

# RoboCup – The evolution of a Robotic Scientific Challenge

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## Abstract

*The RoboCup is a scientific challenge used to foster research in the robotics areas, which main objective consists in developing a robotic football team able to play against a human team in the year 2050. This paper describes the rules of such a competition, the actual state of the art of robotic football players in the middle size league, and describes the main characteristics to take into account in order to build such type of robots. These aspects are described and analysed in terms of further developments.*

## 1. INTRODUCTION

In 1993 the Robotics community decided to start a scientific challenge in order to foster research and development in the many areas associated with robotics.

It would have to be an attractive challenge, with common rules so that everyone could understand and pursue the same objectives although with many different solutions. A good definition is given by the RoboCup Federation in their website: “*RoboCup is an international joint project to promote Artificial Intelligence, robotics and related fields. It is an attempt to foster AI and intelligent robotics research by providing a standard problem where wide range of technologies can be integrated and examined. RoboCup chose to use soccer game as a central topic of research, aiming at innovations to be applied for socially significant problems and industries*”. The ultimate goal of the RoboCup project is “*By 2050, to develop a team of fully autonomous humanoid robots that can win against the human world champion team in soccer.*” [1]

Many areas of research have been pursued like multi-agents, autonomous agents, electronics, strategy, control, cooperation, real-time reasoning, self-localisation, sensorial fusion, robotics, etc.

The RoboCup has two challenges: football and rescue. The rescue leagues will not be described in this work. Regarding the football, several different leagues exist, in order to promote different degrees of challenge. Simulation league, Sony legged robots league, Small Size League, Middle Size League, Humanoids and last but not least the junior league for youngsters. This work describes in more detail the Middle Size League. It is important to point out the growing rate of the RoboCup regarding participating teams and countries.

<b>RoboCup / Location</b>	<b>Teams</b>	<b>Countries</b>
RoboCup 2004 Lisbon	346	37
RoboCup 2003 Padua	277	34
RoboCup 2002 Fukuoka / Busan	188	29
RoboCup 2001 Seattle	119	22
RoboCup 2000 Melbourne	110	19
RoboCup 99 Stockholm	120	35
RoboCup 98 Paris	63	20
RoboCup 97 Nagoya	40	10

This table shows the scientific community interest for this kind of event. A scientific workshop is also held during RoboCup, where the most relevant works are presented and published [2], [3], [4].

## 2. MIDDLE SIZE LEAGUE RULES

As stated earlier, the main goal of this RoboCup challenge is to produce a team of robots capable of playing football against a human team in the year 2050. The state of the art technology cannot cope with human football rules and therefore, although the RoboCup rules are based on the FIFA rules, some adjustments have been implemented to allow the robots to play robotic football. Each robotic football league has a technical committee, with around about 6 or 7 people from all over the world, which is responsible for updating the rules every year in order to increase the difficulty and approaching the rules to the human football until 2050. The latest version of the rules can be read on [5].

Most leagues have the same basic rules: The goals are painted in yellow and blue, the ball is orange, the field is green with the traditional white lines, and the robots should wear mainly black.



Figure 1. Middle Size League Field with Robots

In the MSL league, there are size limitations (50 cm diameter, 80 cm height and 40 kg weight), the robots can communicate through wireless network, but all sensors must be within the robots. Each team has one computer which is connected to a referee box. The referee is human and he inputs game commands into the referee box, which sends them to each team computer and then an access point sends the commands to all robots. The figure below shows the network diagram.

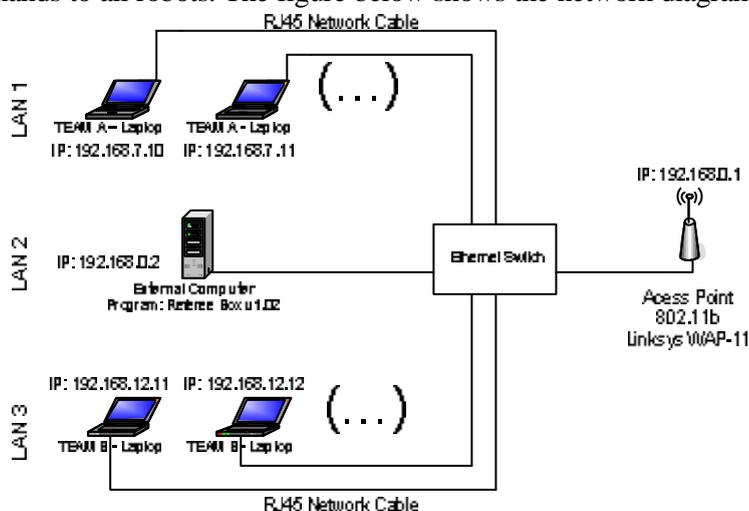


Figure 2. Network setup of a Middle Size League game

The commands sent by the referee box program are character type variables, and instruct the robots whether one of the following occurred: kick off, penalty kick, free kick, corner kick, goal kick, throw in, goal, start and stop.

### 3. MAIN ATTRIBUTES OF THE ROBOT PLAYERS

As one might expect, each research team dedicates most of their time to develop systems related with their area of knowledge. However, many other areas are involved in these types of autonomous systems and need special attention. No knowledge areas should be neglected. No matter how good one system performs, if the others cannot do their job properly. For a successful game, a team of robots must take into account a few characteristics and the main ones consist of:

- Good vision system – in order to recognise the game entities (ball, goals, obstacles, etc.). Teams tend to move towards an omni-directional vision system (cameras pointing towards conic/spherical/hyperbolic/parabolic mirrors). These systems allow robots to have an eye always on all target, reducing reaction time and avoiding game entities search routines.
- Speed - to reach targets faster. Fast motors can be more expensive but they are worth. They should include gearboxes and encoders from the same manufacturer.
- Manoeuvrability – simplifies movements and saves time while moving. There are robots that use two (differential), three (omni-directional) or four (steering or omni-directional) driving wheels. Teams tend to change their robots towards the use of three omni-directional wheels. These are easier to control, the manoeuvrability increases, and three points of contact are used (avoiding a caster wheel).
- Movement Control - to move towards the objective (ball or goal) as efficiently as possible and preferably arriving to the ball or goal without too many manoeuvres, taking the shortest way.
- Ball Control - to carry the ball without loosing it in curve paths. The ball must roll in the direction of its movement and that is achieved only by holding the ball (not allowed in the rules) or by compensating the robot movement behind the direction of the ball. Some devices have been built like [6]. Some teams use only rubber fingers (Brainstormers Tribots team is one example), and others use rolling devices (Phillips on [7] or Minho on [6]).
- Self localization – important for game success. Teams use several different methods for localising each robot position. There are many possible solutions; looking at the corner posts and using triangulation, looking at the two goals, using encoders on the wheels, using lasers, etc.
- Cooperation – in order to have team play. The rules do not allow direct kicks from a throw in, kick off or free kick, and that forces teams to pass the ball. Some teams can control the kick strength and that is crucial to pass success.
- Reliable Communication system – in order to receive all the commands from other robots and from the referee box. The only communication protocols allowed in this league are 802.11a (54Mb/s) or 802.11b (11Mb/s). The problem is the overall number of teams (with 5 or 6 robots each) which make the network traffic a complete jam. If the robots do not communicate, there will be no team play and also the commands from the referee box will not reach the robots. Therefore, only the minimum amount of information should be sent in order to reduce information packets losses.
- Kicking device - strong enough to score from at least 2-3 meters. In the beginning robots use to push the ball with the body and accelerating. But now the goal-keepers are very fast and kicking devices are necessary. Different solutions are used: compressed gas, mechanical springs (Phillips team on [7]), electric coils (Minho Team on [6]), etc.
- Reliable Hardware – to avoid break downs and to avoid playing with fewer players on the field. Although it does not look like, the reliability of the hardware is of extreme importance. When a robot breaks down it needs to be taken out of the field and that leaves voids on the team play.

- Simplified Hardware – There are many ways to interface the hardware to the computer: USB, CAN, I2C, serial port and parallel port between others. The simplicity and response time should be taken into account. A List of the main advantages/disadvantages between these solutions can be read in the Team Description Paper for RoboCup2005 of Minho team.
- Battery Autonomy – at least 3 or 4 hours. To perform software debugging and/or testing new routines, the autonomy should not be low. The capacity of the batterie s should not influence the speed of the motors otherwise they will perform differently along the time.

### 3. ROBOT ARCHITECTURE

Most teams have different players in the team, although that is probably not the best solution. It creates unexpected errors and too many combinations. One example of robot structure is given by MINHO.

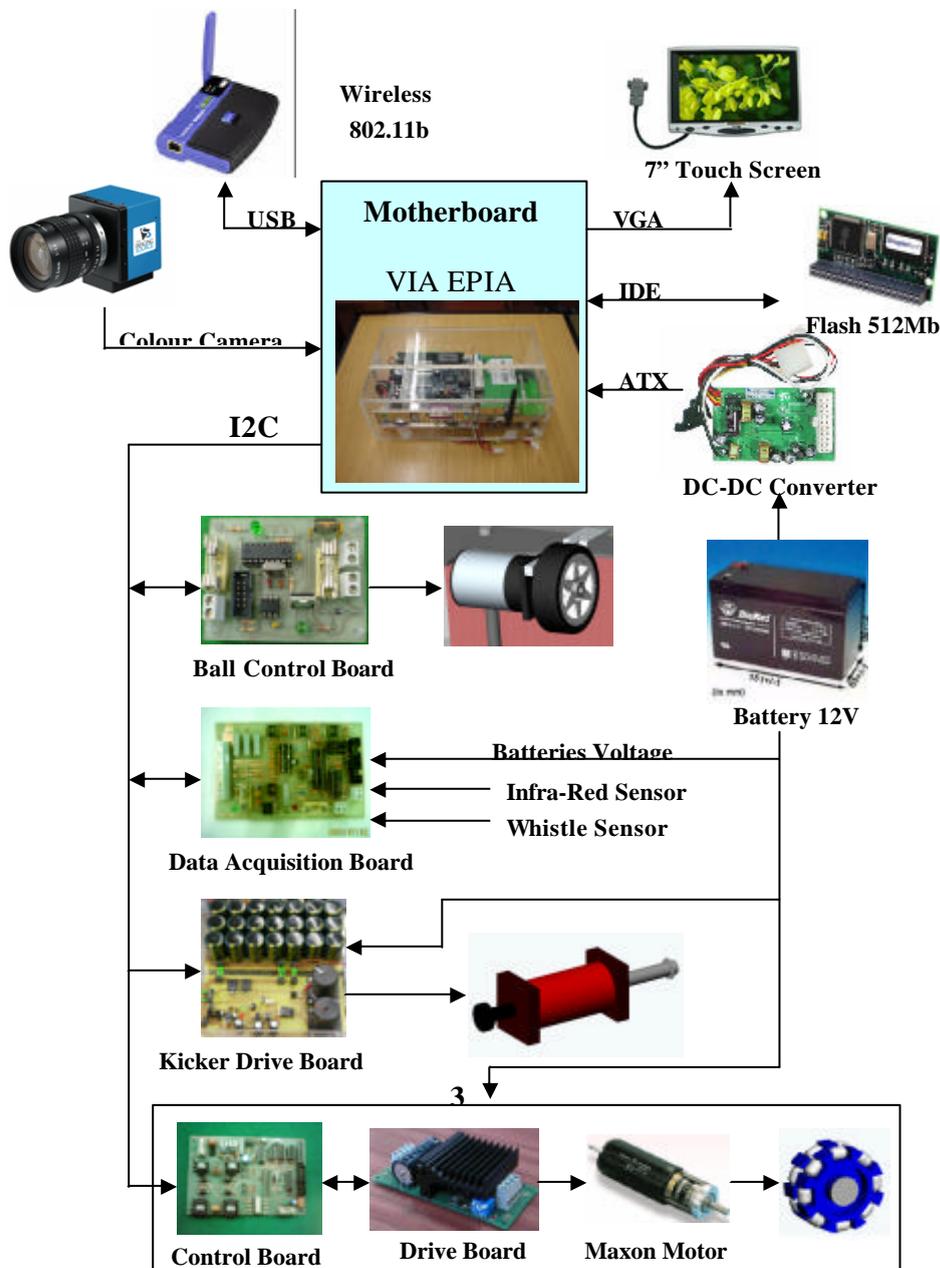


Figure 3. MINHO Robots hardware architecture

Each team presents a different solution although the main trends are omni-direction and omni-vision for the reasons explained before. One hardware solution is described in this work which consists of the Minho team solution (Figure 3).

The whole Hardware system works around a low consumption computer motherboard VIA M10000 running at 1GHz speed, with 256 Mb memory, and a Flash of 512 Mb. A PCI bus frame grabber bt848 based is plugged in a slot, where to an analog colour camera sends the image. A USB wireless network adapter 802.11a based is used for radio frequency wireless communications between the robots. A DC-DC converter powers the computer motherboard being fed by a 12V 7Ah lead acid standard off-the-shelf battery. The I2C protocol takes care of the communication between all the devices and the computer motherboard. A Ball handler control board takes care of the motor which spins the ball, and a data acquisition board reads many states of the robot like each motor current, encoders, battery voltage, etc.

A motor control board receives commands through I2C protocol and sends it to a motor drive board. All these electronic boards were developed by the team in the laboratory. The motors are 150W Maxon DC RE40, with a Maxon GP42C planetary gear head and a digital encoder HEDS55 with 500 pulses per turn and TTL compatible. These motors are very reliable, fast and its consumption is low allowing the batteries to last longer.

Teams use kicking devices to push the ball towards the goal. Most of them use compressed air to punch the ball, although the main disadvantage is that after a few kicks the system runs out of air and it needs recharging (example is the AIS/BIT Team). Other solution consists of pulling in a big spring and releasing it to kick the ball. The main disadvantage is the time it takes to pull the string back, the need for another motor and the impossibility of kicking while the spring is being pulled back (example is the Phillips Team). This kick is much strong than the ones that use compressed air. Another option consists of a magnetically impelled kicker that uses an electric coil, in which a current passes through and attracts a cylindrical iron core. At the other end, a cylindrical shape nylon piece is attached to the metallic core and pushes the ball away. This solution is used by the Minho team ([6]) and is the strongest of all. Some teams are able to lift the ball from the floor having an extra advantage. This is the case of Brainstormers Tribots team, AIS/BIT team and DIT-IC team.

#### **4. FOOTBALL STRATEGY**

Game strategy is of extreme importance towards game success. There are different approaches in order to make robots play football. Cooperation is now the next step and although some teams are trying to start that new challenge, in practice that is still almost inexistent and a bit difficult due to the nature of the game.

Most teams use different programs for each robot. Each person programs one robot independently despite some routines being shared between all the robots. Other teams are starting to use reinforcement learning in order to make the robots learn how to play after a few iterations. Another solution consists of having exactly the same software in all the robots, but each one behaves differently according to its position on the field. For example the one closer to the ball becomes the attacker and the one farther to the ball becomes the defender.

The way to program these robots can be of different ways: by using threads, by using Finite State Machine, and even graphset type solutions, in which a robot has a sequence of steps and follows that chart. These can sometimes become very complex in terms of strategy but works out fine.

But the most important aspect consists in having a good vision system. If the vision software fails the entities perception, the rest of the software will not work properly.

#### **5. CONCLUSIONS**

This paper intends to make a summary of the main aspects to take into account in order to build a robotic football team. With the years of experience that the author has, good advices can be achieved

from here. The RoboCup challenge is quite inspiring, produces practical scientific results, and attracts many people to the robotics areas.

Many papers can be read about these robotic teams to get more experience, but the most important advices are summarised here: Good vision system, enough robot speed, good manoeuvrability, easier movement control, simple and efficient ball control, existence of reliable self localization on each robot, cooperation, build and use a reliable communication system, create an efficient kicking device, build or buy reliable hardware and use batteries which allow long lasting autonomy. One hardware solution is shown and described in this work.

There are many RoboCup events on which a new team can start participating, normally national events. A list of a few of them can be read in [1].

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