RoboCup Standard Platform League (NAO) Challenges & Rule Book

RoboCup Technical Committee

(DRAFT 2021 rules, as of January 29, 2021)

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

Contents

1 Introduction

In 2021, RoboCup will be held virtually around the world, owing to the ongoing COVID 19 situation. The Standard Platform League will take on a new form that is designed to provide all teams an opportunity to competitively measure their skills in robot soccer within the current circumstances. Live streaming of videos will be incorporated into the event to keep the contact between teams alive as well as presenting an entertaining experience for the public and sponsors.

For 2021, the RoboCup SPL competition will consist of four challenges of increasing complexity:

1. Testing game play skills of an individual robot.

2. Testing team coordination.

3. Testing remote competitive game play between different teams.

4. Testing the quality of remote deployment using autonomous calibration.

Conditions of the home venues across all SPL teams tend to vary. Thus, these challenges allow teams to participate in some or all of the challenges depending on their capabilities. The first two challenges allow teams to compete at their home venue exclusively using their own robots. The latter two challenges ask teams to compete by remotely deploying their code onto robots at a neutral host venue, which is an important step towards facilitating fully remote soccer games.

Teams participating in the remote challenges will also be expected to participate as neutral host venues so that robot usage is fairly distributed among teams. To facilitate this, the challenge rules and the guidance for referees have been designed to ensure the safe operation and protection of robot hardware in all venues.

The past years have shown that SPL teams are great at finding a balance between competing with other teams to win awards and maintaining the research focus on RoboCup in advancing the field of computing science through publications. Given the restrictions on any event in 2021 we ask all teams to do their best to make this year's SPL successful and enjoyable for everyone.

1.1 General Setup for all Challenges

The four challenges have been designed for the following general setup:

1. An SPL field of at least 6 x 4 m size (outer field lines), with 2 goals and a green astro-turf or carpet surface. See 6.1.1.

2. For the passing and and 1 vs 1 challenges, a WiFi configuration similar to a typical SPL competition plus GameController.

3. Additional network configuration for venues hosting the 1 vs 1 challenge to allow for remote code setup. See 4.3.

4. A rules focus on the safe operation and protection of robot hardware. Referees should pay special attention to the safe operation of the NAO's.

If teams are unable to support the requirements for a particular challenge, but still wish to participate, then the team should contact the TC to discuss potential options.

1.2 Code of Honour

The TC trust all teams to act fair during competition. Thus, we ask all participants to acknowledge a Code of Honour.

1. The safe operation of the robots is paramount, especially where teams deploy remote their software onto robots owned by other teams. Referees and participants should act to prevent damage to robots, and be proactive in enforcing rules designed to minimise damage.

2. Teams should endeavour to install bug-free and conservative software for remote participation. While remote challenges feature elements of speed, there are strict consequences for damaging robots, and we hope no team will be prevented from competing due to these reasons.

3. Teams and participants should be open and honest in the presentation of their local challenge entries and capability of their software. A live stream should be used where possible, and pre-recorded videos uploaded as close as possible to the scheduled completion of the challenge. The use of features indicating date and time is encouraged.

4. Teams (and host venues) should present a clear view of the field and surrounds. Teams should not use additional sensing equipment or remote control stations.

It is our experience that SPL teams are extremely gracious and congenial, and we expect that the Code of Honour will be honoured. However, violation of this code may result in immediate disqualification.

1.3 Registration

Details on registration procedures will be published and updated here, once a time frame is confirmed by the RoboCup Federation.

1.4 Key dates

2021-01-31	Publishing the first draft or rules with mandatory files.
2021-04-01	Commitment to participate
2021-05-01	Jersey approval for new or modified jerseys
2021-06-01	Feedback for teams with fields smaller than 3/4
2021-06-01	Submission of credentials for arena access to teams
2021-06-01	Arena network access responsible contact person
2021-06-08	Testing hours for arena access with remote teams
2021-06-15	Field_dimension.json
2021-06-22	Start of RoboCup 2021

2 Local Challenge: Obstacle Avoidance

2.1 Idea of the Challenge

Teams at RoboCup 2019 self-reported working on/having finished improvements of their obstacle avoidance. Replacing simple obstacle avoidance implementations (don't walk forward if you don't see field colour in front of you) should be encouraged by the league. This challenge gives teams an opportunity to display their improvements in obstacle avoidance. Teams are challenged to move a ball into the target goal as fast as possible while avoiding obstacles placed in-between the ball and target goal. This behaviour might aid in lowering the amount of pushing during games.

If a team is interested in participating in this challenge, but cannot fulfil all requirements of the setup, they should notify the TC.

2.2 Judges and Assistants

The challenge will be judged by a neutral member of another SPL team via video stream. The competing team needs to designate one person as local challenge assistant. The local challenge assistant assists the judge in setting up the challenge, starting and stopping, scoring and moving the ball/obstacles.

2.3 Setup

This challenge requires:

- 1 active robot.

- 4 inactive robots. The robots may be standing or sitting (crouched).

- the ability to stream a video of the local field (see Section 6.2).

The challenge is attempted on a standard SPL field (see Section 6.1.1) in the local venue of the participating team. For teams using a field that is smaller than standard size please refer to Section 2.4.

One of the goals on the field is designated as the target goal. The other goal is not used as part of the challenge (but remains in place).

A ball is placed in the centre of the centre circle. The challenged robot is placed in front of the centre circle on the opposite side of the of the target goal (equivalent to manual placement of attacking robots during kick-off in SPL games). Between ball and target goal three obstacles are placed.
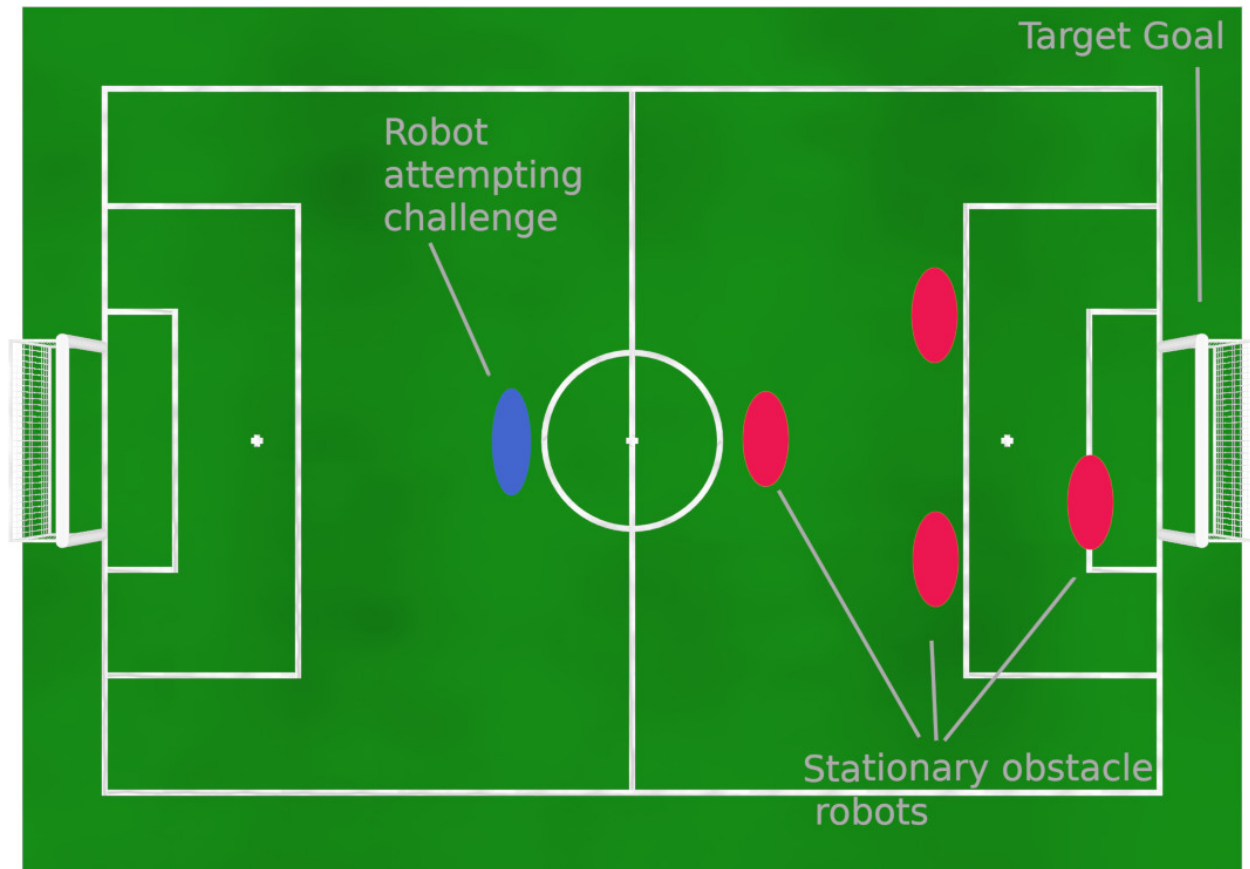
Figure 1: Challenge overview (positions, sizes and distances are not exact)

- A single stationary robot acting as a single obstacle (see Section 6.3.3). The obstacle robot is facing down the long dimension of the field, position centred on the imaginary line between kick-off point and centre of the target goal.

- A single stationary robot acting as a single obstacle. The obstacle robot is facing down the long dimension of the field, position offset to the left or right so its outermost shoulder point is one balls radius away from the imaginary line between kick-off point and centre of the target goal.

- Two stationary robots, together acting as a single obstacle. Both are facing down the long dimension of the field, positioned offset to the sides so dribbling a ball in between them is the fastest route to the target goal. The space in between them is twice the robots' shoulder-to-shoulder width.

Regarding to the position of the obstacles along the long axis of the field:

- One obstacle is placed on the goal box line (see line F in figure 6).

- One obstacle is placed just outside the penalty box, so it does not touch the line (see distance G).

- One obstacle is placed away from the centre line towards the target goal. The distance to the centre line is the radius of the centre circle (half of distance J).

The challenged robot may wear any jersey legal in RoboCup SPL competition or no jersey at all (as decided by the participating team).

The participating team is free to choose which of their goals is used as a target.

The order the obstacles are set up in (i.e., which kind of obstacle is placed in which position, the offset side of the one stationary robot) is randomized by dice throw (or similar randomization tool) during the competition. The participating team will be told the exact setup of the obstacle robots while setting up the challenge. The judge will give the exact setup of the obstacles and will verify the correct field setup. Thus, no team is aware of the exact setup beforehand. Due to this randomization teams might be challenged with any of the setups given in the examples of figure 2.

2.4   Non-standard fields

Teams may compete in this challenge on fields smaller than the standard SPL field (see section 6.1.1), given that:

- the area of the artificial turf is big enough to set up the challenge.

- the distance between the goalposts is the same as a standard SPL goal construction (see figure 7).

Teams are not required to modify or move field lines for this challenge.

During setup of this challenge all measurements and distances must be used as if the challenge is set up on a standard SPL field.

Example: Assuming a team is setting up on a smaller field where the distance from goal to goal is smaller than that of a standard SPL field. The ball is not placed in the centre circle as marked by field lines as the ball would be closer to the target goal compared to a standard SPL field. Instead, the ball is placed independent of centre circle markings so the distance between ball and goal is the same as standard SPL field. All other placements follow the same principle.
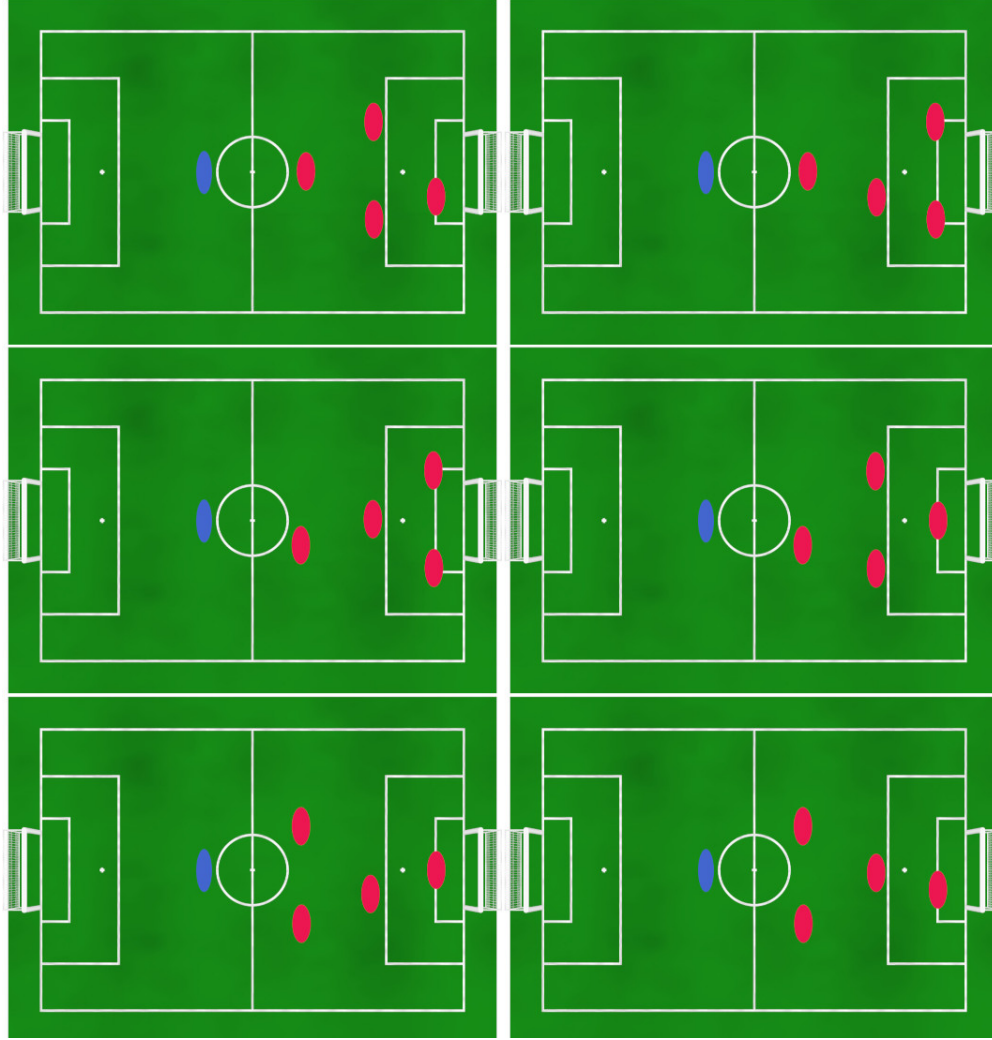
Figure 2: Possible obstacle setups encountered during the challenge (not an exhaustive list of all possible cases)

2.5 Scoring

The challenged robot is tasked to advance with the ball into the target goal. Both dribbling and kicks are permitted to move the ball. The maximum distance for goal shots is restricted for this challenge. Shots that do not score a goal are unrestricted.

Shots into the goal are only allowed with the centre of the ball being within 1.3 meter from the end field line. This threshold is at the same height as the penalty cross (see dimension I in figure 6).

Goals shot from a larger distance do not complete the challenge. In this case, the ball is moved back to the starting position by the local challenge assistant and the robot must score another goal according to the rules of the challenge.

Teams are scored by the time it took to move the ball into the goal (rounded up to full seconds). Lower durations are better. Teams are required to score three goals during this challenge. Each run is timed separately. The obstacle setup will be randomized for each of the three runs to score a goal. The final score used is the median of all three runs to score a goal.

In case of two or more teams being tied on a final score: tied teams are required to repeat the challenge and score two more goals. The final score is recalculated to be the median of all five runs to score a goal. Ties after five runs to score a goal are decided by coinflip.

If the ball is moved out of the field a local challenge assistant takes the ball and places it on the kick-off point.

Touching an obstacle with the ball increases the scored duration of the current run on the goal by five seconds. Touching an obstacle with the challenged robot increases the scored duration of the current run on the goal by 10 seconds.

A robot has at most five minutes (penalties excluded) to complete one run to score a goal.

The team with the lowest final score time is the winner of the challenge. The team with the second lowest time is awarded second place in this challenge (and so on . . .).

2.6   Challenge management and planning

The date and time for the challenge will be announced as part of RoboCup 2021 communication. At least 15 minutes leading up to the challenge the participating teams are given the exact setup of obstacles as determined by randomization.

Participating teams must be ready to compete in the challenge within 15 minutes of being given the obstacle setup. At the end of setup time the challenged robot must be able to stand still and upright (head movement is allowed) and await the start of the challenge. The participating team may use up to 10 minutes to update the challenge setup in-between runs to score a goal. Charging robots is allowed in-between runs. Changing the software used for this challenge is not allowed between runs.

Participating teams must start the robot behaviour of their competing robot via a single chest button press. (This mimics the chest button behaviour of switching between playing and penalized state from previous SPL competitions, see Figure 12) The participating robot must navigate autonomously and cannot be remote controlled during the challenge.

As part of the challenge the participating team must stream their robot navigating the field (see Section 6.2). Details will be scheduled as part of RoboCup 2021 communication.

3   Local Challenge: Passing Challenge

3.1   Idea of the Challenge

Teamwork is an important element in the RoboCup SPL. A fundamental teamwork component is the passing the ball between teammates. The goal of this challenge is to push teams to develop an offensive passing strategy.

The challenge requires two active "attacker" robots, and two static "obstacle" robots (see Section 6.3.3). The attackers' robots must complete as many passes between them as possible within in a 5 minute period. A neutral referee will observe the challenge via a video stream, see 6.2. Teams may make three attempts with their final score being their best attempt. Teams cannot change code between the attempts.
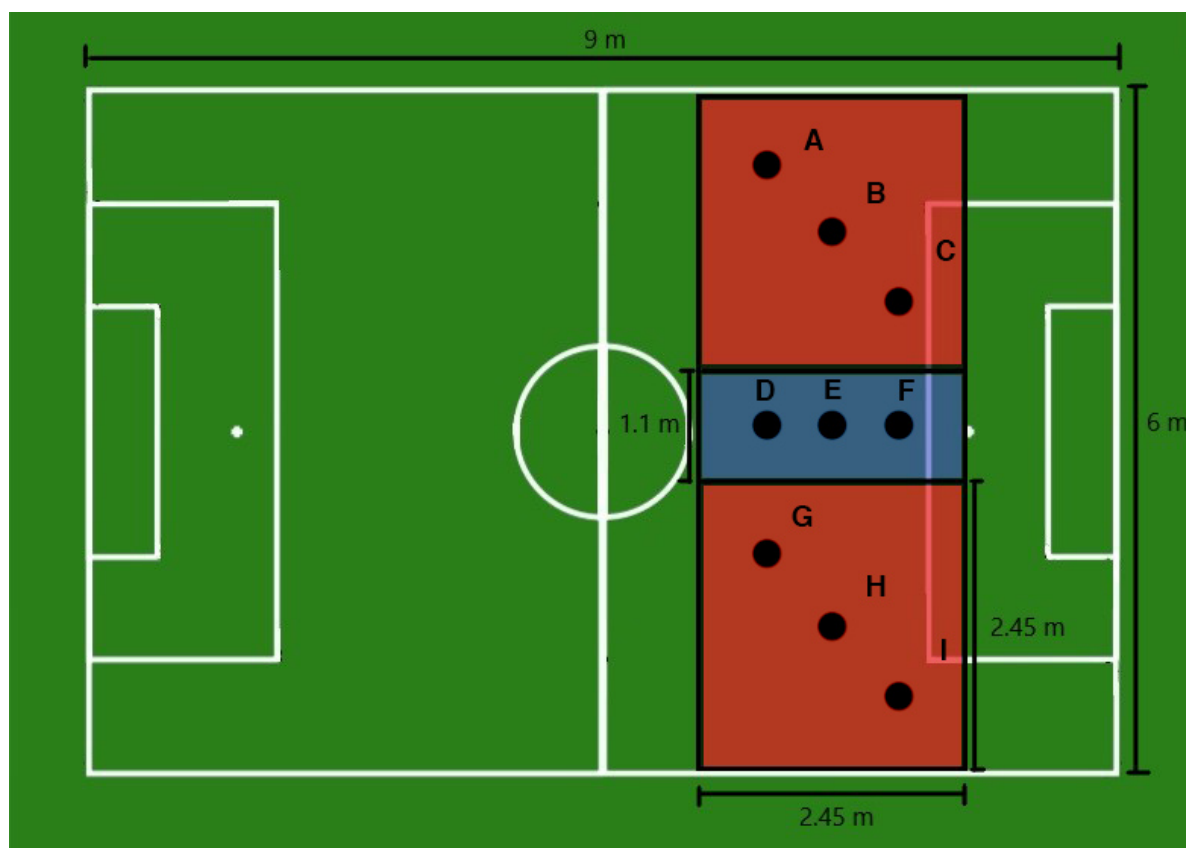
Figure 3: Setup using the standard SPL field (see section 6.1.1). The red zones are for attacking robots, and the blue zone for defending robots.
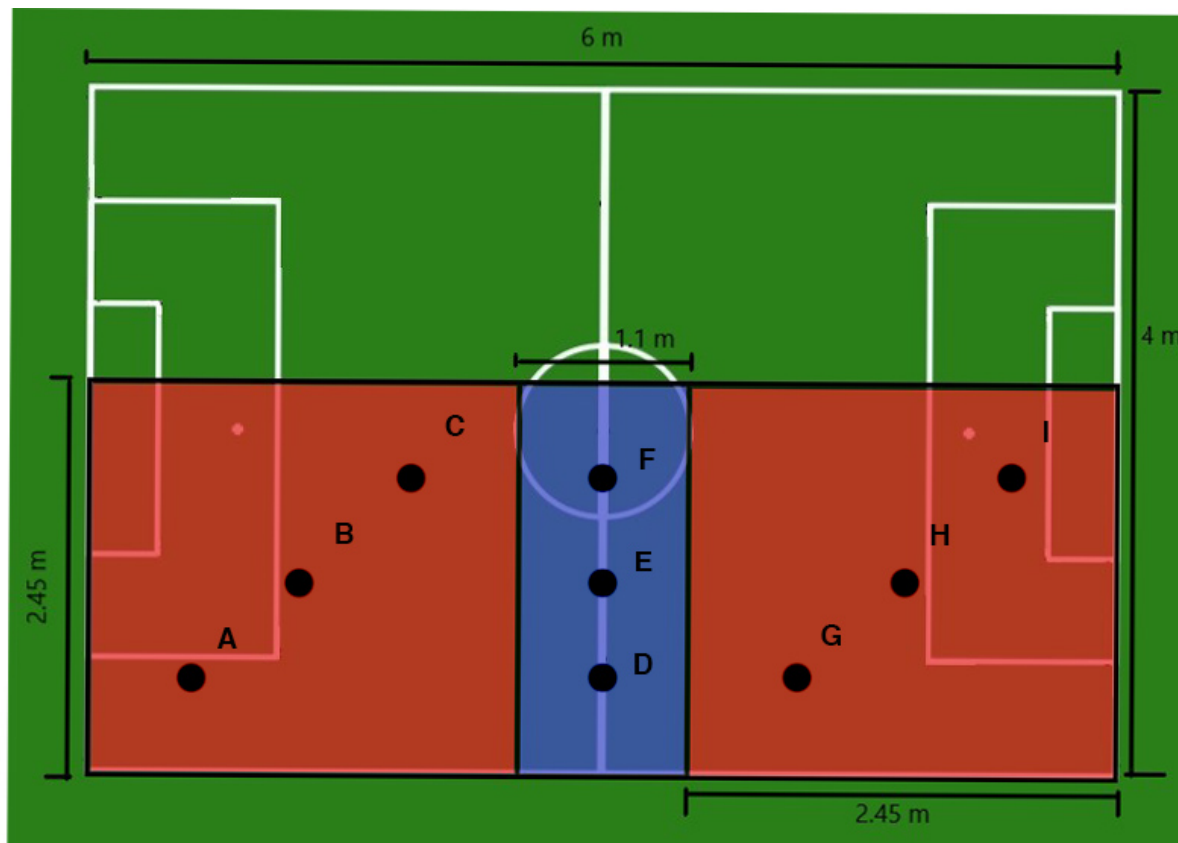
Figure 4: Example setup using the minimum field size (see section 6.1.1). The red zones are for attacking robots, and the blue zone for defending robots.

3.2   Field Setup

This challenge will be conducted within local venue of the participating team. A field of at least 3/4 size is required (see Section 6.1.1). The challenge requires three zones shown in Figure 3 for a standard SPL field and Figure 4 for a minimum size field. The combined zones for the challenge *must be exactly* 6m x 2.45m. This is irrespective of the actual field used and the location of the zones on the field. The red zones represent area available to attacker robots. The blue zone represents the area where the defender robots are placed. The three zones should be made clearly visible to observers including the referee, by demarcating them on the field through the use of a green tape. The tape must not break the regular white field lines. Robots must localize using the regular filed lines.

3.3   Robots positioning

The two active robots are the attacking robots. The defending robots must be turned off and thus act like static obstacle robots (see Section 6.3.3) The starting robot's positions are identified by the points $A, B, C, D, E, F, G, H, I$ in Figures 3 and 4. The robot's positions are:

Standard SPL field (Vertical setup) - the reference frame of each point is put in the lower left corner of the corresponding area.

$A = G = (0.6m, 1.8m)$
$B = H = (1.2m, 1.2m)$
$C = I = (1.8m, 0.6m)$
$D = (0.6, 0.55m)$
$E = (1.2m, 0.55m)$
$F = (1.8m, 0.55m)$

Reduced size field (Horizontal setup) - the reference frame of each point is put in the lower left corner of the corresponding area.

$A = G = (0.6m, 0.6m)$
$B = H = (1.2m, 1.2m)$
$C = I = (1.8m, 1.8m)$
$D = (0.6, 0.55m)$
$E = (1.2m, 0.55m)$
$F = (1.8m, 0.55m)$

One attacking robots is randomly placed at placed in A, B, or C, and the other attacking robot randomly at G, H, or I. One attacking robot is randomly selected to start with the ball. The defenders are positioned randomly D, E, or F. See Figure 3 and Figure 4.

3.4   Challenge Execution

A team may make three attempts at the challenge. For each attempt the attacking robots must be connected to GameController. Before each attempt, GameController is set to Initial. After the robots are positioned, the GameController changes to Ready state and then Set. The attempt commences using the referee whistle and GameController process, as in typical SPL games (see Section 6.4).

The attacking robots pass the ball back-and-forth as often as possible until the attempt ends. The attackers can leave their respective red starting zones for up to 30 seconds, which may be necessary in cases where the ball is near (or at) the edge of the red zone.

If the ball leaves the red zone (such as from a bad pass), then the ball is manually put back at the edge of the red zone where it went out. This is similar to placing the ball for a kick-in in a soccer game (see Section 6.4.6). If the ball went out from a blue zone, it is put back at position A or G, corresponding to the last red zone in which the ball was located.

An attempt ends when:

1. The timeout is reached,

2. The defenders touch the ball,

3. One attacking player stays out of its red starting zone for more than 30 seconds.

Each team may make three attempts at the challenge however, they cannot modify their code between the attempts.

3.4.1   Passing definition

A successful pass is defined as:

1. The ball has been touched by two attacking robots.

2. The ball moved more than one meter from its starting position.

3. The ball crosses the blue zone so that is starts and ends in different red zones.

4. The ball stops moving in a red zone.

3.5   Scoring and Overall Ranking

One point is awarded for each successful pass (see Section 3.4.1). The neutral referee will count and adjudicate successful passes. The score for an attempt is the total number of successful passes.

A team is given a final score that is the best of their three attempts. Teams are ranked overall by their score, from the highest to the lowest.

4 Remote Challenge: 1 vs 1

4.1 Idea of the Challenge

The aim of this challenge is to display competitive gameplay given the current situation.

Two robots play against each other on a full-sized or reduced size field (see section 6.1.1). The goal is to shoot balls from the own half into the opponent's half or goal to score points. Robots are not allowed to leave their own half. Four balls, two on each side, can be shot by the robots.

This challenge focuses on the following aspects:

- Remote deployment with manual or fully autonomous setup of NAO software and standardized settings for game play in a remote arena on foreign robots,

- Automatic or semi-automatic calibration of NAO (vision, motion, etc.),

- One versus One NAO competition in a ladder knock out competition for all teams without much robot-to-robot contact.

Requirements to participate in this challenge are, being able to

- host an arena, see 4.2.2

- deploy your robot's software remotely or fully autonomous setup, see 4.2.1

By providing an autonomous setup, all teams are enabled to host training matches this in their local arena. Even teams not able to compete in RoboCup SPL 2021 benefit from this use case.

4.2 Prerequisites

For this challenge teams need to fulfil multiple requirements, which are listed below in more detail.

To be able to participate, teams have to deploy their software on the NAO remotely. Teams may deploy software interactively via remote control connection or deliver a fully autonomous setup. There will be several opportunities for the teams to talk, discuss, exchange ideas and code over the next few months until RoboCup. Two options will be properly available: Meetings like RoDEO and a spring RoHOW as well as discussions using SPL Discord channels. The second option is a code sharing section like it is available for the V6 support on RC SPL website.

Fully autonomous images allow setup, calibration and challenge play in a teams local venue without external assistance. Teams that are not able to participate in the 2021 competition may download these images for explorative games in their local venues. These explorative games are not part of the ladder system and are outside the competition.

4.2.1 Basic requirements for teams

- A team must be able to deploy their robot software on a NAO V6 remotely or be able to produce a fully autonomous image for a NAO V6.

- A team must be able to host an arena. If not, they have to find a substitute team. Substitute teams take over the hosting arena responsibilities.

- A robot should be able to semi- or fully automatic calibrate itself.

If you cannot fulfil all requirements, but you would like to participate, please contact the TC.

4.2.2 Basic requirements for arenas

Teams have to fulfil the following items to be able to host an arena.

- An SPL field (see 6.1) corresponding to the standard SPL field size or a reduced size that is no smaller than the minimum field size (see section 6.1.1).

- Wi-Fi with standard SPL_A SSID, standard password (as communicated before the competition via e-mail) and standard IP `10.0.0.2` address and DHCP turned off

- Remote network access via:

    - VPN connection,
    - Mobile connection,
    - TeamViewer, remote desktop connection or VPN connection from the arena to the remote team

- Camera, tablet or laptop for on field online calibration with remote team using Discord

- Streaming setup, see 6.2

- The latest Game Controller running

- At least **two** working NAOs V6 per game

- All robots assigned for the whole competition are numbered from **1** to the maximum number with integers.

- More than **two** tiny USB Sticks with 16 GB or more memory for flashing and logging

- At least **four** standard balls

- Assistants for remote setup and autonomous setup

- Referees (1 Head, 1 Game Controller Operator, $>= 2$ Assistants (Who are also volunteers for the teams in setup phases. They are also in the following game local representative for the teams.))

If you cannot fulfil all requirements (equipment or number of people in the field room, etc.) but you would like to host an arena, please contact the TC.

4.3 Arena and organizational setup

This challenge relies on a standardized arena setup as well as on exchanging all information necessary for gameplay. The following sections define the information used to describe local arena conditions.

4.3.1 USB Drive

Tiny (not standing out the surface of the head like `https://www.amazon.com/dp/B077VXV323/`) USB drives remaining inside the head for the whole game are used to flash a robot with a binary image or to store data during the game play of the robot.

During the competition two kinds of USB drive are used. Their purposes are:

Flashing

This kind of USB Drive is used to flash a robot either with the standard SoftBank image or with a team provided one. After flashing, this USB Drive gets replaced by the *storage* USB drive.

Storage

After *Flashing* a robot, a robot will be equipped with a storage USB drive with ext3 file system. It will be used for the following purposes:

- **Configuration**: Configuration files, at least `field_dimensions.json` as explained below, will be copied into the root folder of the USB drive.

- **Logging**: If teams want to store log files or images and get them uploaded in the Nextcloud as explained below, they can store the files in a `logs` folder on the USB-Drive.

4.3.2 Data Exchange

Teams exchange data before and during RoboCup 2021 using a Nextcloud drive. An access link and password will be sent to the team leaders and have to be used with care. The Nextcloud drive will contain a folder for every team according to their team number. Team folders will be used for sharing the following data:

- In folder **field dimensions** each team has to provide a json file (template will be in the root folder of the drive) describing the field dimensions according to the rules (see 6.1.1). The file has to be named `field_dimensions.json`. This file has to be uploaded until the **15th of June 2021**. The file will be used for autonomous setup and game play. To configure the arena the corresponding field desciption will be copied on the USB drive after flashing as `field_dimensions.json` in the folder configuration. This allows the usage of the same image at different arenas.

- In the folder **field images** each team has a folder where photos from the arena from different angles and at different day & night-times with focus on the lighting conditions get uploaded until the 15th of June 2021.

- In **Robot Setup** the arena teams find a binary image for a particular game. Each game has an identifier *Game_ID* and this identifier has to be used as folder name. The binary image has to be uploaded **two hours** before the game starts. Next to the image you have to define to configuration folder for the player. The containing files will be copied in the root on the USB drive. The USB drive will be plugged into the robot after flashing. Within this configuration folders you can also place files to configure your image. There is one mandatory file: `field_dimensions.json`. This file has to be used by the robot's software.

- In **Arena Access** remote teams find an instruction how to access the arena. Each team must provide team specific credentials and share them with the responsible person in each team until the 1st of June. Every team has to announce a responsible person for credentials and remote setup until the 1st of June. The list of responsible people can be found in the root folder of the Nextcloud drive.

- In the root folder you find a `streaming.md` file where every team has to publish a link that can be used by public to watch the game. It will be used on the SPL website / RoboCup 2021 website as well. Further details for streaming, see 6.2.

- Logs and images will be uploaded from the hosts into the folder `Logs/Game_ID`, where *Game_ID* is replaced by the game identifier, after the game when bandwidth is available. It is assumed that logs and images are stored on the USB drive attached to the NAO in the folder `logs`. Other files will be ignored.

4.3.3 Network Setup

The following section defines network requirements for a local venue that hosts remote games. The network infrastructure should be as transparent as possible for remote participants. It should get as close as possible to an on-site experience. Please also contact your local IT administrators and agree your setup with them.

4.3.3.1 General

- Participants need easy access to their robots for uploading code and debugging. No ports should be blocked. ICMP must not be blocked.

- Robots might accumulate a large amount of log files (including images). These logs will be uploaded after games for analysis. Minimum 100Mbit/s (symmetric) is recommended for a venue, favourable 1Gbit/s. Logs can also be uploaded from another network.

- To not overwhelm the network, teams should rate limit their network activity (in particular long log downloads and uncompressed video streams from NAOs during debug sessions)

4.3.3.2 SPL Game specific

- Team Messages (SPLStandardMessages) must be receivable for remote participants.

- Team Messages must not be forwarded from remote participants to 10.0.0.0/16 (SPL_A).

- GameControllerMessages must be receivable for remote participants.

- GameControllerMessages must not be forwarded from remote participants to 10.0.0.0/16 to not allow remote participants to control the game (by accident).

4.3.3.3 Example configuration

- The network could be divided for example into three subnets:

  - 10.0.0.0/16: The actual SPL_A wifi network on at least 2.4 GHz. Each team must use 10.0.TEAM_NO.2-254 for their robots. GameController will be on 10.0.0.2. DHCP is not active.

  - 10.1.0.0/16: The ethernet network for robots. Each team must use 10.1.TEAM_NO.2-254 for their robots. Static addressing is required when robots are assigned to a team. DHCP is active, statically assigning 10.1.0.2-255 to robots that are currently not assigned to any team (pool).
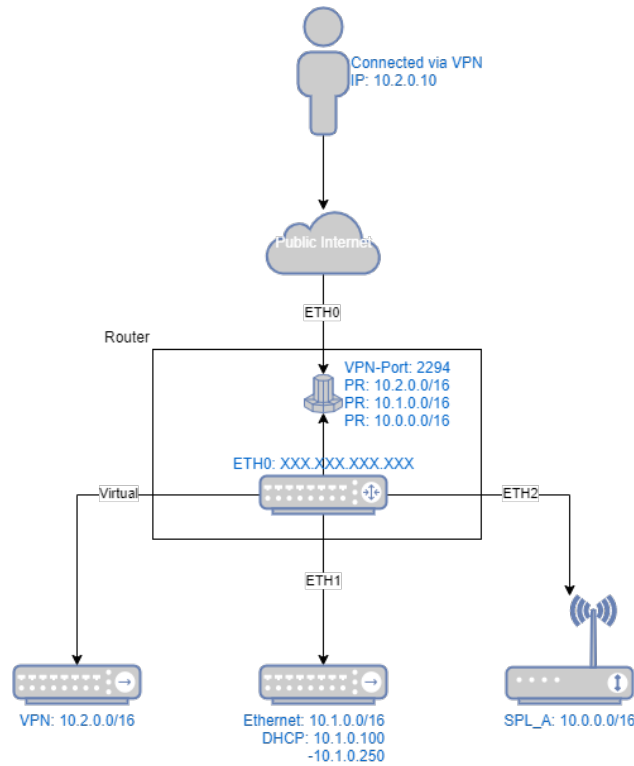
Figure 5: Network setup example

  – 10.2.0.0/16: The VPN network. Remote participants are assigned to this network and
    can access the other networks. Team- and GameControllerMessages are forwarded from
    10.0.0.0/16 to this subnet. DHCP is active. Broadcasting to other subnets is not possible.

- Router (e.g. Ubiquiti EdgeRouter Lite 3-Port Router from Ubiquity `https://www.ui.com/edgemax/edgerouter-lite/`)

  – serves as router for the whole network.

  – has a globally routable (and accessible) IPv4 address.

  – hosts an OpenVPN Layer2 VPN Server

  – opens a network port to allow incoming OpenVPN connections

  – Every team gets one certificate to authenticate via OpenVPN (multiple connections
    allowed).

  – Has broadcast forwarding rules in place to allow VPN users to receive Team-/GC-
    Messages.

  – GameController computer is assigned 10.0.0.2/16

  – `ETH0` could be connected to your university network and is preferably accessible from
    the internet on the specific port (please contact your computer center how to realize
    such a connection). If this is not possible, please check if you can make this network
    accessible from remote using a mobile internet connection. Or you provide a PC

connected to an island network of this structure where people can access the PC using TeamViewer, remote desktop software, or something similar.

If you have questions or problems to set your local network, please contact the TC via email. There will be also a Discord channel for networking to share configuration files and to solve problems.

4.4   Remote & Game Setup

This section describes the setup procedure for a 1 vs. 1 match. The setup procedure distinguishes between fully-autonomous and semi-autonomous setup. The used setup procedure is relevant for scoring the game (see section 4.6).

4.4.1   Button Interface

To give volunteers an interface to command autonomous acting robot, the following button interface sequences are defined:

1. `Head button front + Chest button`: Starting the autonomous calibration mode

2. `1x Chest button`: Stiff robot

3. `All three head buttons`: Unstiff robot

4.4.2   Start: 2h before match

1. Assignment of a volunteer from the host team for each remote team. They create own Discord rooms for communication during the whole setup and game phase and communicate this to the teams.

2. Initial meeting of the volunteers and the representatives from the teams in one of the Discord rooms.

3. Topics of this meeting are: Welcome, answering questions, agree on timing for calibration, and selecting robots.

4. For each team one randomly (see next points) selected functional robot is assigned from the pool.

   (a) The host team has a numbered list of functional robots from 1 to the maximum number.

(b) One volunteer screen shares a proper random number generator (`https://www.random.org/integers/`) with adjusted settings according to the number of available robots.

(c) The volunteer runs the number generator. The first number is the robot number for the home team, away team is second.

(d) If a robot, who wears the selected number, is already taken or not available, than the generator has to be run again.

5. Move to the individual Discord rooms to shortly discuss the team specific setup, calibration and game play procedure with the volunteer.

6. The competing team informs the competition venue if they are using fully-autonomous or semi-autonomous setup.

7. Connect the robot (should already be fully charged) to a charger. If the competing team chose semi-autonomous setup, a LAN cable is connected as well.

8. Each robot gets flashed

   - with the standard SoftBank binary image or
   - with the image provided by the respective team.

9. Each robot gets equipped with a USB drive according to 4.3.1 and started.

10. Teams can set their robot up remotely, if necessary. To reduce the amount of data transferred to set the robot up, teams should reduce this as much as they can and use installable images where possible. If the competing team chose fully-autonomous setup, this step is skipped.

11. The IP address given by the DHCP Server has to be communicated from the local host to the remote team using Discord. If the competing team chose fully-autonomous setup, this step is skipped.

12. According to the official game schedule, the first team named is the home team, plays on the left half of the field and the second called team is the away team and play on the right half of the field from the perspective of the GameController.

13. Dress robots with jerseys (see 6.3.4). The hosting team's 'home' and 'away' jersey are assigned to the 'home' and 'away' starting robot.

4.4.3 Calibration / Testing: 1 hour before match

1. 20 minutes to calibrate the robot supported by one volunteer.

2. The robot than can move over the whole field to calibrate itself. The robot has 10 minutes to calibrate. During this time the field has to stay empty. The volunteer has to actively watch the robot and to be ready to catch him as soon as it would leave the field or fall. The volunteer is allowed to catch the robot. To prevent damage the same rules as in normal game play have to be applied to prevent damage to the robot (see 4.5).

3. Before the calibration starts, on each starting position a ball gets placed. The robot can move any ball. If a ball leaves the field, it gets replaced at its kick-in position (see 6.4.6). If a robot scores a goal, the ball gets moved back to its starting position.

4. **Automatic calibration** is conducted in the following way: The volunteer places the robot on the normal initial position at the field side of an empty field. Then the `front head button + chest button` gets pressed to initialize auto calibration mode (see 6.4.2). At the end of the calibration period, the robot may sit down and get un-stiffed. Otherwise, the robot will be un-stiffed by the volunteer by pressing all head buttons simultaneously (see 6.4.2).

   Semi-automatic calibration: With support of a local volunteer the robot is calibrated remotely. Both volunteer and remote team meet in a Discord room and perform the calibration procedure of the remote team together.

5. Check Wi-Fi and game controller connection

4.4.4   Game Setup

1. Robots are in the game controller

2. Robots sit on field on the game controller's side on their halves on the height of the penalty spot facing the field. With one button press on the chest button the robot has to get up stiffed in the upright position and is waiting for the ready signal from the game controller.

3. The game will be started using the game controller as *Play-off game* and the robot moves to its starting position.

4. In `Set` the balls will be placed and the game will be started using a whistle.

5. In the second half the robots switch their sides.

6. Referees apply rules with focus on preventing hardware damage, because there is no SoftBank Robotics support (see 4.5).

7. When robots receive the finish message they have to sit down and will be brought to the chargers and plugged into network.

4.4.5 After Game

1. After, robots received the finish signal of the second half they sit down.

2. Robots have time to do all post-processing, storing the logs and shutting down.

3. If robots are not switched off after 5 minutes they will be switched off manually.

4. The data from the USB drive will be stored on another device and as soon as possible uploaded in the Nextcloud.

5. Teams are not allowed to download their logs directly.

6. Robots will be returned to pool for the next game.

4.5 Rules

A brief summary of the rule changes will be given here:

Competition Execution:

- The competition consists of three parts, the first half, a half-time break, and the second half. Each half is 5 minutes counted from the initial kick-off. (see Section 6.4.1)

- Software or configuration changes during a game are not possible. Only hardware changes are allowed! In particular, it is permitted to change batteries, fix mechanical problems, reboot the robots. Since the teams are not on site, the assistant referees take over these tasks as if they were a member of the corresponding team. (see Section 6.4.1 and Section 6.4.8)

- Each team has one NAO V6 and by default the two robots are wearing "home" and "away" jerseys of the hosting team with the number 2 on it (see Section 6.3.2)

- The players can be positioned anywhere within their own half, but no player is allowed to touch or exceed the centre / halfway line. (see Section 6.4.5 and Section 6.5.9)

- There is no manual placement of any robot. (see Section 6.4.5)

- The two balls, for each side, are placed onto the corners of the goal box - goal free kick positions - (see Section 6.4.6)

- If a ball goes over a sideline then the assistant referee will replace the ball back on the point of that sideline where it went out. If the ball goes over an end-line then the assistant referee will replace the ball onto the corner of the goal box. (see Section 6.4.6)

- This competition is executed with a GameController and the use of the button interface as a replacement for any GameController commands is not allowed! (see Section 6.4.2)

- If any robot player scores a goal (including own goal) the ball gets replaced by the referees to one of the starting points, on the other half. (see details in Section 6.4.3)

- After the game is in the state playing, the game state remains in it regardless of shot goals or scored points! Exception are the application of the Global Game Stuck rule and a referee timeout. (see Section 6.4.7)

- A Global Game Stuck is applied if, among other things, no ball was played from one half to the other for more than 1 minute. (see Section 6.4.7)

- Each competing team has only one robot as a field player on the field.

- Fields that are at least 3/4 of the original size can also be used for this competition. However, field sizes smaller than the original should be reported by email to the TC by June 1, 2021. (see Section 6.1.1)

Referees:

- All referees are allowed to **prevent robots from crashing** to the ground by catching them beforehand and then laying them down gently (see Section 6.6)! Robots are not allowed to dive for the ball on purpose (see section 6.5.6).

- The head referee decides whether a robot excessively damages itself and should remove it from the field via "Request for Pick-up". (see Section 6.5.3)

- A robot which is unable to autonomously stand up within 20 seconds after a fall and be **at least 10 seconds upright** will be penalized as fallen robot. (see Section 6.5.6)

- Since teams are playing with robots from other teams, there is a **maximum of 3 hardware related penalties**:

    - **fallen robot** or **inactive robot**, see Section 6.5.6
    - **request for pick-up** in the Playing or Ready state - either by the team or by the head referee, see Section 6.4.8 and Section 6.5.3

    After that this robot is excluded for the rest of the competition!

- If it comes to an excluding of a robot, the head referee, in consultation with the two team leaders, must decide whether the hardware errors that occurred were exclusively self-inflicted due to faulty code or whether it was a general hardware problem with the robot.

- Depending on this decision:

– In case of self-inflicted hardware problems will the game continue without this robot till the end of the regular time or till the remaining robot scores more points or has more point scored as the excluded robot.

– For general hardware-related errors of the robot, it will be replaced by another robot and the game will be restarted as soon as possible which depends on how much time this team needs to flash, setup and recalibrate the robot. This must not take longer than the official time for a remote setup (see Section 4.4)!

- A robot exchange can take place at most once per team, in this case this competition would be restarted 2 times! (see Section 6.5)

A detailed description of the rules can be found here in section 6.

4.6   Scoring

For this challenge points can be scored by:

- Shooting the ball in the opponents half (1 Point)

    – The ball has to stop inside the field (see Section 6.1.5)!

- Shooting a goal (1 Point)

    – Afterwards the team which scored the goal gets this ball back (see Section 6.4.3)

If the defending/other robot touches the ball when it was kicked over the centre line and before it comes to a full stop then **NO** points are rewarded! This allows the defending team to intercept balls which are shoot into their half of the field. However, robots are not allowed to dive for the ball on purpose (see section 6.5.6).

The head referee has to call:

- "Point for <colour>" for each scored point.

- "Goal for <colour>" for each scored goal.

and then the points will be counted by the operator of the GameController.

For teams playing with an **autonomously setup player** (see Section 4.2) a multiplication factor of **1.5** is given. This factor is multiplied by the points a team has scored at the end of normal game time (and each extension if applicable) to calculate the final points used to rank teams (see Section 4.7.2).

4.7 Challenge execution

The 1vs1 Challenge is played as a knock-out competition, as the points scored between individual games are not directly comparable.

The clock stops during stoppages of play (such as ready and set state after global game stuck)!

4.7.1 Competition System

It is planned to divide the participating teams into three groups, so that there are 8 teams in each group. Within each group, a ladder system will be used where only the winner of the game will advance.

In the end there will be 3 winners from each group, who will determine their final placing in matches each against each other. If there is a draw between the three final teams, the points scored in the final matches will be used to determine a winner.

The teams are randomly assigned to the groups and no subdivision into challenger shield or champions cup teams is considered. To allow all teams to play at least 3 times, the losers of a match will play in additional ladders.

The exact determination of the multiple knock-out rounds/ladders can only be done when the number of participating teams is known and will therefore be announced shortly before the RoboCup. Also the different time zones have to be taken into account and therefore there should only be two games per day per arena.

4.7.2 Winner and Rankings

The team which scored more points than the other, after the expiration of the regular playing time and by applying the multiplication factor, is the winner of the match. If the two teams scored the same number of points, the game will be a draw. In case of a draw the game duration gets extended by one minute. After each extension the (multiplied) score is evaluated again. At max 5 extensions à 1 minute are allowed.
If the game is still tied after overtime, a coin is tossed to determine a winner!

5 Remote Challenge: Autonomous Calibration

5.1 Idea of Challenge

Autonomous calibration is a challenge for the SPL to reduce the dependence on extensive calibration of robots before each individual SPL game. This challenge tests a team's autonomous calibration software separately from the 1v1 challenges to allow teams to demonstrate the quality of their calibration tools. Autonomous calibration may include adjusting:

- Camera settings to dynamic lighting conditions and individual robots

- Locomotion parameters for stable movement on different fields surfaces and individual robots

Requirements to participate in this challenge are:

1. Deploy your robot's software remotely or via a ready to install and use image

2. Use of the chest/head button interface

3. Use of the head button to denote different stages of the challenge

4. Run the software without GameController or any Wifi connection

5. Use Text-To-Speech for reporting the progress of the robot[1]

6. The host venue will also need a measuring tape

5.2 Prerequisites & Setup

The Prerequisites and Setup for this challenge will follow the same process as described in Sections 4.2 and 4.3 for the "1 vs 1 Challenge", with the following important changes:

1. Autonomous Calibration must be performed, and will be triggered at the start of the challenge using the chest/head button interface.

2. The network will be disabled once the software setup is complete

3. During setup and up until the challenge commences, a *camera shield* will be placed over the robot's camera. The camera shield may be a sheet of opaque paper, or an opaque bag.

---

[1]The TC has discussed the possibility of Text-To-Speech. Softbank provides a `say` executable on the standard Nao image which can be used. The TC permits and will help teams to share how to enable speech-to-text like the V6 remote setup. However, if teams note persistent problems the reporting mechanism will be adjusted.

5.2.1 Timing

Ideally, the challenge will be conducted in parallel with the '1vs1 Challenge', as described in Section 4. This challenge will be conducted before teams *manually* calibrate their robots for the 1vs1 challenge.

5.3 Challenge Execution

The challenge is conducted in two phases:

1. Autonomous Calibration
2. Evaluation

5.3.1 Phase 1: Automatic Calibration

The autonomous calibration phase will commence immediately after a team has confirmed the software has been successfully setup on the robot, and disconnected any from the robot.

The autonomous calibration phase will run as follows:

1. The robot shall be placed at the normal initial position (that is, at the side-line, and in-line with the penalty spot). Two balls shall be placed on the field, one in each half, approximately in the centre of each half, clear of any fields lines.

   - This shall denote the robot's "own half".
   - The other field half is the "opposition half".
   - The camera shield shall remain in place while the robot is placed.

2. The camera shield will be removed.

3. The *front* head button plus the chest button is pressed tapped. The head button press signifies to initialize auto calibration mode (see 6.4.2).

4. The robot has up to 10 minutes to calibrate. The robot may freely move about the field. However it should not touch either ball, nor leave the boundaries of the field area.

5. The robot may choose to end the calibration time early. It does so by standing still and raising one arm[2]. It should also say "Calibration finished".

---

[2]If the arms are not functional, use of the arms can be forgone in agreement with the referee.

- If the robot finishes the calibration time early, the timer should be stopped and the total calibration time recorded.

- The time is rounded to the nearest 5 seconds to avoid human error

6. If the 5 minute period is reached, the robot should immediately stop. The robot may also return to a seated position and unstiffen (see 6.4.2). If it does not do so the referee may use the chest button interface to penalise the robot (informing the robot to stop calibration).

7. The referee may optionally press all head buttons to unstiffen the robot, before processing to the evaluation phase.

8. At the end of the automatic calibration phase, the camera shield is placed on the robot.

5.3.2 Phase 2: Evaluation

1. The robot shall be placed in a stable position at the normal initial position

2. Two balls shall be placed on the field, one in each half. The balls will be placed in a random position, such that

   - The balls are within the field boundaries
   - The balls are not on any field line
   - The balls are fixed to the field with a small amount of tape to prevent them from moving.
   - The positions will be provided to the hosting venue before the challenge commences
   - All robot's participating at the same venue will be given the same fixed positions

3. The camera shield will be removed.

4. If necessary, the head buttons will be pressed to unstiffen the robot (see 6.4.2).

5. The *back* head button plus the chest button is pressed. The head button press signifies the challenge mode, compared to a normal game/challenge mode.

6. The referee will start a timer simultaneously with the above step.

7. During the evaluation phase, the robot must complete 5 tasks in sequence as *quickly* and *accurately* as possible (see points 9/10 for details):

   (a) Report the *field relative* (that is global) position of the ball in the robot's own half.
   (b) Walk to the centre of the goal in it's own half, at any rotation
   (c) Walk to the centre-circle ball kick-off spot, at any rotation
   (d) Report the *field relative* (that is global) position of the ball in the "opposition" half
   (e) Walk to the centre of the goal in the "opposition" half, at any rotation

8. The robot has up to 10 minutes to complete the challenge. The robot may freely move about the field. However it should not touch either ball, nor leave the field area.

9. To report a ball position the robot should:

    (a) Raise one arm

    (b) Say: "The ball is at: x y", where x and y is the *global* co-ordinates of the ball position. The global co-ordinate reference frame is defined in the `SPLStandardMessage.h` header file[3].

    (c) The referee should record the stated position, rounded to the nearest 10cm.

10. To report the desired position is reached the robot should:

    (a) Raise one arm

    (b) Say: "Finished walking"

    (c) The referee should record the robot's position by making the robot's location with a small amount of tape

11. When a robot has completed a task, referee should attempt to allow the robot to continue as quickly as possible. The referee does so by tapping *any* head button. The referee should pause the timer between the robot completing a task, and the referee tapping the head buttons.

12. When the robot completes the final task, the referee should stop the timer and record the total time taken in the evaluation phase, rounded to the nearest 5 seconds, to avoid human error

13. If the 10 minute period is reached or the robot has finished the final task, the chest button of the robot is pressed to penalise the robot and complete the evaluation phase.

14. *After* the conclusion of the evaluation phase, the referee should:

    (a) Measure the distance of the marked position of the robot to the correct position for each of the walking tasks, rounded to the nearest 10cm.

    (b) Compute the distance from the reported ball position to the correct position for each of the ball tasks, rounded to the nearest 10cm.

5.3.3 Termination Conditions

The challenge will be terminated at any stage if any of the following conditions are met:

- The robot falls *three* times

- The robot falls and is unable to return to a standing position after no more than 1 minute.

- The robot leaves the external boundary of the field.

- A robot takes a dangerous action that would result in damaging the robot.

---

[3]Linked here for reference.

5.3.4 Scoring

Scoring is conducted by ranking robots in each of the following categories:

1. Fastest time to complete the automatic calibration phase

2. Fastest time to complete the evaluation phase

3. Closest reported position of the ball in the robot's "own" half.

4. Closest reported position of the ball in the "opposition" half.

5. Closest robot position at the goal in the robot's "own" half.

6. Closest robot position at the centre circle

7. Closest robot position at the goal in the "opposition" half.

5.3.5 Venue Rankings

Due to differences between venues, teams are ranked according to all teams that attempted the challenge at each venue. Teams are ranked separately in each of the 7 categories, with the top ranked team receiving a rank of 1, and other ranks increasing monotonically.

Teams receive a total score equal to the sum of their ranks in each category at the venue. Thus, the team with the *lowest total score* is the best team at the venue.

5.4 Combine Scoring and Final Winner

Teams are given a final score equal to their *average score* across all venues at which they attempted the challenge. A team must attempt the challenge at *at least 3 venues* to qualify for the final ranking[4]. Places are awarded in the challenge teams in increasing average score, starting with the lowest scoring team receiving 1st place.

---

[4]The number of venues and completion of the challenge is subject to scheduling constraints and will be confirmed closer to the competition.

6   Common rules

The challenges are designed to use the rules of RoboCup SPL as published in 2020. However, to facilitate the global participation of all teams, various changes are required.

Therefore, the following re-produces the rules from RoboCup SPL 2020, with various details that have been modified, added, modified and/or omitted. Changes are marked with a colourbox .

6.1   Setup of the Environment

6.1.1   Field Construction (standard and minimum size)

The standard soccer field consists of green 8mm artificial turf mounted on a flat wooden base with outer field line dimensions of 9m x 6m and a total area of length 10.4 m and width 7.4 m. This is termed the **standard SPL field**. 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.

To avoid the need for teams to construct new fields just to participate in RoboCup 2021, fields with outer field line dimensions of at least 6m x 4m can be used for the 2021 competition. Goal dimensions should still be the same as the standard size field. This setup is termed the **minimum size field**. If teams do not have a field of at least minimum size for participation in local challenges, they should report this by email to the TC (`rc-spl-tc@lists.robocup.org`) as soon as possible, and no later than 1 June 2021, to determine if suitable arrangements can be made. Furthermore, it is not required that the field surface is astro-turf. Green carpet will suffice.

The standard dimensions of the soccer field are shown in Figure 6. A more detailed technical drawing is provided in Appendix 6.7 to this document. Note that inclusion of the penalty area lines, first introduced in the 2020 SPL rules, are optional for RoboCup 2021.)

Note that the penalty cross is a cross and there is a dash at centre field. White field lines can be made of the same 8mm 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.

The construction and placement of the goals is depicted in Figure 7 and Figure 8. The support structure for the net shall be made with small black, white, or grey bars or cylinders. The support structure shall be constructed exactly as shown in Figure 8.

6.1.2 Field Colours

The colours of the soccer field are as follow:

- The field (artificial turf) itself is green (colour 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.
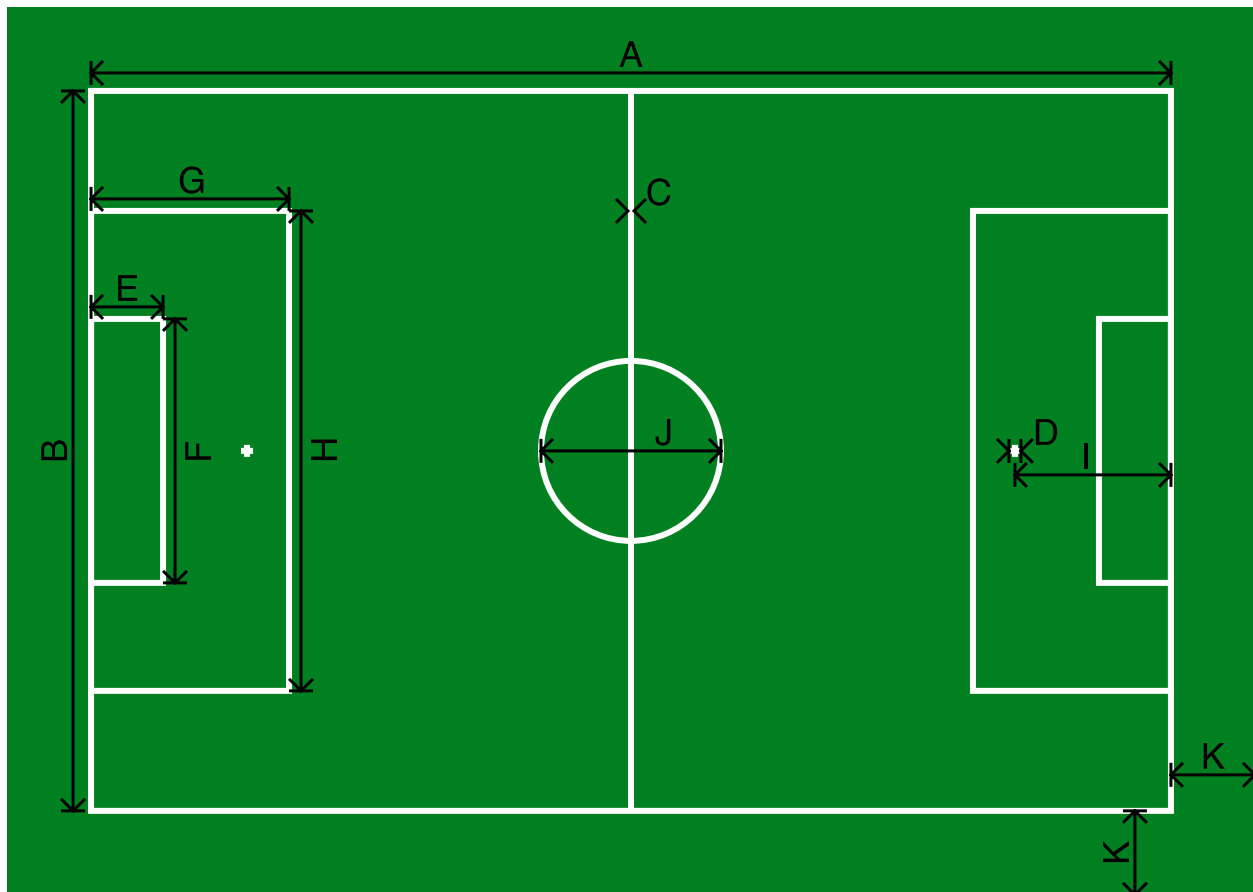
ID	Description	Length (in mm)	ID	Description	Length (in mm)
A	Field length	9000	G	Penalty area length	1650
B	Field width	6000	H	Penalty area width	4000
C	Line width	50	I	Penalty cross distance	1300
D	Penalty cross size	100	J	Centre circle diameter	1500
E	Goalbox area length	600	K	Border strip width	700
F	Goalbox area width	2200			

Figure 6: Schematic diagram of the standard soccer field (not to scale) and corresponding dimensions in mm. Note that measurements on this diagram are made to the centre of lines.
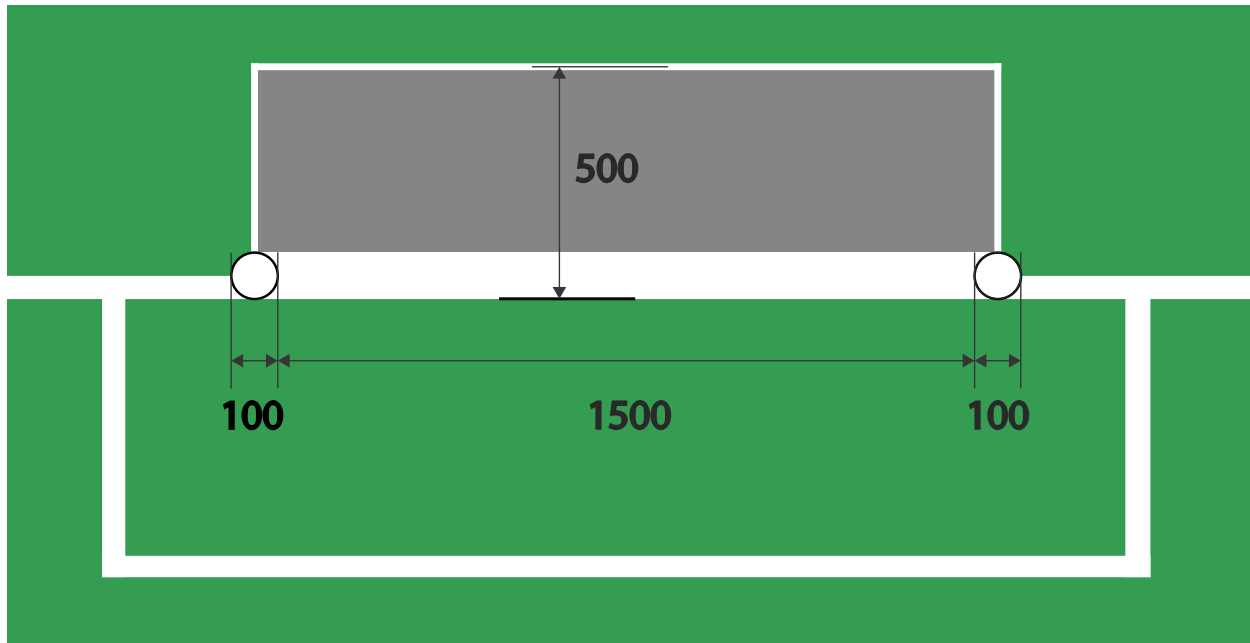
Figure 7: Dimensions of the goal (in mm), viewed from above, and its placement on the field.
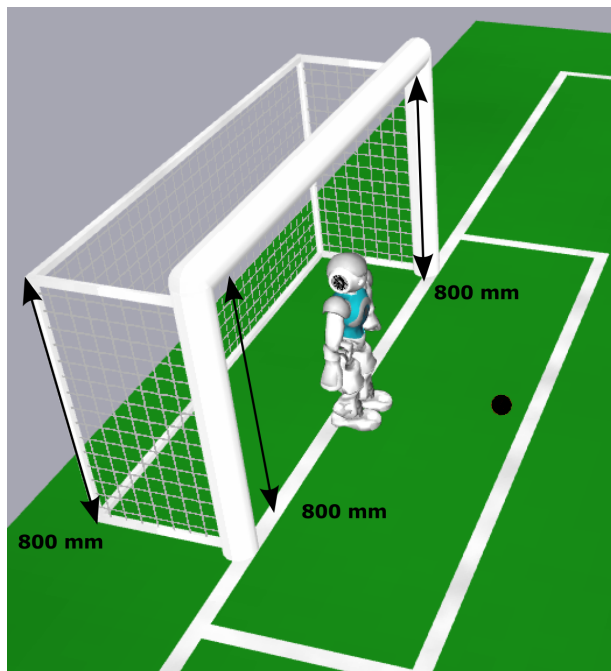
The goalposts and crossbar are made from 3 white cylinders with a diameter of 100mm. The net:

- has a height of 800mm

- is of white, grey or black colour

- is tightly supported via the support structure, in a way to minimize interference with the goal keeper

- has a weave with holes smaller than the ball diameter.

Figure 8: Appearance and dimensions of the goals.

- Goals (see Figure 8). The posts and top cross bar of both goals are white. The net and the support structure for the net are white, grey, or black.

Figure 9: A NAO and the official ball.

6.1.3 Lighting Conditions

The lighting conditions depend on the actual game venue . SPL fields may be placed near or under windows where possible. Whether or not 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).

Nevertheless, it is not expected that teams should change the lighting setup in their local venue for the purpose of RoboCup 2021.

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.

6.1.4 Ball

The official ball is a soft foam ball with a black and white soccer ball print (see Figure 9). They are 100mm in diameter and weigh 44 grams. These balls are available by writing to `info@ sportpaint.de` (in German or English) and asking to order the "pu schaumstoffball 10cm 100ss". Each ball costs EUR 2.50 plus shipping, where shipping cost depends on the destination.

6.1.5 Definition of Inside and Outside

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

- The field boundary lines are part of the field

- The penalty box lines (and the end field line inside of the goal) part of the penalty box

- The centre circle lines are part of the centre circle

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

6.2 Challenge streaming setup

There are three use cases for the streaming setup:

- Allow remote referees to judge a remote challenge.

- Allow participating teams to watch their robot's challenge

- Allow visitors to watch the games and challenges.

These cases should be taken into account when setting up a suitable streaming setup with respect to hardware equipment and internet connectivity. You can think of streaming on YouTube/Discord/BigBlueButton/Zoom ..., whatever is available (If bandwidth in the lab is limited, re-streaming should be considered on system with better network connection). You should consider that referees should get prioritised access to the stream. In the root folder of the NextCloud drive (see 4.3.2) you find a `streaming.md` file where every team has to publish a link that can be used by public and teams to watch the challenges and if available another link that can be used by the referees to watch the challenge. The public link will be published on the SPL website / RoboCup 2021 website.

TODO: Make NAO Devils stream setup as example available?

6.3 Robot Players

A match is played by two teams, each consisting of *one player*. All robots are *field players* and no robot is designated as *goalkeeper*.

6.3.1 Hardware

All teams must use a NAO humanoid robots in version 6 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.

6.3.2   Field Players

Each field player has a jersey number from the set $\{2, 3, 4, 5, 6\}$. However, by default, the number "2" is used for the field player. This assignment can be changed due to availability of jerseys.

6.3.3   Stationary Obstacle Robots

Some of the challenges use stationary obstacle robots.

All stationary obstacle robots are allowed to stand upright or sit down and can remain turned off for the duration of the challenge. Static obstacle robots may not lay down on the field. Stationary obstacle robots are not required to be V6 edition NAO robots. It is allowed to use any NAO edition that was legal to use in a RoboCup SPL competition in the past.

Stationary obstacle robots are required to not wear any jerseys.

6.3.4   Team Markers

Robots use coloured jersey shirts as team markers in the "home" and "away" colours of the hosting arena team. Each jersey shirt has a player number (1-6) printed on it. The use of player number 1 is disallowed in the challenges of the 2021 competition. The team markers are worn as shown in Figure 10.

Teams may use any jersey that was approved for a RoboCup SPL competition in the last 4 years without needing to reapprove it in 2021.

Teams may design and manufacture their own jerseys in any colour (multi and many colour jerseys are acceptable), but must follow these guidelines:
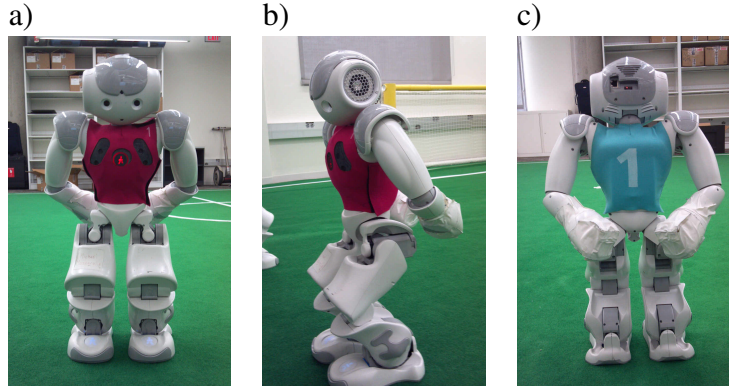
Figure 10: Team markers. a) Front view. b) Side view. c) Back view.

- 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 10. 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 must have a primary colour 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.

- 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. The use of player number 1 is disallowed in the challenges of the 2021 competition.

- Teams must have two sets of jerseys that are significantly different in terms of their primary colour.

- Designs must be submitted to rc-spl-tc@lists.robocup.org for approval by May 1st, 2021. 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/arena must designate a "home" colour and an "away" colour when asked about one month before RoboCup. Robots must wear the 'home' jerseys when they are "home" (the first team

listed on the schedule). The "away" team (the second team listed on the schedule) will wear the "away" jerseys.

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 11). A box drawn around the non-white area of these logos must not cover more than a 25 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.

6.3.5 Wireless Communications

The robots must play without human control. Communication is only allowed between a robot and the GameController.

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

Figure 11: Example Sponsor/Team Logo placement on legs.

Each team will get a range of IP addresses that can be used both for their robots and their computers/remote connections. The network configuration (e. g. IP addresses, channels, SSIDs, and required encryption) of the fields will be announced (see Section 4.2.2) .

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

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 6.4.2.

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.

6.4 Game Process

6.4.1 Structure of the Competition

Unless otherwise specified, a competition consists of three parts, the first half, a half-time break, and the second half. Each half is 5 minutes counted from the initial kick-off.

The half-time break is five minutes and code changes are prohibited in the half-time! It is mainly used to cool down the robots and to charge them.

The head referee signals the commencement of each half with a single whistle blow (that is, the Initial kick-off, see Section 6.4.4). 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.

6.4.2 Robot States

Robots can be in *eight* different *primary* states (see Figure 12). 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 use of the button interface as a replacement for any GameController commands is not allowed in the 1vs1 competition!

Should both robots have problems with the Wifi/GameController connection the head referee should issue a referee timeout (see Section 6.4.9).

If only one robot does not respond to the GameController then it is not included in the game (via a 'Request for Pick-up', see Section 6.4.8), and the game starts without the offending robot.

Initial. After booting, the robots are in their *initial* state. 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.

Ready. In this state, the robots walk to a legal position on their half . They remain in this state, until the head referee decides that there is no significant progress, up to a maximum of 45 seconds.

Set. In this state, the robots stop and wait for Kick-Off (see Section 6.4.5). Illegally positioned robots are penalized. 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 6.5.6). 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.

Playing. In the *playing* state, the robots are playing the competition. Shortly pressing the chest button will switch the robot to the *penalized* state.

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.

Unstiff. *This state has been added in 2021.* It helps to facilitate a consistent and safe handling of the robots for remote competition. During the Initial, Ready, Set or Penalised states, if all head buttons are pressed, the robot should move to a safe seated/crouched position and unstiffen all joints. Pressing all three head button while in the Unstiffen state, permits the robot to stiffen it's joints and return to the previous state, or a state as indicated by GameController. (Note, this is not currently shown in Figure 12.)

Calibration. *This state has been added in 2021.* This state denotes the robot is acting with automatic calibration. This state may only be entered from Initial/Ready by pressing the *front* head button plus the chest button.

TW: Added Unstiff state. Please review for consistency with 1vs1 and calibration challenges.

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. Robots that begin moving their legs or
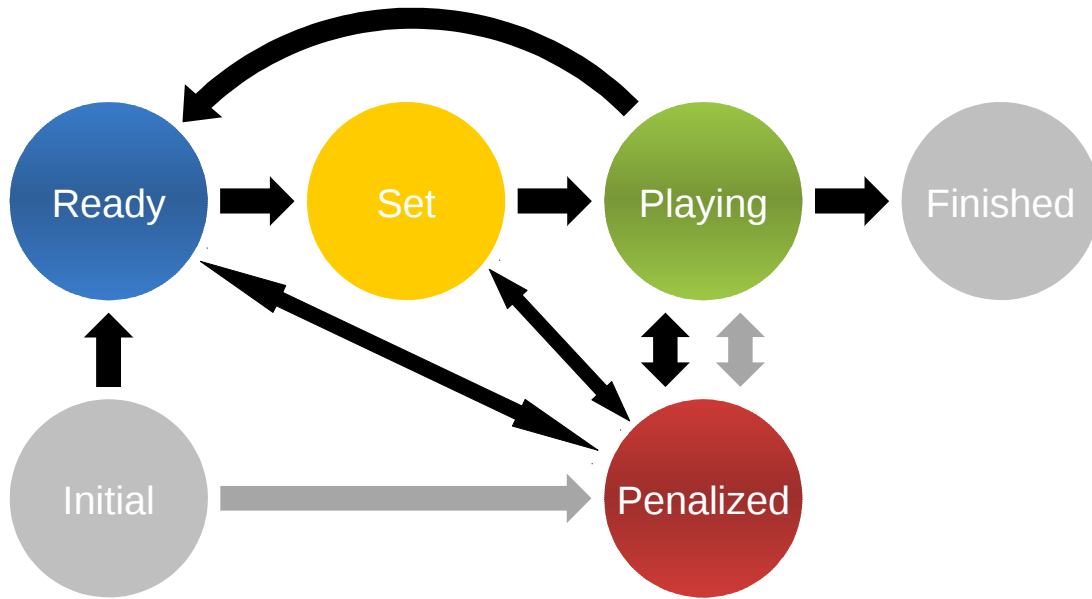
Figure 12: Robot states. Button interface transitions are shown in grey. GameController transitions are shown in black. However, any transition possible should be sent by the GameController.

locomoting 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 6.5.5) GameController signal (and moved back to their original position if they have moved significantly before becoming penalized) until the GameController transmits the *Playing signal*.

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

- Initial: Off
- Ready: Blue
- Set: Yellow
- Playing: Green
- Penalized: Red
- Finished: Off

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.

6.4.3 Goal

A goal (including own goal) is achieved when the entire ball (not only the centre of the ball) goes over the goal-side edge of the goal line, i. e. the ball is completely inside the goal area[5].

If any robot player scores a goal (including own goals) the ball gets replaced by the referees to one of the ball starting points. The ball gets placed on the half opposite to the player that scored the goal. The ball is placed in the ball starting point farthest away from the player that scored the goal (unless blocked by a robot or ball then, the other goalbox corner is used). The ball can be played again without delay.

The head referee signals a goal by a single whistle blow, followed by the call "Goal <colour>". However no GameController action shall be performed.

After the game is in the state playing, the game state remains in it regardless of shot goals or scored points! Exceptions are the application of the Global Game Stuck rule and a referee timeout, see Section 6.4.7 and Section 6.4.9

6.4.4 Initial Kick-off

The first kick-off at the start of each half is the initial kick-off. Before the initial kick-off, i. e. before the start of each half, both robots must be in the initial state and must be placed on the sidelines, closest to the GameController, in their own half of the field at the height of the penalty spot. Once the robots receive the *ready* signal from the GameController, they are to proceed as described in Section 6.4.5.

6.4.5 Kick-off

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

In the ready state, the robots should walk to their legal kick-off positions. The players can be positioned anywhere within their own half, but no player is allowed to touch the centre / halfway line.
All robots that do not reach legal positions will be penalized with the "Illegal Position" penalty (see Section 6.5.4).

In the *set* state, the robots must not locomote (see Section 6.4.2). A referee places the two balls, for each side, on the goal free kick positions (see Section 6.4.6). If the ball is moved by one of the robots during *set* it is replaced by one of the referees.

---

[5]The goal line is part of the field.

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 signalled the kick-off, the robot's state is switched to *playing* by the GameController.

6.4.6   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 goes over a sideline then the assistant referee will replace the ball back on the point of that sideline where it went out.

If the ball goes over an end-line then the assistant referee will replace the ball onto the corner of the goal box 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 box meets the goal line. If the corner is blocked by a robot or ball then the other goalbox corner is used.

Note that no GameController action is required.

6.4.7   Global Game Stuck

In the event of no "substantial change"[6] in the game state for 30 seconds OR no ball was played from one half to the other for more than 1 minute , this is considered a global game stuck and the referee calls "Global Game Stuck".

Once the referee calls Global Game Stuck, players enter the Ready state and a new kick-off (see Section 6.4.5) is awarded.

6.4.8   Request for Pick-up

Either team may request that 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.

Only hardware changes are allowed during a request for pick-up! In particular, it is permitted to change batteries, fix mechanical problems, reboot the robots. Since the teams are not on site, the assistant referees take over these tasks as if they were a member of the corresponding team.

---

[6]"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)

However it is prohibited to change the robot's control program or any configuration file.

Any strategic "Request for Pick-up" is not allowed. That is, gaining an advantage by removing the robot from the competition. 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 leaders should make a "Request for Pick-up".

The returning robot may be returned following the normal replacement procedure once at least 45 seconds 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. Note here, that the returning 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.

6.4.9   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 are only allowed to do hardware changes during these timeouts and 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.

6.5   Forbidden Actions and Penalties

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

Since teams are playing with robots from other teams, there is a maximum of 3 hardware related penalties:

- **fallen robot** or **inactive robot**, see Section 6.5.6

- **request for pick-up** in the Playing or Ready state - either by the team or by the head referee, see Section 6.4.8 and Section 6.5.3

- Robots are not allowed to dive for the ball on purpose, see section 6.5.6.

After that this robot is excluded for the rest of the competition!

If it comes to an excluding of a robot, the head referee, in consultation with the two team leaders, must decide whether the hardware errors that occurred were exclusively self-inflicted due to faulty code or whether it was a general hardware problem with the robot.

Depending on this decision:

- In case of self-inflicted hardware problems will the game continue without this robot till the end of the regular time or till the remaining robot scores more points or stop if it has more points scored than the excluded robot.

- For general hardware-related errors of the robot, it will be replaced by another robot and the game will be restarted as soon as possible which depends on how much time this team needs to flash, setup and recalibrate the robot. This must not take longer than the official time for a remote setup (see Section 4.4)!

A robot exchange can take place at most once per team, in this case this competition would be restarted 2 times!

6.5.1 Penalty Procedure

When a robot commits an infraction , the head referee shall call out the infraction committed, the primary jersey colour 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.

6.5.2 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 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 signalled to the robot, it is not allowed to move in any fashion. The removed robot will be placed outside of the field facing away from the field of play.

The initial duration of the standard removal penalty time is 45 seconds. Unless otherwise specified, the penalty time increases by 10 seconds each time a team commits any infraction. That is, the first infraction will result in a penalty time of 45 seconds, the second infraction (of any type) results in a penalty time of 55 seconds, the third infraction is 65 seconds, etc.

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 seconds 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 and on the sideline that is nearest to the GameController. The robot should be placed close to the position where the penalty spot projects on the sideline. This is illustrated in Figure 13.

With approximately 5 seconds 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.

6.5.3 Forbidden Actions

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

Manual Interaction by Team Members Manual interaction with the robots, either directly or via some communications mechanism, is not permitted.
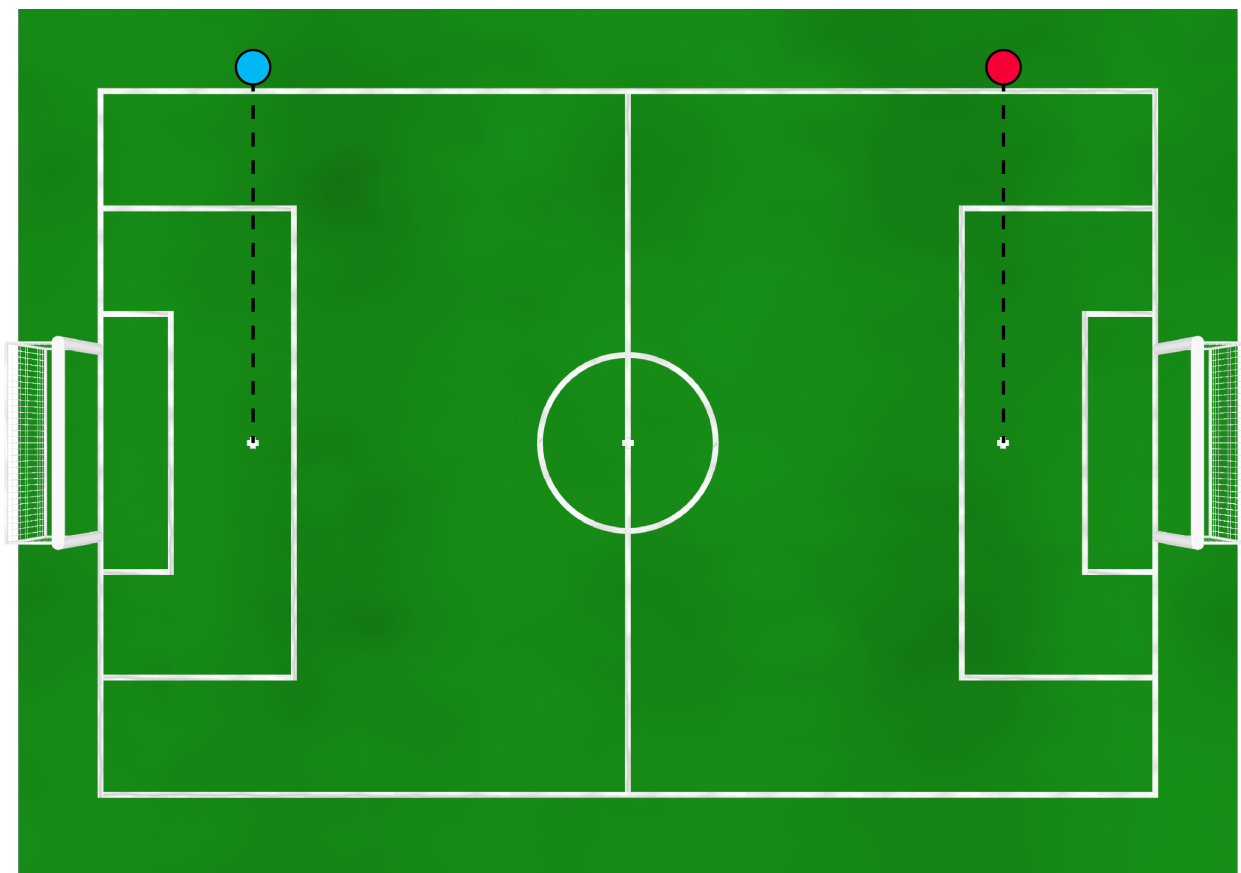
Figure 13: For robots coming back from a standard removal penalty, re-entry points are inline with the penalty spot in their own half, on the sideline on the side away from the ball.

Locomotion Type   Robots should clearly demonstrate bipedal walking similar to human walking. Other types of locomotion involving other parts than feet (crawling etc.) are strictly forbidden. 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.

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 competition .

Damage to the Robot   The head referee decides whether a robot excessively damages itself and should remove it from the field via "Request for Pick-up". All referees are allowed to prevent robots from crashing to the ground by catching them beforehand and then laying them down gently. Robots are not allowed to dive for the ball on purpose (see section 6.5.6).

6.5.4 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 6.5.2). The head referee will call "Illegal Position <robot>".

For simplicity, Illegal Positioning penalties during the *Set* state (for kick-off) do not count towards the incremental penalty count[7].

Refer to Section 6.1.5 for the definition of *inside/outside* of a region of the field.

"Illegal Position" shall be imposed if a robot is not inside its own half at the time the Set state starts. It will then be penalized and removed for 15 seconds. The centre line does not count as part of the own half for this penalty, nor does the area inside the goal!

6.5.5 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. It will then be unable to move until it receives 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.

6.5.6 Fallen or Inactive Robots

If a robot falls during the game, it should start executing a getup action within 5 seconds. If it does not commence a get up action within 5 seconds, it will be penalized and removed for 45 seconds. A robot which is unable to autonomously stand up within 20 seconds after a fall and be at least 10 seconds upright will be penalized and removed for 45 seconds. In both cases, the head referee will call "Fallen Robot <robot>".

No robot is permitted to 'dive' (that is deliberately fall in a way that might cause its torso, arms or hands) to intercept the ball. The robots should be programmed to attempt to remain upright – that is, supported by its feet.

A robot that has ceased activity for 10 seconds or has turned off will be removed and penalized for 45 seconds. 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.

---

[7]Historically, the Illegal Positioning penalty only occurred during a kick-off, and other illegal actions were termed Illegal Defender. Illegal Positioning & Defender have been merged, but the penalty count left unchanged.

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'.

6.5.7 Player Stance

In order to intercept kicked balls the robots are allowed to go into a wide stance as long as they come back to a normal stance within 5 seconds and do not excessively damage the robots [8]. Robots are not allowed to stay in a stance that is wider than the width of the robot's shoulders for more than 5 seconds. Staying in a wide stance for longer than 5 seconds will result in the standard removal penalty.
If the robot has fallen down, it must start getting up within 5 seconds.

6.5.8 Playing with Arms/Hands

Playing with arms/hands occurs when a field player 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 6.4.6). Goals resulting from a ball contact with the arms/hands during a fall or get-up do not count and result in a kick-in (see Section 6.4.6) as if the ball went over the goal line next to the goal.

6.5.9 Leaving the Field

A robot that intends to leave the 7.4 m × 3.7 m carpeted area of its **own half** will be subject to the standard removal penalty (see Section 6.5.2)!

A touching/exceeding of the centre/halfway line also leads to this standard removal penalty.

---

[8] "excessively" is decided by the head referee in order to limit damages to robots

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 into the goal area for more than 5 seconds, 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).

6.6 Judgment

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

The local team of an arena has to provide the referees. The number of referees depends on local regulations and can be reduced to a head referee and an operator of the GameController.

All referees are allowed to prevent robots from crashing to the ground by catching them beforehand and then laying them down gently!

6.6.1 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/spectators or the teams and the head referee.

The head referee also decides whether a robot excessively damages itself and should be removed from the field (see Section 6.5.3).

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[9]. 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. 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 6.4.5), a goal (see Section 6.4.3), and ending a half of gameplay (see Section 6.4.1).

---

[9]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.

The head referee should avoid handling the ball (except for placing the balls for a 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, are too far away or had to be dropped due to local regulations.

6.6.2 Assistant Referees

The, in the ideal case, two assistant referees handle the robots and the balls. They start the robots if they are not using the GameController, they move the robots, if a manual placement is needed, they take the robots out when they are penalized, and they put the robots in again. An assistant referee will also replace the ball when it goes off the field or becomes stuck between a players feet.

If a team requests to pick up a robot, an assistant referee will pick it up and put it on the sideline. Also the assistant, on behalf of the teams, can do hardware changes to robots on the sideline, i. e. reboot it or change and secure the battery.

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 or to catch a falling robot.

6.6.3 Operator of the GameController

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 seconds 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 global game stuck, and continues it at the kick-off). They should count aloud the remaining seconds in a half once the time remaining is 5 seconds or less. Finally, they should repeat the calls of the head referee to make sure it was heard correctly.

6.6.4 Referees During the Match

The head referee and the assistant referees should wear clothing and socks *of black or dark blue colour* (blue jeans are acceptable) and avoid reserved colours 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 or to catch a falling robot . They should avoid interfering with the robots as much as possible.

6.6.5 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-coloured 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.

6.7 Technical Field Drawings

50

100

50

50

50

50

100

50

50

50

25

Dimensions are in millimeters. The penalty cross is symmetric about both axes (shown in blue).