

Request for Proposals

HRC*Husker**RoboSports**Corporation*

Soccer Division

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Robotic Soccer Playing System¹

Executive Summary

An autonomous mobile robotic system is being designed by HRC to compete in the annual RoboCup F-180 League, an international robotic soccer (a.k.a. football elsewhere) competition.

HRC seeks a prototype of an autonomous robotic system consisting of two robotic soccer players that can play against another such system in a game of simplified soccer. The prototype should be able to perform various operations, such as detecting and then kicking the soccer ball in the desired direction, detecting and avoiding colliding with other robotic players, etc., while abide by the game rules.

This RFP provides specifications for a robotic soccer-playing system and solicits proposals for a detailed design, simulation results, prototype, and performance analysis of the system, as well as a bit for the cost per unit.

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Deadline: May 5, 2003, 5:00PM

¹This RFP is adapted from Dr. Sharad Seth's CSCE489 RFP and official rules of the RoboCup F-180 League (<http://arti.vub.ac.be/RoboCup/rules/rules.html>; <http://www.robocup.org/regulations/4.html>)

1 Introduction

The Husker RoboSports Corporation (HRC) is developing an autonomous mobile robotic system (hereafter called AMS) that can compete in the annual RoboCup F-180 League, an international competition resembling the game of soccer (a.k.a football outside the US). Playing against an opposing team (of similar capabilities) on a scaled-down soccer field, roughly 5' by 8'10" in dimension, and composed of two robotic soccer players on each side, AMS should be able to perform a number of manoeuvres, such as detecting and then kicking the soccer ball in the desired direction, detecting and avoiding colliding with other robotic players, starting or stopping upon the referee's signalling, etc., while abide by the game rules.

A successful proposal must present a detailed design, simulation results, a prototype (with a performance analysis), and a bid of the cost per unit, broken down into development costs, parts, and mark-up.

2 Terminology and Notation

In the context of this RFP, the words "shall", "should" and "may" have specific definitions.

Shall: indicates a non-negotiable requirement of the specification. Thus, the words "shall" and "must" are treated as synonymous.

Should: specifies an optional, but highly desirable feature. The intent is that any item indicated by "should" shall be adhered to unless it proves to be impractical or counterproductive.

May: indicates an option left entirely to the discretion of the sub-contractor.

3 Functional Specifications and Game Rules

- There are two robots in the AMS, all must be autonomous and meet all the requirements of this RFP.
- Each robot shall be started or stopped by a designated operator from the contractor design team, taking cue from the official referee.
- Ideally, however, each robot should be able to start or stop on its own, triggered by the signalling of the referee (i.e., sound detection).
- Two robots on the team may communicate with each other using wireless devices to coordinate the game, or otherwise may use wireless communication to computers or networks located off the field.
- The use of a global vision system or external distributed vision systems may be permitted, but not required, to identify and track the position of robots and balls. This is achieved by using one or more cameras.

- Once started, no robot shall be allowed any support from an operator except during an emergency or given permission by the referee.
- Emergency situation should be avoided at all costs, but if one should arise, the robot should fail safe, i.e., it should stop in a safe state (not moving or posing a hazard to any one or any thing) and signal for help using an audio signal, a visual signal, or both.
- The soccer game shall be played out in a closed arena, a scaled-down field, with the center circle, the defense zone on each side, penalty kick positions and free kick positions clearly marked in light color and the soccer ball being a brightly colored golf ball.
- At the back of each goal nest shall be a polarized beacon; the two goal nests are distinguished respectively by vertical and horizontal polarizations.
- The **dimensions** of the arena are as follows:²
 - Field length, $x = 274cm$, width, $y = 152cm$
 - Center circle, $diameter = 50cm$
 - Goal width, $y = 50cm$, depth, $x = 18cm$
 - Defense zone width, $y = 100cm$, depth, $x = 22.5cm$
 - Penalty spot: $45cm$ from the goal line
 - Free kick spots: $15cm$ from the x (side) wall, $37.5cm$ from the y (end) wall
- **Robots** should meet the following specifications:
 - **Shape**: any autonomous robot complying with these criteria.
 - **Kicking devices**: kicking devices are permitted.
 - **20 cm rule**: the robot should fit inside a 20cm diameter cylinder.
 - **Height**: the robot should be 22.5cm or less in height.
 - **Robot colors**: each team should have a visual symbol on each player distinguishing itself from other teams.
 - **Locomotion**: robot wheels shall be made of a material that does not harm the playing surface. Metal spikes and velcro are specifically prohibited.
 - **Team**: a team shall consist of two robots.
- **Length of the game**: the games consist of the first half, break, and the second half; each is 10 minutes. All time for stoppages will be added to the end of the half they occur in.
Each team will be allowed some set up time at the start of the game. Before the beginning of the second half,
 1. teams must switch sides;

²The actual measures may vary according to the existing arena in the CSE Dept.

- **Timeouts/delay of game:** each team will be allocated three timeouts at the beginning of the game. A total of 15 minutes is allowed for all timeouts (e.g. a team may take two one-minute timeouts followed by one 13-minute timeout). In case a team is not ready to start at the scheduled time, they may use their timeouts to delay the game up to 15 minutes.

During a game, timeouts will only be granted during a break in play.

- **Substitution and removal of damaged robots:** in general, substitutions are only allowed for damaged robots during a break in play. However, if in the opinion of the referee, a damaged robot is likely to cause serious harm to humans, other robots or itself the referee will stop the game immediately and have the damaged robot removed. In this case, the game will be restarted with a free kick for the opposing team (the team that did not have the damaged robot). If there is no immediate danger however, the referee may allow the game to continue.

To replace a robot by substitution the following conditions must be observed:

1. a substitution can only be made during a stoppage in play.
2. the referee is informed before the proposed substitution is made,
3. the substitute is placed on the field after the robot being replaced has been removed,
4. the substitute is placed on the field in the position from which the replaced robot was removed.

- **Goal Keepers:** Each team may designate one robot as a goal keeper. The goal keeper can hold and manipulate a ball for up to **15 seconds** within its defense zone. After releasing the ball the keeper must not recapture the ball until the ball touches an opponent or a member of its own team outside the defense zone. If the ball is released by the keeper and it reaches the half way line without touching any other robot, the opponent is given an indirect free kick positioned anywhere along the half way line (borrowed from Futsal rule). Any of the robots may change roles with the goal keeper (and thus be permitted to manipulate the ball) provided the referee is informed before the change and that the change is made during a stoppage in play.

- **Movement of Robots by Humans:** In general, movement of robots by humans is not allowed. However, at kick-offs and restarts one member of the team is allowed on the pitch to place robots. Gross movement of robots is not allowed, except: before kickoffs, to place the designated kicker for a free kick or to ensure robots are in locations required for penalty and free kicks.

Humans are not allowed to free stuck robots except during a stoppage in play, and then they should move the robots only far enough to free them.

- **Play stoppage**

- When a goal is scored.
- When the ball is kicked out of play.
- Fouls resulting in a free kick.

- Fouls resulting in a penalty kick.
- Fouls resulting in a yellow card.
- At the end of a half.
- **Robot halting:** Once play has been stopped robots should cease movement until play is restarted by the referee. The referee may check or adjust the placements of the players prior to restart.
- **Kick-off:** All robots shall be in located on their side of the field. The ball will be positioned at the center of the field and all robots on the team not kicking off must be outside the center circle. The ball has to go forwards at a kick-off or the kick-off will be restarted.
- **Penalty Kick:** Only a goal keeper shall be in the defense zone, and the ball shall be located 45 cm from the goal along the lengthwise centerline of the field. All other robots shall be located at least 30 cm behind the ball.

Robots cannot move until the referee signals the resumption of play (by whistle, etc.).

- **Free Kick:** Free kicks are taken after a foul or a stoppage in play.

If the free kick is taken after a foul the ball is placed at the point where the foul was committed (or as close as possible to that point).

If the free kick is taken after a stoppage in play, the ball remains in place. In either case, the ball should be placed at least 15 cm from any wall.

If the ball is within 15 cm of a defense zone, it should be moved to the closest free kick marker.

The nearest robot of the kicking team to the ball is to be designated as the kicker. It may be moved into position by a designated human for the kicking team. If the nearest robot is the goalie robot, then the kicking team has the option of using the next nearest robot.

Except for the kicking team, all robots must be at least 15cm from the ball.

In case of a free kick for the offense, the defending team is not allowed to move its robots.

None of the robots may move until play is resumed by the referee.

- **Yellow Cards:**

1. Stoppage of play and free kick

Play is stopped when a yellow card is assigned. A free kick is provided to the opposing team at the location where the foul occurred, or at the nearest free kick marker as deemed appropriate by the referee.

2. Assignment of yellow cards and player removal

Yellow cards are assigned to the team and not the player.

Each time a team receives two yellow cards, it must remove one player from the field (the number of players on the field is reduced by one after every two yellow cards).

Once a robot has been removed from the field, it may only be used to replace a robot. For example, should a team start the game with two robots and receive two yellow cards, it must remove a robot and continue play with one robot. The removed robot may only be used as a replacement for a robot. If the removed robot is entered into the game again, a different robot must be taken out of the game (for example, to replace a broken down robot in the remainder of the game).

3. Pushing

Pushing by a robot is defined as contact with an opponent robot with a movement vector through the opponent robot. Pushing another player, even when in pursuit of the ball, is a "yellow card" offense also resulting in a free kick for the opposing team. The pushed robot is the kicker. Incidental contact between robots (except the goalie) is allowed.

Pushing "through the ball" to another player is not a foul, but the referee should take immediate action to reposition the ball to a neutral position.

4. Non-moving robots

If the referee determines that a robot is not moving for a period of 20 seconds or longer, he will remove it from play and give the team a yellow card.

Participants may repair the robot and ask that it be put back in play if they desire. A second failure of the same robot to move for 20 seconds will result in a red card and permanent removal of the robot from the game.

5. Damage to other robots

During play, if a player utilizes a device or an action which continuously exerts, or is likely to exert serious damage to another robot, it will be presented a yellow card and ordered to go outside the court and correct the problem. This includes excessively hard kicking of the ball that may damage another robot.

Once the correction is made, the robot can resume play after approval by the referee. In case the problem is repeated, the referee presents a red card to the responsible player telling it to leave the game (in this special case the referee may direct that a specific robot be removed).

- **Fouls Resulting in a free kick**

1. **Contact with the Goalie**

Contact with the goalie is a foul if the point of contact is within the defense zone. A free kick is awarded to the defense.

2. **Shot on Goal Too High**

If the ball crosses the goal line 15cm above the field, the goal is disallowed and a free kick is awarded to the defending team.

3. **Ball kicked out of field**

If the ball is kicked out of play, a free kick is assigned to the opposing team at a location near where the ball left the field. Determination of responsibility for kicking the ball out is made by the referee.

4. **Too many attacking robots in defense zone**

Only one attacker may enter this area. Brief passing and accidental entry of other robots is permitted, but intentional entry and stay is prohibited.

5. **Stuck ball**

If the ball gets stuck (as determined by the referee) in a corner or along a wall adjacent to a goal, play is stopped and a free kick is awarded to the offense.

Otherwise, when a ball is stuck, the referee will reposition the ball away from the wall in a location that does not provide an advantage to either team (play is not stopped). The referee will use a black/grey stick or some other device to reduce the chance of interference with vision systems.

- **Fouls resulting in a penalty kick**

1. **Too many defending robots in defense zone**

When more than one robot of the defending side enters the defense zone and substantially affects the game play will be stopped, and a penalty kick will be declared.

A robot substantially affects the game if

- (a) The robot contacts the ball.
- (b) The robot prevents another robot from movement towards the ball.
- (c) The robot is in a position that blocks a portion of the goal, i.e. it could potentially block a shot when a shot (the ball is pushed towards the defender's goal by either team) is taken. Notice that this does not require that the robot actually block the shot only that the robot was in a position to prevent a goal when the shot was taken.

2. **Ball Holding**

A player cannot 'hold' a ball unless it is a goal keeper in its defense zone. Holding a ball means taking a full control of the ball by removing all of its degrees of freedom; typically, fixing a ball to the body or surrounding a ball using the body to prevent accesses by others. 80% of the ball area should be outside the convex hull around the robot. It is up to the referee

to judge whether a robot is holding the ball. In general a robot should be able to remove the ball from another player. If a robot is deemed to be holding the ball then a free kick will be declared. If this happens in the defense zone by the defense team, a penalty kick will be declared.

4 Physical Specification

Each AMS robot will only be constructed from parts provided by HRC, including LEGO components, motors, sensors, and the Handy Board controller. Additional parts will require approval from HRC and a bid adjustment commensurate to the design cost increase.

5 Deliverables

At the conclusion of this project, the contractor shall deliver the following items to HRC.

- A final written proposal presenting a detailed description of the design. The report shall adhere to the style specifications of Appendix A and to the content specifications of Section 5.2.
- A final oral presentation, not to exceed 45 minutes in length, summarizing the written proposal. This presentation shall adhere to the style specifications of Appendix B. HRC may also request a demonstration of the prototype at this time.
- A prototype of the design, i.e. the source files of the design (provided on a 3.5 inch floppy diskette) and the physical LEGO robot(s).
- A complete user's manual.

5.1 Deadlines

The written proposal must be delivered to HRC by 5:00 p.m. on the deadline date shown on the cover page of this RFP³. All other deliverable objects shall be presented to HRC during the previous work week⁴ at a time and place yet to be determined.

5.2 Proposal Contents

The written proposal shall contain sufficient detail to permit HRC personnel to determine conformance to specification, estimate performance, and evaluate the credibility of claimed attributes. Specific information shall include, but need not be limited to, the information listed below.

³I.e. Monday of the finals week

⁴I.e. the dead week. You have now been informed in writing prior to the eighth week of classes

5.2.1 Design Description

Provide a detailed description of the product's functions and design, including a high-level block diagram and sufficient text to explain the functions of and relationships between the main components.

- **Diagrams** – Include flow charts, state diagrams, and/or logic diagrams as necessary to adequately illustrate the design. Smaller diagrams shall appear as figures in the main body of the text. Large detailed logic diagrams and source code should be confined to appendices, and referenced where relevant in the text.
- **Software** – Complete listings of all software source code shall appear in the appendices. Flowcharts, high-level pseudo code or other explanatory material must be presented in the main body of the text to facilitate understanding of the design by HRC personnel.
- **Definitions and Signal Naming Conventions** – Include tables defining variable names, signal names, module names, and any other naming conventions useful in understanding the design.

5.2.2 User's Manual

One appendix of the written report shall be a short *User's Manual*, sufficient to allow HRC personnel to test the prototype themselves.

5.2.3 Performance Analysis

Provide an analysis of the performance of the AMS prototype, including as a minimum:

1. Simulations that verify correct functionality of the design.
2. The amount of time required to find and then kick the ball in the desired direction.
3. The maximum distances, respectively, for detecting the ball, the wall, the opponent robot.
4. Effective battery life for a given robot design.

5.2.4 Cost Bid

Provide a bid of the cost per unit, broken down into development costs (e.g. cost of labor and parts for AMS development by the engineers involved), unit parts (i.e. costs of all components in a production AMS), and mark-up by the contractor. The cost per unit may be a function of the number of units ordered, e.g. if the development costs are amortized over several units.