RoboIME: on the road to RoboCup 2014

Andre O. P. Barcelos, Jan L. L. Segre, Lucas O. de Lima, Naum A. F. Barreira, Renan Gemignani, Robinson Calou M. B. Filho, Vitor H. F. Betio, Victor Bramigk, and Paulo F. F. Rosa

Instituto Militar de Engenharia (IME)
Praca General Tiburcio, 80 - Praia Vermelha, Urca
Rio de Janeiro - RJ - Brazil
roboime@googlegroups.com

Abstract. This paper describes the electronic, mechanical and software designs developed by RoboIME Team in order to join RoboCup 2014. All designs are in agreement with the rules of Small Size League 2014. This is the third RoboIME participation in a world level RoboCup event, although the team has already challenged three times in Brazil and Latin America.

1 Introduction

RoboIME is a small-size league soccer robot team from IME, Rio de Janeiro, Brazil. This is only the 5th time the team is taking part in competitions. The main result was in 2012 when the team achieved second place in Latin American Robotics Competition.

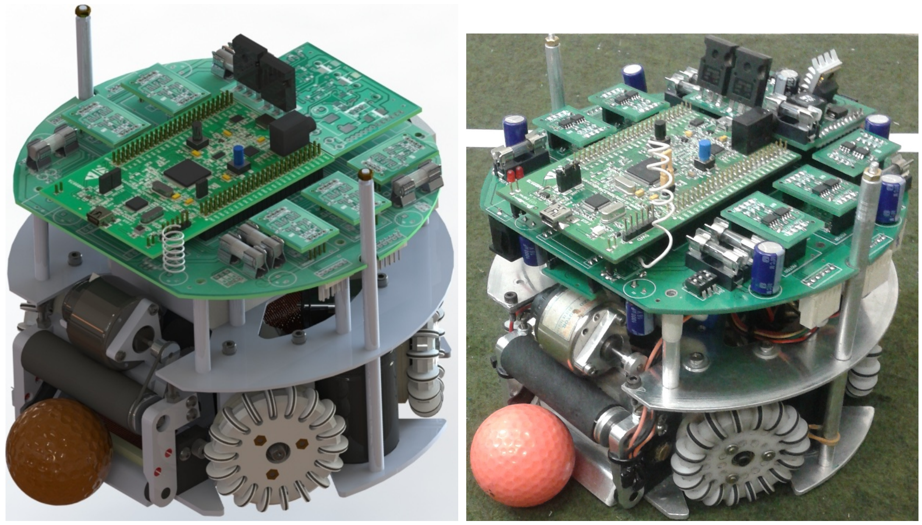
All students that work in this project are members of the Laboratório de Robótica e Inteligência Computacional at IME. The previous studies [1][5] provided the basis for the current structure of software and hardware team's. This paper describes the computer, electronic and mechanical designs.

This work is organized as follows. First the mechanical design of RoboIME robots is presented at section **??**. Then the firmware and electrical project is presented at section 3. After, the software system is presented at section 4. Finally at section 5 discussion and future work are described.

2 Mechanical Design

The mechanical project of the robot is completely redefined. New devices such as the chip kick and the improvement of the transmission system were developed. This robot was designed and built using CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing) software, moreover extensive testing was done to validate the current project.

Most of our robot parts were CNC machined: made out of 7075 aluminium and high density polyoxymethylene (POM). The POM have some excellent properties such as: high rigidity, good impact resistance, a non-stick characteristic



(a) (b)

Fig. 1. (a) 3D model view. (b) Robot real view.

and is a highly machinable material. In this way some parts of the robots, like the plunger stopping body, are more suitable to be made out of POM than aluminium. For example, the dribbler arm is a pivot-rotating mechanism, using POM eliminates the need for a bearing within the assembly.

2.1 Dimensional Constraints

In compliance with the SSL rules, the height of the robot is 149 mm and the maximum projection of the robot on the ground is 180 mm.

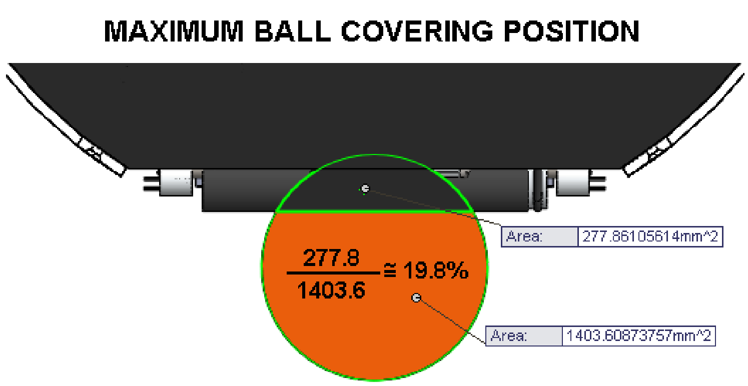


Fig. 2. Maximum covered area of the ball

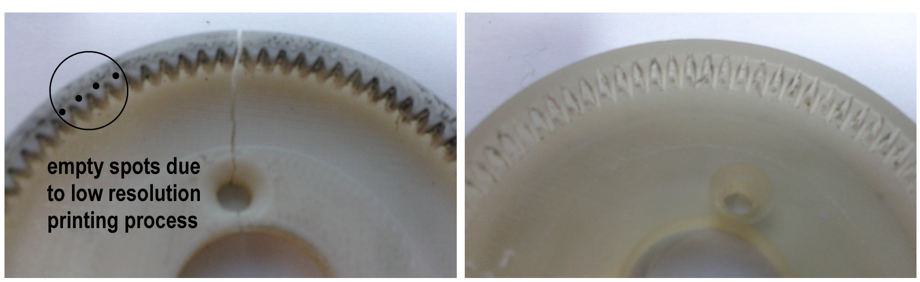
Using a CAD software we were able to measure the percentage of the ball area that was covered by the robot. The maximum percentage of ball coverage found was 19,8 %, according to the 20/80 rule of the league. The hight of the dribbler cylinder it's also adjustable so we are able to find the optimum point for the best ball control.

2.2 Transmission System

A system of internal gears was made to transmit the power of the motors to the wheels. This system has several advantages compared to traditional gear meshing. Avoiding debris entering the motors, creating a cavity to apply grease for lubrication of gears and an overall smaller size are some of them.

However there are some difficulties in the manufacture of this part, mainly due to the small size of the teeth needed to mesh with standard motor gear (the motor being used is the Hsiang Neng DC brushed motor type HN-GH35GMB). At this motor the distance between two consecutive teeth is less than 1 mm, thus it was not feasible to machine the internal gear. So it was decided for the 3D printing in ABS plastic as the manufacturing process.

Some prototyping have been done ensure accuracy and strength to the gear. The traditional fused filament deposition method for 3D printing, in geometries smaller than the filament itself, create cavernous structures that weaken the piece. Applying the stereolithography 3D printing process (when a laser beam cure a liquid resin layer by layer), we manage to achieve a higher resolution. This way we can precisely print the teeth profile, avoiding failures due to empty spots and achieving a more solid and precise component.



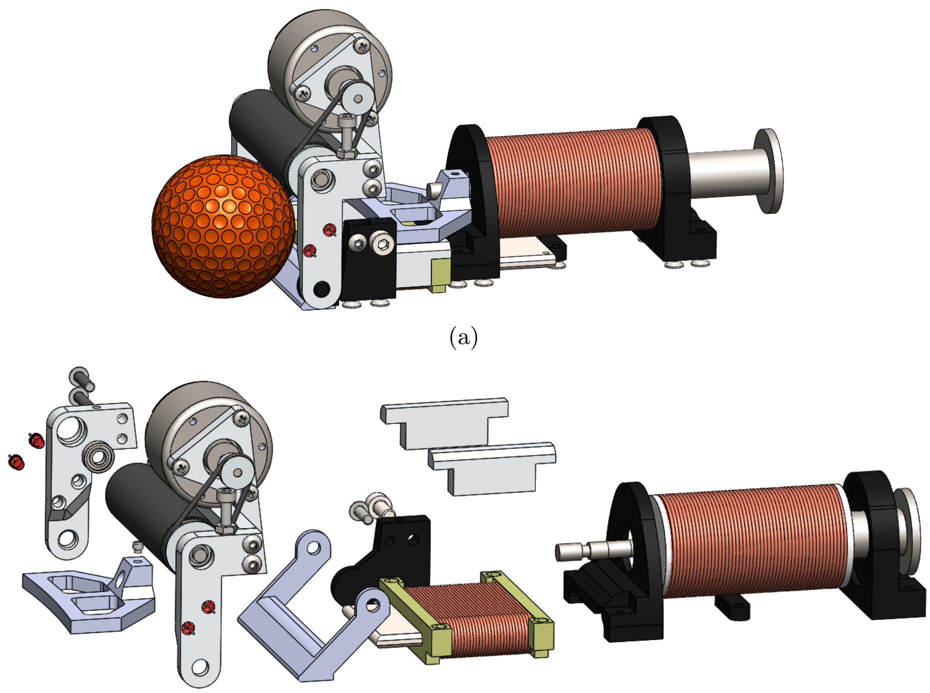
(a) (b)

Fig. 3. (a) Cracked gear (lower precision). (b) Stereolithography printed gear.

In previously models the gears were made out of aluminium, much harder than the ABS plastic, therefore there were some concern about breaking this piece when submitted to a large load. Full power stoppage tests were performed, locking the motor, bringing the gear to its limit. Satisfactory result were achieved making the system very reliable.

2.3 Chip Kick

The chip kick is based on a flat solenoid, which is mounted in a slot at the chassis (close to the ground). When activated the core of mild steel is accelerated against the rear of the chip, which revolves around it's axis and makes the ball rise. Due to the limited space, complex construction and details, we also have chosen the 3D printing as the manufacturing process.



(a)

(b)

Fig. 4. (a) Dribbler, chipper and kicker assembly. (b) Exploded view.

The flat solenoid is assembled in a way that work as a guide rail for the kick plunger as well. We are using rubber-bands to pull back the chipper and kicker plungers, keeping the simplicity of the mechanism. The final dribbling/kicking mechanism is a very neat assembly and can be easily adaptable for any other chassis.

3 Embedded System

RoboIME electronics consist of seven boards: (a) the Main board, responsible for communication between the other boards; (b) the Stamp board, responsible for the embedded computation; (c) the Kicker board, responsible for maintaining high voltage to activate the kick shoot; (d) four motor controller board which are responsible for robot's motion control. These boards are described in details in this section.

3.1 Main Board

The Main Board features a socket to plugin the boards: kick's sensor, dribble's motor, four wheel's motor, four encoders and the power supply. There is a RFM12b SMD embedded which is a wireless transceiver operating in the 434 MHz band, set as up to 115.2 kbps, fully in agreement with FCC and ETSI regulations.

The communication protocol used between the Stamp Board and the transceiver was Serial Peripheral Interface Bus (SPI), that is a synchronous serial data link standard that operates in full duplex mode.

3.2 Stamp Board

This board is responsible for performing all the logic functions. It is like a brain of the electronic system. There is an embedded micro-controller STM32F407, with ARM Cortex M4 as main CPU, 1 MB Flash, 192 KB RAM memory, working in 168 MHz, that was programmed with C language using the interface development CoIDE and Eclipse IDE.

3.3 Kicker Board

This board is responsible for controlling the kick strength. There are two kinds of kick, the kick shoot and the high kick. Two capacitors of 2200 μF, 200 V are used to store the voltage in a boost circuit. The charge is discharged in a solenoid and depending on the PWM signal the kick device is activated, it is possible to control the kick velocity.

3.4 Motor Controller Board

The idea of the RoboIME electronic is to modularize the electronic project. So, there is controller module board for each wheel's motor. If one of them burns out, it is possible to exchange it quickly. Each board has two TC4427 (MOSFET driver) and two IRF7319 (half H bridge). These ICs create a H-bridge, allowing velocity control in both directions.

4 Software Solutions

The software systems consist of three projects: pyroboime (AI), ssl-webclient (graphical client), grSim (simulator).

4.1 Artificial Intelligence

The AI, pyroboime, is based on the STP (Skill-Tactic-Play) architecture and implemented in python. It has the following components: interface with the ssl-vision, ssl-refbox and grSim, it also has a built-in communication module for the radio transmitter system.

The STP is a three tier architecture where the lowest level, skills, enables the low level manipulations on a single robot. The middle layer, tactics, makes use of the skill layer to execute higher level behaviour, possibly enabling coopration, but still acting on a single robot. The upper layer, plays, coordinates the tactics associated to each robot in order to maximize performance, each play is implemented to behave according to specific states: stop, halt, indirect kicks and normal play. A higher level layer implmented as a play switches between other plays based on the current referee state. This architecture is better depicted in figure 5.

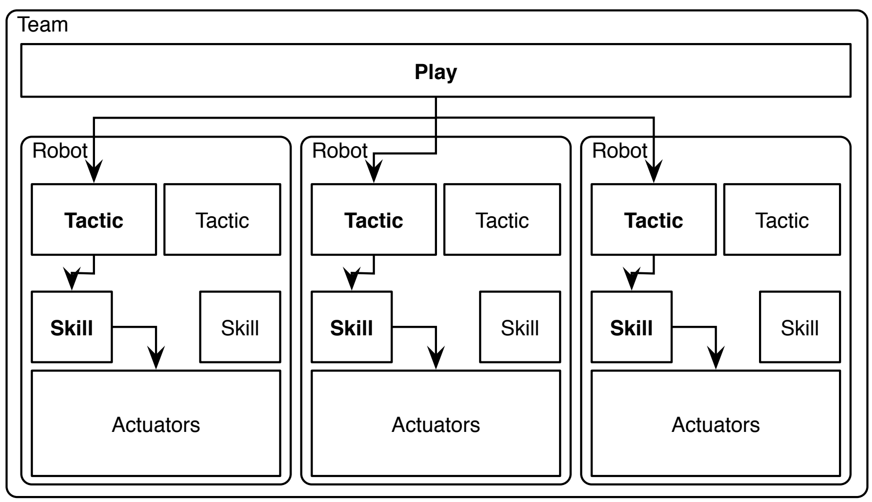


Fig. 5. STP Diagram

There is also a skill implemented to redirect inputs from a joystick such that it is possible to test the robot with little effort.

The interface is structured as a filter stack which connects the AI to a flexible collection of updaters (which receive state information) and commanders (which deliver commands to the robots, in both the simulated and real environments). It abstracts the external environment where the game is played from the AI. Among the filters in said stack is a Kalman filter that reduces the noise comming from the updater data.

The built-in radio trasmitter system interfaces with libusb to control the transmitter hardware, which is connected via USB.

4.2 Support systems

The graphical client, ssl-webclient, is a Web interface implemented in nodejs using WebSockets, HTML5, SVG and ZeroMQ. It has the following functionality: displaying and altering the AI state, broadcasting games through the internet and playing log files.

Lastly the simulator, grSim, originally developed by Parsian Robotic, was customized to fit our needs. It provides the following functionality: simulating the game environment and exposing an ssl-vision compliant protocol.

Fig. 6. Snapshot of the simulator

4.3 Source

All of the projects above have been open sourced with GPL-like license, with the main difference being that a derived work used on a competition must have its source released by the next edition of that competition. The sources of those projects are available on the team's github page: http://github.com/roboime/.

5 Discussion and Future Works

The development of the Robocup 2014 mechanical project was concluded last year, based on the one we created for Brazilian Robotics Competition 2012. The six robots have already been manufactured, with only a few parts still needing rework.

Some electronic prototypes were made, yet stabilizing efforts are still ongoing. Problems with kicker board due to hight welding temperature were observed. The solution was to use a welding temperature below 260^{o}C.

The five modules of the AI system have already been implemented but they still need to be brought to perfection. Research in machine learning was started last year to predict enemy behaviour, but an implementation is not planned for Robocup 2014.

For the July competition, following goals are being sought: rework the remaining parts on the mechanical project such as making improvements on the coiling of the solenoid coil; stabilize the electronic project, including robot feedback and conclude the implementation of planning algorithms to be used in support decision making.

Acknowledgements

This research was partially supported by Fundacao Carlos Chagas Filho de Amparo a Pesquisa do Estado do Rio de Janeiro -FAPERJ(grant E-26/111.362/2012); Fundacao Ricardo Franco (FRF) and Fabrica de Material de Comunicação e Eletronica (FMCE/IMBEL). The team also acknowledges the assistance of Mr. Carlos Beckhauser from FMCE. Special thanks to Diego Felix de Almeida, Luis Renault L. Rodrigues, Stefano H. Rodrigues, Thiago A. Navarro do Amaral and Vitor L. Horta Ferreira, former team members that made this project possible.

References

1. Alexandre Tadeu Rossini da Silva: Comportamento social cooperativo na realização de tarefas em ambientes dinâmicos e competitivos. Instituto Militar de Engenharia, Rio de Janeiro (2006)
2. Madeira, B. E., de Almeida, D. F., de C. Maia Jr., E., Rodrigues, L. R. L., Rosa, P. F. F., Rodrigues, S. H., and do Amaral, T. A. N.: RoboIME: Team Description Paper for RoboCup 2012.
3. B. Browning and J. Bruce and M. Bowling and M. Veloso: STP: Skills, tactics and plays for multi-robot control in adversarial environments Carnegie Mellon University, Pittsburgh, PA (2004)
4. Khatib, O.: Real-Time Obstacle Avoidance for Manipulators and Mobile Robots. In International Journal of Robotics Research, vol. 5, no. 1, p. 90-98 (1986)
5. Marco Antonio Firmino de Sousa: Uma Plataforma para Cooperação Autónoma de Múltiplos Robôs Instituto Militar de Engenharia, Rio de Janeiro (2008)
6. Russell, Stuart J.; Norvig, Peter: Artificial Intelligence: A Modern Approach (2nd ed.) Upper Saddle River, New Jersey: Prentice Hall, pp. 163-171 (2003)
7. Stefan Zickler: Physics-Based Robot Motion Planning in Dynamic Multi-Body Environments Carnegie Mellon University, Pittsburgh, PA (2010)
8. Welch, G. and Bishop, G.: An introduction to the Kalman filter. Technical Report TR 95-041, Department of Computer Science, University of North Carolina (2001)