NomadZ Call For Participation 2024

Giuliano Albanese[1], Filippo Spinelli[1], Arka Mitra[1], and Zichong Li[1,3]

[1] ETH Zurich, Rämistrasse 101, 8092 Zürich, Switzerland
[2] Automatic Control Laboratory, Physikstrasse 3, 8092 Zürich, Switzerland
[3] Computer Vision Lab, Sternwartstrasse 7, 8092 Zürich, Switzerland
[4] NCCR Automation, Physikstrasse 3, 8092 Zürich, Switzerland

Abstract. NomadZ is a team playing in the RoboCup Standard Platform League affiliated with ETH Zürich. We are pre-qualified for RoboCup 2024, where we intend to participate in the regular team competition, Champions Cup division, and possibly the shared autonomy technical challenge. In RC24 we plan to deploy our new ROS2-based framework, which would represent an important contribution for the whole league due to the virtually unbounded potential and the countless opportunities it would allow to pursue.

1 Team information

We are team NomadZ [5] from ETH Zürich. The team was founded in 2012 by the Computer Vision Lab (CVL) and the Automatic Control Laboratory (IfA) of the Department of Information Technology and Electrical Engineering. Our team is composed of 18 students and alumni who work together to develop the main football framework, while academic projects are run to investigate advanced research questions. These projects can last between 280 to 400 hours, according to the amount of credits they provide, and are managed by scientific supervisors: Dr. Jan-Nico Zäch from CVL and Dr. Raffaele Soloperto from IfA. Professor Fisher Yu (CVL) and Professor John Lygeros (IfA) officially head the organization, which is supported by NCCR Automation.

Our team currently has 12 NAO V6, even though we are planning to bring only 9 due to bad hardware conditions and warranty issues. The robots are used during competitions as well as for public events. At Robocup 2024, we will participate to the soccer tournament, Champions Cup, and we aim to compete in the shared autonomy challenge.

2 Code Usage

In the last two years we have developed a new robot soccer framework based on ROS 2 which led to a complete substitution of our previous modules, which were

[5] Website: https://robocup.ethz.ch, Email: nomadz@list.ee.ethz.ch
Teamleaders: Zichong Li, Giuliano Albanese, Filippo Spinelli

based on B-Human's 2013 code release. Most of our code is now being rewritten from ground-up. However, we are integrating approaches used by other teams, namely the field feature detection modules and part of the motion control stack from from B-Human 23. Our old code is publicly available on GitHub[6]. The new one will be published after next RoboCup.

We are rewriting our existing modules on top of a new core framework based on the latest version of ROS 2, which unlike ROS 1 has been designed with real-time performance constraints in mind. We believe that this transition will significantly increase our development speed, as ROS 2 encourages modularity and isolation between components by design, and makes it simpler for newcomers to contribute. It also provides a widely popular collection of open source packages for robot software development actively maintained by a large community. While building our new codebase we focused our effort to maintain it pseudo-backward compatible, such that porting of old modules (or modules from other teams using the B-Human framework) is possible with limited complexity. This would allow an easy integration of many functionalities developed by the robotics community, as well as an easier collaboration among the SPL teams and beyond.

3 Own Contributions

The development of a new framework allowed us to integrate some features we have been working on in the past years and to entirely rewrite some modules to better adapt to the nowadays robotics needs.

- **Reinforcement Learning Bipedal Walking |** RL has been proved to work more reliably than model-based control for locomotion on challenging terrain [4] and to achieve tasks which would require a complex mathematical formulation. Since in the past our team struggled in achieving similar locomotion performances among the different venues, we decided to implement an RL walking controller. Thanks to domain randomization, our training environment covers a large set of different terrains, with changing friction, reaction forces and even inclination. The policy learnt in such conditions would therefore be able to generalize well enough during any competition settings.

- **Distributed Robotic Swarms Coordination |** Last year we introduced an optimal positioning planner based on the Feedback Equilibrium Seeking algorithm [3]. By using generalized equations which can model a broad spectrum of useful objectives and accounting for the local information each robot can extract from the environment, our approach can be used for any number of robots without variations. We built upon these results, by including additional costs to shape the playing tactics according to the game settings. Also, by leveraging game-theoretic self-organization theory, we have defined

[6] https://github.com/nomadz-ethz/nomadz-code-release

a graph-based algorithm used for high-level decision making in offensive scenarios. Our ball holder robot will periodically compute the scoring probability based on Gaussian distributions, with a 3-steps prediction horizon. The other players will optimize their position according the optimization problem, which inherently increases the goal scoring probabilities.

- **Multi-Agent RL |** Besides model-based methods, we are also investigating the feasibilty of using model-free reinforcement learning to solve the football multi-agent objective function. Oftentimes in the past RL has been used to learn decision-making logics for single agents; however, when dealing with systems of multiple robots, some pitfalls arise. In order to obtain a proper multi-robot cooperative behavior, it is needed to tackle the exploration-exploitation trade-off with innovative viewpoints, so that agents continuously try to learn better and better strategies according to an everchanging scenario. This is achieved also exploiting adversarial training.

- **Automated Data Labelling |** Each year, the goals in RoboCup progress towards that of real football. Additions like natural lighting, and different fields bring new challenges for the vision. Unlike human perception which is quite generic, the models that are deployed on the robots are specific to the domain they have been trained on. This results in retraining of the network parameters whenever the domain shifts. However, recent trends in computer vision have shown that large models can recognize objects in various domains. These models are quite big and have low latency and thus cannot be deployed directly on the robots. But they can be used to quickly collect ground truth data to train smaller models. This reduces the manual work of annotating the images in the new domain for different objects. The automated annotations are then used to train a smaller neural network that is specific to new domain, as done in the past.

- **Model Compression |** One of the drawbacks of neural network models is the lower latency compared to classical approaches. However, the neural networks do not require extensive feature engineering but still provide optimized metrics. To reduce the latency while making the model have the same performance, we looked into neural architecture search for finding the best model. We also looked into separable convolutions, sparsification and quantization of the network to reduce the latency of the overall pipeline.

- **Visual Referee |** In 2022 the visual referee challenge was introduced, and was tackled by the league in 2023 too. Because the number of actions was increased from 2022 to 2023, datasets had to be created again. However, the creation of a dataset takes a lot of effort from the participants so we looked into other methods to increase the generalization of the model. To achieve that, we simulated a synthetic environment where a 3D model is performing the different actions. However, due to the sim-to-real gap, the synthetic dataset alone does not perform that well. When used in conjuga-

tion with real-world examples, the synthetic dataset drastically reduced the number of different subjects that were required to achieve the same accuracy.

4 Past History

In 2014 we participated at our first events, the German Open in Magdeburg, the Night of Science in Frankfurt and the RoHOW in Hamburg. We continued in 2015 with the Iran and German Open, the drop-in player competition and technical challenges at RoboCup 2015. In 2016 the European Open in Eindhoven and RoboCup 2016 were attended, followed by the German Open in 2017, the RoboCup event and the Phoenix Contact Robotics Cup. In 2018, we participated in the German Open and the RoboCup. In 2019, we joined the German Open, the RoboCup, the Night of Science in Frankfurt and the Makerfaire in Rome. We qualified for Robocup 2020 in Bordeaux, but due to the Covid pandemic it wasn't held. In 2021, due to persistent Covid restrictions, we only participated in the remote Robocup 2021. In 2022 we joined the RoboCup 2022 in Bangkok, also competing in 2 of the 4 technical challenges. 2023 saw us take part in GORE and Robocup 23, where we also joined 2 challenges.

Results history

- **2023**
  We participated in GORE to test some new features and expose our newest members to the challenges of the RoboCup competition. Results were a bit underwhelming, given our final 9^{th} position, but we gathered a lot of useful experience.

NomadZ vs. Dutch Nao Team 1:4	NomadZ vs. Naova 1:1	Nao Devils vs. NomadZ 8:0
Bembelbots vs. NomadZ 2:1	R-Zwei Kickers vs. NomadZ 4:2	HULKs vs. NomadZ 4:0

  We then drove to Bordeaux to attend RC23. There, we competed in the main soccer competition, Champions Cup league, where we ranked 6^{th}, losing in the quarter finals against HULKs. We also joined 2 challenges: Visual Referee and Data Minimization. We ranked 4^{th} with 28.1 points overall. These results allowed us to pre-qualify for RC24.

SPQR Team vs. NomadZ 1:3	Bembelbots vs. NomadZ 2:2	B-Human vs. NomadZ 10:0
NomadZ vs. Berlin United 0:0	HTWK Robots vs. NomadZ 6:0	HULKs vs. NomadZ 8:0

– **2022**
We weren't able to joint the GORE and we directly participated in the RoboCup22 in Bangkok. We joined the soccer competition and 2 challenges: the Visual Referee Challenge and the Open-Research Challenge. Our results in the soccer competition allowed us to pass the Seeding round as 8^{th} team overall. We then lost the quarter-finals match against B-Human. We achieved the 2^{nd} position in the Visual Referee Challenge collecting 22.5 points, the 3^{rd} position in the Open Research Challenge for 21.9 points, overall ending as 3^{rd} team.

NomadZ vs. UPennalizers 2:0	NomadZ vs. HULKs 0:9	NomadZ vs. SABANA Herons 0:1
NomadZ vs. Dutch Nao Team 0:0	NomadZ vs. SPQR Team 1:0	NomadZ vs. B-Human 0:10

– **2021**
We participated in the 1vs1 challenge, starting from a Round Robin group stage with HTWK Robots and Berlin United - NaoTH. HTWK got a 1.5 multiplier due to the autonomous calibration, process that we weren't able to implement. We played the Play-ins as 2^{nd} team in the group, then we reached the Quarter Finals against B-Human (also endorsed with the multiplier) where we ended our adventure, as 5^{th} team. We also participated in the Obstacle Avoidance challenge, ending in position 10. Overall, we were the 10^{th} classified team in the Robocup 2021.

NomadZ vs. HTWK 5:10.5	NomadZ vs. Berlin United 5:4
NomadZ vs. Naova Naova forfeited	NomadZ vs. B-Human 10:22.5

5 Impact

Over the recent years, we continuously contributed to the university's PR activities. We are regularly approached by student associations to present our work at open lab days and similar events. We are able to tell students about our exciting project and fascinate them with robotics demonstrations. In the past months, our involvement was particularly important, since we joined 5 (inter)nationally relevant events. In September 23 we had the opportunity to tell our journey during the IEEE conference WESYP, while in the fall we joined Herofest and Treffpunkt Science City, events open to the large public meant to explain important topics such as robotics and AI and allow people to familiarize with them. Our most important events have been the Swiss Robotics Day 23 and in the

coming months the AI for Good Global Summit. These are globally known conferences, and we were lucky to reach such a broad audience to promote RoboCup and SPL. All these events have been made possible by the support from NCCR Automation.

For the first time in recent years, we also have a consistent publication record. In particular, we built upon our research in the technical challenges to publish at RoboLetics: Workshop on Robot Learning in Athletics during CoRL 2023 [1],[5] and at WACV 24 [2]. These are top conferences in Learning and Vision for Robotics.

Team NomadZ provides to ETH students, who want to get more experience with a physical robotic platform, a great environment to apply the theory learnt during classes and to learn a more practical side of robotics. Over the years the student members of our team have worked on several research projects within the scope of RoboCup whose outcomes have been documented and made available on our website. Table 1 shows a list of the most recent ones. We believe that these will help other SPL teams with their research.

Table 1. Most recent projects supervised by our group

NomadZ Student Projects	
Title	Year
Advanced Strategy for Multi-Robot Systems in RoboCup	2023
Learning Humanoid Locomotion on Small Scale Robots	2023
Distributed Coordination for Multi-Robot Systems in RoboCup	2023
Deep Goal Post Detection for RoboCup SPL	2022
Visual Referee Detection on Nao Robots for RoboCup SPL	2022
Design of a Dynamic Omnidirectional Kick Engine for NAO Bipedal Robots in RoboCup	2021
Real to Synthetic Image Translation for Pose and Image Understanding in RoboCup	2021
CenterLine: Convolutional Neural Network to Detect Semantic Line Segments	2021

Furthermore, we organize 2 classes for ETH Bachelor students. From 2020 to 2022, we have provided the lab course "Vision and Control in RoboCup". It covers all theoretical fundamentals required to successfully play and provides the students with first hands-on experience using NAO. Since 2023 the class has been renamed Robocup: Learning and Control, focusing more on the modeling and control areas. Since 2021 we also provide the course Introduction to Program Nao Robots for Robocup Competition, a more practical class where Bachelor students can code and test basic functionalities on NAO V6 robots.

6 Conclusion

We had great experiences at the RoboCup tournaments in Hefei, Leipzig, Nagoya, Montreal, Sydney, the remote tournament in 2021, Bangkok and Bordeaux. We are looking forward to share again with the RoboCup community this exceptional event. Let's continue the journey with the RoboCup 2024 in Eindhoven!

Thank you for your work and for keeping Robocup the amazing competition it is. We know from our own experiences that Robocup is able to fascinate many (prospective) students to work in robotics by showing how much fun it can be!

References

1. Albanese, G., Mitra, A., Zaech, J.N., Zhao, Y., Chhatkuli, A., Van Gool, L.: Optimizing long-term player tracking and identification in nao robot soccer by fusing game-state and external video. In: RoboLetics: Workshop on Robot Learning in Athletics@ CoRL 2023 (2023)
2. Albanese, G., Mitra, A., Zaech, J.N., Zhao, Y., Chhatkuli, A., Van Gool, L.: Optimizing long-term robot tracking with multi-platform sensor fusion. In: Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision. pp. 6992–7002 (2024)
3. Belgioioso, G., Liao-McPherson, D., de Badyn, M.H., Bolognani, S., Lygeros, J., Dörfler, F.: Sampled-data online feedback equilibrium seeking: Stability and tracking. In: 2021 60th IEEE Conference on Decision and Control (CDC). pp. 2702–2708. IEEE (2021)
4. Lee, J., Hwangbo, J., Wellhausen, L., Koltun, V., Hutter, M.: Learning quadrupedal locomotion over challenging terrain. Science robotics **5**(47), eabc5986 (2020)
5. Mitra, A., Molnar, L., Zaech, J.N., Wu, Y., Heo, S., Yu, F., Van Gool, L.: Multi-domain referee dataset: Enabling recognition of referee signals on robotic platforms. In: RoboLetics: Workshop on Robot Learning in Athletics@ CoRL 2023 (2023)