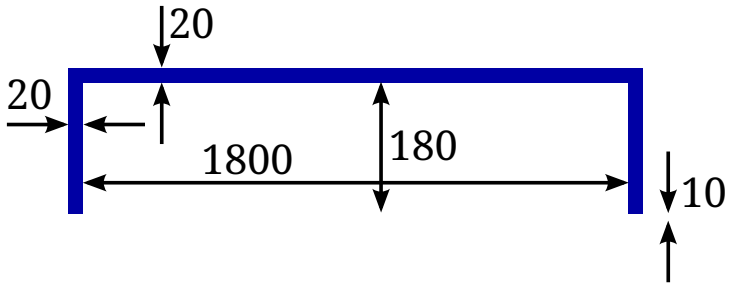


Figure 3. The goal in detail for division A

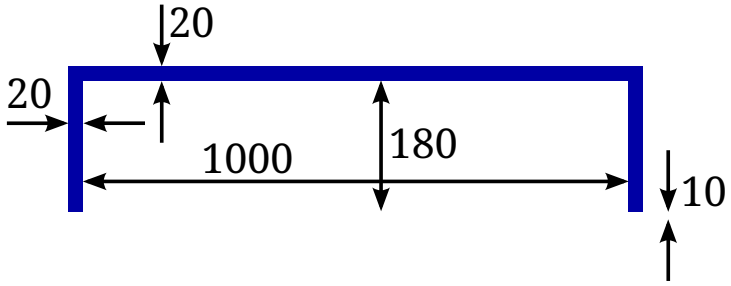


Figure 4. The goal in detail for division B

2.2. Ball

The ball is a standard orange golf ball. It weights approximately 0.046 kilograms and its diameter measures 0.043 meters.

For official matches, the organizing committee provides the ball.

2.3. Shared Software

The shared software used in the Small Size League is maintained by the technical committee, though everyone is encouraged to contribute. The technical committee members however guarantee that any changes made less than three months before the next RoboCup do not break compatibility.

2.3.1. Vision

Each field is provided with a shared central vision server and a set of shared cameras. This shared vision equipment uses the community-maintained SSL-Vision software (https://github.com/RoboCup-SSL/ssl-vision) to provide localization data to teams via Ethernet in a packet format that is to be announced by the shared vision system developers before the competition. Teams need to ensure that their systems are compatible with the shared vision system output and that their systems are able to handle the typical properties of real-world sensory data as provided by the shared vision system (including noise, latency, or occasional failed detections and misclassifications). The vision patterns on the top of the robots must adhere to the specifications of SSL-Vision, and must be of the standard color paper as specified in the SSL-Vision documentation.

Besides the shared vision equipment, teams are not allowed to mount their own cameras or other external sensors, unless specifically announced or permitted by the respective competition organizers.

SSL-Vision defines an additional tracker protocol that contains filtered and enriched tracking data. Messages are not published by SSL-Vision itself, but for example by some automatic referees. It is meant to be used by the game controller and by teams that do not yet have their own sophisticated filter.

2.3.2. Game Controller

A game is controlled by the community-maintained ssl-game-controller (https://github.com/RoboCup-SSL/ssl-game-controller). It is operated by the game controller operator. The software translates decisions of the referee and the automatic referee into Ethernet communication signals that are broadcast to the network. It maintains the state of the game, tracks all events and acts as a proxy between all participating parties in the game.

The game controller has a network interface for the playing teams. They can automatically change their keeper id, they can signal a robot substitution intent for the next opportunity, and they can send an advantage choice for handling game stopping after yellow cards.

2.3.3. Automatic Referee

One or more automatic referee applications can supervise a game and report offenses to the game controller. At least one automatic referee is required per game. If more than one automatic referee is connected to the game controller, a majority vote can be applied.

New automatic referee implementations can be provided, given that the source code is open-sourced. New implementations must be announced at least three months before the competition. The technical committee decides if an implementation will be used or not.

The Game Event Table shows which game events an automatic referee implementation must be able to detect. Individual game events can be disabled completely or in some automatic referee implementations if both teams and the technical committee agree.

2.3.4. Remote Control

A remote control for each team can optionally be provided by the tournament organizers. It is a physical device that allows entering the following commands:

- Raise a challenge flag
- Request a timeout
- Request robot substitution
- Request emergency stop
- Change the keeper id

It may also provide feedback information, like:

- Number of yellow cards and when they are due
- Number of robots currently allowed
- Number of robots currently on the field

The remote control may only be used by the robot handler. There is always only one remote control per team, per match.

The official implementation for the league can be found on GitHub: https://github.com/RoboCup-SSL/ssl-remote-control.

2.4. Communication Flags

The communication flags are used to avoid gesturing and yelling with the referee during a match. These flags are responsible for communicating various intents, such as: timeouts, emergency stops, manual robot substitution and challenges.

The referee or game controller operator has to acknowledge the communication flag. Any gesturing and yelling will be considered unsporting behavior, punished by a red card after the first warning.

The communication flags are provided by the organizers of the competition. A remote control software or device can be provided and replace physical flags. Any other solution that the organizers find feasible can also be used.

3. Robots

3.1. Number Of Robots

A match is played by two teams, with each team consisting of not more than 11 robots in division A and not more than 6 robots in division B, one of which may be the keeper. Each robot must be clearly numbered according to its vision pattern so that the referee can identify it during the match. The id of the keeper must be chosen before the match starts (see Choosing Keeper Id).

An exception is made during the Division A group phase, where the number of robots is limited to 8 if at least one of the two teams prefers it.

3.2. Hardware And Software Constraints

The referee may force a team to remove a robot from the field if it does not satisfy the rules. Members of the technical committee may also check the hardware and software constraints of robots at any point of the tournament.

If a team is not able to provide at least one robot that satisfies the rules, the team is forced to forfeit.

3.2.1. Safety

A robot must not pose danger to itself, another robot, or humans. It must not damage or modify the ball or the field.

The referee has to force a team to remove a robot from the field if he considers it a potential safety threat.

3.2.2. Shape

A robot must fit inside a 0.18 meters wide and 0.15 meters high cylinder at any point in time. Additionally, the top of the robot must adhere to the standard pattern size and surface constraints.

3.2.3. Dribbling Device

Dribbling devices that actively exert spin on the ball, which keep the ball in contact with the robot are permitted under certain conditions:

- The dribbling device must not elevate the ball from the ground
- Another robot must be able to remove the ball from a robot with the ball.
- A robot must not take full control of the ball by removing all of its degrees of freedom.
- 80% of the area of the ball when viewed from above has to be outside the convex hull around the robot. This limitation applies as well to all kicking devices, even if such infringement is momentary.

3.2.4. Vision Pattern

All participating teams must adhere to the given operating requirements of the shared vision system. In particular, teams are required to use a certain set of standardized colors and patterns on top of their robots.

To ensure compatibility with the standardized patterns for the shared vision system, all teams must ensure that all robots have a flat surface with sufficient space available on the top side. The color of the robot top must be black or dark grey and have a matte (non-shiny) finish to reduce glare. The standard vision pattern is guaranteed to fit within a circle with a radius of 0.085 meters that is linearly cut off on the front side of the robot to a distance of 0.055 meters from the centre, as shown in figure 5. Teams must ensure that their robot tops fully enclose this area.

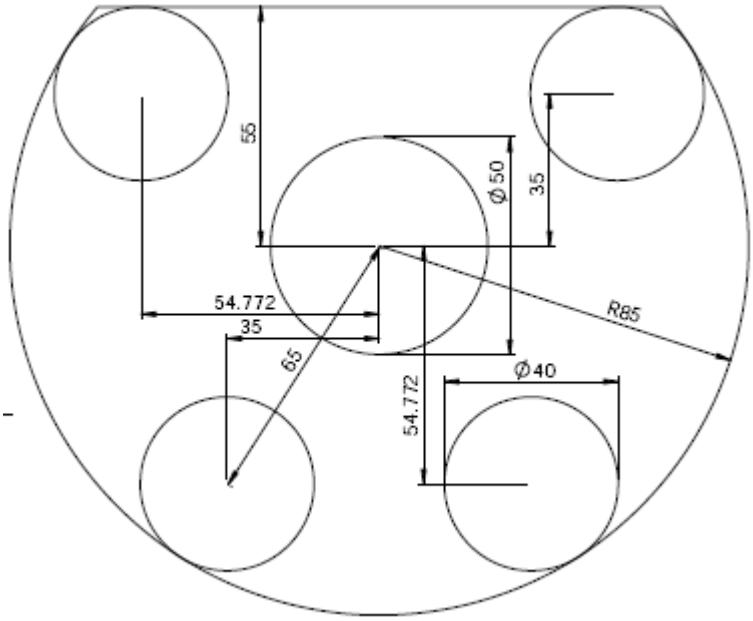


Figure 5. Standard Vision Pattern Dimensions

Every robot must have one of the 16 patterns shown in figure 6. No two robots are allowed to use

the same pattern.

The center dot color determines the team and is either blue or yellow (see Choosing Team Colors). The other four dot colors encode the id of the robot. To ensure that every team uses the same colors, the organizing committee provides enough colored paper at the competition.

Teams are encouraged to prefer color assignments with ids 0 to 7 because they have been experimentally found more stable, as there is no risk that the back two dots “color-bleed” into each other.

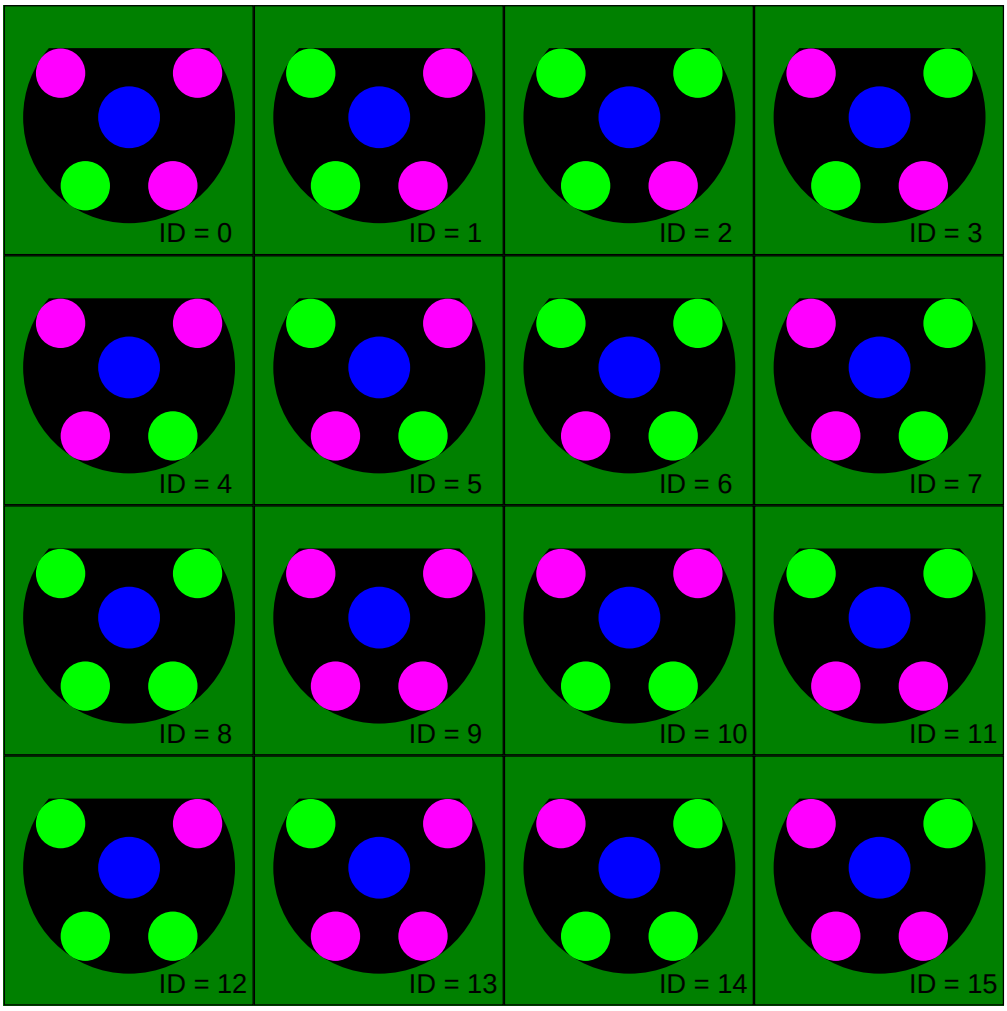


Figure 6. Standard Vision Pattern Colors

3.2.5. Radio Communication

Participants using wireless communications must notify the organizing committee of the method of wireless communication, power, and frequency. The organizing committee must be notified of any change after registration as soon as possible. In order to avoid interference, a team must be able to select from two carrier frequencies before the match. The type of wireless communication has to follow legal regulations of the country where the competition is held. Compliance with local laws is the responsibility of the competing teams, not the RoboCup Federation.

The type of wireless communication may also be restricted by the local organizing committee. The local organizing committee will announce any restrictions to the community as early as possible.

Bluetooth is not allowed since it cannot be fixed to frequency channels.

3.2.6. Autonomy

The robotic equipment has to be fully autonomous. Human operators are not permitted to enter any information to the system during a match, except in breaks or during a timeout. Disregarding this rule is considered unsporting behavior.

4. Game Structure

4.1. Impartial Roles

To play an official match in the Small Size League, four impartial roles must be filled:

- the referee
- the assistant referee
- the game controller operator
- the vision expert

Usually, these roles are filled by two non-playing teams, with one team providing the referee and the game controller operator and the other team providing the assistant referee and the vision expert. The assignment of the roles is up to the organizing committee.

Every participating team is required to be able to provide enough people who are familiar with these roles.

4.1.1. Referee

Each match is controlled by the referee. He has full authority to enforce the rules of the Small Size League in connection with the match to which he has been appointed. The referee is encouraged to use the designated walking area next to the field (see Field Setup).

The referee is assisted by the automatic referee software. The human referee is allowed to override any decision made by the automatic referee software.

The decisions of the referee regarding facts connected with play are final. The referee may only change a decision on realizing that it is incorrect or, at his discretion, on the advice of an assistant referee, provided that he has not restarted play.

The rules do not define all circumstance and their consequences in every detail. The referee is thus advised to judge in an adequate way, if the rules are not explicit. The usual procedure is to issue a warning on the first occurrence and an Unsporting Behavior on repetition.

The referee is not held liable for any kind of injury suffered by an official or spectator, any damage to property of any kind nor any other loss suffered by an individual, club, company, association, or other body.

The robot handler is the only team member that may talk to the referee.

Duties

- The referee ensures a safe match for all humans and robots
- The referee ensures a fair match according to the rules of the Small Size League
- The referee ensures that there is no interference by unauthorized persons or team members
- The referee or assistant referee places the ball for kick-offs and penalties (division A) or after every stoppage (division B). Subsequently, the referee resumes the match
- The referee ensures that the game is started and resumed in time

4.1.2. Assistant Referee

The assistant referee supports the referee wherever he can. He is encouraged to use the designated walking area next to the field, opposite the referee.

No team members are allowed to talk to the assistant referee.

Duties

- The assistant referee indicates when misconduct or any other incident has occurred out of the view of the referee
- The assistant referee discusses unclear situations with the referee
- The referee or assistant referee places the ball for kick-offs and penalties (division A) or after every stoppage (division B)

4.1.3. Game Controller Operator

During a match, the game controller operator uses the game controller software as an interface between the referee, the automatic referee and the team software.

No team members are allowed to talk to the game controller operator, except the robot handler for robot substitution intents.

Duties

- The game controller operator configures the game controller before the game begins
- The game controller operator enters the signals of the referee into the game controller
- The game controller operator watches the game event log for any events that need attention, like detections of an automatic referee or elapsed timers and notifies the referee

4.1.4. Vision Expert

During a match, the vision expert is in charge of the shared vision system on the field.

Team members are generally advised not to talk to the vision expert, unless they experience major vision problems.

Duties

- The vision expert checks the vision hardware and reports any kind of hardware problems to the technical committee
- The vision expert monitors the shared vision system during the match and reports any kind of problems to the referee instantly
- The vision expert recalibrates the vision system if the referee deems it necessary

4.2. Team-Specific Roles

4.2.1. Robot Handler

Before the start of the match, every team has to designate one robot handler. The robot handler represents the team during the match.

Duties

- The robot handler helps preparing the match.
- The robot handler asks the referee for timeouts if necessary.
- The robot handler can substitute a robot during game play.
- The robot handler asks the referee for the permission to substitute a robot in the next stoppage and, if the referee agrees, substitutes the robot.
- The robot handler voices concerns of the team (for example network issues or vision problems).

4.3. Match Preparation

All people that fill a role in the match (impartial or team-specific) have to be ready at least 10 minutes before the start of the match to allow the referee to make the following preparations:

4.3.1. Game Result Sheet

The referee obtains a game result sheet from the organizing committee. After the game, the referee fills in the final score, collects the required signatures and submits the sheet to the organizing committee.

While obtaining the game result sheet, the referee can also take an official ball and referee equipment such as a whistle or red and yellow cards (if provided).

4.3.2. Testing The Network

The referee ensures that both teams receive vision data and referee commands.

4.3.3. Choosing Team Colors

The referee asks the robot handlers of the teams about their preferred team color (either blue or yellow). If the teams agree on a color assignment, the colors will be used for the entire match.

However, if both teams prefer the same color, the referee assigns the colors by chance. In this case,

the teams switch the colors after the first half of the match as well as after the first half of the overtime if applicable.

4.3.4. Choosing Side And Kick-Off

The referee tosses a coin with both robot handlers. The winning team chooses the goal it will attack in the first half of the match. The other team takes the kick-off to start the match.

4.3.5. Choosing Keeper Id

The referee asks both robot handlers which robot they will use as the keeper and forwards this information to the game controller operator.

The keeper id can be changed anytime during the game if the ball is either out of play or in the opponent's field half by:

1. Using the game controller network interface
2. Asking the game controller operator to change it in the game controller. The game controller operator must not change the keeper id until the ball is at a valid position.

Teams should only ask for a change once the requirements are met. The game controller operator is responsible for complying to the rules.

If a team does not want to use a keeper, it may select the id of a robot that is not on the field.

4.4. Game Stages

4.4.1. Overview

An official match of the Small Size League consists of the following stages:

Game Stage	Duration
First Half	300 seconds of playing time
Half-Time Break	300 seconds pause
Second Half	300 seconds of playing time

If the match is an elimination match (draw is not a possible outcome) and the score is even after the regular game time, the match goes into overtime and the following game stages are added:

Game Stage	Duration
Pre-Overtime Break	300 seconds of pause
Overtime First Half	150 seconds of playing time
Overtime Half-Time Break	120 seconds of pause

Game Stage	Duration
Overtime Second Half	150 seconds of playing time

If the score is even after overtime has been played, the following stages are added:

Game Stage	Duration
Pre-Shoot-Out Break	120 seconds of pause
Shoot-Out	unlimited

The match timer is paused whenever no team is allowed to manipulate the ball. This includes stop, halt and the preparation states of kick-off and penalty kick. Additionally, it is paused during ball placement.

As a result, the time needed for a match is much greater than the playing time.

4.4.2. Timeouts

The robot handler has to ask the referee for a timeout. Timeouts are handled like breaks, meaning that both teams are allowed to make modifications to their software and hardware (see Autonomy).

Each team is allocated 4 timeouts at the beginning of the match. A total of 300 seconds is allowed for all timeouts. Timeouts may only be taken during a game stoppage. The time is monitored and recorded by the game controller operator.

For example, a team may take 3 timeouts of 60 seconds duration and thereafter have only one timeout of up to 120 seconds duration.

During overtime, both teams can use 2 timeouts with a total time of 150 seconds. The number of timeouts and the time not used in regular game are not added.

No timeouts are possible in the shoot-out stage.

4.4.3. Early Termination At A Score Of 10

Before the shoot-out stage, when a team manages to shoot 10 goals, the match is automatically terminated as soon as the goal difference is greater than one and the team with more goals is declared the winner.

During the group phase, the number of goals scored is used as tie-breaker, so the absolute number of goals matter for overall scoring. The rule applies to all game types for simplicity.

5. Referee Commands

An overview of the referee commands and how they interact with the game state, is given in Game States.

5.1. Stopping The Game

5.1.1. Stop

Definition

When the stop command is issued, all robots have to slow down to less than 1.5 m/s. Additionally, all robots have to keep at least 0.5 meters distance to the ball and are not allowed to manipulate the ball.

If the ball moves very quickly, it is hard to always keep the required distance to the ball, especially since the speed of the robots is limited during stop. Therefore, it is sufficient if it is obvious to the referee that the robots try their best to follow the distance rule.

Usage

The stop command is used to pause the game after the ball crossed the field lines (including goals) or an offense occurred as well as to prepare the start or resumption of the game after halt, timeouts and automatic ball placement. The robot speed limit and the minimum distance to the ball allow the referee or assistant referee to place the ball safely and without interference.

5.1.2. Halt

Definition

When the halt command is issued, no robot is allowed to move or manipulate the ball.

There is a grace period of 2 seconds for the robots to brake.

Usage

The halt command allows the referee to interrupt the game immediately whenever an emergency occurs (for example when a robot gets out of control). It is also used to recalibrate the vision software during a game if the vision expert considers it necessary and the referee agrees and for robot substitution. Additionally, the referee is free to issue the halt command at will.

The halt command is always followed up by stop. Enough preparation time should be given to teams, before the game is continued. The game controller will wait for up to 10 seconds after a halt command, but the game can be continued if robots are prepared already.

As a rule of thumb, the game should always be halted when humans other than the referees are entering the field.

5.2. Ball Placement

Definition

After the game was stopped, the ball must be placed on the appropriate position, depending on the event that occurred. The automatic ball placement is the preferred way to place the ball at the designated position on the field by the robots of the teams without human interaction. If this is not

possible, the referee places the ball manually.

During manual ball placement, the game should be in stop to allow robots to prepare for game continuation.

No ball placement is required if all of the following constraints are fulfilled:

- The ball is closer than 1m to the designated position.
- The ball is inside the field.
- The ball is at least 0.7m away from any defense area.
- The ball is stationary.

In this case, the game can be continued as soon as all robots keep the required distance for stop.

A ball is considered placed successfully by the robots if

- no more than 30 seconds passed since the placement command
- there is no robot within 0.05 meters distance to the ball if the next command is a free kick for the placing team
- there is no robot within 0.5 meters distance to the ball if the next command is a force start
- the ball is stationary
- the ball is at a position within 0.15 meters radius from the requested position

No further commands will be issued by the game controller until the automatic placement is complete. The game will be continued by the game controller as soon as the ball is successfully placed, but not earlier than 2 seconds after the ball placement command has been issued. A failed placement will result in a free kick for the opposing team. If this team failed to place the ball as well, the ball is placed by the referee and game continues with the original command.

For each team a ball placement failure counter is incremented on each placement failure and decremented for successful placements. It can not get negative.

The non-placing team must not interfere the ball placement task.

Usage

When the ball goes out of play, the following rules decide, if automatic ball placement is applied:

1. The referee has to place the ball for all kickoffs and all penalty kicks
2. For a free kick, the team that brings the ball into play must place the ball
3. For a force start, a team is drawn by chance and must place the ball
4. The ball must be visible and must not be inside a field corner, a goal corner or behind the goal, before the ball placement starts
5. The referee can decide to place the ball manually at any time
6. The referee can decide to disable automatic ball placement for the rest of the game. TC/OC must agree with this decision

7. When a teams placement failure counter reached 5, it is not allowed to place the ball for the rest of the game half. All free kicks that were a result of the ball leaving the field, are awarded to the opposing team. For all other rule violations or when both teams failed to place the ball, the ball is placed by the referee
8. If no team can place the ball, the ball is placed by the referee or the assistant referee. Both the referee as well as the assistant referee are advised to use a so-called ball handler (a long, preferably black stick-like device) to move the ball.

The ball may still be moving when the placement command is issued.

The game commences directly after ball placement. The team receiving the ball may shoot immediately and leave the opposing team little time to arrange defensive actions if needed.

It is allowed to enter the defense area during ball placement.

Ball placement is mandatory for all teams in division A. Teams in division B may decide, at any time before or during the game, not to place the ball for the rest of the game by talking to the referee, who in turn tells the game controller operator to disable ball placement for this team. In this case, the team is allowed to bring the ball into play, after the ball was placed by the opposing team. If the opposing team fails to place the ball or no team can place the ball, it is placed by the referee or the assistant referee.

5.3. Resuming The Game

After the ball has been placed, the game is resumed using one of the following commands.

5.3.1. Normal Start

Definition

For two-staged referee commands, when normal start is sent, an attacker may manipulate the ball. A match cannot be resumed directly via normal start.

Usage

Normal start is used for kick-offs and penalty kicks.

5.3.2. Kick-Off

Definition

The ball has to be placed in the center of the field by the human referee.

When the kick-off command is issued, all robots have to move to their own half of the field excluding the center circle. However, one robot of the attacking team is also allowed to be inside the whole center circle. This robot will be referred to as the kicker. No robot is allowed to touch the ball.

When the normal start command is issued, the kicker is allowed to shoot the ball. A goal may be

scored directly from the kick-off.

When the ball is in play, the kicker may not touch the ball until it has been touched by another robot or the game has been stopped (see double touch). Also, the restrictions regarding the robot positions are lifted.

Usage

Both half times as well as both overtime periods (if needed) start with a kick-off. Chapter Match Preparation describes how to determine the attacking team.

Additionally, after a goal has been scored, the receiving team restarts the game with a kick-off.

5.3.3. Free Kick

Definition

The ball placement position for a free kick depends on the event that led to the free kick. This position is valid if there is at least 0.2 meters distance to all field lines and 1 meter distance to either defense area. If an event requires the ball to be placed at a position that contravenes this rule, it has to be placed at the closest valid position instead.

When the free kick command is issued, robots of the attacking team are allowed to approach the ball while robots of the defending team still have to stay at least 0.5 meters distance away from the ball (the same distance as in stop). One robot of the attacking team is allowed to shoot the ball. This robot will be referred to as the kicker. A goal may be scored directly from the free kick.

When the ball is in play, the kicker may not touch the ball until it has been touched by another robot or the game has been stopped (see double touch). Also, the restrictions regarding the robot positions are lifted.

Usage

Free kicks are used to restart the game after a foul has occurred. Additionally, goal kicks and corner kicks are mapped to free kicks.

5.3.4. Force Start

Definition

When the force start command is issued, the game is immediately resumed and both teams are allowed to approach and manipulate the ball again.

Usage

A neutral forced start is used in situations where no team is clearly in favor, such as:

- the game had to be stopped without a specific reason.
- both teams are at fault.

5.3.5. Penalty Kick

Definition

The procedure of a penalty kick is as follows:

1. The ball is placed by the human referee on the penalty mark.
2. When the penalty command is issued:
   a. The defending keeper has to move to the goal line and keep touching it.
   b. One attacking robot is allowed to approach the ball but not allowed to touch the ball.
3. Throughout the penalty kick procedure, all other robots have to be 1m behind the ball such that they do not interfere the penalty kick procedure.
4. When the normal start command is issued, the attacker is allowed to manipulate the ball. The ball has to only move towards the opponent goal, as measured by its x coordinate in the coordinate system of SSL-Vision.
5. When the ball is in play, the defending keeper may move freely again.
6. If the ball is still in play after 10 seconds, the game is stopped.

A goal is awarded if:

- the ball touches the inner surface of a goal wall or the ground of the goal of the defending team, starting from when the normal start command is issued.
- the defending team commits any foul.

The game is continued with a kick-off when a goal is awarded.

A goal is not awarded if:

- the ball crosses any field lines outside the goal.
- the defending keeper touches the ball such that the ball speed vector changes direction by at least 90 degrees in 2D space.
- the attacking team violates any rule.
- the ball is still in play after 10 seconds.

The game is continued by a goal kick for the defending team when a goal is not awarded.

The restrictions defined for scoring goals, including the ball height limit of 0.15 meters, do not apply here. Other rules like the excessive dribbling limitation for example do.

Additional time is allowed for a penalty kick to be taken at the end of each half or at the end of periods of overtime.

Usage

Penalty Kicks are used to punish unsporting behavior and multiple defenders.

5.4. Ball In And Out Of Play

When the match is stopped, the ball is considered **out of play** until it has been brought into play.

When the match is resumed, the ball is considered **in play** until the next stoppage occurs. The match is resumed when

- force start has been issued.
- the ball moved at least 0.05 meters following a kick-off, free kick or penalty kick.
- 10 seconds passed following a kick-off.
- 5 seconds (Division A) or 10 seconds (Division B) passed following a free kick.

see double touch for the rationale of the 0.05 meter distance

5.5. Sanctions

5.5.1. Yellow Card

Definition

If the yellow card is shown as a result of unsporting behavior, the referee may decide to immediately halt the match. In this case, the match continues with a free kick for the other team.

Upon receipt of a yellow card, the number of robots allowed on the field for the penalized team decreases by one. If, after this decrease, the team has more robots than permitted on the field, a robot must be taken out.

A yellow card does not lead to a stop automatically. If the ball is in play, the team will have 10 seconds to automatically remove the robot. If a robot is not taken out within time, the game is stopped for manual substitution and continues with a Forced Start. The 10 seconds can be extended indefinitely by the other team by sending an advance choice to the game controller.

This rule implies that after receiving a yellow card, the game might not be automatically stopped. However, the game will be stopped if the foul that led to the yellow card causes a game stoppage, e.g. dropping parts. Therefore, if one of those fouls occurred, the team is allowed to manually remove the robot.

No penalty will be given to the team that couldn't get the robot out of the field in time. However, in the future there will be a penalty like this: If the robot gets manually substituted, the ball is placed on the goal-to-goal line and 1.5 meters away from the teams defense area and the opposing team gets a free kick.

A team cannot score a goal while having more than the allowed number of robots on the field.

After 120 seconds of playing time (measured by the game controller), the yellow card expires and the number of allowed robots is increased by one. The team may put a robot back in during the next opportunity.

When a team has two not yet expired yellow cards and receives another yellow card, this card will be turned into a red card instead.

Usage

Yellow cards are used to punish teams that committed multiple fouls.

Yellow cards can also be given by the referee to punish fouls or unsporting behavior.

5.5.2. Red Card

Definition

A red card behaves like a yellow card, except: It does not expire until the end of the game.

Usage

Red cards are given by the referee to punish severe fouls or unsporting behavior.

For example, serious violent contact by the robots or disrespectful behavior towards the referees can result in a red card.

5.5.3. Forced Forfeit

Definition

A Forced forfeit means that a team instantly loses the current game with a score of 0 to 10.

Usage

A team can be forced to forfeit if it is unable to play with at least one robot that satisfies the rules.

A team can only be forced to forfeit in agreement with members of the technical committee and the organizing committee.

5.5.4. Disqualification

Definition

A Disqualification means that a team immediately drops out of the tournament and places last. It will not be eligible to receive any trophies.

Usage

A team can be disqualified if members of this team don't follow safety guidelines, rules of the venue or commit similarly severe offenses.

A team can only be disqualified in agreement with members of the technical committee and the organizing committee.

6. Ball Leaves The Field

When the ball leaves the field by fully crossing the field line, the game will be stopped, the ball will be placed and the game will be restarted depending on the position of the field line crossing as well as on the team that last touched the ball.

6.1. Touch Line Crossing

Touch lines are the long field lines at both sides of the playing field.

6.1.1. Throw-In

Definition

The ball has to be placed 0.2 meters perpendicular to the touch line where the ball crossed the touch line. Its distance to the goal lines must be at least 0.2 meters.

After the ball has been placed, a free kick is awarded to the opponent of the team that last touched the ball before it left the field.

Usage

A throw-in is used to restart the game after the ball left the field by crossing the touch line.

6.2. Goal Line Crossing

Goal lines are the short field lines at both ends of the playing field.

6.2.1. Goal Kick

Definition

The ball has to be placed 0.2 meters from the closest touch line and 1 meter from the goal line.

After the ball has been placed, a free kick is awarded to the opponent of the team that last touched the ball before it left the field.

Usage

A goal kick is used to restart the game after the ball left the field by crossing the goal line of the team that did not touch the ball last.

In division B, the aimless kick rule might apply instead.

6.2.2. Corner Kick

Definition

The ball has to be placed 0.2 meters from the closest touch line and 0.2 meters from the goal line.

After the ball has been placed, a free kick is awarded to the opponent of the team that last touched the ball before it left the field.

Usage

A corner kick is used to restart the game after the ball left the field by crossing the goal line of the team that touched the ball last.

6.2.3. Aimless Kick (*Division B only*)

Definition

The ball has to be placed at the position from where the ball was kicked (see the free kick rules for the exact ball position rules).

After the ball has been placed, a free kick is awarded to the opponent of the team that last touched the ball before it left the field.

Usage

A kick is aimless when after the ball touched a robot, it subsequently crossed the halfline and then its opponent's goal line outside the goal without touching another robot.

A kick-off kick cannot be aimless, as the ball is located on the halfway line and does therefore not cross it.

7. Scoring Goals

A team scores a goal when the ball fully enters the opponent goal between the goal posts, provided that:

- The team did not exceed the allowed number of robots when the ball entered the goal.
- The height of the ball did not exceed 0.15 meters after the last touch of the teams robots.
- The team did not commit any non stopping foul in the last two seconds before the ball entered the goal.

"The team" refers to the scoring team that is awarded a goal, not the team that kicked the ball. For example, an own goal is not possible while the opponent team has too many robots on the field.

During penalty kicks, more specific rules apply.

If the goal is considered invalid, the game will be continued as if the ball crossed the goal line outside the goal.

8. Offenses

8.1. No Progress In Game

If there is no progress in the game for 5 seconds (Division A) or 10 seconds (Division B) while both teams are allowed to manipulate the ball, the game is stopped and continued by a forced start.

8.2. Double Touch

When the ball is brought into play following a kick-off or free kick, the kicker is not allowed to

touch the ball until it has been touched by another robot or the game has been stopped.

The ball must have moved at least 0.05 meters to be considered as in play.

A double touch results in a stop followed by a free kick from the same ball position.

It is understood that the ball may be bumped by the robot multiple times over a short distance while the kick is being taken. This is why a distance of 0.05 meters is used to decide whether a robot violates this rule or not. Remaining in contact with the ball for more than 0.05 meters also counts as double touch, even though technically the robot only touched the ball once.

8.3. Unsporting Behavior

Unsporting behavior can lead to yellow cards, red cards, penalty kicks, a forced forfeit or a disqualification. The human referee chooses an appropriate sanction, depending on the severity of the offense.

For minor infringements, a Yellow Card is adequate, while on more severe infringements, that gave the team an advantage, a Red Card or Penalty Kick can be issued.

For harder sanctions, the referee is advised to refer to members of the technical committee or the organizing committee.

If the referee is not sure which sanction to choose, he may confer with the assistant referee and members of the technical committee or the organizing committee.

Some examples of unsporting behavior are listed below.

8.3.1. Damaging Other Robots

It is not allowed to damage or modify robots of other teams.

8.3.2. Damaging The Field Or The Ball

It is not allowed to damage or modify the field or the ball.

8.3.3. Disrespect Procedures

Not following defined procedures repetitively, like for example:

- Robot handler puts a robot on the field, while it is not allowed
- Robots do not keep required distance to the ball during stop
- Robots do not conform to the positioning rules during a penalty kick and need to be moved or removed manually

8.3.4. Showing Lack Of Respect

A team member must show appropriate respect to everyone involved in the game. Infringements of this rule include but are not limited to:

- insulting the opponent, the referee or other persons holding an impartial role
- annoying the referee or other persons holding an impartial role
- not obeying the orders of the referee

8.4. Fouls

The number of fouls per team is tracked by a counter. Each foul will increase the counter by one. Every third increase to the foul counter causes a yellow card to be awarded.

Violations in this section and its subsections increase the foul counter if not stated otherwise.

Regardless, of the prescribed penalties in this section, if a foul is severe or repeated, the referee can choose to immediately issue a yellow card or in extreme cases a red card.

8.4.1. Stopping Fouls

Fouls in this section cause the game to stop and then resume with a free kick from the position where the ball was located when the foul began happening.

Robot Too Close To Opponent Defense Area

During stop and free kicks, before the ball has entered play, all robots have to keep at least 0.2 meters distance to the opponent defense area.

There is a grace period of 2 seconds for the robots to move away from the opponent defense area.

Pushing

A robot pushes an opponent robot if both robots keep contact to the ball or to each other while the robot exerts force onto the opponent robot, such that both robots travel towards the opponent robot.

If both robots are pushing each other with similar force, no team is at fault.

Ball Holding

Robots must not surround the ball to prevent access by others.

Tipping Over Or Dropping Parts

A robot must not tip over, break or drop parts on the field that pose a potential threat to other robots.

A robot violating this rule has to be substituted.

Metal parts (screws for example) as well as larger parts generally pose a potential threat, very small non-metal parts (for example rubber subwheel rings) don't.

Multiple Defenders

This rule does not use the standard sanctions defined for fouls.

Robots other than the keeper must maintain best-effort to fully stay outside the own defense area. Infraction of this rule can be rated as unsporting behavior.

If a robot other than the keeper touches the ball while this robot is entirely inside its own defense area, the game is stopped and a penalty kick is awarded to the other team. The foul counter is **not** increased.

Boundary Crossing

A robot must not kick the ball over the field boundary such that the ball leaves the field.

Keeper Held Ball

The ball must not be kept in the defense area for more than 5 seconds (Division A) or 10 seconds (Division B).

Excessive Dribbling

A robot must not dribble the ball further than 1 meter, measured linearly from the ball location where the dribbling started. A robot begins dribbling when it makes contact with the ball and stops dribbling when there is an observable separation between the ball and the robot.

Dribblers can still be used to dribble large distances with the ball as long as the robot periodically loses possession, such as kicking the ball ahead of it as human soccer players often do.

8.4.2. Non Stopping Fouls

Fouls in this section do not cause a stop. Instead, the game continues normally.

The same no stop foul cannot be triggered again until the foul condition has stopped being violated or there has been 2 seconds since the foul was first triggered. This is to allow teams to adjust their robots' positions, ball speed or any other property that is causing the violation before being penalized additional times.

Attacker Touched Ball In Opponent Defense Area

The ball must not be touched by a robot, while the robot is partially or fully inside the opponent defense area.

Ball Speed

A robot must not accelerate the ball faster than 6.5 meters per second in 3D space.

Crashing

At the moment of collision of two robots of different teams, the difference of the speed vectors of both robots is taken and projected onto the line that is defined by the position of both robots. If the length of this projection is greater than 1.5 meters per second, the faster robot committed a foul. If the absolute robot speed difference is less than 0.3 meters per second, both conduct a foul.

8.4.3. Fouls While Ball Out Of Play

Fouls in this section can only occur when the ball is out of play.

Each foul has a grace period of 2 seconds per team until it is raised again.

If multiple robots commit the same foul within 2 seconds, only the first foul counts.

If a robot keeps committing a foul, it will be punished again after the grace period.

Defender Too Close To Ball

A robot's distance to the ball must be at least 0.5 meters during an opponent kick-off or free kick. When the foul is committed, the timer of the opponent team for bringing the ball into play is reset.

The human referee may decide to repeat the kick-off or free kick on significant disturbances.

During stop, there is no automatic sanction for being too close to the ball. The referee may still punish a team for unsporting behavior by issuing a yellow card if it does not respect the required distance. See stop for further explanation.

Robot Stop Speed

A robot must not move faster than 1.5 meters per second during stop. A violation of this rule is only counted once per robot and stoppage.

There is a grace period of 2 seconds for the robots to slow down.

This rule does not apply to ball placement.

Since the stop command is used for manual ball placement and robot substitution, the intention of the robot speed limit is to avoid robots harming the people on the field.

Ball Placement Interference

During ball placement, all robots of the non-placing team have to keep at least 0.5 meters distance

to the line between the ball and the placement position (the forbidden area forms a stadium shape).

If a robot of the non-placing team is too close to the line between the ball and the placement position for more than 2 seconds, it commits a foul. In this case, 10 seconds are added to the ball placement timer. Only one interference foul per ball placement phase counts towards the foul counter, but the placement timer is always incremented.

This rule does not cover all cases of ball placement interference. The referee is encouraged to call fouls if the non-placing team is obviously interfering with the ball placement.

If a robot keeps interfering the ball placement (for example if it is stuck or can not move), the human referee is encouraged to stop the placement and place the ball manually.

Excessive Robot Substitutions

If a team has used up their free robot substitution budget, every additional robot substitution is a foul. The match is resumed with a corner kick for the opponent team. If both teams committed this foul in the same stop, the match is resumed with the original command.

9. Robot Substitution

Definition

Robots are substituted by the robot handler of the respective team. No other team member is allowed to take robots out or put robots in.

The robot handler should prefer to use long sleeves and colors that won't interfere with the vision system.

Robots can always be taken in and out during game play without notifying the referee if all the following conditions are met:

1. The robot is at least partially inside the field margin.
2. The robot is at a distance from the halfway line that must not exceed 1 meter.
3. The ball must be at least 0.5 meters away from the robot.

Additionally, robots can be taken out from any position on request using the procedure below:

1. The robot handler requests robot substitution at any time.
2. The game controller will halt the game at the next opportunity.
3. The robot handler may enter the field and touch robots now.
4. The robot handler takes robots out.
5. The robot handler informs the referee when done.
6. When both teams finished the robot substitution, the referee informs the game controller

operator.

7. The game controller operator performs a stop followed by continuing the game.

The maximum allowed number of robots of the team on the field must not be exceeded at any time when putting robots in.

Usage

Robots can be substituted for any reason. A substitution grants the team 10 seconds to take robots out. After that time, a new substitution is started. Each team has 5 free substitutions per halftime. Every additional substitution will result in an excessive robot substitutions foul for the team.

A robot substitution intent can be made by:

1. A robot handler by informing the game controller operator who in turn enters the intent into the game controller.
2. A robot handler by using the remote control, if provided.
3. A team software by sending a request to the game controller.
4. The game controller itself if a team exceeds the maximum number of robots (for example after a team receives a yellow or red card).

If the game was halted due to a substitution intent by a team, at least one robot must be taken out by this team. A substitution intent can be revoked unless the game was not already halted for substitution.

If a robot substitution intent for either team is present just before the game would continue after ball placement, the game controller automatically halts the game.

10. Shoot-Out

Definition

Both teams alternately attempt to score a goal with a penalty kick until each team has performed 5 attempts. If both teams have the same score after those 5 attempts, each team takes another attempt in the same order as before until the score of the two teams is different.

Only up to one attacking robot and one keeper is allowed per team. During a shoot-out attempt, the attacking robot and the opponent keeper are the only ones allowed to move and manipulate the ball. Other robots are not allowed to interfere.

If a team is clearly not able to prepare for a penalty kick, a goal is automatically awarded to the opposing team.

Robots may be substituted between shoot-out attempts. The new robot may be put in right away.

Note that timeouts are not allowed during shoot-out.

If there is no clear progress in determining a winner (after 10 shoot-outs, if both teams time out doing shoot-outs, or if both teams cannot prepare and execute the

> penalty kick), the human referee can give both teams a certain amount of time (like 5min) to change their system. This time can be applied multiple times, if needed, to eventually determine a winner.

Usage

Shoot-Out is used to determine the winner of an elimination match if both teams scored the same amount of goals in previous game stages.

11. Emergency stop

Definition

A team can ask to stop the game immediately after a grace period of 10 seconds or at the next stoppage, whichever happens first regardless of the current situation. It will receive a yellow card for this and must take a timeout immediately. If the team is out of timeouts, it is still allowed to remove robots from the field, but can not use any remaining timeout time.

> This rule is supposed to be used in extreme situations only, e.g. a software crash or when robots are damaging themselves significantly.

When the game is stopped due to this rule, there are three possibilities that may have happened:

1. The grace period has passed and the game is stopped.
2. The human referee stopped the game earlier.
3. The game is stopped earlier due to the ball leaving the field or because of a foul.

For these possibilities there are two methods to proceed the game:

1. For **1** and **2**, the game is continued with a free kick for the opposing team.
2. For **3**, the game is continued like after a regular timeout.

Usage

An emergency stop intent can be made using communication flags.

> The referee may stop the game earlier if there is no promising play in action.

12. Challenge Flags

A challenge flag allows teams to challenge a decision of the referee:

1. If referees decision was correct, team loses a timeout.
2. If referees decision was incorrect, the correct decision is applied and the team doesn't lose a timeout.

> The flag is consumed in both cases.

Only one ruling may be challenged at a time.

The team must have at least one timeout left before using a challenge flag.

Each team will receive **three flags** at the start of the game.

This rule is inspired by challenge flags in American football.

13. Rule Changes During Competition

Rule changes between years can have unforeseen consequences. If a rule is found to cause significant negative impact to the competition, the rules may be adapted under the following conditions:

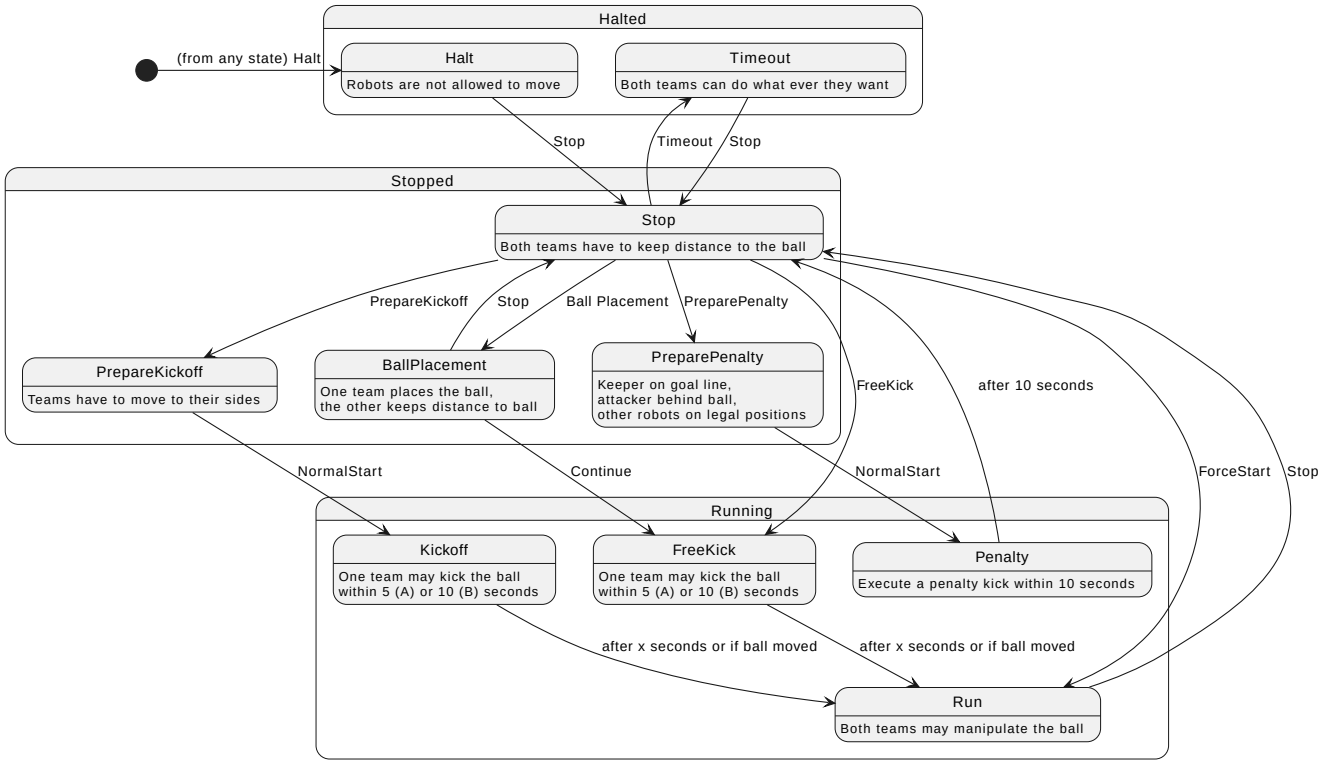
- Only between phases of the competition, like round-robin and knockout
- Only for major problems, as a last resort
- The change must be approved by all team leaders (by an unanimity vote)

Appendix A: Terminology

A.1. Ball Manipulation

Shooting and dribbling is considered as manipulating the ball, the ball accidentally bouncing off the hull is not.

Appendix B: Game States



Appendix C: Game Events

The following game event table is a compilation of the different game events and their consequences. It also lists what all Automatic Referee implementations must be capable of handling.

The information shown in this table here may be incomplete. Please read the sections of the respective events for the full definitions.

Event	Applicability	Consequence	Increments Foul Counter	Initiated By
While Match is Running				
NO_PROGRESS_IN_GAME	ball in play	Stop → Force Start	no	game controller
ATTACKER_DOUBLE_TOUCHED_BALL	ball in play	Stop → Free Kick	no	auto referee
Ball Leaving the Field				
POSSIBLE_GOAL	ball in play	Halt	no	auto referee
BALL_LEFT_FIELD_TOUCH_LINE	ball in play	Stop → Free Kick	no	auto referee
BALL_LEFT_FIELD_GOAL_LINE	ball in play	Stop → Free Kick	no	auto referee
AIMLESS_KICK	ball in play	Stop → Free Kick	no	auto referee
Fouls				
DEFENDER_IN_DEFENSE_AREA	ball in play	Stop → Penalty Kick	no	auto referee
KEEPER_HELD_BALL	ball in play	Stop → Free Kick	yes	game controller
BOUNDARY_CROSSING	ball in play	Stop → Free Kick	yes	auto referee
BOT_DRIBBLED_BALL_TOO_FAR	ball in play	Stop → Free Kick	yes	auto referee
ATTACKER_TOUCHED_BALL_IN_DEFENSE_AREA	ball in play	-	yes	auto referee
BOT_KICKED_BALL_TOO_FAST	ball in play	-	yes	auto referee
Penalty Kick				

Event	Applicability	Consequence	Increments Foul Counter	Initiated By
PENALTY_KICK_FAILED	during Penalty Kick	Stop → Free Kick	no	auto referee, game controller
Always				
BOT_CRASH_UNIQUE	always	-	yes	auto referee
BOT_CRASH_DRAWN	always	-	yes	auto referee
During Free Kick and While Match is Stop				
ATTACKER_TOO_CLOSE_TO_DEFENSE_AREA	during Stop and Free Kick	Stop → Free Kick	yes	auto referee
While Match is Stopped				
Fouls				
BOT_TOO_FAST_IN_STOP	during Stop	-	yes	auto referee
DEFENDER_TOO_CLOSE_TO_KICK_POINT	ball out of play	timer for bringing the ball into play is reset	yes	auto referee
Ball Placement				
BOT_INTERFERED_PLACEMENT	during Ball Placement	placement timer increased by 10 seconds	yes	auto referee
PLACEMENT_SUCCEEDED	during Ball Placement	continue	no	auto referee
PLACEMENT_FAILED by team in favor	during Ball Placement	Stop → Free Kick (div A) / previous command (div B)	no	game controller
PLACEMENT_FAILED by opponent	during Ball Placement	Stop	no	game controller
Informational				
MULTIPLE_FOULS	-	Yellow Card	no	game controller
MULTIPLE_CARDS	-	Red Card	no	game controller
TOO_MANY_ROBOTS	-	Stop	no	game controller
INVALID_GOAL	-	Stop → Free Kick	no	game controller

Event	Applicability	Consequence	Increments Foul Counter	Initiated By
BOT_SUBSTITUTION	during Stop	Halt (after next stoppage), then Stop	no	remote control
CHALLENGE_FLAG	always	-	no	remote control
EMERGENCY_STOP	always	Halt → Timeout + Yellow Card	no	remote control
Manual				
GOAL	-	Stop → Kick-Off	no	human referee
BOT_PUSHED_BOT	always	Stop → Free Kick	yes	human referee
BOT_HELD_BALL_DELIBERATELY	ball in play	Stop → Free Kick	yes	human referee
BOT_TIPPED_OVER	always	Stop → Free Kick	yes	human referee
UNSPORTING_BEHAVIOR_MINOR	always	Stop → Yellow Card	no	human referee
UNSPORTING_BEHAVIOR_MAJOR	always	Stop → Red Card	no	human referee

A visualized graph of the game events is stored as graphml and can be viewed at yed-live.

Appendix D: Overview of Timings

Situation	Div A Time	Div B Time
Remove robot for Yellow Card	10 s	10 s
penalty kick	10 s	10 s
kick-off	10 s	10 s
free kick	5 s	10 s
Keeper Held Ball inside Defense Area	5 s	10 s
No Progress In Game	5 s	10 s

Appendix E: Differences Between Divisions

This is a complete list of differences between division A and division B.

- Division A plays on a larger field with larger goals than division B. As a result, a penalty kick is taken from a greater distance as well.

- Division A plays with more robots than division B.
- The automatic ball placement procedure is mandatory for division A and optional for division B.
- The aimless kick rule only applies to division B.
- Division A has shorter timeouts in some situations.