ITAndroids Humanoid Survey for RoboCup 2024

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Abstract. ITAndroids is a robotics competition group associated with the Autonomous Computational Systems Lab (LAB-SCA) at Aeronautics Institute of Technology (ITA). ITAndroids is a reference team in Latin America, having won more than 75 awards in robotics competitions in the last 12 years. In 2017, the team developed the Chape humanoid robot and built four units to participate in RoboCup Humanoid KidSize for the first time. Since then, the team has been evolving the robot's hardware and software while participating in many competitions, especially RoboCup and the Latin American Robotics Competition (LARC). The team also designed the Chape G2 robot, the second generation of Chape, which is currently under construction and testing. This work describes our recent development efforts for RoboCup 2024.

1 Team Name

ITAndroids

2 Is your software fully or partially open source? If so, where can it be found?

Some parts of our code, especially those associated withpublications, can be found at:
https://gitlab.com/itandroids/open-projects

3 Do you have a kinematic or dynamic model of your robot(s)? If so, how did you create it (e.g. measure physical robot, export from CAD model)?

We have both kinematic and dynamic models. Most of the parameters were obtained from the CAD files through Solidworks. However, some elements were configured in Solidworks based on experiments, e.g. the center of mass of the NUC computer was estimated by experiments. Moreover, some kinematic parameters were initially measured directly on the physical robots, but the CAD is synchronized now. We have done work on estimating dynamic parameters from experiments using pressure sensors on the feet for the Darwin robot [1], but we still need to replicate this using our current robot (Chape).

[1] Silva, C., Vacarini de Faria, D., Herculano Vasconcelos Barroso, D., Maximo, M.R., & Sandoval Góes, L.C. (2019). THREE-DIMENSIONAL IDENTIFICATION OF A HUMANOID ROBOT. Proceedings of the 25th International Congress of Mechanical Engineering.

4 Are you using Inverse Kinematics? If so what solution (analytic, (pseudo)inverse jabcobian, etc...) are you using?

Yes, we use an analytic solution for inverse kinematics assuming that the feet are parallel to the ground. For more information, please see [1].

[1] Maximo, M. R. O. A. Automatic walking step duration through model predictive control. Diss. PhD thesis, Aeronautics Institute of Technology, 2017.

5 Are you simulating your robot? If so what are you using simulation for?

We simulate our robot in the simulators Gazebo, Webots, and one that is house-made. Gazebo is mostly used for simulating motion and perception, while Webots are used for simulating matchlike situations, with a focus on behavior and localization. Our simulator abstracts away the control and perception system, to facilitate testing the behaviors and localization in a simpler environment.

6 What approach are you using to generate the robot's walking motion?

For walking, we use the ZMP-based algorithms described in [1]. We augment these algorithms with gravity compensation and a torso stabilization controller. Since these techniques strongly rely on dynamics models, we use accurate information from the CAD files to determine the mass properties of each robot's piece.

[1] Marcos R. O. A. Maximo. Omnidirectional ZMP-Based Walking for a Humanoid Robot. Master's thesis, Aeronautics Institute of Technology, 2015.

7 What approach are you using to generate motions for standing up?

For the motions for standing up, we use keyframes and interpolate the positions linearly in the joint space.

8 What approach are you using to generate kicking motions?

For kicking, we use an approach similar to the one used for walking. We use the ZMP-based algorithms described in [1]. We augment these algorithms with gravity compensation and a torso stabilization controller. Since these techniques strongly rely on dynamics models, we use accurate information from the CAD files to determine the mass properties of each robot's piece. The kicking algorithm is based on cubic splines.

[1] Marcos R. O. A. Maximo. Omnidirectional ZMP-Based Walking for a Humanoid Robot. Master's thesis, Aeronautics Institute of Technology, 2015.

9 Do you use any other motions than the previously mentioned? If so, what approaches are you using to generate them?

No.

10 Which datasets are you using in your research? If you are using your datasets, are they public?

We use Bit-Bot's TORSO-21 Dataset for training and testing our vision system.

11 What approaches are you using in your robot's visual perception?

Our approach to computer vision is based on the Nimbro team's paper [1]. It uses a convex hull algorithm to detect the field and a hough line detector for the field lines. The team made this code from scratch. The ball, goalposts, the T and L intersections, penalty mark, and field center are detected using a convolutional neural network (CNN) algorithm. We use a custom YOLOv8-nano model to do those detections. Furthermore, the information that our team uses is made accessible by the team Bit-Bots to train the model. The data is available at [4].

[1] H. Farazi et al. A Monocular Vision System for Playing Soccer in Low Color Information Environments

[2] Joseph Redmon, et al. You only look once: Unified, real-time object detection

[3] L. Steuernagel, et al. Convolutional Neural Network with Inception-like Module for Ball and Goalpost Detection in a Small Humanoid Soccer Robot. Latin American Robotics Symposium (LARS), 2020

[4] M. Bestmann, et al. TORSO-21 Dataset: Typical Objects in RoboCup Soccer 2021, 2021, https://github.com/bit-bots/TORSO_21_dataset

12 Are you planning with objects in Cartesian or image space? If you are using Cartesian space, how do you transform between the image space and Cartesian space?

We plan with objects in Cartesian space using Inverse Perspective Mapping.

13 How is your robot localizing?

To solve the global localization problem, we use a standard particle filter, *i. e.* Monte Carlo Localization, as described in [1, 2]. The landmark ambiguity makes initializing the filter using a uniform distribution risky, since the filter may converge to the wrong side of the field. Therefore, at the beginning, our algorithm distributes the particles in the field border, as dictated by the rules. Then, resampling is disabled while the head does a 180º scan, accumulating information from the whole scan in the particles' weights before the first resampling. Parameters were tuned for it to work better, especially the resetting policy using Game Controller states.

[1] W Burgard S., et al. Probabilistic Robotics. MIT Press, 2005.

[2] Alexandre Muzio, et al. Monte Carlo Localization with Field Lines Observations for Simulated Humanoid Robotic Soccer. Latin American Robotics Symposium (LARS), 2016.

14 Is your robot planning a path for navigation? Is it avoiding obstacles? How is the plan executed by the robot (e.g. dynamic window approach)?

We use potential fields for path planning. To execute the path, we use some control loops and heuristics.

15 How is the behavior of your robot structured (e.g. Behavior Trees)? What additional approaches are you using?

Our decision-making is based on a tree of behaviors. The execution begins at a very high-level behavior depending on the robot's role, such as Attack, and goes to lower-level behaviors, such as Position to Kick, until arriving at the behaviors which will request actions to the control module. Some behaviors are modeled as finite-state machines. Our head policy switches between scanning the field for localization features and tracking the ball (when it has been seen). For navigation, we are using potential fields [1]. Since we have been focusing on developing the low skills of our robots in the last years, we still lack some basic mechanisms, such as positioning. We are refactoring our behaviors into a formal open-source framework for behavior trees we developed [2], to maximize the code modularity, organization, and efficiency.

[1] O. Khatib. Real-Time Obstacle Avoidance for Robots.

[2] G. L. Silva, et al. A minimalist open source behavior tree framework in C++. LARS 2021

16 Do you have some form of active vision (i.e. moving the robot's camera based on information known about the world)?

After finding the ball, the robot camera moves to focus on it for a couple of seconds. Then, it scans around to gather information about its position and goes back to focus on the ball. Besides that, the scan pattern is fixed, alternating between some scan heights.

17 Do you apply some form of filtering on the detected objects (e. g. Kalman filter for ball position)?

We use the Kalman filter for estimating the ball's position and velocity.

18 Is your team performing team communication? Are you using the standard RoboCup Humanoid League protocol? If not, why (e.g. it is missing something you need)?

We do not have any form of team communication for the moment.

19 Please list contributions your team has made to RoboCup

We have a partially open source code and a full open source webots model that can be downloaded at the Humanoid League website.

We have taught a course on humanoid walking (in Portuguese) in two Brazilian events: the Brazilian Humanoid Robot Workshop (BRAHUR) 2019 and the

Brazilian Congress of Automatics (CBA) 2020. The CBA version is publicly available online (in Portuguese):
https://www.youtube.com/watch?v=v2cxlF8oExE.

Some teams in Brazil have reported that this course has helped them to understand more about humanoid walking.

Moreover, we have a YouTube channel with research videos and courses:
https://www.youtube.com/@ITAndroids.

We have participated in many competitions, as shown below, sharing our experience with other teams and the whole league:
- 1st place Latin America Robotics Competition (LARC) 2023;
- Top 8 - Participated in RoboCup 2023;
- 2nd place in Humanoid League Virtual Season 2022/23
- 1st place Latin America Robotics Competition (LARC) 2022;
- Participated in RoboCup 2022;
- 4th place in Humanoid League Virtual Season 2021/22
- 2nd place Latin America Robotics Competition (LARC) 2021;
- Participated in RoboCup 2021;
- 1st place Latin America Robotics Competition (LARC) 2020;
- Top 8 - RoboCup 2019;
- 1st place - Latin America Robotics Competition (LARC) 2019;
- Top 8 - RoboCup 2018;
- 1st place - Latin America Robotics Competition (LARC) 2018;
- Top 16 - RoboCup 2017.

Moreover, we have participated in Bit-Bot's Humanoid League Survey:
https://robocup.informatik.uni-hamburg.de/en/2022/07/results-of-humanoid-league-survey-2/

20 Please list the scientific publications your team has made since the last application to RoboCup (or if not applicable in the last 2 years).

– Eric Guerra Ribeiro and Marcos R. O. A. Máximo. Orienting a humanoid robot I a soccer field based on the background. Robot World Cup Initiative (RoboCup), 2023.
– Francisco Bruno D., Marcos R. O. A. Máximo et al. Calibration of Inverse Pespective Mapping for Humanoid Robot. Robot World Cup Initiative (RoboCup), 2023.
– Otavio Guimaraes, Marcos R. O. A. Maximo and José Parente de Oliveira. Comparison of Encoder-Decoder Networks for Soccer Field Segmentation. Latin American Robotics Symposium (LARS), 2023.

Publication: LARS 2023

21 Please list the approaches, hardware designs, or code your team is using that were developed by other teams.

Our code and hardware designs have been made by the team.

22 What operating system is running on your robot and which middleware are you using (for example Ubuntu 22.04 and ROS2 Galactic)?

We are currently using Ubuntu 20.04 and ROS1 Noetic. However, we are in the process of transitioning to Ubuntu 22.04 and ROS2.

23 Is there anything else you would like to share that did not fit the previous questions?

No.

24 If you have a description document of your software you would like to share, you may do so here.

Upload Software Description.

25 Why is your team Participating in RoboCup? (Individual answers to this question will be excluded from review and publication)

Education, Development, and Research.