Team Description Paper - Joint Team Rinobot-Jaguar

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1 Team Information

Our team is formed by the union of two Brazilian teams: Rinobot Team and Team Jaguar. The Rinobot Team was founded in 2016 and is based at the Federal University of Juiz de Fora (UFJF), located in the city of Juiz de Fora, MG, Brazil. Their contact email are rinobot.team@gmail.com or spl.rinobot.team@gmail.com. The team has over 60 members, including the captain, Marcelo Rother. Its members study Electrical Engineering, Mechanical Engineering, Production Engineering, Computer Science, Computer Engineering, Exact Sciences, Communication, and other fields, under the guidance of UFJF professors specializing in areas such as Electrical Engineering and Computing. The team is divided into seven areas: Management (responsible for planning, marketing, outreach, finance, and performance analysis) and six competition categories: Very Small Size Soccer (VSSS), Line Follower, Lego Sumo, Mini Sumo, Combat, and Standard Platform League (SPL), in addition to a new education-focused division (EducaRino), contributing to teaching robotics in schools. The SPL category consists of six members, including the leader Lucas Chaves. These members are undergraduate students in Exact Sciences, Computer Science, Computer Engineering, Electrical Engineering, and Information Systems.

The Jaguar Team was founded in 2012 and is based at the Federal Institute of Rio de Janeiro (IFRJ), on the campus located in the city of Volta Redonda, RJ, Brazil. Their contact email is contato@equipejaguar.com.br. The team has 23 members, including the leader, Helton Sereno. Aside from him, who is a professor at IFRJ and holds a degree in Mechanical Engineering from the Catholic University of Petrópolis (UCP), the other members are enrolled in the Industrial Automation Technician program. The team's main area of focus is the SPL category, which consists of 10 active members, all students of the Industrial Automation Technician program. Recently, they also started competing in the Lego Junior categories.

2 Code Usage

Rinobot-Jaguar uses the HULKs team's framework HULK [1] as a coding base for its participation in the RoboCup. The team's repository is named Tamboreijn and contains the robot control program and the associated tools used by the HULKs team in the RoboCup SPL, which has been the basis of our code since 2023. The software, developed in Rust, is an advanced system for NAO robots, featuring a modular framework optimized for soccer matches. It includes a computer vision system that identifies the ball and players in real-time and a decision-making mechanism based on hierarchical behavior and machine learning. Additionally, It utilizes the HULA and LoLA middleware framework for communication with the robots sensors and actuators. The software architecture allows for easy adaptation and improvements, enabling Rinobot to adjust strategies and work on enhancing the movement and vision of NAO robots. This open-source code provided by the HULKs serves as an excellent starting point for optimizing performance in the competition.

3 Own Contribution

3.1 CNN Ball Detection

Since 2018, the Rinobot and Jaguar teams have relied on a Haar cascade classifier to detect the black-and-white ball. Although this method is computationally efficient, it has demonstrated unreliability due to a high incidence of false positives. To improve detection accuracy, a transition was made to a multi-stage Convolutional Neural Network (CNN) pipeline, incorporating pre-classification, classification, and positioning networks optimized for recall, speed, and precision.

The proposed approach comprises two stages. Initially, a Haar cascade classifier identifies candidate regions of interest within the image. These candidate regions are subsequently processed by a CNN for further analysis. The current implementation employs a multi-stage object detection pipeline, which has exhibited promising results in terms of both accuracy and processing speed.

The CNN architecture consists of 24 layers and processes a 32x32x3 input. This configuration enables detailed analysis of small image regions, effectively reducing false positives and improving detection accuracy. By leveraging the advantages of both the Haar cascade classifier and the CNNs, we achieve high detection accuracy while maintaining real-time performance.

The incorporation of CNNs marks a significant advancement over the previous Haar cascade classifier, as it enables more sophisticated image processing and improved differentiation between true and false positives.

3.2 Anti-fall System and Lifting choreography

During the course of the game, falls are inevitable and can occur for various reasons, such as collisions between robots, incorrect movements, or errors in executing routines. To address this challenge, a general recovery process was developed using both Choregraphe and tools of our authorship, enabling the robot to autonomously stand up after any fall. This solution ensures that the robot can quickly return to action, minimizing downtime and maintaining efficiency during gameplay.

The recovery routine is triggered the moment the robot falls and detects that it is on the ground. Depending on whether it is lying face down or on its back, it executes one of two predefined routines to stand up smoothly and efficiently. This approach is significantly faster than manually coding recovery routines, allowing the robot to maximize game time while reducing interruptions caused by falls. A routine that is faster then the current league standard was achieved, but it is still flawed, some robots cannot perform this choreography with balance and proceed to fall during it. We are working on adjustments to improve consistency and repeatability.

However, a better solution than optimizing fall recovery is to avoid falling in the first place. To that end, we are working on an anti-fall system of our own. It is not certain that it will be in a usable state by Robocup 2025, but it is important to mention it in this document. Initially, we want to implement a multi-perceptron neural network with a Rectifier Layer Unit responsible for predicting, interpreting, and correcting joint angles, providing reactive responses to common external stimuli during the game that alter the robot's balance, such as pushes, kicks, and obstacles. This system is being implemented and tested primarily in a simulator, and we intend to publish about it as soon as we have satisfactory results.

3.3 Strategy

To manage the complexity of programming behaviors and strategies in dense and intricate frameworks, an abstraction layer is introduced using the Lua language. Lua's lightweight nature, especially when using the LuaJIT compiler[2], and straightforward syntax make it easy to learn, while its ability to generate scripts that interact with Rust-based routines provides a flexible and efficient way to define high-level behaviors. This abstraction enables developers to focus on strategic decision-making rather than low-level implementation details, streamlining the development process.

By leveraging Lua scripts, the system can dynamically adapt to various scenarios the robot may encounter, facilitating the creation of more sophisticated behaviors without significantly increasing development overhead. Additionally, this approach lowers the cognitive burden required to understand the strategic process as a whole, making it more accessible for both experienced developers and newcomers working on robotic frameworks.

4 Results

In recent years, the Rinobot-Jaguar team has been dedicated to improving its strategies and technologies in the Standard Platform League (SPL), participating in national and international competitions. Below, we present a summary of our recent competition results as well as the main improvements and developments implemented since the last RoboCup edition.

4.1 Competition Results

After our participation in RoboCup 2023, we faced technical challenges that prevented us from fully competing. However, our team has a well-established trajectory in previous competitions, standing out in the following events:

Table 1. Results of Rinobot games in RoboCup 2018

Games	Gametype	Results
Rinobot x MiPal	First Round Robin Pool	0 - 0
Rinobot x NTU RoboPal	First Round Robin Pool	0 - 0
Rinobot x Camellia Dragons	Challenge Shield	0 - 3
Rinobot x UPennalizers	Challenge Shield	0 - 1
Rinobot x MiPal	Challenge Shield	1 - 0
Rinobot x Aztlan	Challenge Shield	0 - 0
Rinobot - MiPal	Penalty Kick Competition	1 - 0
Rinobot - BHuman	Penalty Kick Competition	0 - 2

Table 2. Jaguar results in past competitions

Competition	Ranking
LARC 2O16	2º (second)
LARC 2017	2º (second)
LARC 2018	3º (third)
LARC 2019	1º (first)
LARC 2022	2º (second)

Furthermore, we continue to refine our strategic and technological approach, bolstering our presence in SPL and striving for an increasingly competitive performance. It is important to note that these results are specific to the SPL category of each team and therefore do not cover all of our competitive results.

4.2 Publications

Our team has produced academic papers and technical materials documenting our progress. The following works have been recently published or submitted by team members:

- *A. d. A. Cardoso and H. R. d. S. Sereno*, "O promissor uso da linguagem Rust na programação do robô humanoide NAO v6," in Proceedings of the V Brazilian Humanoid Robot Workshop (BRAHUR) and VI Brazilian Workshop on Service Robotics (BRASERO), 2024.
- *L. C. Chaves, M. Rother, et al.*, "A Lua Interface on a Rust-Based Framework for NAO Robots Applied on Robot Soccer and Education," Rinobot Team - Federal University of Juiz de Fora, 2025.

These results reflect the Rinobot-Jaguar team's continuous commitment to innovation and advancement in SPL, contributing not only to competition performance but also to the development of autonomous robotics in Brazil and worldwide.

5 Impact

Participation in competitions such as RoboCup and others is not limited solely to technological advancement and innovation in game tactics; it also promotes the dissemination of knowledge and social inclusion. In this regard, the EducaRino project is one of the main drivers of our impact, bringing robotics and programming to schools and local communities. The project showcases our team's work and provides programming and robotics classes for children and young people, fostering interest in the fields of science, technology, engineering, and mathematics. By introducing robots into schools, we enable direct interaction with technology, sparking the curiosity and imagination essential for future careers.

This initiative not only prepares future professionals but also nurtures a culture of innovation from an early age, expanding opportunities and enhancing digital literacy throughout society. It combines technical excellence in high-level competitions with a strong commitment to education and inclusion, demonstrating how a model that blends competition with the promotion of science and technology can inspire young talent, strengthen educational partnerships, and attract investment for the continuity and expansion of our projects.

In parallel, the Jaguar team has made a significant impact on its surroundings by using NAO robots as tools for education and recreation for the elderly, especially those diagnosed with Alzheimer's and Dementia. This project promotes social inclusion and improves the well-being of older adults by offering innovative ways to interact and engage with technology, helping a population that is often marginalized in the realm of technological innovation.

Overall, the contributions of both the EducaRino project and the Jaguar team extend beyond practical technological outcomes. Their work reflects a deep commitment to the community by promoting access to technology, social inclusion, and well-being across different age groups. By integrating education, technology, and social responsibility, these initiatives not only inspire future generations but also consolidate a culture of innovation that transforms lives. Together, the teams reaffirm their mission to prepare citizens for future challenges, creating a legacy of progress, solidarity, and hope for society as a whole.

References

1. HULKs, *HULKs RoboCup Team – Official Website*. Available at: https://github.com/HULKs/hulk. Accessed: February 10, 2025.
2. LuaJIT, *LuaJIT – Just-In-Time Compiler for Lua*. Available at: https://luajit.org/. Accessed: February 10, 2025.