

The NUManoids' Team Description for 2008

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1 Introduction

The NUManoid team is a collaborative effort between the University of Newcastle in Australia, who have previously participated in the Four-Legged League of Robocup as the NUbots, and the National University of Ireland, Maynooth.

Central goal of the NUManoid team is to be a high performance competitive robot soccer team in the standard platform league at RoboCup. The aim of several other research projects associated with the NUManoid team 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. Some of our projects therefore emphasise anthropocentric and biocybernetic aspects in robotics research.

The present paper describes the team, and addresses associated research projects and relevant aspects of the study and research environment of the involved institutions, the University of Newcastle in Australia, and the National University of Ireland, Maynooth.

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 NUbots team was founded which from then on participated in the following international competitions of the standard platform league which was formerly called Sony Four-Legged League:

- *RoboCup 2002 in Fukuoka, Japan*: The new NUbots team entered the Sony Four-Legged League and instantly achieved a third place.

- *RoboCup 2003 in Padova, Italy*: The NUBots achieved third place. They were only beaten in the semi finals by the team of the University of Pennsylvania 3-4 on penalties. 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.
- *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.
- *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.
- *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 [24].
- *Robocup 2007 in Atlanta*: In 2007 the NUBots achieved second place, beaten by the Northern Bites in the final.

More details on the history including a list of previous team member is available from the NUBots/NUManoids homepage.

3 Background of the NUManoids' Team Members

3.1 Team component of the University of Newcastle

- *Dr. Stephan Chalup* is a senior lecturer in computer science and software engineering and the director of the Newcastle Robotics Lab. He is one of the initiators of the University of Newcastle's RoboCup activities since 2001. His research area is machine learning and anthropocentric robotics.
- *Naomi Henderson* is studying for a Doctor of Philosophy. Naomi is the leading developer and responsible for the vision system. She has been working on automating the colour calibration process. Her PhD topic is "Integrated Image Detection Algorithms for Robust Object Recognition".
- *Kenny Hong* is studying for a Doctor of Philosophy. His research area is human-computer/robot interaction where he investigates various aspects of face recognition and emotion classification.
- *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.
- *Jason Kulk* is studying for a Masters by Research. Jason has been working on the application of a human-like reflex control system to bipedal stance and locomotion. His PhD title is "Anthropomorphic biped locomotion for complex topologies."
- *Steven Nicklin* is studying for a Doctor of Philosophy. Steven has been working on locomotion and movement and the software architecture.

- *Aaron Wong* is studying for a Doctor of Philosophy. Aaron works in the areas of communications, machine learning and acoustics. His PhD topic is “New Applications of Machine Learning in Anthropocentric Computing”.

There are several other students, research assistants, and academics who are members or associates of the Newcastle Robotics Laboratory and the Interdisciplinary Machine Learning Research Group (IMLRG) in Newcastle, Australia. Details are linked to the relevant webpages at www.robots.newcastle.edu.au.

3.2 Team component of the National University of Ireland, Maynooth (NUIM)

- *Alexander Buckley* has completed his 3rd year of undergraduate study towards a B.Eng. (Electronic) at NUIM. He is currently employed as a summer student intern at the Hamilton Institute, NUIM, working on robot motion and image processing.
- *Prof. Rick Middleton* was member of the NUbots in Newcastle from 2002-2007, when he shifted to NUIM. His research interests include 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) and robotics.
- *ShekMan Tang* has completed his 3rd year of undergraduate study towards a B.Sc. (CSSE) at NUIM. He is currently employed as a summer student intern at the Hamilton Institute, NUIM, working on robot localization using sigma point Kalman filters.
- *John Macdonald* is a lecturer at the Department of Computer Science, NUI Maynooth, and a member of the Computer Vision and Imaging Laboratory at the same department. His research interests include computer vision and pattern recognition, dimensionality reduction techniques, shape representation, facial image analysis, intelligent vehicle systems, digital holography, and geotechnologies.
- *Dr Adam Winstanley* is a head of the Department of Computer Science, NUI Maynooth, leader of the graphical systems research group and a member of the National Centre for Geocomputation on the same campus. His research interests include shape representation and classification, object analysis, intelligent vehicle systems, longitudinal spatial behaviour and geotechnologies.

There are further researchers associated with the NUManoids team at NUIM. Details can be obtained from <http://www.hamilton.ie>.

4 Research Areas

4.1 The University of Newcastle

Robot Vision: Vision is one of the major research areas associated with the Newcastle Robotics Lab. 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 [1, 3, 6, 11, 16, 17, 19, 22–25, 27, 28].

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].

Development of the Robot Bear: In a collaborative effort with the company Tribotix and colleagues in design a bear-like robot was developed [4]. It is a high quality robot with metal gears, substantial processing power and a range sophisticated sensors. Control concepts for this platform are currently implemented as part of an engineering final year project.

Legged Robot Locomotion: In previous years we analysed existing gaits of the AIBO robot and included low level controller parameters in the NUbots' locomotion engine. Gait optimisation involved evolutionary learning in a poorly structured high dimensional parameter space. We achieved one of the fastest walks for the Sony AIBO ERS-210a [6, 12, 20, 22].

We investigate biped locomotion over rough terrain using central pattern generators for gait, supplemented with a biomimetic reflex system to provide fast responses to unexpected perturbations given limited processing power. Another project develops spiking neural networks for robot locomotion control with focus on the acrobot and on dynamic biped locomotion [29]. For the new Nao robot we intend to use similar machine learning optimisations for the biped gaits, as well as investigate methods in areas such as control, to make use of the feedback values available to us for improved robustness.

Traction Monitoring: Methods to monitor traction measures were developed and employed for collision detection, to increase the speed of the AIBO robots, and to find a good strategy to deal with situations where the legs of two robots get entangled (*leg-lock*) [21, 20]. The techniques used are examples of applications of fault detection ideas, which may further find use in monitoring other collisions and unusual situations.

Manifold Learning: In several projects we investigate the application of non-linear dimensionality reduction methods in order to achieve a better understanding and more precise and efficient processing of high-dimensional data [7, 18, 30].

4.2 National University of Ireland, Maynooth

Robot Vision: In the past (see for example [15], [13], [14]) we have developed a Hough transform based technique for the detection of road lane markings as part of an intelligent vehicle systems project. We would like to investigate the

applicability of similar Hough based approaches to the detection of pitch boundary markings. Here the geometric configuration of the lines on the ground plane can be used to constrain the Hough algorithm with resultant improvements in efficiency and robustness.

Sigma Point Kalman Filters for Localization: The extended Kalman filter has proved to be a useful technique for robot localization and world modeling for several years. However, recent research results in unscented and sigma point Kalman filters give alternate algorithms with substantially improved performance. Efficient implementation of these algorithms, together with enhancements such as multiple models are being investigated.

5 Related Research Concentrations

5.1 The University of Newcastle

The *Interdisciplinary Machine Learning Research Group (IMLRG)* 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: Dimensionality reduction, vision processing, acoustics, robotics control and learning, neurocomputing, evolutionary computation, reinforcement learning, and kernel methods.

The *ARC Centre for Complex Dynamic Systems and Control (CDSC)* 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. For more details see <http://www.ee.newcastle.edu.au/cdsc/>

5.2 National University of Ireland, Maynooth

The *Hamilton Institute* (<http://www.hamilton.ie>) at NUIM is an applied mathematics research department of NUIM. It has important themes of application in Control and Dynamic Systems, Systems Biology, and Communication Networks, with a number of other themes also represented. Robotics research is examined primarily within the Control and Dynamic Systems group.

6 Robotics Education

6.1 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 machine learning and robotics. Details are available at <http://www.newcastle.edu.au/school/elec-eng-comp-sci/>

Information about Masters and PhD studies at the University of Newcastle are available from <http://www.newcastle.edu.au/research/rhd/>

For enquiries about 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.

6.2 NUI Maynooth

NUI Maynooth includes undergraduate and postgraduate coursework related to robotics. At undergraduate level, the department of Computer Science runs advanced courses on robotics, computer vision, neuro-computation and other advanced concepts in computer science. At the postgraduate level, the Hamilton Institute is lead in a fully funded coursework Masters program in *Network Mathematics* (<http://www.networkmaths.ie>). This coursework program includes a range of relevant modules in dynamics, optimization and probability.

The Computer Vision and Imaging Laboratory is part of the Department of Computer Science at NUI Maynooth. It has strengths in Computer Vision, Pattern Recognition, Optical Information Processing, and Digital Holography. Its member have research interests in areas including facial image analysis, human motion capture and analysis, noise modelling and reduction, 3D shape reconstruction and registration, biomedical image analysis, dimensionality reduction (both linear and non-linear), and super-resolution imaging techniques. <http://vision.cs.nuim.ie>.

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

<http://robots.newcastle.edu.au/>

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