The NUbots Team Description Paper 2014

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Abstract. The NUbots team, from The University of Newcastle, Australia, has had a strong record of success in the RoboCup Standard Platform League since first entering in 2002. The team has also competed within the RoboCup Humanoid Kid-Size League since 2012. The 2014 team brings a renewed focus on software architecture, modularity, and the ability to easily share code. This paper summarizes the history of the NUbots team, describes the roles and research of the team members, gives an overview of the NUbots' robots and software system, and addresses relevant research projects within the the Newcastle Robotics Laboratory.

1 Introduction

The NUbots team, from the University of Newcastle, Australia, competed in the Four Legged League from 2002-2007, within the Standard Platform League from 2008-2011 and subsequently within the Kid-Size Humanoid league since 2012. The NUbots have had a strong record of successes, twice achieving a first place; in 2006 in Bremen, Germany, and, again in 2008 as part of the NUManoid team in Suzhou, China.

The central goal of the NUbots is to be a high performance competitive robot soccer team at RoboCup. The vision of the research projects associated with the NUbots team is to develop and program robots that can support humans not only for routine, challenging, or dangerous tasks, but also to improve quality of life through personal assistance, companionship, and coaching. Our mission is to contribute to a responsible development and application of robotics. Some of our projects therefore emphasize anthropocentric and biocybernetic aspects in robotics research [5]. This includes new aspects of human robot interaction and perception. The Newcastle Robotics Lab hosts several postgraduate and undergraduate research projects that are associated with the NUbots.

2 Commitment to RoboCup 2014

The Nubots commit to participation at RoboCup 2014 upon successful qualification. We also commit to provision of a person, with sufficient knowledge of the rules, available as referee during the competition.

3 History of the NUbots' participation at RoboCup

The NUbots team was founded in 2002 and participated for the first time at RoboCup in Fukuoka in the Sony Four-Legged League (3rd place). Since then the team has a strong history of competition and success in the RoboCup SPL/Four-Legged League, obtaining many top three placements and winning the title in 2006 and 2008.

During the previous two years the NUbots SPL code base has been ported to the DARwIn-OP platform and the majority of modules previously used on the NAO robot in the SPL were fielded for RoboCup 2012. Since then the majority of modules have undergone major revision in order to allow more effective use of the newer platform and in response to recent changes in the league rules.

4 Background of the NUbots Team Members

- *Josiah Walker* is studying for a Doctorate of Philosophy in Computer Science in Reinforcement Learning and Robotics. He works on robot behaviour and machine learning for various NUbot systems. He is the NUbots team leader for 2013-2014.
- *Brendan Annable* is a 3rd year undergraduate student studying Software Engineering currently working on network infrastructure as well as a browser-based debugging environment.
- *Alex Biddulph* is a 4th year undergraduate student studying Computer Engineering and Computer Science. His final year project is to improve the vision system and develop an alternative controller platform for the Darwin.
- *A/Prof. Stephan Chalup* is the head of the Newcastle Robotics Laboratory. He is an Associate Professor in Computer Science and Software Engineering. 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.
- *Jake Fountain* is an honors year undergraduate student studying computer science, with undergraduate degrees in mathematics and science. His main interests lie in machine learning and artificial intelligence.
- *Dr. Robert King* is a Lecturer in Statistics at the University of Newcastle. His research focus is on flexibly-shaped distributions, statistical computing and Bayesian knowledge updating. He joined the NUbots in 2004 and has developed a special interest in the RoboCup rules and refereeing.

- *Mitchell Metcalfe* is a fourth year undergraduate student studying combined degree in Mathematics and Computer Science. He is working on the NUBots' localisation system, and maintains the support tools for the NUBots' compiler environment.
- *Peter Turner* is technical staff in the School of Electrical Engineering and Computer Science. Peter provides hardware support and assists the team with physical robot design upgrades.
- *Taylor Johnson*
- *Jordan Johnson*
- *Anita Sugo*
- *Andrew Dabson*
- *Trent Houliston*

We also acknowledge the input of colleagues from the Newcastle Robotics Laboratory, team members of previous years and the Interdisciplinary Machine Learning Research Group (IMLRG) in Newcastle, Australia. Details are linked to the relevant webpages at `www.robots.newcastle.edu.au`. Other robotics lab members who have contributed over the past six months include:

- *Shannon Fenn*
- *Madison Flannery*
- *Dr. Alexandre Mendes*

5 Hardware and Software Overview

The NUbots use the DARWIN-OP robot with footsensors. The team has five of these robots that are of the standard design with the exception of a slightly reduced footsize. The team also hopes to field modified DARWIN-OP consisting of a full HD camera, an ODROID computer (ref) and an updated motor communications board as a part of a student project.

The NUbots team's major research focus is on using machine learning methods within the software systems of the robot to achieve increased performance and autonomy [8]. The current NUbots software source is available from [22] and is covered under the GPL. This includes associated toolkits for building and deploying the software. Our software is designed to work on multiple robotic platforms, and all of the individual modules have been designed to be easily used in other systems. The sensors and actuators are accessed using a standard format, regardless of the robot running the software [20].

This year marks a major change in the software architecture of the NUBots, with improved software modularity coming from a cutting edge event based message passing system. The NUBots' architecture now has strong parallels with ROS (although without the associated overheads) and interoperability of modules is planned. The NUBots software is designed to allow new teams and team members to easily understand and innovate on existing code. We plan to provide a full code release post Robocup 2014.

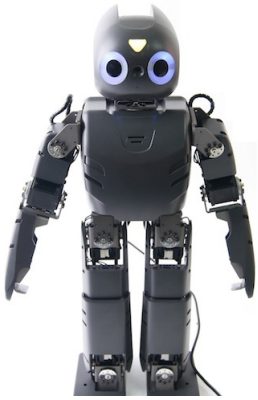

Fig. 1. The DARWIN-OP Robot.

6 Acknowledgement of Use of Code

The NUbots Darwin-OP robots use a walk engine ported from the 2013 Team Darwin code release. We acknowledge the source of this code. The NUBots have ported this code to C++ and restructured the logic, and also made changes including improving the inverse kinematic calculations.

7 Enhancements since RoboCup 2013

Since Robocup 2013, improvements have been made in the area of software architecture and hardware. As the league moves to more realistic game conditions, we are trialling a hardware control platform composed of the following:

In response to the increase in field size, the Logitech C905 is being replaced with a Logitech C920. The new camera will provide a HD 1080p image, allowing the robots to detect and classify objects at a greater distance.

The Main Controller (CompuLab fit-PC2i) is being replaced by an ODROID-XU to help provide the extra processing power that is required for processing the HD images from the Logitech C920 while also allowing the software architecture to be further paralleled.

A prototype hardware replacement for the ROBOTIS CM730 Sub Controller, named the TAJ3850, is being developed as part of a Computer Engineering Third Year Project. The TAJ3850 provides power to all system components, a battery monitoring system featuring a low-voltage alarm and an extremely low-voltage automatic cut-off, an improved six-axis motion processing unit, a temperature sensor, and five dedicated motor buses. The TAJ3850 also exposes peripheral connections from the ODROID-XU to the back panel of the robot (HDMI, USB3, LAN, Audio output), monitors the three back-panel control buttons, and controls the status LEDs on the back panel and in the head.

The remaining robots will have the standard Logitech C905, fit-PC21 and CM730 configuration.

8 Research Areas

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, model fitting and colour classification using ellipse fitting, convex optimization and kernel machines. Recent work has resulted in a fully-autonomous method of colour look-up table generation using k-means clustering and support vector machines, as well as evaluation of colour spaces for unsupervised learning and occluded feature detection. Publications are available e.g. from [2, 3, 12, 23, 25, 11].

Localisation and Kalman Filters: Research on the topic of localisation focused on Bayesian approaches to robot localisation including Kalman Filter and particle filter based methods. We are interested in modifications of the Kalman Filter to handle non-ideal information from vision, incorporate increased information from multiple agents, and effectively utilise non-unique objects.

Development of the Robot Bear: In a collaborative effort with the company Tribotix and colleagues in design a bear-like robot (called Hykim) was developed [4]. The idea was to have a modular open platform using high quality Dynamixel servos.

Biped Robot Locomotion: The improvement of walking speed and stability has been investigated by the NUbots for several years and on different platforms: On the AIBO robot we achieved one of the fastest walks at that time by walk parameter evolution [24, 8]. On the Nao robot we improved existing walk engines by modifying the joint stiffnesses, or controller gains, [17, 18, 16]. The stiffnesses were selected through an iterative process to maximise the cost of transport. We investigated the application of Support Vector Machines and Neural Networks to proprioception data for sensing perturbations during pseudo quiet stance. Walk improvements have been primarily done via optimisation techniques [19, 21] with recent improvements to our framework for online optimisation of bipedal humanoid locomotion. The use of spiking neural networks has been trialled in simulation [26]. Prior to RoboCup 2012 the walk engine developed by the leading SPL team BHuman [10] was ported to the DARwIn-OP platform, and a variety of optimisation techniques were developed and successfully applied to improve walking speed and stability of the Darwin-OP. Similar optimisations are in process for the Team Darwin 2013 walk.

Reinforcement Learning, Affective Computing and Robot Emotions: We investigate the feasibility of reinforcement learning or neurodynamic programming for applications such as motor control and music composition. Con-

cepts for affective computing are developed in multidisciplinary projects in collaboration with the areas of architecture and cognitive science. The concept of emotion is important for selective memory formation and action weighting and continues to gain importance in the robotics community, including within robotic soccer. A number of projects in the Newcastle Robots lab already address this topic [9, 7, 13, 14, 30].

Gaze analysis and head movement behavioural learning: We investigated methods for human and robot pedestrian gaze analysis in [15, 28]. In another project we focus on detection analysis of salient regions/objects and wayfinding [1]. Recently we applied reinforcement learning techniques to optimising head movement behaviour, providing a robust algorithm by which a robot learns to choose landmarks to localise efficiently during a soccer game.

Manifold Learning: In several projects we investigate the application of nonlinear dimensionality reduction methods in order to achieve a better understanding and more precise and efficient processing of high-dimensional visual and acoustic data. [6, 27, 29, 28].

Other new projects: Much work has been focused on the underlying software architecture and external utilities to enable flexibility and extensibility for future research. Projects undertaken include improving the configurability of the software system via real-time configuration updates, development of a web-based online visualisation and debugging utility and the application of software architectural principles to create a multithreaded event-based system with almost no run-time overhead. Some of this work is currently still in progress as part of the 2013/2014 robotics lab summer projects by new undergraduate students who have joined the team.

9 Related Research Concentrations

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, robotics control and learning, neurocomputing, evolutionary computation, optimisation, reinforcement learning, and kernel methods.
Links to publications can be found at the NUbots' webpage

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

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