

The NUbots Team Description Paper 2026

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Abstract. The NUbots team is a multidisciplinary team from the University of Newcastle, Australia made up of both undergraduate and post-graduate students, with academic guidance from Prof Stephan Chalup, Dr Alexandre Mendes, and Dr Khaled Saleh. The team has a long history and an outstanding pedigree in RoboCup, competing every year since 2002, and winning first place twice. Last year, the team won third place in the Humanoid League with the NUGus platform, which it intends to use again this year in the small division. However, the team also intends to form a secondary joint team in the middle division, as part of this application, along with two other Australian teams, rUNSWift and Redback Bots, applied separately. This joint team will be made up of Booster K1 robots. For the software, NUbots intends to use NUClear, the same message-passing framework used in the NUGus platform, and to port over as much of the same high-level modules as feasible. As for the joint team, each team will contribute to and develop a shared high-level layer for robot-communication and team-play. This application is only for the NUbots part of the joint Australian team, exact details of which are to be decided.

1 Lessons Learnt

At last year's RoboCup, there was a stark contrast between the traditional custom-made platforms in the Humanoid League and the newer commercial platforms, namely the Booster K1. Furthermore, given the new league along with a general push tending towards bigger commercial platforms, it is clear that the team needs to adopt one of these new robots in order to stay relevant to the scientific endeavour of RoboCup.

Last year, the NUbots team competed in the RoboCup Asia-Pacific Beijing Masters. During which, the team had access to a shared pool of Booster T1's. They along with rUNSWift used the RoboCup demonstration-code provided by Booster. However, the team found that the software was quite hard to work with which. For example, the software compiled very slowly on the robot and did

allow cross-compilation. The modules and behaviour tree was also disorganised and hard to maintain.

It was found at both last year’s RoboCup and the Beijing Masters that most games devolved into a series throw-ins since robots would often mislocalise.

Because of the introduction of heavier and taller K1 robots last year, the former Humanoid League had tighten the enforcement of contact-rules. As a result, all robots must be able to competently avoid other robots lest they are penalised or get a red card from the referee. Thus, the team needs to improve the robots’ ability to avoid obstacles without jeopardising contention over the ball.

Last year, the team spent much time developing a kick of various methodologies, i.e. scripted key-frame animation, spline-based inverse-kinematics, and an in-step kick. The last of which was the most stable but even then not stable enough to warrant much use in games, only when deemed needed at the time. The team has found in the last few years that the robot’s ability to kick is quite important in order to progress through more advanced games where passing the ball is important.

2 Major Challenges

Given a new platform in this middle division, namely the Booster K1, the team must decide how to structure and develop both the software and the stack. One option is to build off from the open-source demonstration-code already provided by Booster, written with ROS2, and suited specifically for RoboCup.[5] However, given the experience at Beijing last year as aforesaid above, the team will likely develop its own high-level stack using its own existing message-passing framework called NUClear which has been used on the team’s NUGus platform in the Humanoid League.[4] The team will still interface with the low-level software provided by Booster out of the box for the RL walk, sensors, etc. This ambitious approach obviously gives a challenge in reinventing most of the stack. However, the transition to a new platform is already ambitious either way; if the ROS2 demonstration-code were used, then the team would likely need to learn a new system, whereas the team would otherwise use an already familiar framework.

Furthermore, the team will attempt to carry over as many of the existing NUClear modules used in the NUGus platform as possible, e.g. for localisation, path-planning, etc. One challenge with this transition is finding a way for these modules to interface with the low-level signals, messages, etc.

One problem with the K1 development at Beijing was that software must be compiled locally on the robot. This is inconvenient for not only development but also simulation which is often run on an external computer. Not only that, but any change, no matter how small, would trigger a full rebuild which would take at least five minutes. This was quite inconvenient and slow for development, especially for tuning parameters.

Although the existing NUGus¹ robot can localise reasonably well when it sees enough field-features and landmarks, it often fails in edge-cases, particular when it is near the edge of the field and cannot see many features. Furthermore, the robot’s localisation collapses after it has fallen and gotten itself back up.

As said in lessons learnt, robots must be able to avoid obstacles not only to follow the rules but to also avoid falling over. The challenge for this capability is to avoid an obstacle but at the same time not jeopardise possession or contention of the ball. That is, the robot must still be as near to the ball as it can without pushing another robot. Both the path-planning and the locomotion need to be accurate and precise so that it can position without too much error.

3 Planned Changes and their Status

A major issue that must be solved first before anything else is the compilation. Right now, progress has been made in developing a Docker environment and toolchain to allow easy development with the K1. Furthermore, work must be made to develop cross-compilation so that the software can be compiled on a user’s computer but built specifically for the ARM architecture on the robot itself even though the user’s computer may be x86 architecture. This change should allow convenient development on any computer, e.g. a desktop in the laboratory, a team-member’s laptop at RoboCup, etc.

As stated above as a major challenge, the NUbots team is planning to develop its own high-level stack using the NUClear framework. Therefore, the team will reuse the same software-modules already used for the NUGus platform. The NUClear framework is compiled in C++ and therefore should run easily on the robot itself. However, work must be done so that the NUClear modules can interface with the low-level operations such as the RL walk, IMU data, etc. Information and specifications will be gathered from Booster, and if needed, testing will be done on the real robot to reverse-engineer the low-level data.

As well as making the self-localisation generally more robust, the team will investigate using other teammate robots on the field to share robot-localisation and thus add redundancy when there are fewer features seen on the field. That way, if a robot strays towards the edge of the field, then other robots can share where they think the robot is. Furthermore, it can help when a robot’s self-localisation has flipped because of the field’s symmetry. So far, robot-to-robot communication has already been established. Messages that are sent between robots need to be specified, and an algorithm to converge different estimates needs to be developed.

In anticipation for more advanced gameplay, the team has been working on the ability to plan an optimal path so that the robot can dribble the ball around an opponent and avoid it as an obstacle. So far, the algorithm has been tested both in the *Webots* simulation-environment and on the real NUGus robot in the laboratory.

¹ Here, the NUGus platform is referred since we will likely use the same localisation module on the K1.

4 Contributions to RoboCup

The NUbots team has been active in the RoboCup community since 2002. Most recently, the team participated in 2025 in the Humanoid League kid-size division and finished at third place. Before that, the team have participated in the Four Legged League (2002-2007), the Standard Platform League (2008-2011), the Kid-Size Humanoid League (2012-2017, 2022-2024), and the Teen-Size Humanoid league (2018-2019). NUbots were the Four Legged League world champions in 2006. The team won the first Standard Platform League in 2008 as team NUManoid in collaboration with the National University of Maynooth, Ireland.

The team has taken part in outreach and publicity events for the host institution, namely the University of Newcastle, Australia. Team-members have given tours of the team's robotics laboratory to school pupils of various stages in both primary and secondary education in order to inspire interest in science, technology, engineering, and mathematics (STEM) for younger people.

Mid last year before leaving for Salvador, the team was interviewed and showcased on the local news, broadcasted in Newcastle, Australia and surrounding areas.[8] This televised appearance inspired interest and enthusiasm in robotics in the local community. The local masthead, the *Newcastle Herald* also reported on the team at the same time.[6]

The NUbots team has a long history of contributing to research in robotics, especially for RoboCup. Just last year, the team has published and presented research on zero-shot learning at the 2025 RoboCup Symposium which was chosen as an oral presentation among a select few.² It dealt with a technique to allow robots to classify untrained sounds in various environments picked up by a microphone. The team has also published three papers at the 2024 RoboCup symposium in Eindhoven.[11–13]

Furthermore, the team has worked on visual simultaneous localisation and mapping (VSLAM) on the robot to improve its localisation on the field. This research has been published and presented at the yearly Australasian Conference on Robotics and Automation (ACRA) in December 2025 along with one other paper.[2, 9]

In addition to published research, the team's RoboCup robot software [7], hardware [14], firmware [3], and debugging tools [1] are open source on GitHub.

Furthermore, the team maintains a comprehensive documentation resource in the form of a public website [10], providing detailed information about the hardware and software systems, as well as guides on various aspects of our systems. Not only does this resource aim to help new members of the team become acquainted with the systems, but it also aims to be useful to other RoboCup teams, as well as the wider robotics and AI community.

² The paper is awaiting proceedings-release and is titled "Zero-Shot Environmental Sound Classification Onboard a Resource-Constrained Robot" authored by Ysobel Sims, Alexandre Mendes, and Stephan Chalup.

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