RoboFEI Humanoid Team 2018: Team Description Paper for the Humanoid KidSize League

Sylvio R. J. Neto, Aislan C. Almeida, Danilo H. Perico, Thiago P. D. Homem, Isaac J. da Silva, Claudio O. Vilão Jr., Vinicius N. Ferreira, Jade C. C. Gali, João Paulo A. Paula, Lucas M. Carregaro, Guilherme P. Oliveira, Gustavo D. Fernandes, Rodrigo B. Coelho, Gustavo M. Matos, Jonas H. R. de Oliveira, Felipe S. A. de Freitas, Rodrigo W. S. Soares, Lucas D. Chagas, Breno H. F. de Souza, Mariana A. de Oliveira, Plinio T. Aquino Jr., Flavio Tonidandel, Reinaldo A. C. Bianchi
Department of Electrical Engineering and Department of Computer Science
Centro Universitário FEI
São Bernardo do Campo, Brazil
{flaviot, rbianchi}@fei.edu.br

***Abstract*—RoboFEI is a recurring team on the KidSize League from RoboCup's competition, participating in this category since 2014, in the competition that took place in João Pessoa/PB, in Brazil. In order to participate in this year's competition in KidSize League Category, that will be held in João Pessoa, PB, this paper presents the actual team's configuration, regarding hardware and software of the robots that will be used by RoboFEI team in this year's competition.**

***Index Terms*—Humanoid Robots, Team Description Paper, KidSize League**

I. Introduction

The RoboFEI team dates from 1998, when Prof. Reinaldo Bianchi and his team started to develop soccer playing robots at Centro Universitário FEI. It was a team of the Very Small Size Category that became the runner-up in 2003. Since then, there was a 2D RoboCup Simulation Team, which became the Brazilian Champion. The Very Small Team evolved into a Small Size team, which became six times champion in the Latin American Robotics Competition (LARC). And in 2012, the Humanoid KidSize team started, with students designing and building a humanoid robot from scratch. Later, in 2015 the RoboFEI team started their work in the category @Home.

The RoboFEI is a recurrent competitor in the RoboCup's Humanoid KidSize League since 2014, participating in 2014 in João Pessoa, Brazil, in 2015 in Heifei, China, in 2016 in Leipzig, Germany, 2017 in Nagoya, Japan, and 2018 in Montreal in Canada. The team also participates in LARC since 2014, and became the champion in three editions 2014, 2016 and 2017. Figure 1 shows the teams participation in a match in RoboCup 2017, held in Nagoya, Japan, and Figure 2 shows the teams participation in a match in LARC 2017, held in Curitiba, Brazil.

The objective of this paper is to present the team's robots, the research interests and the work in progress in order to participate in Latin American Robotics Competition (LARC) 2018, to be held in João Pessoa/PB, in Brazil.

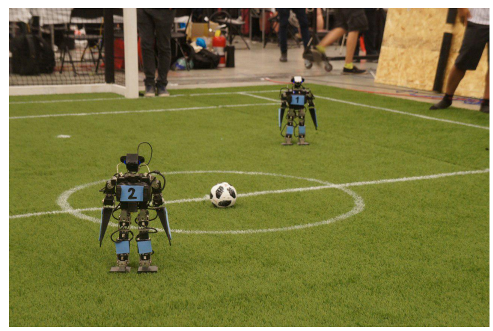


Fig. 1: Match played in Robocup 2018, Montreal

Fig. 2: Match played in LARC 2017, Curitiba

II. Hardware

Until the last competition, the RoboFEI team had only robots of 49 cm high to compete the KidSize category, that can be seen in the figure 1 and 2, this robots were an adaptation of Darwin OP project [1], changing some aspects in order to port a Intel NUC Core i5-4250U, 8GB SDRAM and 120 GB SDD as computation unit. The gait pattern generator used by the DARwIn-OP is the same used by the B1 robots, been the only software module not made by the team. Their parts are made of aluminum or 3D printed in ABS, where some of the 3D printed parts are coated in carbon fiber, increasing their resistance with minor weight increase. 20 servo-motors Dynamixel RX-28 grants 20 degrees of freedom to the robots, and they use as sensory input a UM7 Ultra-Miniature Orientation Sensor and a Logitech HD Pro Webcam C920 (Full HD).

Nowadays the RoboFEI team developed a robot with 90 cm tall and 9.4 kg, so it can compete on both categories, the KidSize and the teenSize leagues. The new robot is a evolution made from the robots b1. The new robot have his own adaptations too, it is made of aluminum and plastic coated in carbon fiber, where the plastic parts were designed by the team members and using a 3D printer, 22 servo motors giving 20 degrees of freedom using 2 motors on each of the knee's joints, preventing the motors to failure by exceeding its torque. The legs uses the Dynamixel MX-106, the arms uses the MX-64 and head uses Dynamixel RX-28. As sensory input, a Inertial Measurement System and a webcam are used, the same as robots B1.

Table I presents all the hardware specifications.

TABLE I: Sirius Robot Characteristics

Robot Name	Sirius
Height	90 mm
Weight	9.4 Kg
Degrees of Freedom	20 in total: 6 per leg, 3 per arm , 2 on the head
Type of motors	Dynamixel RX-28/ MX-64/MX-106
Sensors	UM7 Ultra-Miniature Orientation Sensor
Camera	Logitech HD Pro Webcam C920 (Full HD)
Computing Unit	Intel NUC Core i5-4250U, 8GB SDRAM, 120GB SDD

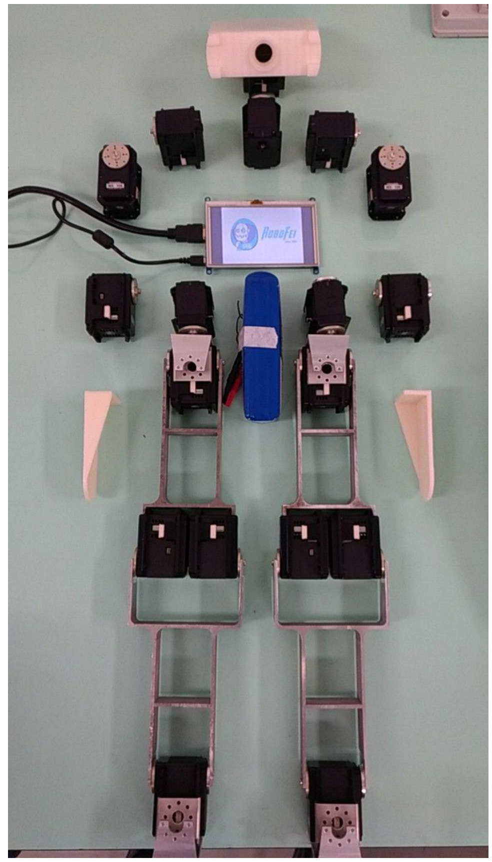


Fig. 3: New teen sized robot

The robot uses a helmet in order to protect the camera from falling damage and to fasten fish-eye lens, used to increase the robots field of view. A touchscreen was attached to the robot's chest, in order to create an easy access to the internal robot's state, making it ease to diagnose the failures in the system without the need of an external computer screen.

Figure 4, shows a picture of the Robot in RoboCup 2018 competition.

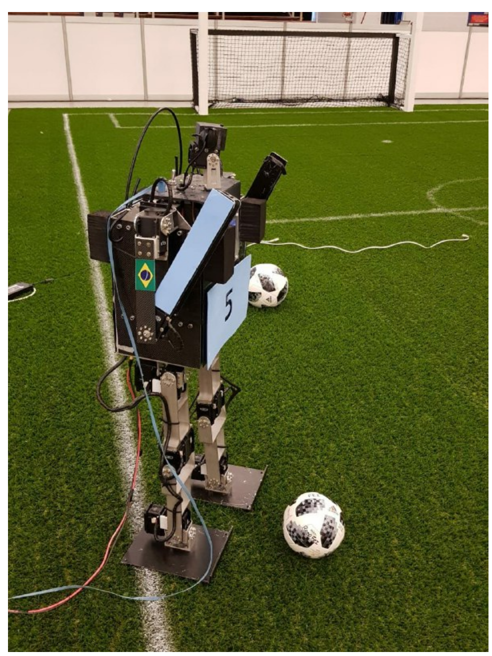


Fig. 4: Robot player in Robocup 2018, Montreal

III. Software

The software that controls the operation and processing of the robot data is made upon the a Cross Architecture [2], which allows all processes to communicate with each other through the shared memory called blackboard. This section describes the processes.

A. Vision

In order to create a vision system that is capable of detecting a ball in the middle of the field, the RoboFEI team uses white segmentation and Deep Neural Network (DNN) to classify the images. The DNN recognize two classes: Ball and No ball.

First the RGB image collected by the robot's camera is converted to YUV, extracting the Y channel. Then binary thresholds highlights the white regions, and apply morphological transformations to them. The image frame is sliced into 4 vertical regions, which are related to the distance between the robot and the ball. This regions are called: at, close, far and very far. This sections in the image captured by camera were made so it can perform different morphology transformations in each of the regions. For this approach, the robots head is considered to turn horizontally.

Finally, the slices of the images that contains white regions are extracted, so that the DNN can classify this regions as containing ball or not.

The image collected by the camera has the dimensions of 1280x720, and the DNN has 2 convolutional and 2 fully connected layers, having as input from the network, a 32x32x3 image. The first convolutional layer has 20 kernels, each of them made of 5x5 with stride 1 with the input image. The second convolutional layer is made of 32 kernels of 5x5 with stride 1. The first fully connected layer have 128 neurons, and the second fully connected layer have 2 neurons. The max-pooling is applied in the first and second convolutional layers with 3x3 kernel size and stride 2. The time spent to classify an image by this DNN architecture on the computer used by the robot is about 10 milliseconds. The code of the DNN showed can be find in https://github.com/Isaac25silva/Ball_detect-DNN.

The networks training was performed in an Intel i7-7700HQ 2.8 GHz computer, 32GB DDR4 2133MHZ of RAM memory, 480GB of SSD, NVIDIA GeForce GTX 1060 6GB DDR5, running Linux Ubuntu 14.04. The DNN was implemented in Python and Caffe [1].

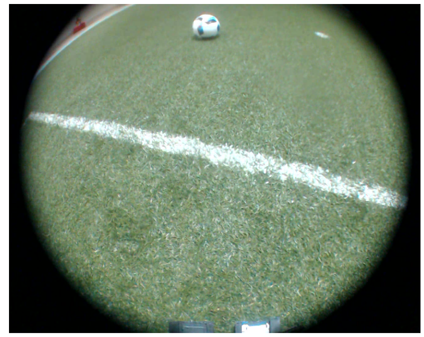
Figure 5 shows the steps for the detection of the ball in the field.

B. Visual Memory

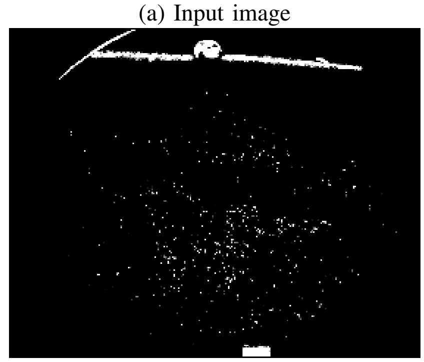
The team proposes the implementation of a system that is responsible for saving information about objects detected by the vision system for a short period of time, in case the vision loses the track of that object. It implements a Kalman Filter that tracks moving objects on the frames obtained by the vision system, then its position is kept for a time while the identifying other objects on the screen, such as landmarks, robots and the ball. The method is capable of presenting constant information about the object's position even if its out of the field of view, predicting its position using its speed information.

C. Localization

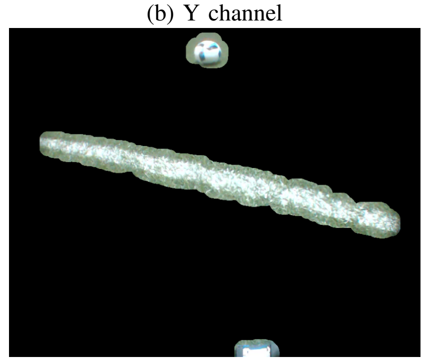
The Localization system uses the information passed by the visual memory module as input information to determine the robot's position on the field. The implementation of this system is made by a Monte-Carlo Localization (MCL) method, described by Almeida, Costa and Bianchi [3], which uses the standard deviation of the particles position in order to change the quantity of particles used by the method, uses the particle's weight as an error factor in order to scatter particles with lower values of weight, enabling the MCL to recover from the kidnapped robot problem.



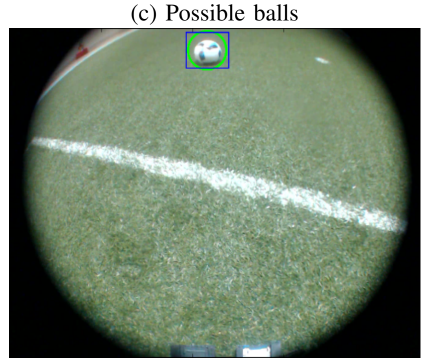
(a) Input image



(b) Y channel



(c) Possible balls



(d) DNN's classification

Fig. 5: Vision's ball classification

The evaluation of this method was made in simulation, testing the system to solve three main localization problems: Global localization, where the module determines the robot position with no initial information; the position tracking, that is the capacity of keep the robot's position even when it moves; and the kidnapped problem, this happen when the robot suffer from a unmodeled movement error, such as been moved, then the localization needs to find its correct localization in the field.

[1] http://caffe.berkeleyvision.org/

D. Decision

The decision module is responsible of finding the best action the agent can perform given the actual conditions of the robot passed by the vision and localization modules, aiming to score a goal or a setplay between robots. Thus, as already presented by Perico et. al [2], all the processes of the RoboFEI-HT system communicate following the Cross architecture.

This years competition, the decision was updated, been capable of modifying the robot's behavior according to its function, such as: goalkeeper, defender, midfielder and striker. The decision process analyses the data from the localization, vision and the role played by the robot in the game so it can determine the correct action for that moment, initially staying in a specific region of the field, while searching for the ball.

The actions that the decision process can take depending of the robot's role is performed as follows:

- Goalkeeper: the goalkeeper is placed in the goal area, searching the ball. When it finds the ball and, if the ball is near to the robot, it walks to it, aligns, kicks the ball forward and walks back to the goal area;
- Defender, Midfielder and Striker: each robot is self-positioned in its area and, when the robot finds the ball, it walks to it, dribbles, passes or kicks to the goal. The strategy of the performed action follows our previous researches that uses Qualitative Spatial Reasoning, Case-Based Reasoning and Reinforcement Learning, as presented in [4]–[6].

E. Movement Control

The movement of the gait pattern generator used by the RoboFEI's robots are the same as the DARwIn-OP, used to generate a sinusoidal pattern in order to control the robot's servo-motors, enabling the robot to walk. Each movement has a particular set of attributes, which changes the patterns of the sinusoidal movement generated according to its actions. The control module is responsible of controlling the pattern movements, changing its attributes and communicating these patterns to the servo-motors.

F. Communication

The communication module is the responsible to keep the communication among robots of the same team, with the game controller and the broadcast of variables used by the telemetry system. The communication is done using the UDP protocol through wi-fi connections, sending and receiving information.

G. Telemetry

The remote monitoring of each robot is made by the telemetry system, monitoring the robot's state during the matches or experiments. The information is received by broadcast using a communication module, interpreting and presenting the robot's information on screen. Some of the presented information in the telemetry system are: the robot's believed position and orientation on field; it's battery's conditions; which of the modules are working and, the specific data from each module. This helps the team to understand the robot's behavior in each situation.

IV. Work in Progress

The team has been working on improvements along the year, in order to improve the capability of the robots to play soccer competitively.

A. Control Feedback

In order to improve the robot movement's accuracy, the team proposes the use of strain gauges in the robot's feet. The main idea is to use strain gauges in each cleat of the robot's feet. Knowing the pressure that is been created in some parts of the robot's feet, the system is capable of calculate the point of maximum pressure on the feet, having this way, a better control of walking according to the situation, knowing if the robot is prone to falling and, correct its center of mass.

B. Odometry System

In order to calculate the position of the robot considering its initial position as the zero in the field, the team is building a odometric system that computes, by kinematics, the position of the center of the chest in relation to its support point, been in this case its feet. To calculate the chest position in each step of the movement, the system uses the position of each motor in the kinematic chain between the support feet and the center of the chest, the geometrical properties of the robot and the information of the inertial sensors. This information can be used by the localization system to predict the robot's position.

V. Publications

The group has publications on the main robotics journals and conferences in the world. The team published ten papers in the International Latin American Robotics Symposium [2], [3], [7]–[14], one paper published in the International RoboCup Symposium [15], and eight other major publications [6], [16]–[23].

The team also contributes with image sets for the Imagetagger[2].

VI. Conclusion

Thus, this work presented the teams development towards its participation in this years LARC, to be held in João Pessoa/PB in Brazil. The team commits to participate in the competition and to enable a team member to be a referee with sufficient knowledge of the rules.

References

[1] Romela. Darwin op: Open platform humanoid robot for research and education. [Online]. Available: http://www.romela.org/main/DARwIn_OP

[2] D. Perico, I. Silva, C. Vilao, T. Homem, R. Destro, F. Tonidandel, and R. Bianchi, "Hardware and software aspects of the design and assembly of a new humanoid robot for robocup soccer," in *Robotics: SBR-LARS Robotics Symposium and Robocontrol (SBR LARS Robocontrol), 2014 Joint Conference on*, Oct 2014, pp. 73–78.

[3] A. C. Almeida, A. H. R. Costa, and R. A. C. Bianchi, "Vision-based monte-carlo localization for humanoid soccer robots," in *2017 Latin American Robotics Symposium (LARS) and 2017 Brazilian Symposium on Robotics (SBR)*. IEEE, 2017.

[2] https://imagetagger.bit-bots.de/users/team/21/

[4] T. P. D. Homem, D. H. Perico, P. E. Santos, A. H. R. Costa, and R. A. C. Bianchi, "Improving Reinforcement Learning results with Qualitative Spatial Representation," in *BRACIS 2017 - Brazilian Conference on Intelligent Systems*, Uberlandia, MG, 2017.

[5] T. P. D. Homem, D. H. Perico, P. E. Santos, A. H. R. Costa, R. A. C. Bianchi, and R. L. de Mantaras, "A hybrid approach to learn, retrieve and reuse qualitative cases," in *LARS/SBR 2017 - 14rd Latin American Robotics Symposium and 5th Brazilian Symposium on Robotics*, Curitiba, PR, 2017.

[6] T. P. D. Homem, D. H. Perico, P. E. Santos, R. A. C. Bianchi, and R. L. de Mantaras, "Retrieving and reusing qualitative cases: An application in humanoid-robot soccer," *AI Communications*, vol. 30, no. 3-4, pp. 251–265, jul 2017.

[7] D. H. Perico, T. P. D. Homem, A. C. Almeida, I. J. Silva, C. O. Vilão, V. N. Ferreira, and R. A. C. Bianchi, "A robot simulator based on the cross architecture for the development of cognitive robotics," in *Robotics Symposium and IV Brazilian Robotics Symposium (LARS/SBR), 2016 XIII Latin American*. IEEE, 2016, pp. 317–322.

[8] D. H. Perico, P. E. Santos, and R. A. C. Bianchi, "Vision-based monte carlo localization without measurement: A qualitative approach during update phase," in *SBR-LARS Robotics Symposium (SBR LARS), 2015 Joint Conference on*, Oct 2015.

[9] I. J. Silva, D. H. Perico, T. P. D. Homem, C. O. Vilao, F. Tonidandel, and R. A. C. Bianchi, "Using reinforcement learning to improve the stability of a humanoid robot: Walking on sloped terrain," in *SBR-LARS Robotics Symposium (SBR LARS), 2015 Joint Conference on*, Oct 2015.

[10] I. J. Silva, D. H. Perico, A. H. R. Costa, and R. A. C. Bianchi, "Using reinforcement learning to optimize gait generation parameters of a humanoid robot," in *XIII Simpósio Brasileiro de Automação Inteligente*, 2017.

[11] I. J. Silva, D. H. Perico, T. P. D. Homem, C. O. Vilão, F. Tonidandel, and R. A. C. Bianchi, "Humanoid robot gait on sloping floors using reinforcement learning," in *Latin American Robotics Symposium*. Springer, 2016, pp. 228–246.

[12] I. J. Silva, C. O. Vilão, A. H. R. Costa, and R. A. C. Bianchi, "Towards robotic cognition using deep neural network applied in a goalkeeper robot," in *2017 Latin American Robotics Symposium (LARS) and 2017 Brazilian Symposium on Robotics (SBR)*. IEEE, 2017.

[13] C. O. Vilão, L. A. Celiberto Jr., and R. A. C. Bianchi, "Evaluating the performance of two visual descriptors techniques for a humanoid robot," in *SBR-LARS Robotics Symposium (SBR LARS), 2015 Joint Conference on*, Oct 2015.

[14] C. O. Vilão, D. H. Perico, I. J. Silva, T. P. D. Homem, F. Tonidandel, and R. A. C. Bianchi, "A single camera vision system for a humanoid robot," in *Robotics: SBR-LARS Robotics Symposium and Robocontrol (SBR LARS Robocontrol), 2014 Joint Conference on*, Oct 2014, pp. 181–186.

[15] R. A. C. Bianchi and A. H. R. Costa, "Implementing computer vision algorithms in hardware: an FPGA/VHDL–based vision system for mobile robot," in *RoboCup–01: Robot Soccer World Cup V*, ser. Lecture Notes in Artificial Intelligence, A. Birk, S. Coradeschi, and S. Tadokoro, Eds., vol. 2377. Berlin, Heidelberg: Springer Verlag, 2002, pp. 281–286.

[16] R. A. C. Bianchi, M. F. Martins, C. H. C. Ribeiro, and A. H. R. Costa, "Heuristically-accelerated multiagent reinforcement learning," *Cybernetics, IEEE Transactions on*, vol. 44, no. 2, pp. 252–265, Feb 2014.

[17] R. A. C. Bianchi, L. A. Celiberto, P. E. Santos, J. P. Matsuura, and R. L. de Mantaras, "Transferring knowledge as heuristics in reinforcement learning: A case-based approach," *Artificial Intelligence*, vol. 226, pp. 102–121, 2015.

[18] R. A. C. Bianchi, P. E. Santos, I. J. da Silva, L. A. Celiberto, and R. L. de Mantaras, "Heuristically accelerated reinforcement learning by means of case-based reasoning and transfer learning," *Journal of Intelligent & Robotic Systems*, pp. 1–12, 2017.

[19] L. A. Celiberto, C. H. C. Ribeiro, A. H. R. Costa, and R. A. C. Bianchi, "Heuristic reinforcement learning applied to robocup simulation agents," in *RoboCup*, ser. Lecture Notes in Computer Science, U. Visser, F. Ribeiro, T. Ohashi, and F. Dellaert, Eds., vol. 5001. Springer, 2007, pp. 220–227.

[20] J. Gurzoni, Jose Angelo, M. F. Martins, F. Tonidandel, and R. A. C. Bianchi, "On the construction of a robocup small size league team," *Journal of the Brazilian Computer Society*, vol. 17, no. 1, pp. 69–82, 2011.

[21] T. P. D. Homem, D. H. Perico, P. E. Santos, R. A. C. Bianchi, and R. L. de Mantaras, "Qualitative case-based reasoning for humanoid robot soccer: A new retrieval and reuse algorithm," in *International Conference on Case-Based Reasoning*. Springer, 2016, pp. 170–185.

[22] D. H. Perico, I. J. Silva, C. O. Vilão, T. P. D. Homem, R. C. Destro, F. Tonidandel, and R. A. C. Bianchi, *Robotics: Joint Conference on Robotics, LARS 2014, SBR 2014, Robocontrol 2014, São Carlos, Brazil, October 18-23, 2014. Revised Selected Papers*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2015, ch. Newton: A High Level Control Humanoid Robot for the RoboCup Soccer KidSize League, pp. 53–73.

[23] D. H. Perico, T. P. D. Homem, A. C. Almeida, I. J. Silva, C. O. Vilão, V. N. Ferreira, and R. A. C. Bianchi, "Humanoid robot framework for research on cognitive robotics," *Journal of Control, Automation and Electrical Systems*, vol. 29, no. 4, pp. 470–479, Aug 2018. [Online]. Available: https://doi.org/10.1007/s40313-018-0390-y