

RoboCup Soccer Humanoid League Rules and Setup

for the 2010 competition in Singapore

Draft of March 2nd, 2010

Changes from 2009 to 2010 are **marked in green text color**.

RoboCup Humanoid League Mailing List (to be used for rule discussion and questions): <https://lists.cc.gatech.edu/mailman/listinfo/robocup-humanoid>

RoboCup Humanoid League Home Page: <http://www.tzi.de/humanoid/>

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Preamble

These rules are intended to ensure a fair competition in the RoboCup Soccer Humanoid League. They want to encourage creativity and technical development. The rules are oriented towards the FIFA Laws of the Game. However, they still deviate in many points from the FIFA laws, but it is intended to decrease these deviations in the future, in order to work towards the long-term goal of playing with humanoid robots against human soccer teams.

Among the research challenges that are specific to the Humanoid League is maintaining the dynamic stability of the bipedal robots while they are walking, running, kicking, and performing other tasks. Another example is the coordination of perception (with a human-like limited field of view) and locomotion. The humanoid soccer robots must also be robust enough to deal with challenges from other players.

Size Classes

As it is not feasible to have humanoid robots of very different sizes play against each other, the competitions are held in **three** size classes: KidSize, TeenSize and AdultSize. See Section 4 for the definition of these classes.

Male and Female

References to the male gender in the rule book in respect of referees, assistant referees, players and officials are for simplification and apply to both males and females.

1 The Field of Play

The competitions take place on a rectangular field, which contains two goals, field lines, and two landmark poles, as shown in Fig. 1.

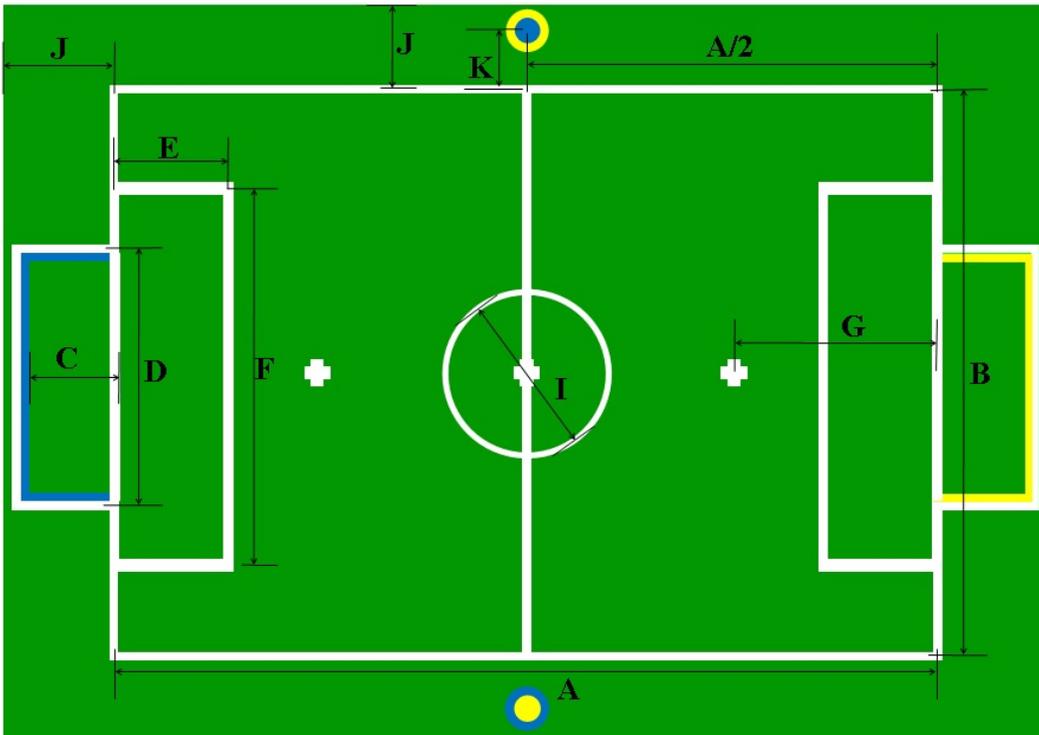


Figure 1: Humanoid robot soccer field (not to scale).

1.1 Playing Surface

The field consists of a flat and even ground which is covered with green carpet. The white lines are 5cm wide. Line segments of 10cm length are used to denote penalty mark and the kick-off position (center mark). The longer outer field lines are called touch lines, whereas the shorter outer field lines are called goal lines. The field is surrounded by a border strip, which is also covered with green carpet. The world outside the border strip is undefined.

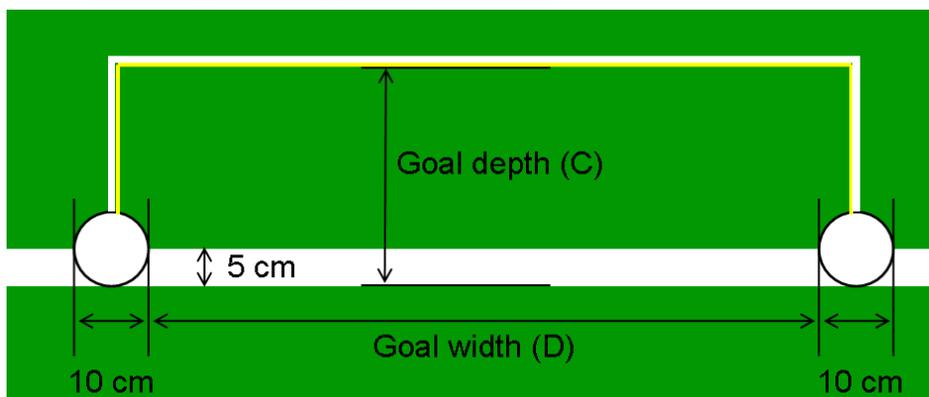
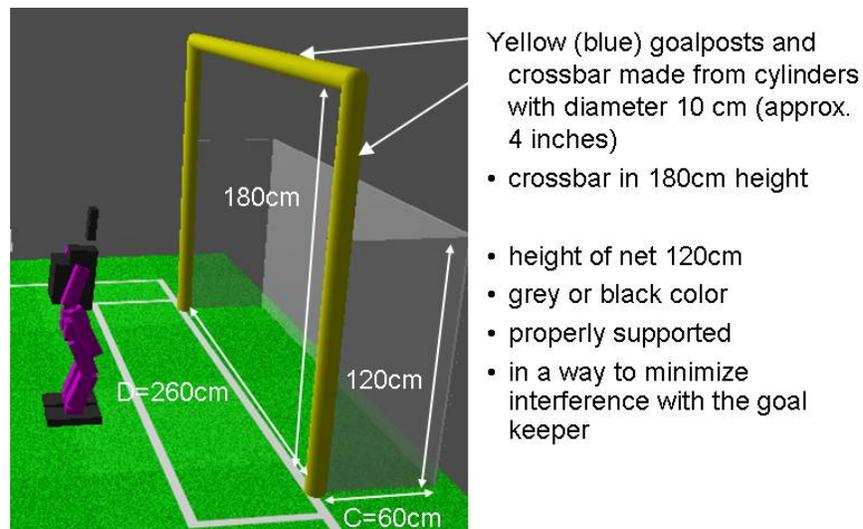
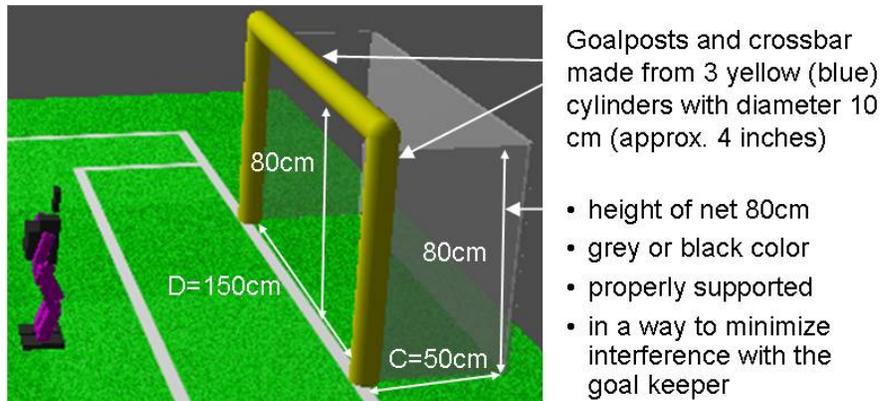


Figure 2: KidSize (top) and Teen-/AdultSize (middle) goals; birds eye view of goal layout (bottom).

Table 1: Dimensions of the rectangular field of soccer play (in cm).

		KidSize	TeenSize & AdultSize
A	Field length	600	
B	Field width	400	
C	Goal depth	50	60
D	Goal width	150	260
E	Goal area length	60	
F	Goal area width	300	
G	Penalty mark distance	180	
I	Center circle diameter	120	
J	Border strip width (min.)	70	
K	Distance of pole to field	40	

1.2 Goals

A goal is placed in the middle of each goal line. One of the goals has a colored yellow frame. The other goal frame is colored blue. Nets in grey or black color are attached to the goals and the ground behind the goal, provided that they are properly supported and do not interfere with the goalkeeper. The goals for the KidSize field have a crossbar at a height of 80 cm. The height of the net is the same and it is open from the top (see Fig. 2). The TeenSize and AdultSize goals have a crossbar at height of 180cm and the height of the net is 120cm. The goal posts and crossbars are white and cylindrical and have a diameter of 10cm (see Fig. 2).

1.3 Landmark Poles

The two landmark poles are placed at each of the two intersection points between the touch line and the center line. The landmark poles have a diameter of 10 cm. They consist of three segments of 15 cm height, placed above each other. The lowest and the highest segments are colored in the same color as the goal at its left side (see Fig. 3).

1.4 Lighting

The lighting conditions depend on the actual competition site. Lighting temperature may differ significantly from previous years, as only ceiling lights are used.

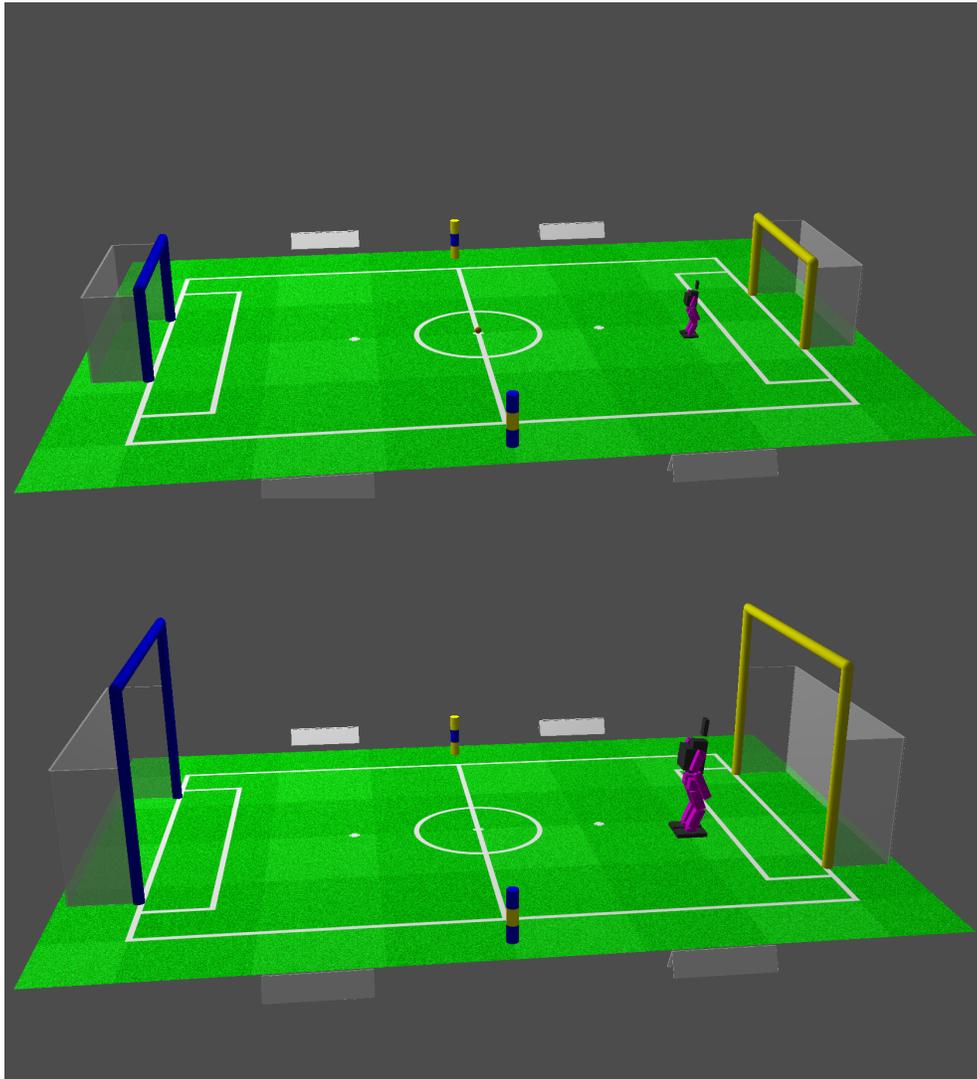


Figure 3: Humanoid soccer fields with KidSize (top) and Teen-/AdultSize (bottom) goals (to scale).

The field is illuminated presuming a sufficient bright and constant lighting on the field (i.e. no daylight).

1.5 People Area

Around the field of play (Figure 1) a field zone is defined on site in which only the referee (Section 5), the assistant referees (Section 6) and the two robot handlers are allowed to stay during the game. **The field zone must give sufficient space to the referees and robot handlers for passing behind the landmark poles and the goals.** All other people (including other team members, organizational staff, representatives of the press and the media etc.) must stay outside the field zone.

2 The Ball

Each size class uses its own ball:

1. KidSize: Standard size orange tennis ball,
2. TeenSize **and AdultSize**: Orange beach handball, size 2 (18.0cm diameter, 294g).

3 The Number of Players

A match is played by two teams, each consisting of not more than three players in KidSize and not more than two players in TeenSize, one of whom must be designated as goalkeeper. A match may not start if either team consists of less than one player.

3.1 Incapable Players

Players not capable of play (e.g. players not able to walk on two legs, players not able to stand, or players with obvious malfunctions) are not permitted to participate in the game. They must be removed from the field. It is up to the referee to judge whether a player is capable of play. The referee may ask the team leader of a player suspected to be incapable of play to demonstrate playing ability at any time. A field player that is not able to get back into a stable standing or walking posture from a fall within 20 seconds will be removed from the field for 30 seconds removal penalty and has to reenter the field according to 3.3.

3.2 Substitutions

Up to two players per game can be substituted by other players of the same team. The referee must be informed prior to the substitution. A substitute only enters the field after the player being replaced left the field and after receiving a signal from the referee. Any of the other players may change places with the goalkeeper, provided that the referee is informed before the change is made and that the change is made during a stoppage of the match. Exchanging a field player with a goalie does not count as substitution.

3.3 Temporal Absence

Servicing robots on the playing field is not permitted. A robot may be taken out of the field for service, after receiving permission from the referee. Taking out a robot for service does not count as a substitution. A serviced robot may not come into play again before 30s elapsed after it was taken out. It has to enter the field at the one of the two endpoints of the halfway line which is further away from the current ball position. It has to face the center of the field when entering.

4 The Design of the Robots

Robots participating in the Humanoid League competitions must have a human-like body plan, as shown in Fig. 4. They must consist of two legs, two arms, and one head, which are attached to a trunk. The robots must be able to stand upright on their feet and to walk on their legs. The only allowed modes of locomotion are bipedal walking and running.

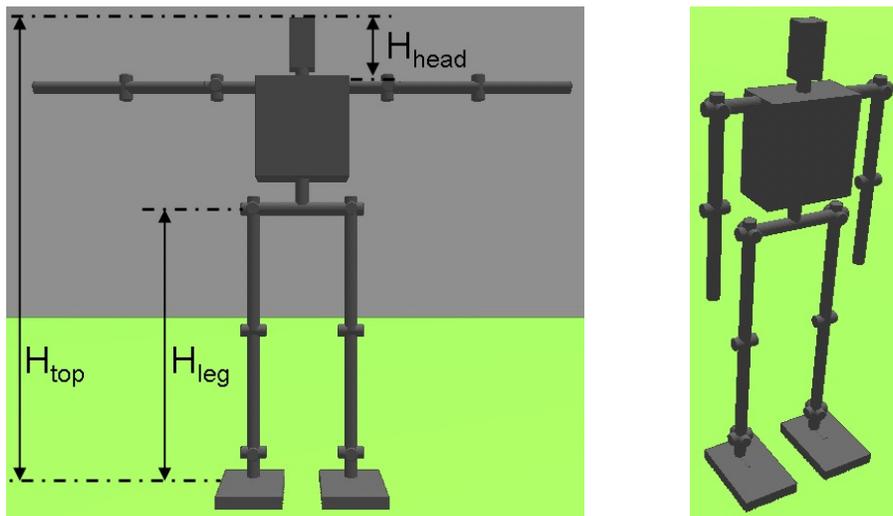


Figure 4: Example of a humanoid robot body plan (left) and standing upright pose (right).

4.1 Robot Height

4.1.1. The height H of a robot is determined as follows:

$$H = \min \{ H_{\text{top}}, 2.2 \cdot H_{\text{com}} \}, \quad (1)$$

where H_{top} denotes the height of the robot when standing upright (with fully extended knees, cf. Fig. 4 right) and H_{com} denotes the height of the robot's center of mass, measured in upright posture.

4.1.2. Based on H , the following size restrictions apply:

- $30\text{cm} \leq H \leq 60\text{cm}$ to play in the KidSize class,
- $100\text{cm} \leq H \leq 160\text{cm}$ to play in the TeenSize class.

- $100\text{cm} \leq H \leq 120\text{cm}$ to play in the TeenSize class.
- $130\text{cm} \leq H \leq 160\text{cm}$ to play in the AdultSize class.
A robot larger than 160cm may be allowed to play in the AdultSize class, provided that:
 - $H < 180\text{cm}$ and
 - the robot fits at all times into a vertical cylinder of diameter 130cm.

4.2 Weight Restrictions

The maximum weight for robots allowed to play in the TeenSize class is 20 kg.

4.3 Size Restrictions

All robots participating in the Humanoid League must comply with the following restrictions:

1. Each foot must fit into a rectangle of area $H^2/28$.
2. Considering the rectangle enclosing the convex hull of the foot, the ratio between the longest side of the rectangle and the shortest one, shall not exceed 2.5
3. The robot must fit into a cylinder of diameter $0.55 \cdot H$.
4. If the arms are maximally stretched in horizontal direction, their extension must be less than $1.2 \cdot H$.
5. The robot does not possess a configuration where it is extended longer than $1.5 \cdot H$.
6. The length of the legs H_{leg} , including the feet, satisfies $0.35 \cdot H \leq H_{\text{leg}} \leq 0.7 \cdot H$.
7. The height of the head H_{head} , including the neck, satisfies $0.05 \cdot H \leq H_{\text{head}} \leq 0.25 \cdot H$. H_{head} is defined as the vertical distance from the axis of the first arm joint at the shoulder to the top of the head.
8. The leg length is measured while the robot is standing up straight. The length is measured from the first rotating joint where its axis lies in the plane parallel to the standing ground to the tip of the foot.

4.4 Sensors

Teams participating in the Humanoid League competitions are encouraged to equip their robots with sensors that have an equivalent in human senses. These sensors must be placed at a position roughly equivalent to the location of the human's biological sensors. In particular,

1. The only active external sensor allowed is sound (“human-like” with respect to volume and frequency) with one loudspeaker on the robot. The loudspeaker may be placed in the head, neck or trunk of the robot. Any other active sensor (emitting light, sound, or electromagnetic waves into the environment in order to measure reflections) is not allowed.
2. External sensors, such as cameras and up to two microphones, may not be placed in the legs or arms or the torso of the robots. They must be placed in the robot's head and above any neck joint.
3. The field of view of the robots is limited at any time to 180 degrees. This means that the maximum angle between any two points in the overlap of the field of views of all cameras mounted on the robot must be less than 180 degrees. Also the pan-tilt motion of the head and the cameras mounted on the robot's head is restricted to be more human like not only with respect to the field of view but also to the range of motion of the neck joints. Therefore, the mechanism to pan the camera is limited to 270 degree pan which means ± 135 degrees from the position looking straight ahead. The mechanism to tilt the camera is limited to ± 90 degrees (measured from the horizontal line). Furthermore, if positioned at the center mark the robot may not be able to see both goals in any tilt angle and in any standing or walking posture of the robot.

“Field of view” refers to the field of view of all cameras together and of how much of the soccer field all cameras together can view at most at one time. By how much the soccer field can be viewed by the robot at most one time is defined by a half sphere with its center axis pointing in the forward direction with respect to the robot's frontal plane as shown in the Figure 5.

4. The number of cameras is limited to a stereo vision setup (i.e., max. 2 cameras with a large overlap) only. Monocular vision is also allowed.
5. Touch sensors, force sensors, and temperature sensors may be placed at any position on the robot.

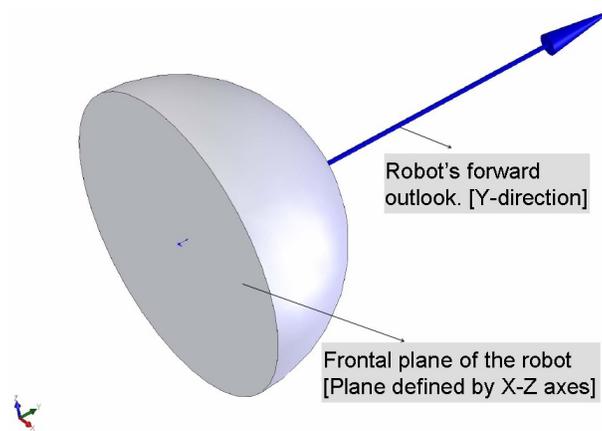


Figure 5: Illustration of field of view.

6. Sensors inside the robot may measure all quantities of interest, including (but not limited to) voltages, currents, forces, movements, accelerations, and rotational speeds. They can be at any position inside the robot.

4.5 Communication and Control

4.5.1. Robots participating in the Humanoid League competitions must act autonomously while a competition is running. No external power supply, teleoperation, remote control, or remote brain of any kind is allowed.

4.5.2. Robots may communicate only via the wireless network provided by the organizers which must support the referee box. The total bandwidth of the robots belonging to one team may not exceed 1MBaud. The robots must not rely on availability or quality of the wireless network. They must be able to play if the network is not available or of low quality. Only robots are allowed to communicate by WLAN. Any other computers of team members are only allowed to communicate by tethered LAN. No other wireless communication is allowed onsite. All other wireless hardware must be deactivated. A team may be disqualified if one of the team members violates this rule.

4.5.3. Robots of a team may communicate with each other at any time during a game. They may receive start and stop signals from an off-the field computer. This computer is only allowed to listen to the wireless communication while the ball is in play. It may be used to send game-control signals (e.g. kick-off, penalty, free kick, ...) to the robots during game stoppages. Any other kind of transmission from an external computer to the robots is prohibited. The start and

stop signal are to be sent via UDP when the ball is not in play (e.g. from a game controller/referee box via UDP broadcast). This implies that any monitoring is only done by receiving UDP communication from the robots. Sending any other transmission from an external computer to the robots has to take place during a timeout or using a direct cable between the computer and the robot during maintenance of the robot.

In 2009 a prototype of a game controller/referee box **has been** introduced. It uses UDP to broadcast information to the robots like elapsed time, current score, game state (ready, set, playing, finished) and the robot-specific penalized state. The source code is open.¹ **To encourage teams to use the referee box, 10s advantage is given to teams using the referee box in any stoppage of the game (cf. Section 8).**

4.5.4. No humans are allowed on the field while the ball is in play. Robot handlers must receive permission from the referee prior to entering the field. Each team may designate only one person as robot handler. The robot handler of a team may not touch a robot of another team in order to avoid any (unintentional or intentional) damage to that robot.

4.6 Colors and Markers

4.6.1. Robots participating in the Humanoid League competitions must be mostly black or of dark grey color (i.e. RAL 7011 Iron Grey or darker) and non reflective. Less than 10% of the total body surface may have a higher reflectance, e.g. gray or white. Less than 1% of the total body surface may be colored. Any color used for the field (green, yellow, blue) or the ball (orange) must be avoided. Arms, legs and bodies of the robot must be of solid shape appearance.

4.6.2. The robots must be marked with team markers. These markers are colored magenta for one team and cyan for the other team. Robot legs and arms must be covered by team markers. If both teams cannot agree, which team color to use, a coin will be flipped 15 minutes prior to the game to assign the team colors.

4.6.3. The robots of each team must be uniquely identifiable. They must be marked with numbers or names. The goal keeper robot must be marked uniquely that it can be easily distinguished from the other robots of a team by the referees.

¹The source code of the game controller/referee box is available from <http://sourceforge.net/projects/robocupgc/>, see also <http://www.tzi.de/humanoid>.

4.7 Safety

4.7.1. Robots participating in the Humanoid League competitions must not pose any danger to humans, other robots, or the field of play. Anyone is allowed to take every action necessary to prevent urgent harm.

4.7.2. The robots must be constructed in a way that offenses described in Section 12 are avoided. Robots violating above safety requirements will be excluded by the referee from the ongoing game. They may be excluded by the league organization committee from the remainder of the tournament.

4.8 Robustness

Robots participating in the Humanoid League competitions must be constructed in a robust way. They must maintain structural integrity during contact with the field, the ball, or other players. Their sensing systems must be able to tolerate significant levels of noise and disturbance caused by other players, the referees, robot handlers, and the audience.

5 The Referee

- 5.1. Each match is controlled by a referee who has full authority to enforce these rules in connection with the match to which he has been appointed.
- 5.2. The referee ensures that the field and the ball are in proper condition. He ensures that the robot players meet the requirements of Section 4.
- 5.3. The referee acts as timekeeper and keeps a record of the match. He stops, suspends or terminates the match, at his discretion, for any infringements of the rules or because of outside interference of any kind.
- 5.4. The referee allows play to continue when the team against which an offense has been committed will benefit from such an advantage and penalizes the original offense if the anticipated advantage does not ensue at that time.
- 5.5. He punishes the more serious offense when a player commits more than one offense at the same time and takes disciplinary action against players guilty of cautionable and sending-off offenses. He is not obliged to take this action immediately but must do so when the ball next goes out of play.
- 5.6. The referee takes action against team officials who fail to conduct themselves in a responsible manner and may, at his discretion, expel them from the field of play and its immediate surrounds. He ensures that no unauthorized persons enter the field of play.
- 5.7. The referee acts on the advice of assistant referees regarding incidents which he has not seen. Some referee duties, like time keeping and keeping a record of the match, may be delegated to one of the assistant referees.
- 5.8. The decisions of the referee regarding facts connected with play are final. The referee may only change a decision on realizing that it is incorrect or, at his discretion, on the advice of an assistant referee, provided that he has not restarted play.

6 The Assistant Referees

- 6.1. One or more assistant referees are appointed for a match whose duties, subject to the decision of the referee, are to indicate when the whole of the ball has passed out of the field of play, which side is entitled to a corner kick, goal kick or throw-in, and when misconduct or any other incident has occurred out of the view of the referee.
- 6.2. The assistant referees might be assigned additional duties, such as time keeping and keeping a record of the match.
- 6.3. The assistant referees also assist the referee to control the match in accordance with these rules.
- 6.4. In the event of undue interference or improper conduct, the referee will relieve an assistant referee of his duties and make a report to the league organizing committee.

7 The Duration of the Match

7.1 Periods

7.1.1. The match lasts two equal periods of 10 minutes. Players are entitled to an interval at half-time. The half-time interval must not exceed 5 minutes.

7.1.2. Allowance is made in either period for all time lost through, e.g. substitution(s), timeouts, and wasting time. The allowance for time lost is at the discretion of the referee.

7.1.3. In the knock-out games of a tournament two further equal periods of 5 minutes each are played if the game is not decided after the regular playing time. If during regular playing time none of the two teams in a knock-out match was able to kick the ball to reach their respective opponent's goal the extra time is skipped and the game immediately continues by the five alternating penalty kick trials (cf. Section 14).

7.2 Timeouts

A team may extend a stoppage of the game by taking a timeout. During a timeout robots may be serviced. Each team may take at most one timeout per period. If a team is not ready to resume the game when the referee wants to start the game, it has to take a timeout. If there is no timeout left, the referee will start the game anyway. A timeout ends automatically after 120 s. A timeout also ends when the team signals its end to the referee.

8 The Start and Restart of Play

8.1 Preliminaries

8.1.1. Access to the field is given to both teams at least 15 minutes prior to the scheduled kick-off time. A coin is tossed and the team which wins the toss decides which goal it will attack in the first half of the match. The other team takes the kick-off to start the match. The team which wins the toss takes the kick-off to start the second half of the match. In the second half of the match the teams change ends and attack the opposite goals.

8.1.2. If both teams cannot agree on the color of their team markers, a coin is tossed and the markers are exchanged at halftime.

8.1.3. A match must start at the scheduled time. In exceptional situations only, the referee may re-adjust the time for starting the game in accordance with both team leaders. All robots of a team are started (and stopped) by receiving a signal through wireless communication from outside the field. In exceptional cases, starting and stopping robots manually may be allowed by the referee.

8.2 Kick-off

8.2.1. A kick-off is a way of starting or restarting play at the start of the match, after a goal has been scored, at the start of the second half of the match, at the start of each period of extra time, where applicable. After a team scores a goal, the kick-off is taken by the other team.

8.2.2. A goal may not be scored directly from the kick-off. Either the ball must move 20 cm from the kick-off point or must be touched by another player before being kicked towards the goal.

If the ball is kicked directly towards the goal the kick-off is awarded to the opposing team.

8.2.3. The procedure for kick-off is as follows:

- The referee gives the signal “READY” that all robots have to reach their own half of the field. Robots not being able to position autonomously in their own half may be placed by their respective robot handler.
- The opponents of the team taking the kick-off are outside the center circle until the ball is in play.

- The referee gives the signal “SET”. The referee calls robots illegally positioned to be set back manually by the respective robot handler to the outer line of their goal area. One field player of a manually or illegally positioned team suffers a removal penalty (cf. Section 12).
- The ball is stationary on the center mark.
- The referee gives the signal “PLAY” or whistles.
- The ball is in play when it is touched or 10 seconds elapsed after the signal.

8.2.4. Robots being able to autonomously reposition themselves can take any position on the field that is consistent with above requirements. Robots not able to autonomously reposition themselves, e.g. robots being carried or joysticked around by human team members, have to start from a position not closer to the field halfway line than the outer line of the goal area. If all robots of the team executing the kick-off cannot autonomously reposition themselves, then one robot may be placed into the center circle.

8.2.5. If one or both of the teams in a match have permission to use a manual startup procedure, the referee gives the two signals “SET” and “PLAY” with an interval of exactly 10 seconds. Robot players without remote start capability may be started on the field after the “SET” signal. They may not move before the “PLAY” signal was given by the referee. Robots with autonomous positioning ability are given between 15 and 30 seconds for re-positioning after a goal has been scored by one of the teams before the “SET” signal for kick-off is given by the referee. All human team members must leave the field of play immediately after the “SET” signal and before the “PLAY” signal.

8.2.6. A team which uses manual kick-off and not kick-off with the referee box is punished by a penalty of having to wait for 10 s after the signal “PLAY” before they are allowed to locomote. If such a team has kick-off then at the signal “PLAY” the referee immediately moves the ball from the kick-off position to a position somewhere on the center line and outside of the center circle and the ball is in play.

8.2.7. If a robot is moving for a significant time between “SET” and “PLAY” signals or repeatedly violates Rules 8.2.3 or 8.2.6, it will be punished by a removal penalty (cf. Section 12).

8.2.8. If a robot handler has not left the field by the “PLAY” signal, a yellow card is shown to the robot closest to the incident. If the game has been influenced,

the kick-off will be repeated and the team committed the offence has to start from a position not closer to the field halfway line than the outer line of the own goal area.

8.3 Dropped Ball

8.3.1. A dropped ball is a way of restarting the match after a temporary stoppage which becomes necessary, while the ball is in play, for any reason not mentioned elsewhere in the rules. In particular, the referee may call a game-stuck situation if there is no progress of the game for 30 s.

8.3.2. The game is continued at the center mark. A goal can be scored directly from a dropped ball. The procedure for dropped ball is the same as for kick-off, except that the robots of both teams must be outside the center circle. The ball is in play immediately after the referee gives the signal.

8.3.3. If a player moves too close to the ball before the referee gives the signal, a kick-off is awarded to the opponent team.

9 The Ball In and Out of Play

- 9.1. The ball is out of play when it has wholly crossed the goal line or touch line whether on the ground or in the air or when play has been stopped by the referee.
- 9.2. The ball is in play at all other times, including when it rebounds from a goalpost, crossbar, corner pole, or human and remains in the field of play.

10 The Method of Scoring

- 10.1. A goal is scored when the whole of the ball passes over the goal line, between the goalposts and under the crossbar, provided that no infringement of the rules has been committed previously by the team scoring the goal.
- 10.2. The team scoring the greater number of goals during a match is the winner. If both teams score an equal number of goals, or if no goals are scored, the match is drawn.
- 10.3. For knock-out matches ending in a draw after regular time, extra time, penalty kicks, and scoring times will be used to determine the winner of a match.
- 10.4. An abandoned match is replayed unless the league organization committee decides otherwise. If a team chooses to forfeit a match in the round robin games the other team plays on an empty goal. If a team chooses to forfeit in a knock-out game the other team continues in the competition. Teams may choose to forfeit games at any stage prior to the end of the game.
- 10.5. If the current score in a match has a goal difference of 10 goals (e.g., 10:0, 11:1, 12:2 etc.), then the referee will terminate the match and the score will be recorded as the current score.

11 Offside

The offside rule is not applied.

12 Fouls and Misconduct

12.1 Ball Manipulation

Manipulation of the ball by robot players is guided by the following principles:

1. Players may exert force onto the ball only by direct physical contact with one of their body parts, excluding their hands, arms, and shoulders.
2. The ball may be kicked with the whole foot. Kicking devices which differ from the human body are not allowed.
3. Contact with the ball must be instantaneous. Actively touching the ball for more than 1 s is considered ball holding. Inside the goal area, the goal keeper may hold the ball for not more than 5 s. Physical contact may be exerted repeatedly by the same player, if the ball is free to move between contacts for the majority of the time.
4. It will also be considered ball holding, if the ball cannot be removed from a robot by other players for more than 1 s. More than half of the ball's volume must be outside the convex hull of the robot, projected to the ground, for the ball to be considered removable. If the ball enters the convex hull repeatedly, it must be removable in between for the majority of the time. If more than one robot of a team is in the vicinity of the ball, the convex hull is taken around all the robots of a team, which prevent removal of the ball.

12.2 Physical Contact

Contact between robot players is guided by the following principles:

1. Physical contact between players of different teams must be minimized.
2. If physical contact is unavoidable, the faster moving robot must make efforts to minimize the impact. The goal keeper enjoys special protection inside its goal area. The attacking player always has to avoid to obstruct the goalie in any way.
3. Extended physical contact must be avoided. Both robots must make efforts to terminate contact, if the contact time exceeds 1 s.

4. If entangled robots fail to untangle themselves, the referee might ask designated robot handlers of both teams to untangle the robots. Untangling must not make significant changes to robot positions or heading directions. **Untangled robots must be laid on the ground not closer than 50cm to the ball and in a way not gaining an advantage.**

12.3 Attack and Defense

12.3.1. Not more than one robot of each team is allowed to be inside the goal or the goal area at any time. If more than one robot of the defending team is inside its goal or goal area for more than 10s, this will be considered illegal defense. If more than one robot of the attacking team is inside the opponent's goal or goal area for more than 10s, this will be considered illegal attack.

12.3.2. The referee may delay the call of illegal defense or illegal attack if the robots make serious attempts to leave the goal area or if they are hindered from leaving the goal area by robots of the opponent team. The referee allows play to continue when the team against which an illegal defense or illegal attack has been committed will benefit from such an advantage and penalizes the original offence if the anticipated advantages does not ensue at that time.

12.3.3. The player committing an illegal defense or an illegal attack will be removed from the field for 30 seconds removal penalty and has to re-enter the field from the center of the one of the two touch lines which is further away from the current ball position.

12.4 Indirect Free Kick

12.4.1. An indirect free kick is awarded to the opposing team if a player commits any of the following offenses in a manner considered by the referee to be careless, reckless or using excessive force: kicking, tripping, jumping at, charging, striking, and pushing an opponent.

12.4.2. An indirect free kick is also awarded to the opposing team if a player commits any of the following offenses:

1. tackles an opponent to gain possession of the ball, making contact with the opponent before touching the ball,
2. holds an opponent,

3. holds the ball,
4. handles the ball deliberately (except for the goalkeeper within his own goal area),
5. makes an opponent fall,
6. charges an opponent, which is in control of the ball, from behind by physical contact exerting significant forces on this robot.

12.4.3. An indirect free kick is awarded to the opposing team if a goalkeeper, inside his own goal area, commits any of the following offenses:

1. takes more than four steps while controlling the ball with his hands, before releasing it from his possession,
2. touches the ball again with his hands after it has been released from his possession and has not touched any other player,
3. touches the ball with his hands after it has been deliberately kicked to him by a team-mate,
4. wastes time,
5. blocks more than half of its goal line for more than 15s or for the majority of the time.

12.4.4. An indirect free kick is also awarded to the opposing team if a player, in the opinion of the referee:

1. plays in a dangerous manner,
2. impedes the progress of an opponent,
3. prevents the goalkeeper from releasing the ball from his hands,
4. commits any other offense, not previously mentioned in Section 12, for which play is stopped to caution or dismiss a player.

12.4.5. An indirect free kick is taken from where the offense occurred.

12.4.6. An indirect free kick is awarded to the opposing team, if a human member of a team, in the opinion of the referee, commits any of the following offenses:

1. interfering with the game on the field, e.g. through touching the ball while removing a robot,
2. interfering with the game remotely through wireless communication, e.g. by remotely joysticking a robot, or sending commands to robots that convey information about the position of objects on the field or activate particular patterns of actions on the robots,
3. behaving otherwise in an unsportsmanlike manner.

In this case, the indirect free kick will be started from the penalty mark position in the half of the opponent of the awarded team.

12.4.7. **All indirect and direct free kicks are replaced by time removal penalties to the robot committing the foul or misconduct.**

1. Time penalties of 30 seconds for field players and 0 seconds for the goalie inside its goal area are called by the referee. When a penalty is called, the designated robot handler has to remove the robot as soon as possible and by that interacting as little as possible with the game.
2. A penalty is not called, if the punished team would take advantage of the removal, e.g. if a robot blocks a teammate that kicks the ball towards the goal.
3. A robot suffering a penalty (except called for inactivity or service) may not be serviced. A robot suffering a penalty due to a foul or misconduct has to stay out of play for a minimum of 60 seconds if it is serviced during the penalty time.
4. The referee and assistant referees are in charge of timing the penalties and notifying the teams to put back their robots to play.
5. A field player or goal keeper suffering a time penalty will be removed from the field and has to re-enter the field after the penalty time has elapsed from the center of the one of the two touch lines which is further away from the current ball position.

12.5 Yellow and Red Cards

12.5.1. A player is cautioned and shown the yellow card if he commits any of the following offenses:

1. is guilty of unsporting behavior,
2. persistently infringes the rules,
3. delays the restart of play,
4. fails to respect the required distance when play is restarted with a free kick.

12.5.2. A player is sent off the field and shown the red card if he commits any of the following offenses:

1. is guilty of serious foul play,
2. is guilty of violent conduct,
3. receives a second caution in the same match.

13 Free Kicks

All direct and indirect free kicks are replaced by time removal penalties to the robot committing the foul or misconduct (cf. 12.4.7).

- 13.1 All free kicks are indirect. The ball must be stationary when the kick is taken. The kicker may not score directly from an indirect free kick. The ball must move at least 20cm from the position where the kick was taken or must be touched by another player before being kicked towards the goal. If an indirect free kick is kicked directly into the opponents goal, a goal kick is awarded to the opponent team.
- 13.2 All players of the team not taking the free kick must be at a distance greater than 60cm (for KidSize) or 90cm (for TeenSize and AdultSize) from the ball. If, when a free kick is taken, an opponent is closer to the ball than the required distance, the kick is retaken.
- 13.3 The ball is in play when it is touched, or 10 seconds after the referee has given the signal.

14 The Penalty Kick

- 14.1 A goal may be scored directly from a penalty kick.
- 14.2: The player taking the penalty kick is placed at a distance of at least $1.5 \cdot H$ from the penalty mark.
- 14.3: The defending goalkeeper is placed in upright position on the middle of his goal line, facing the kicker. It must remain upright between the goalposts until the ball has been touched by the kicker.
- 14.4: No other players are allowed on the field.
- 14.5: When both players are ready, the ball is placed randomly within 20cm (KidSize) or 30cm (TeenSize and Adultsized) of the penalty mark.
- 14.6: After the referee gives the start signal, the striker has 60s to kick the ball once or multiple times. After this time, the trial ends if the movement of the ball obviously does not result in a goal. Otherwise, the trial is extended until the ball stops.
- 14.7: The striker is not allowed to touch the ball during this extension. The striker is also not allowed to touch the ball after the ball has been touched by the goalie.
- 14.8: The goalie is not allowed to move forward or to fall until the ball is touched by the striking robot.
- 14.9: The trial also ends if the ball stops in the marked area around the goal or leaves the field.
- 14.10: Both robots are not allowed to touch or cross the line around the goal area.
- 14.11: If the goalie robot violates the rules in any way, the referee will let the trial continue. If the striker robot scores a goal, then the goal counts. If the striker does not score a goal, the trial is retaken. If the goalie violates the rules after causing two restarts, a technical goal is awarded to the striker.
- 14.12: If the striker violates the rules in any way, the referee will let the trial continue. If the striker robot is unable to score a goal, the trial ends. If the striker scored, the trial is retaken without counting the goal. If the striker violates the rules after causing two restarts, the trial will end with 'no goal'.

14.13: Both teams conduct five alternating trials.

- If after the first five trials none of the teams was able to kick the ball to the goal line then the winner is determined by flipping a coin.
- If there is still a draw in knock-out games, the alternating trials continue up to five more times, until one team leads after an equal number of trials.
- If there is still a draw in knock-out games, the alternating trials continue up to five more times without goalies, until either one striker is able to score and the other striker fails to score or both strikers score. In the latter case, the goal is awarded to the striker that needed the shortest time for scoring.
- If there is still a draw in knock-out games, the winner is determined by flipping a coin.

15 The Throw-In

A throw-in is necessary if the ball leaves the field of play, by fully crossing a touch line or a goal line (outside the goal posts or above the cross bar) either on the ground or in the air.

If the ball leaves the field it will be replaced on the field by the referee or an assistant referee. There is **no** stoppage in play.

The positions for replacement of the ball are described in the following with respect to the touch lines and always meant to be in a distance of about 40 cm orthogonal to the position on the touch line and inwards to the playing field.

If the whole of the ball passes over a touch line then the assistant referee will replace the ball back on the field on the same side of the field as the ball went out of play. The ball will be replaced in one of three positions:

- If the referee cannot determine which robot was the last to touch the ball before it left the field, then the ball is replaced directly in from the point at which the ball left the field.
- Otherwise, the ball is placed one meter back from the point it went out, where “back” is defined as being towards the goal of the team that last touched the ball.

In any case, the ball cannot be placed closer than the length of the goal area to either end of the field.

If the whole of the ball passes over a goal line then the ball will be replaced back on the field according to the following rules:

- If the referee cannot determine which robot was the last to touch the ball before it left the field, then the ball is replaced in about 1 meter distance from the corner of the field.
- If the ball was last touched by the defensive team then the ball is replaced in a distance of about the goal area length from the closest corner of the field.
- If the ball was last touched by the offensive team then the ball is placed on the halfway line on the side of the field the ball went out.

Balls are deemed to be out based on the team that last touched the ball, irrespective of who actually kicked the ball.

16 The Goal Kick

The goal kick is performed without stopping play according to the throw-in procedure.

17 The Corner Kick

The corner kick is performed without stopping play according to the throw-in procedure.

18 The Dribble and Kick Competition (AdultSize)

The dribble and kick competition is a 1 versus 1 competition between two teams. It is a kind of combination of a penalty kick and a soccer game. The striking robot starts in the middle of the playing field facing the yellow goal. The goal keeper of the other team is in the yellow goal. After the robots are placed, the ball is placed randomly on the imaginary line segment in parallel to the goal lines and through the penalty mark in the half of the field with the blue goal (that is the half behind the robot). After the referee blows the whistle, the striker has to acquire the ball and score a goal. A goal is only valid if the last point of contact between the striker and the ball was within the half of the field with the yellow goal (that is the attacking robot must move the ball into the yellow half before kicking it into the goal).

The goalkeeper starts in walking posture in the middle of the goal. It is allowed to move freely inside of the goal area. The goal keeper must remain in walking posture until the ball has been kicked at the goal. The goalie is then allowed to fall to try to block the ball. If the attempt still continues after the goal keeper has jumped for the ball it has to get back into upright standing or walking posture after not later than 15 seconds.

Neither robot is allowed to cross the goal box area, i.e. the defending goal keeper is not allowed to leave the goal area as well as the attacking striker is not allowed to enter it. In one run the same robot of one team has to perform both roles of the goal keeper and the striker of its team.

The maximum time for an attempt is 2 minutes.

Everything else remains the same as in the penalty kick competition.

19 The Technical Challenge

It is not allowed to use robots which are specialized for a specific technical challenge. **Only the robots used for the soccer games are allowed to participate in the technical challenges. No hardware modifications on the robots are allowed for the Technical Challenges** (i.e., a robot cannot be modified from the configuration it had in the soccer games).

The team scheduled for the technical challenge must have access to the field five minutes prior to the scheduled starting time. The referee will give the start signal at the scheduled time.

This year's challenge consists of three parts A, B and C. Each of the parts A, B and C can be attempted multiple times, in any order. The team might terminate a trial at any time, in order to reattempt the same part or switch to another part of the challenge. A trial terminates automatically when 25 minutes elapsed after the referee gave the start signal. This concludes the technical challenge for the team. The time is taken for each of the trials, if completed successfully. The minimum time is used for scoring each part of parts A, B and C of the challenge. The team with the minimal time receives 10 points. The second fastest team receives 7 points. The third fastest team receives 5 points. All other teams who successfully managed this part of the challenge receive 3 points. Intermediate scoring applies to parts A, B and C as detailed in the following sections. The intermediate scoring rules in the technical challenge do only apply to the best three teams if there are no three teams which can pass the respective challenge completely.

In KidSize and TeenSize robot handlers are not allowed to enter the field during the technical challenge, unless the referee asks them to remove a robot.

In AdultSize one robot handler is permitted to stay on the field during the trial subject to the following restrictions:

- The robot handler is not allowed to touch the robot.
- The robot handler is not allowed to interact with the robot's sensors in any way

In the moment the handler either touches the robot or interacts with the robot in any way the trial is finished and counted as unsuccessful.

19.1 Part A: Throw-In Challenge

The robot starts in the center standing on the center point and facing one of the two goals. A ball is placed 1.5 times the ball diameter outside of the field around

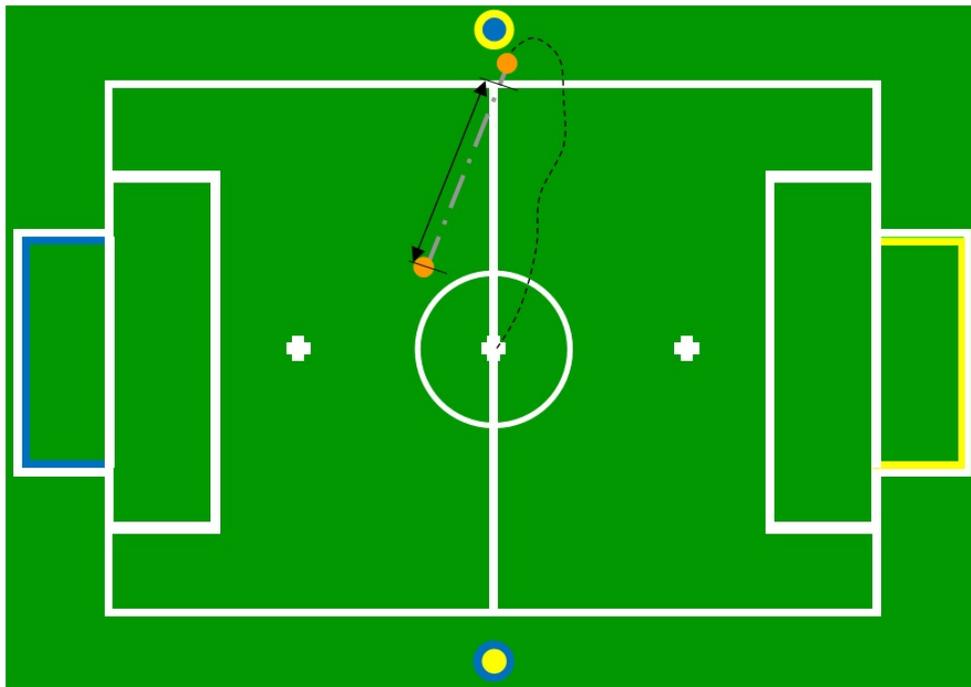


Figure 6: Throw-in challenge with example trajectories of the robot and the ball (not to scale). A possible motion of the ball is indicated by a gray, dash-dotted line.

one of the end points of the halfway line. The ball is placed at least 30cm away from the nearest pole. The robot must go to the ball, move with it towards the touch line, pick it up with its hands, and throw it back from there into the field. At the moment of delivering the ball, the thrower:

- faces the field of play,
- has part of each foot either on the touch line or on the ground outside the touch line,
- uses one or both hands,
- delivers the ball from behind and over its head or, if the robot cannot perform this type of motion, it must perform the closest possible motion.

The robots are ranked by the distance the ball has been thrown into the field. It is measured on the line connecting the robot position at throw-in and the final position of the ball. The distance is taken from the intersection of this line with the center of the touch line.

Intermediate Scoring for Throw-In

- The robot picks up the ball from the ground and holds it for at least 3 seconds. — 4 points
- The robot throws the ball. — 8 points

19.2 Part B: Obstacle Avoidance and Dribbling

Six black obstacles (cylinders of diameter 20 cm and height 90 cm) are put in the half of the field in front of the yellow goal, as defending players. In KidSize the obstacles are placed within the area between the penalty mark and the goal. The obstacles are put at arbitrary positions by the referees, just before the start of each trial, when the robot is already waiting at the starting position and are rearranged at each trial. The distance between the obstacles is at least 50 cm for KidSize and at least 100 cm for TeenSize and Adultsize. No obstacles are placed in the center circle. The ball is placed at the center mark and the robot directly behind it facing the yellow goal. The robot must reach the goal with the ball by dribbling the ball, enter in it, by crossing at least once the line between two obstacles and by avoiding touching all obstacles. This means that it is not allowed to walk either left or right around the cluster of obstacle poles to reach the goal. The robot must dribble the ball through the obstacles in the

goal. Therefore, only gentle kicks of no more than 20cm distance are allowed. A minimum of 10 touches/kicks is required before the ball is moved over the goal line.

The trial ends without success, if the robot bumps on any obstacle or if the robot or the ball leaves the field.

The trial ends with success, if the robot touches the goal line and the ball is inside the goal. The teams are ranked by the time needed to complete the task. Poles are only re-arranged once the robot has actually made an effort to navigate and to dribble the ball around the poles.

Intermediate Scoring for Obstacle Avoidance and Dribbling

- Robot and ball reach the penalty area by dribbling and a minimum of 7 touches/kicks. — 5 points

19.3 Part C (KidSize): Double Pass

Both robots A and B start in one goal area of the field. The task is to perform four specific double passes and to play the ball into the other goal. Two black obstacle poles simulating other players are placed onto the field. The first obstacle pole is placed within a circle of 20cm radius around the center mark and the second obstacle pole within a circle of 20cm radius around the penalty mark. At the beginning the ball is placed onto the penalty mark in front of the start goal area.

- The trial starts when the first robot leaves its goal area.
- The first double pass to perform is from player A to player B inside the own half of the field.
- The second double pass to perform is from player B to player A between the first obstacle and the own goal.
- The third double pass to perform must pass in between the two obstacles.
- The fourth double pass to perform must pass in between the second obstacle and the other goal.
- The trial ends successfully if after the fourth double pass the receiving robot plays the ball into the other goal.
- The ball can be dribbled in between double passes.

- The trial ends if the ball leaves the field or enters the other goal without having performed all double passes. The trial also ends without success if one of the robots leaves the green carpet.

Intermediate Scoring for Double Pass (between robot A and B (A: first kicking))

- 1st double pass from robot A to robot B — 0 points
- 2nd double pass from robot B to robot A — 4 points
- 3rd double pass from robot A to robot B — 6 points
- 4th double pass from robot B to robot A — 8 points
- Robot A plays the ball into the goal — 10 points

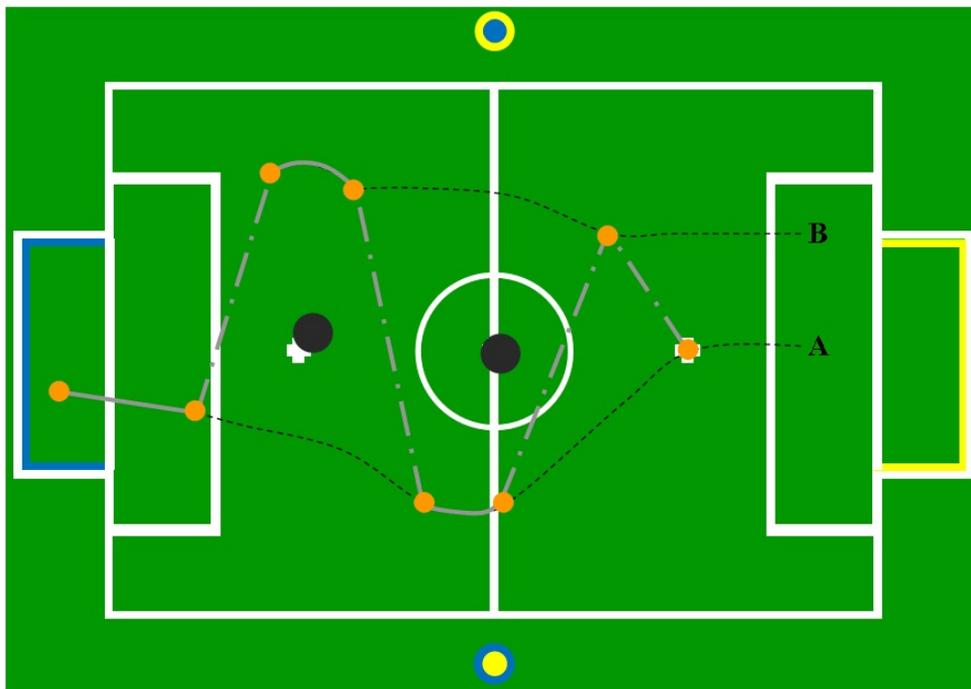


Figure 7: Double pass challenge with example trajectories of the ball and the two robot players A and B (not to scale). A possible motion of the ball is indicated by gray lines. The four double passes are indicated by dash-dotted lines.

19.4 Part C (TeenSize and AdultSize): The Footrace

The footrace in the TeenSize consists of several runs depending on the teams preference and the available time. A run goes from one touch line to the other touch line and back to the first touch line. The team places their robot in front on the border strip, outside the field, in front of the touch line. The robot must be in an upright standing posture. The team may use either side of the field. Different robots might be used for multiple runs.

After the referee gives the start signal, the robot walks as fast as possible across the half of the field towards the opposite touch line, makes a U-turn there and walks back. The opposite touch line must be touched or crossed by each of the robots feet. ~~Robot handlers are not allowed to enter the field, unless the referee asks them to remove a robot.~~ If the robot touches the start line before the referee gave the start signal, the start is invalid. This robot receives a warning and the start is retaken. The warnings of a team accumulate within a footrace. Every third warning results in an unsuccessful attempt of a run.

If the robot crosses the final touch line the time is measured. Both feet must be outside the field on the border strip again. If a robot falls, it must get up by itself to continue the run.

If a robot leaves its half of the field, its run terminates at the position where it left the field. If 90s after the start signal the robot does not cross the goal line, the attempt has failed. The team must place their robot in front of the start line within 60s after the end of a run.

The shortest time out of all successful runs counts for the technical challenge.

20 The Competitions and Trophies

20.1 Setup and Inspections

The competitions in the Humanoid League are preceded by a setup and inspection period of at least 24h. During this time, every robot will be inspected by the league organizing committee for compliance with the design rules detailed in Section 4. All robots will be photographed during the inspection. A reinspection becomes necessary after any change that could affect the compliance to the design rules. A reinspection might be requested by any team leader up to 10 minutes prior to a game.

20.2 Referee Duty

Each team must name at least one person who is familiar with the rules and who might be assigned for referee duties by the league organizing committee.

20.3 Competitions

20.3.1. The competitions consist of:

1. Soccer Games for KidSize (3 vs. 3) and TeenSize (2 vs. 2)
2. Dribble and Kick for AdultSize,

The technical challenges consist of:

1. Throw-In Challenge (KidSize, TeenSize and AdultSize)
2. Obstacle Avoidance and Dribbling (KidSize, TeenSize and AdultSize)
3. Double Pass (KidSize)
4. Footrace (TeenSize and AdultSize)

20.3.2. Both, Dribble and Kick (AdultSize) and Soccer Games (KidSize and TeenSize) are organized in one or more round robins and playoffs. For the first round robin, the teams are assigned to groups at random. All teams of a group play once against each other. The round robin games may end in a draw. In this case, both teams receive one point. Otherwise, the winning team receives three points and the not winning team receives zero points.

20.3.3. After games of a round robin have been played, the teams of a group are ranked based on (in decreasing priority):

1. the number of earned points,
2. the goal-difference,
3. the absolute number of goals,
4. the result of a direct match,
5. the time needed to score a penalty kick into an empty goal (up to five alternating attempts to score, until at least one team scored),
6. the drawing of a lot.

20.3.4. At least two teams of every group will enter the next round robin or the playoffs.

20.3.5. The game plan needs to be announced prior to the random assignment of teams to groups.

20.4 Best Humanoid

20.4.1. The teams of **all three** size classes are ranked in separate lists to determine the overall best humanoid.

20.4.2. The ranking is based on the aggregated number of points earned in the individual competitions.

20.4.3. The points earned in the technical challenge are used directly.

20.4.4. For the Dribble and Kick competitions (**AdultSize**) and the Soccer Games (**KidSize and TeenSize**) the winner receives 60 points. The second best team receives 42 points. The third best team receives 30 points.

20.4.5. As **KidSize, TeenSize and AdultSize** robots do not compete directly, a jury decides the overall best humanoid robot, 2nd best humanoid robot, 3rd best humanoid robot. The jury consists of the team leaders of all teams, except for the teams ranked first ~~and second~~ in the **KidSize, TeenSize and AdultSize** lists. The jury decides by majority vote. In case of a draw, the president of the RoboCup federation decides the vote.

- The teams ranked first in the KidSize, TeenSize and AdultSize lists are candidates for the best humanoid. The jury decides from the general picture of the performance according to the criteria:

- A. Robustness
- B. Walking ability
- C. Ball handling
- D. Soccer skills

for the robot that is the best humanoid.

- Of each, KidSize, TeenSize and AdultSize, the best robot that was not chosen to be the best humanoid robot is candidate for the 2nd best humanoid robot. Criteria are the same as for the best humanoid.
- ~~The robot ranked first in the KidSize, TeenSize or AdultSize lists that was not chosen for 1st or 2nd best humanoid is the 3rd best humanoid robot. If the best and the second best humanoid robot are chosen from the KidSize class then the best humanoid robot from the TeenSize list is the third best humanoid robot. If the best and the second best robot are chosen from the TeenSize class then the third best humanoid is the best robot from the KidSize list. Otherwise, the third best humanoid robot is chosen between the 2nd best robots from the KidSize and TeenSize lists according to the same criteria as before.~~

20.5 Trophies

20.5.1. A trophy is awarded to the winner of each of the individual competitions and technical challenges.

20.5.2. A trophy is awarded to the teams second and third in the KidSize 3-3 soccer game, the TeenSize 2-2 soccer games and the AdultSize Dribble and Kick competition.

20.5.3. Certificates are awarded to the teams second and third in the technical challenges and to the teams ranked second and third in the Best Humanoid list.

20.5.4. The Louis Vuitton Humanoid Cup is awarded to the team ranked first in the Best Humanoid list.

Appendix

A The Trend in Rule Evolution for the Next Years

In this section the Technical Committee (TC) wants to make explicit the trends to be followed in the rules in the next year in order to improve the scientific level of the robots developed by the RoboCup teams. The evolution of rules in the humanoid league has been following a biennial schedule where major changes (like the number of players per team) have been introduced every two years and only incremental changes every other year.

- The Layout of the Field

- Size of the playing field may increase with the number of players.
- Instead of the massive and specifically colored goals more natural goal shapes may be introduced.
- Landmark poles and special marks on the playing field will be removed.

- The Design of the Robots

- **The foot size of all robots will be decreased.**

This is to foster the development of more advanced walking algorithms. By reducing the size of the foot the intrinsic stability of the humanoid robot is reduced and dynamic walking is encouraged (e.g. from $H^2/26$ in following years in steps of $H^2/28$, $H^2/30$ etc. to finally reach human-like proportions). For 2010 the maximum foot size of 2009 ($H^2/28$) will be used. For 2011 the reduction will be continued to $H^2/30$.

- **More human like vision.**

In 2008 the Humanoid League has undertaken a first large step towards more human like vision by restricting the field of view to 180 degrees. For 2010 the TC would like to improve the rules further towards human like vision with one or two eyes in a way that takes into account the number of cameras, their individual lines of sight and fields of view. (This has already been included in the rule changes decided for 2010 by majority of team leader vote.)

- **The minimum height of TeenSize robots may be increased year after year.**

This is to foster the teams to develop taller robots and to apply more advanced technologies with respect to KidSize robots that are intrinsically more stable. The minimum size of 100cm will be kept also for 2009 but may thereafter be increased, e.g., to 120cm. (In 2010 this has been taken care for by the introduction of the new TeenSize and the new AdultSize, the latter with robots of minimum size of 130cm.)

- **Robot colors:**

Other, non reflective colors than black or dark grey for the robots may be allowed like silver or light grey.

- Rules of the Game

- **The number of players in soccer games will be increased.**

This is to encourage team play and cooperation among humanoid robots. In 2008 3 on 3 games in KidSize and in 2010 2 on 2 games in TeenSize have been introduced and in the following years the number of players should be increased further.

- **Game Controller (aka: Referee Box)**

Standard game controlling/refereeing software may be introduced for soccer games. A prototype of a game controller / referee box will be introduced in 2009 and may become mandatory in 2010.

B Human Reference Data

Corresponding to the robot data of Section 4 data of a three year old girl have been obtained during RoboCup 2009. They can serve as a reference to assist in guiding the rule evolution with respect to robot design.

Height H_{top}	95cm
Height, when the arm is stretched over the head	110cm
Arms stretched sideways	90cm
Length of the legs H_{leg}	50cm
Height of the knee	25cm
Height of the center of mass H_{com}	55cm
Distance between shoulders	24cm
Height of the head (from the shoulder) H_{head}	23cm
Arm length	25cm
Distance between the eyes	6cm
Size of one shoe (enclosing rectangle) $S = 15\text{cm} \times 6.8\text{cm} =$	102cm^2

According to Eq. (1) from page 11

$$H = \min \{H_{\text{top}}, 2.2 \cdot H_{\text{com}}\} = \min \{95, 2.2 \cdot 55\} = 95.$$

From $H^2/S = 95^2/102 = 88.48$ a possible target footsize limit of $H^2/88$ may result for Section 4.3 by 2050 or earlier.

Acknowledgements

These rules evolved from previous versions of the RoboCup Humanoid League rules. The 2008 version of the rules was compiled by Pasan Kulvanit and Oskar von Stryk, the 2007 version of the rules by Emanuele Menegatti and the 2006 version by Sven Behnke, who did a remarkable job improving the rule document and gearing it towards the FIFA Laws of the Game. The improvements of the 2005 version were compiled by Norbert Michael Mayer. Other input came earlier from the rules of the RoboCup MiddleSize and Four-Legged Leagues.

The rules were continuously discussed within the technical and organizing committees of the league and also on the humanoid league mailing list. Especially the following members of the technical committee for 2009 contributed to the rule evolution: Jacky Baltès, Pasan Kulvanit, Norbert Michael Mayer, Chee Meng Chew, Hideaki Minakata, Oskar von Stryk, Changjiu Zhou. Special thanks go to Martin Friedmann for the contribution of several figures.

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