RoboFEI-HR Team Description Paper for the IEEE Humanoid Robot Racing Competition

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Abstract— **This paper presents the description of the RoboFEI-HR Humanoid team, as it stands for the Latin American Robotics Competition 2019 in Rio Grande, Brazil. This work presents the mechanical, electrical and software modules, designed to enable the robot to compete in the IEEE Humanoid Robot Racing Competition.**

I. Introduction

In this paper we describe the mechanical, electrical and software aspects of the RoboFEI-HR IEEE Humanoid Robot Racing Competition robot, designed to compete in this year's Latin American Robotics Competition.

In 2014, we competed in our first RoboCup World Competition, held in João Pessoa, Brazil, with 4 humanoid robots: two Newton Robot [12] and two humanoids robots based on DARwIn-OP [13] with some structural differences, that we called B1 Robot. At RoboCup 2014, we finished in the top 16 teams and, three months later, the team competed in the Latin American Robotics Competition (LARC 2014) and became the champion in the LARC RoboCup Humanoid Kid Size league.

In 2015, in Heifei, China, we competed with one Newton Robot[12] and three new B1 Robots[13], we adjusted the B1 Robot project to attend to the new requirements of field and ball. Three months later, in the LARC 2015, we finished in second using the same team.

In 2016, on Leipzig, Germany, the team competed with four robots, finishing in the top 8 teams, by showing a great improvement on the walking capability on artificial grass. Then in the same year, the team became the champion of the LARC 2016.

In 2017, on Montreal, Canada, the team competed with four robots, three Kid Sized robots and one with the possibility to compete in both Kid Size and Teen Size leagues.

The same robots competing in the Humanoid KidSize League are able to compete in the IEEE Humanoid Robot Racing Competition.

II. Research interests

Our group consists of 2 Faculty Professors (one from the electrical and one from computer science departments) 2 Ph.D. and 18 undergraduate students.

Our current research interests in the humanoid racing are:

- Mechanical design of humanoid robots: how can a robot be built, using lighter parts and new kinematic configurations? In particular, we are studying Topology Optimization [14] as a way to build stronger and lighter parts for the robots.
- Gait generation and optimization: how to automatically generate gaits and optimize them? We are using Reinforcement Learning, Particle Swarm Optimization and Simulated Annealing.
- Stabilization Methods: most researchers use Center of Gravity or Zero Moment Point methods to stabilize the robot. Can Reinforcement Learning be used to prevent the robot from falling down, dynamically?

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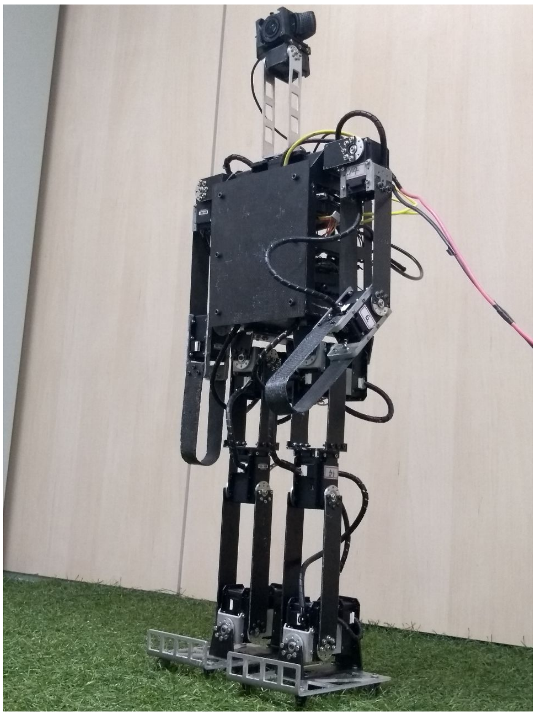


Fig. 1: Mirzam Robot.

III. Hardware Design

B1 Robots as well as Mirzam Robot were developed by us, their mechanical parts were based on DARwIn-OP [13]. The robot will be described in this section.

A. Mechanical Design

Based on the mechanical of the Darwin-OP Robot[13], we developed B1 Robot, as depicted in Fig. 2. B1 Robot's specifications can be seen in Table I. Based on B1 robots, we

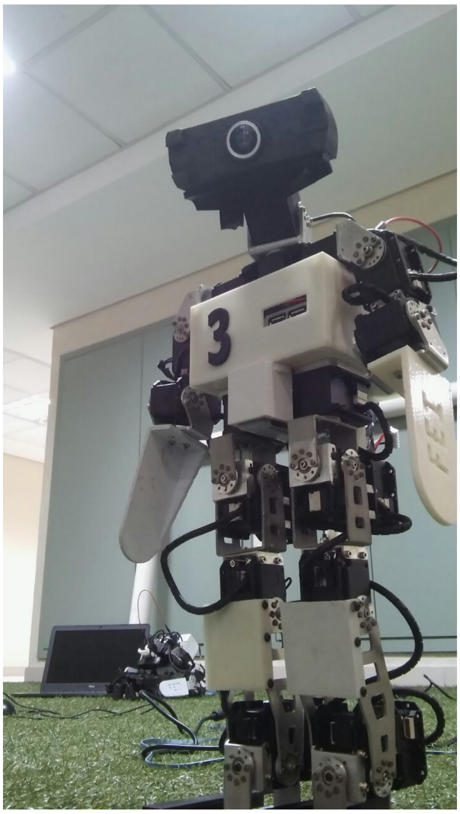


Fig. 2: B1 Robot.

developed our Teen Size robot Mirzam which characteristics are in Table II.

B1 Robot is composed of 20 degrees of freedom, as follows: six in each leg, three in each arm and two in the neck. The servomotors used are the Dynamixel RX-28, as depicted in 3. Mirzam Robot is composed of 19 degrees of freedom of which, six in each leg, three in each arm and one in the neck. The servomotors used are the Dynamixel MX-106, MX-64 and XM-430.

B. Electronic and Electrical Design

As a project goal, we decided to minimize the use of electronic parts in the robot. Our aim was to reduce all possible processing units and other accessory hardware, concentrating all the processing in one computer. We decided to control the motors using the computer's USB port. Thus, we eliminated the use of microcontrolled boards, that is often used as an intermediate step between the computer and the motors.

We chose the Next Unit of Computing (NUC) developed and produced by Intel to be the robot's computer. A picture of the NUC can be seen in Fig. 4.

As the serial communication port is not easily available on today's computers (especially the smaller ones), we use a USB/RS485 adapter to allow communication between the computer and the motors.

TABLE I: B1 Robot Characteristics

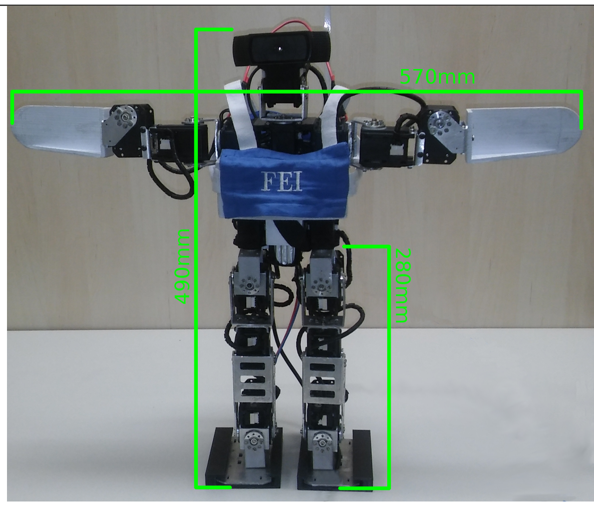
ROBOT PICTURE	
	
ROBOT DIMENSIONS	
Max Height	490 mm
Max Width	570 mm
Leg Length	280 mm
Weight	3.1 Kg
Skeleton Materials	Plastic and Aluminium
Walking speed	20 cm/s
DOF	20 in total: 6 per leg, 3 per arm, 2 in the neck
Type of motors	Dynamixel RX-28
Motors com protocol	RS-485
IMU Sensor	CH Robotics UM6
Camera	Logitech Full-HD Pro Webcam C920
Computing unit	Intel NUC Core i5, 8GB SDRAM 120GB SDD
Battery	LiPo 18.5V - 2000mAh
INTERNAL SENSOR	
Compass	For orientation
Acelerometer	To detect falls
Gyroscope	To control the robot balance
Conversor USB/RS485	To comunicate with the motors
EXTERNAL SENSOR	
Single Camera	For detection of the arena to run.

TABLE II: Mirzam robot Characteristics

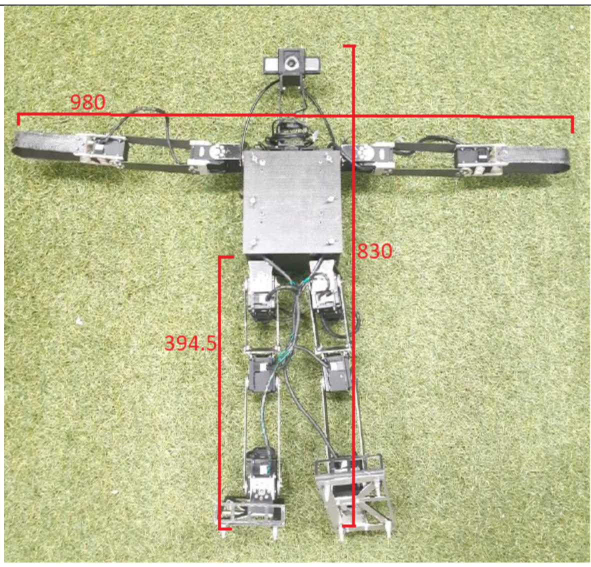
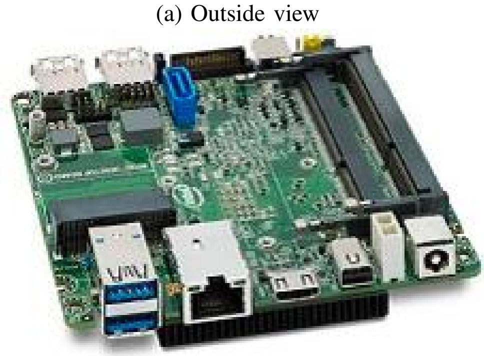
ROBOT PICTURE	
	
ROBOT DIMENSIONS	
Max Height	830 mm
Max Width	980 mm
Leg Length	394.5 mm
Weight	5.9 Kg
Skeleton Materials	Plastic, Aluminium and Carbon Fiber
Walking speed	40 cm/s
DOF	19 in total: 6 per leg, 3 per arm, 1 in the neck
Type of motors	Dynamixel MX-106, MX-64, XM430
Motors com protocol	RS-485
IMU Sensor	CH Robotics UM6
Camera	Genius WideCam F100
Computing unit	Intel NUC Core i5, 8GB SDRAM 120GB SDD
Battery	LiPo 14.8V - 3300mAh
INTERNAL SENSOR	
Compass	For orientation
Acelerometer	To detect falls
Gyroscope	To control the robot balance
Conversor USB/RS485	To comunicate with the motors
EXTERNAL SENSOR	
Single Camera	For detection of the arena to run.

Fig. 3: RX-28 servomotor.

(a) Outside view



(b) Inside view

Fig. 4: Intel NUC

IV. Software Design

The team's software was completely developed by our group, using no software from other teams. We used a hybrid architecture, named Cross Architecture shown in Fig. 5, where each one of the solid line box in the Cross Architecture is a completely independent process for the computer [12], composed by a vision, localization, decision, planning, communication, sense and control systems.

The most important systems in this competition is the Movement Control and Vision systems.

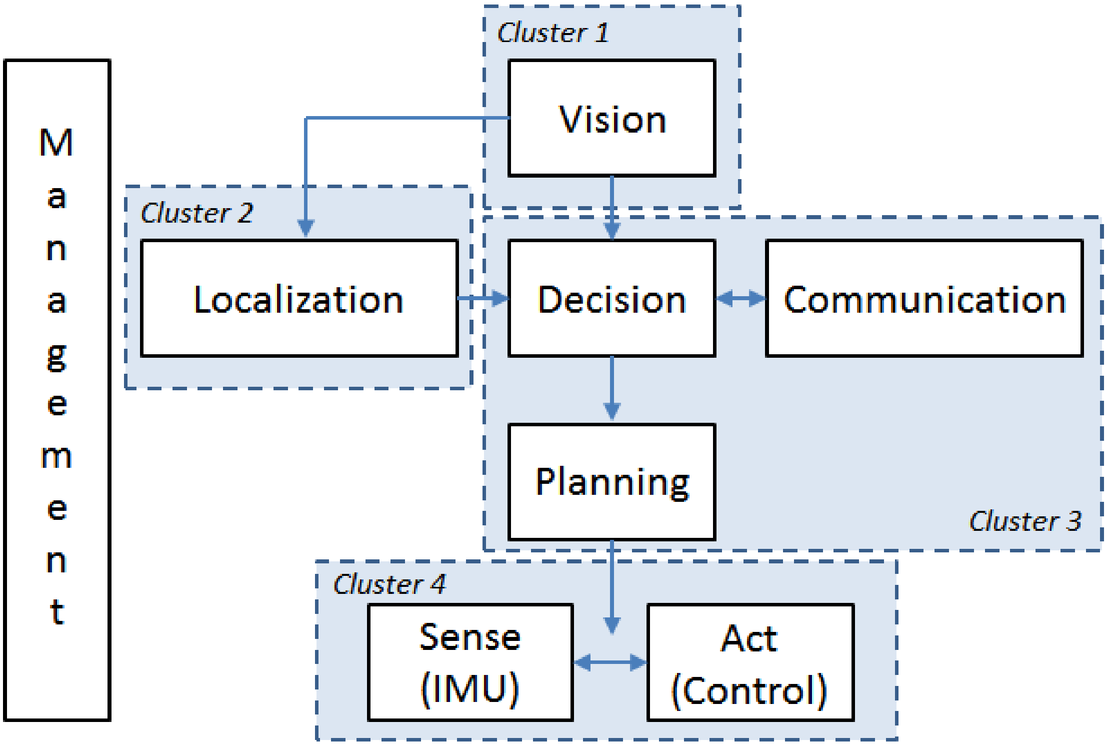


Fig. 5: The Cross Architecture.

A. Movement Control

The Control system is in charge of controlling all servomotors of the body, except the ones of the head, that are controlled by the Vision system. Control process keeps checking if the robot is standing or fallen, if it's fallen the process will make it stand up. The Control also monitors the battery voltage, when it gets below the safe operating range, the robot sits down and turn off the servomotors.

Through the performed experiments to improve and speed up the walking on artificial grass, we found that for each kind of movement we needed to adjust the parameters in order to seek a fast and dynamically balanced gait.

In the config.ini archive we have added sections related to the each kind of action. The control process holds the attributes related to the configuration parameters of the movements, and according to the action that the robot will perform, it updates the parameters to the gait pattern generator.

B. Vision System

Vision is responsible for obtain images and process them. The robot must be able to perceive the track boundaries, as well to be able to identify obstacles. By using color segmentation, it is possible to identify the obstacles, and also keep the robot moving in the center of the track toward the finish line.

V. Work in Progress

Performing some experiments on Control Process, we proposed an approach that uses Reinforcement Learning to learn the action policy that will make a robot walk in an upright position, in a lightly sloped terrain. The results shown that the use of a gyroscope is not sufficient to maintain the stability of the robot in this type of ground, and the use of other sensors such as an accelerometer, combined with Reinforcement Learning techniques to help the robot to stabilize itself during the walk seems very promising.

We are also working on the optimization values of the gait pattern generation for Darwin-Op and we propose a reinforcement learning algorithm with temporal generalizations that aims to optimize this parameter. There are several gait generation techniques that have been developed for humanoid robots and Darwin-OP robot uses a method to generate the gait pattern based on coupled oscillators that perform sinusoidal trajectories. However this gait pattern generation has several parameters for its configuration. We performed experiments in a simulated environment and the results has shown that the algorithm was able to learn what are the best parameters values, through the evaluation of the humanoid robot's walk performance.

On Vision Process, our first approach proposes a vision system with threads, allowing the robot to track objects and providing information such as distances and estimated localization for the robot, simultaneously. Only one of these threads have the control of the pan-tilt at a given time, but all the algorithms will continue to capture information from the environment, no matter where the camera is heading to.

VI. Conclusion

In this paper we have presented the specifications of the hardware and software of RoboFEI-HR humanoid robot racing team, designed to compete at the Latin American Robotics Competition 2019 in Rio Grande, Brazil. Our team will be composed of a B1 Robot and Mirzam Robot.

Today, the research team is composed of two Faculty Professors, two Ph.D. students and eighteen undergraduate engineering students. The team developed a Robot Simulator [8], which is used for developing cognitive algorithms without the need of real robots. In order to make possible for the robot to walk in upright position in a lightly sloped terrain Silva et al. [16] proposed the use of Reinforcement Learning to learn the action policy which will keep the robot in upright position. Perico et al. [9] developed a collaborative communication system of spatial perceptions for vision-based robots; in order to obtain human like categorization of space it was used the Elevated Oriented Point Algebra ($\mathcal{EOPRA}$). Homem et al. [6] proposes the use of Conceptual Neighborhood Diagram to compute the similarity in cases used in the Case-Based Reasoning using qualitative spatial discretization. Finally, the team has more six papers published on International Latin American Robotics Symposium [12], [18], [11], [17], [15], one paper published in the International RoboCup Symposium [1], four books' chapters [4], [10], [7], [19], and three papers published in major journals [2], [5], [3].

Acknowledgments

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