The NUbots' Team Description for 2007

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Abstract. The NUbots are the **current world champions** in the Sony Four-Legged League of RoboCup using the AIBO ERS-7 robots. The present paper describes the team, and how its strategy and approach evolved from RoboCup 2002. The paper also addresses associated research projects and relevant aspects of the study and research environment of the NUbots' host institution, the University of Newcastle in Australia.

1 Introduction

One of the central aims of current robotics research is to develop and program robots that can support humans with routine as well as dangerous or expert tasks. Our mission is to contribute to a responsible development and application of robotics. Future robots should help people and improve safety and quality of our life and environment.

The NUbots are the University of Newcastle's RoboCup team. They were founded in 2002 in the first instance to become a high performance competitive robot soccer team at RoboCup. Although the NUbot competition team is the most well-known section of the Newcastle Robotics Laboratory there are other research focused projects associated with the laboratory. They address topics which integrate the areas control, machine learning, and statistics in robotics applications.

Education of postgraduate and undergraduate students in the Newcastle Robotics Lab addresses general methods of software engineering, systems design, agent technologies and project management as well as robotics specific skills such as computer vision methods, experimental evaluation, and algorithms for optimisation and control.

2 History of Achievements in Previous Competitions

The University of Newcastle's RoboCup initiative started in 2001. After the introduction of new robotics and machine learning related courses and projects two undergraduate students participated in RoboCup Junior in Seattle and won the world title. After their return the NUbot team was founded which from then on participated in the following competitions of the Sony Four-Legged League:

- *Australian Open Competition 2002 in Newcastle:* This was the first competition for the newly founded and unexperienced NUbot team. It was defeated by the University of New South Wales team 13-0, and the University of Melbourne team 6-0. Finally the University of Melbourne beat the NUBots 4-3 in a penalty shootout.
- *RoboCup 2002 in Fukuoka, Japan:* The new NUbot team entered the Sony Four-Legged League and instantly achieved a third place.
- *Australian Open Competition 2003 in Sydney:* In a dramatic match the NUbots played 3-5 against the team of UNSW/NICTA and became second before the teams of UTS and Griffiths University.
- *RoboCup 2003 in Padova, Italy:* The 2003 NUbot team achieved third place in RoboCup 2003. It was only beaten in the semi finals by the team of the University of Pennsylvania 3-4 on penalties. The playoff for third place saw the NUbots beat last year's world champions Carnegie Mellon 4-1. The NUbots achieved the most goals for (83), and fewest goals against (3). It was noticed that they matched the previous record for the highest score in a legged league game at RoboCup by winning a match 16-0 against one of the other competitors.
- *Australian Open Competition 2004 in Sydney:* In the 2004 Australian Open Competition the NUbots achieved a second place and defeated the reign world champion rUNSWift. All teams except the winning team had recently switched to the new ERS-7 robots and the Australian Open was a first test of their new hardware in a competitive game situation.
- *RoboCup 2004 in Lisbon, Portugal:* The 2004 NUbot team again achieved a 3rd placed finish. Again the NUbots were undefeated in round-robin competition with the only loss in the tournament coming in the semi final match at the hands of the eventual world champions, The German Team.
- *Australian Open Competition 2005 in Brisbane:* The NUbots achieved a second place finished at the Australian Open Competition behind the team representing UNSW/NICTA. 2005 has seen a complete re-write of all code in the NUbots system, given this fact the performance at the Australian Open was pleasing.
- *RoboCup 2005 in Osaka, Japan:* 2005 saw the NUbots finish in second place at RoboCup 2005. The team went undefeated until the final, where we were beaten 4-3 in a penalty shoot-out.
- *Australian Open Competition 2006 in Sydney:* The NUbots again achieved a second place to rUNSWift at the Australian Open Competition held at the UNSW campus.
- *RoboCup 2006 in Bremen, Germany:* 2006 was the year of the NUbot. The NUbots did not concede a goal until the final when we won 7-3 in an all Australian contest against rUNSWift [4].
- *German Open Competition 2007 in Hannover:* The German Open was a good opportunity to test new modules of code in preparation for RoboCup 2007. We achieved second place against the competitive German Team.

3 Background of the NUbots' Team Members

- *Robin Fisher* is studying for a Masters by Research. He has been focused on field line detection in vision and integration of field lines into localisation.
- *Naomi Henderson* is studying for a Masters by Research. Naomi is responsible for the colour classification system in vision and has been working on automating the colour calibration process.
- *Steven Nicklin* is studying for a Masters by Research. Steven has also been working on many aspects related to vision, he is also working on challenges and aspects of robot behaviour and movement.

All student developers are students in the School of Electrical Engineering & Computer Science at the University of Newcastle. Three academic team members provide guidance and research supervision:

- *Dr. Stephan Chalup* is lecturer in computer science and software engineering at the University of Newcastle. He is one of the initiators of the University of Newcastle's RoboCup activities since 2001. His background is machine learning, mathematics and neurobiology. He has published in the areas of machine learning, neural networks, and robotics. He is supervisor of several research students and coordinator of the Interdisciplinary Machine Learning Research Group (IMLRG). Stephan Chalup is member of the Australian Research Network in Robotics (`http://www.robotics.edu.au`).
- *Dr. Robert King* is a lecturer in statistics at the University of Newcastle with particular interests in flexibly-shaped distributions, statistical computing and Bayesian knowledge updating. He joined the NUbots in 2004.
- *Prof. Dr. Rick Middleton* is member of the NUbots since RoboCup 2002. He has published research results in a range of areas including electric machine control, adaptive control, robot control, digital control systems theory using delta operators, multirate and sampled-data systems, performance limitations in feedback control systems (including multivariable and nonlinear systems), metal rolling control problems, robotics. He is co-author of the text "Digital Control and Estimation: A Unified Approach" (Prentice-Hall). He has been involved in industrial applications of systems and control to radio astronomy, satellite tracking, metals processing industries, power electronic inverter controls and various applications of Kalman filtering. He has served as an associate editor of both the IEEE Transactions on Automatic Control and the IEEE Transaction on Control System Technology. He is an Associate Editor of Automatica and is Director of the ARC Centre for Complex Dynamic Systems and Control (CDSC) at the University of Newcastle.
- *Dr. Michael Quinlan* is a PostDoc at the University of Newcastle. He is the leading developer and member of the NUbots since 2002. In his research Michael investigates applications and implementations of machine learning methods in the Sony four-legged league.

4 Research in the Newcastle Robotics Laboratory

The following subsections provide brief summaries of some current research projects in the Newcastle Robotics Laboratory as well as links to corresponding publications.

4.1 Robot Vision

Vision is one of the major research areas associated with the NUbot team. Several subtopics have been investigated including object recognition, horizon determination, edge detection, and colour classification using ellipse fitting, convex optimization and kernel machines. Publications are available e.g. from [17, 4, 18, 5, 1, 3, 7, 12, 15, 16, 20, 21].

4.2 Localisation and Kalman Filters

Research on the topic of localisation focused on Bayesian approaches to robot localisation including Extended Kalman Filters and particle filter based methods. We are particularly interested in further modifications of the Kalman Filter to handle non-ideal information from vision or alternative Bayesian methods with non-Gaussian errors. For information about our current approach see [1, 3, 9, 10].

4.3 Legged Robot Locomotion

We analysed existing gaits of the AIBO robots and included low level controller parameters in the NUbots' locomotion engine. The task of gait optimisation involves learning in a poorly structured high dimensional parameter space. For this purpose we developed and tested different optimization schemes based on evolutionary computation [15]. The outcome of the training experiments was one of the fastest walks for the Sony AIBO ERS-210a [7, 13, 15]. Current work investigates how to find a suitable gait for the new ERS-7 robots when used in the four-legged league.

Another project is about the application of spiking neural networks to robot locomotion control with particular focus on bi-ped locomotion.

4.4 Traction Monitoring

Methods to monitor traction measures are developed and employed for collision detection, to increase the speed of the robots, and to find a good strategy to deal with situations where the legs of two robots get entangled (*leg-lock*) [14]. The techniques used are examples of applications of fault detection ideas, which may further find use in monitoring other collisions and unusual situations.

4.5 Experimental Design

We are interested in applying the principles of experimental design to the assessment of algorithms. Simulated robots and Sony AIBO robots are used to evaluate machine learning methods specifically designed for robot learning.

5 Related Research Concentrations

The *ARC Centre for Complex Dynamic Systems and Control (CDSC)* is linked to the School of Electrical Engineering and Computer Science at the University of Newcastle, Australia. The Centre provides significant industrial and manufacturing performance advances by working on approaches to control and scheduling. These approaches aim to unify the use of disparate technologies, namely, mathematical modelling through to computer systems, electromechanical machinery, scheduling systems and chemical processing. This will bring about an increase in the performance of industry in key areas including product quality, plant efficiency, safety, productivity, waste minimisation, pollution control and operational flexibility. For more details see `http://www.ee.newcastle.edu.au/cdsc/`

The *Interdisciplinary Machine Learning Research Group (IMLRG)* a research group in the Discipline of Computer Science and Software Engineering at the University of Newcastle. It investigates different aspects of machine learning and data mining in theory, experiments and applications. Particular emphasis is put on interdisciplinary projects. The IMLRG's research areas include: Data mining, machine learning, robotics, control and learning, neuroscience, bioinformatics, evolutionary computation, reinforcement learning, and statistical learning. For more details see `http://www.cs.newcastle.edu.au/Research/IMLRG/`

6 Robotics Education at the University of Newcastle

The School of Electrical Engineering & Computer Science offers a range of undergraduate courses which are an excellent preparation for postgraduate research studies in the area of robotics. Of particular interest are the following courses:

- *Comp3330 Machine Intelligence* is a 3rd year elective course which provides an overview of topics at the intersection of Artificial Intelligence and Machine Learning.
- *Comp4110 Advanced Machine Learning* approaches topics from the areas of machine learning, data mining, neuroinformatics, and robotics. The course includes an introduction to research techniques and literature/library tools.
- *Seng4160 Advanced Robotics* uses as primary platform Sony AIBO robots.
- *Elec2120 Sensors and Actuators* combines a theoretical background with practical experience of sensors, actuators and electronic transducers commonly used in measurement and control of modern industrial plants.
- *Elec3710 Microprocessor Systems* involves learning assembly language programming on the Intel 80x86 architecture, 'C' language programming for embedded applications, handling interrupt driven I/O, the fundamentals of real time operating systems, and interfacing to I/O devices.
- *Elec3850 Introduction to Electrical Engineering Design* includes some or all of: Electrical, electronic, communications, computing, software, signal processing, control, and mechanical systems.
- *Elec4700 Advanced Computer Systems* introduces students to advanced concepts in computer architecture and design emphasizing quantitative methods for performance evaluation.

This is only a small selection of courses relevant to robotics. More details about the undergraduate programme can be obtained form the following page
`http://www.eng.newcastle.edu.au/eecs/current/courses.html`
Information about Masters and PhD studies at the University of Newcastle are available from the "Research Higher Degree Candidate's Guide":
`http://www.newcastle.edu.au/research/rhd/guide/contents.html`
Information about funding and scholarships can be obtained from
`http://www.newcastle.edu.au/research/rhd/guide/schols.html`.
For enquiries about local scholarships or exchange arrangements please contact the school's office: School of Electrical Engineering and Computer Science, Faculty of Engineering and the Built Environment, The University of Newcastle NSW 2308, Australia Phone: +61 2 492 15330, Fax: +61 2 492 16929, URL: `http://www.eecs.newcastle.edu.au/` or contact directly Dr. Stephan Chalup (email: `chalup@cs.newcastle.edu.au`) or Professor Richard Middleton (email: `rick@ee.newcastle.edu.au`).

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Links to the NUbots' publications can be found at the NUbots' webpage

`http://robots.newcastle.edu.au/`

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