# WF Wolves – Humanoid KidSize System Description Paper for RoboCup 2024

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**Abstract.** In this system description paper, the currently used algorithms are described. Additionally, the fields of research, the developed software and future work are illustrated. Hereby WF Wolves apply for participation at the RoboCup 2024 for **Team Competition** in Eindhoven, Netherlands.

## 1 Introduction

RoboCup 2023 in Bordeaux, France, was our first competition after the COVID induced break. We introduced multiple changes in localization, image processing, motion planning, locomotion and hardware of our robots in the mean time. Unfortunately, we ignored concerns about reliability, which led to several failures during the competition.
For RoboCup 2024 we are focussing on increasing the reliability of our robots in software and hardware.

## 2 Software Description

Since 2016 the WF Wolves are using the Robot Operating System (ROS)[1] based framework for our software architecture. In 2017, the framework was revised together with the Hamburg Bit-Bots to strengthen a team spreading cooperation. This modularity of the framework which enables code exchanges in an easier way among the teams is also one of the biggest advantages. ROS is used by more and more teams each year in RoboCup, which increases the ability to exchange software modules with other teams [2]. Since parts of our software stack was heavily relying on legacy code we adapted our software closer to ROS standards and had the chance test and evaluate new algorithms.

### 2.1 Walking

Our current walking engine consists of a basic walking loop using inverse kinematics, supported by PID-controllers. It is quite unstable since the switch to

[1] https://ros.org/

artificial grass and unwieldy to change. This approach relies heavily on a random parameter pushing (RPP) tuning process as we would like to call it. The dark arts of RPP try to optimize multiple parameters based on experience without measurable data, which results in highly fluctuating outcomes. However, it provides flexibility to tune the robot for different surfaces.
For RoboCup 2023 we were working on a new walking engine based on Central Pattern Generators (CPGs) [13,8,1]. CPGs use a natural approach found in biology in essential neuronal cells. Further, these neurons create a pattern that is usually applied subconsciously and is used for motions, e.g. walking, flying, or swimming. Patterns are created via a Hopf Oscillator including ordinary differtial equations (ODE). Unfortunately, the new walker still needs a lot of fine-tuning and initial quirks made usage during competition no possible. Prioritization and time management regarding this new approach has to be evaluated.
While, a faulty control loop resulted in a bad walking result from our old walker we managed to fix partially. Further, multiple walking engines, like the ex-RoboCup team Ichiro's Aruku [2] and Rhobans IKWalk [3] are based on inverse kinematics. Currently, we are evaluating our walker against the prior due to similarities and try to at least improve the performance of our old walker, until a migration to our new approach is viable. Subsequently, our developed kick motion generator [9] was ported to ROS, allowing the robots to kick in nearly every direction depending on the ball position. Utilizing vector calculus, the kick-engine calculates required movements in real time in every direction.

### 2.2 Vision

Classification is provided by a YOLOv7 [15] model, which was tested in the competition at RoboCup 2023 for ball detection in an experimental state. The results showed a good improvement in comparison to our previous solution based on MobileNet [7,14] regarding accuracy while maintaining a sufficient performance. Based on this results we plan to use YOLOv7 for the RoboCup 2024 as well, while already added custom classes for goal posts and robots. For Annotation, the Bit-Bots Imagetagger is used [5]. The model is running on our built-in Jetson which improves ball classification and calculation time a lot, rendering classical computer visual approaches, as well as previously used cascade classifiers obsolete.

### 2.3 Localization

Since first approaches using a visual compass weren't as robust and were computationally intense, further difficulty increased by adding natural light scenarios in 2019. While trying to emphasize ROS capabilites we developed early prototypes using Monte Carlo based localization. This approach normally relies on

[2] https://github.com/ichiro-its/aruku
[3] https://github.com/Rhoban/IKWalk

odometry and laser scan data, we extended these approaches to fit with visual features feedback e.g. lines [10].

However, this approach generates a rather insufficient position, and vision processing is still done by a classical approach and requires manual color space adaptions during setup days to match field color and lighting. Additionally, we noticed it lacks in utilizing additional optical field features which we are currently integrating in our existing vision pipeline to increase accuracy and reducing the need of on premise parameter tuning.

### 2.4 Team Communication

The team communication is solved via the official Mixed Team Communication protocol (MiteCom) [4]. While we use it to transfer basic information and use it for simple error correction, not much tactical gameplay is embraced yet.

### 2.5 Behavior

Our robot behavior is based on a state machine using FlexBE [5]. The role of the robot is configurable, therefore actions are dependent on the current role and situation. Current existing roles are striker and goalie, while defender behavior is still in development. FlexBE allows us to design complex robot workflows also used in DARPA and ARGOS challenges. Thus we are able to build, analyze and adapt our robot behavior more easily, while mainting ROS standards and lowering the entry barrier for new members of the team.

## 3 Contributions to the RoboCup community

Since our team mostly consists of students, publications mostly rely on theses. Early work included walking of robots including a dynamic kick engine allowing for a target direction to kick without having to rotate behind the ball and kicking forward. [9] Further early localization utilizing the ROS Framework approaches were evaluated [10] as well as the use and benefits of security enhanced ROS (SROS) [6] and early ROS2 in [11]. We further improved our Robot control in [12].

Besides student theses a close interaction with the Hamburg Bit-Bots [7] exists. We helped designing a common ROS architecture for the Humanoid League resulting in a master thesis [2]. Combined knowledge was used to test new hardware e.g. Jetson and implement CNNs for Ball Detections [6]. Subsequently, due to the similarity in hardware, we participated as a joint team in RoboCup 2018 [4] & 2019 [3] to more easily evaluate different software approaches.

[4] https://github.com/RoboCup-Humanoid-TC/mitecom
[5] https://github.com/FlexBE/flexbe_behavior_engine
[6] https://wiki.ros.org/SROS
[7] https://robocup.informatik.uni-hamburg.de/en/

## References


1. Baltes, J.: Central Pattern Generators. https://jackybaltes.github.io/Central-Pattern-Generators/
2. Bestmann, M.: Towards Using ROS in the RoboCup Humanoid Soccer League. . Introduction p. 38 (2017)
3. Bestmann, M., Brandt, H., Engelke, T., Fiedler, N., Gabel, A., Guldenstein, J., Hagge, J., Hartfill, J., Heuer, T., Poppinga, M., Salamanca, I.D.R., Speck, D.: Hamburg Bit-Bots and WF Wolves Team Description for RoboCup 2019 – Humanoid TeenSize –p. 8 (2019)
4. Bestmann, M., Fiedler, N., Gabel, A., Guldenstein, J., Hamann, N., Hartfill, J., Heuer, T., Jobski, J., Lorenz, T., Paetzel, M., Poppinga, M., Reher, D., Reichardt, B., Salamanca, I.D.R., Sengpiel, O., Speck, D., Stelter, S., Stiddien, F., Szczypien, N.: WF Wolves & Hamburg Bit-Bots Team Description for RoboCup 2018 – Humanoid TeenSize –p. 8 (2018)
5. Fiedler, N., Bestmann, M., Hendrich, N.: ImageTagger: An Open Source Online Platform for Collaborative Image Labeling. In: Holz, D., Genter, K., Saad, M., von Stryk, O. (eds.) RoboCup 2018: Robot World Cup XXII, vol. 11374, pp. 162–169. Springer International Publishing, Cham (2019)
6. Gabel, A., Heuer, T., Schiering, I., Gerndt, R.: Jetson, Where Is the Ball? Using Neural Networks for Ball Detection at RoboCup 2017. In: Holz, D., Genter, K., Saad, M., von Stryk, O. (eds.) RoboCup 2018: Robot World Cup XXII. pp. 181–192. Lecture Notes in Computer Science, Springer International Publishing, Cham (2019)
7. Howard, A.G., Zhu, M., Chen, B., Kalenichenko, D., Wang, W., Weyand, T., Andreetto, M., Adam, H.: MobileNets: Efficient Convolutional Neural Networks for Mobile Vision Applications (Apr 2017)
8. Islam, S., Carter, K., Yim, J., Kyle, J., Bergbreiter, S., Johnson, A.M.: Scalable Minimally Actuated Leg Extension Bipedal Walker Based on 3D Passive Dynamics. In: 2022 International Conference on Robotics and Automation (ICRA). pp. 207–213. IEEE, Philadelphia, PA, USA (May 2022)
9. Krebs, O.: Closed-Loop Kinematic Scheme for Kicking Motion of Humanoid Soccer Robots. Bachelorthesis, Ostfalia-University of applied Sciences (2015)
10. Lorenz, T.: Visuelle Lokalisierung eines humanoiden Fußballroboters anhand von Feldlinien. Bachelorthesis, Ostfalia-University of applied Sciences (2016)
11. Lorenz, T.: Evaluation von Security und Privacy in ROS-basierten Robotern. Bachelorthesis, Ostfalia-University of applied Sciences (2018)
12. Röhrs, T.: Bewegungskontrolleinheit eines humanoiden Roboters. Bachelorthesis, Ostfalia-University of applied Sciences (Aug 2022)
13. Ruppert, F., Badri-Spröwitz, A.: Learning plastic matching of robot dynamics in closed-loop central pattern generators. Nature Machine Intelligence 4 (Jul 2022)
14. Sandler, M., Howard, A., Zhu, M., Zhmoginov, A., Chen, L.C.: MobileNetV2: Inverted Residuals and Linear Bottlenecks (Mar 2019)
15. Wang, C.Y., Bochkovskiy, A., Liao, H.Y.M.: YOLOv7: Trainable bag-of-freebies sets new state-of-the-art for real-time object detectors (Jul 2022)