The NUbots Team Description Paper 2013

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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 was also competitive within the RoboCup Humanoid Kid-Size League in 2012. The 2013 team comprises a new team leader and several new students. 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 2013

The Nubots commit to participation at RoboCup 2013 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.
- *Brendan Annable* is a 2nd year undergraduate student studying Software Engineering currently working on network infrastructure as well as a browser-based debugging environment.
- *Sophie Calland* is a third year undergraduate student studying Computer Engineering and Computer Science. She is working on the NUbots configuration system to consolidate system parameters.
- *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.
- *Shannon Fenn* is in the final semester of a Computer Engineering and Computer Science degree, who completed his Honours thesis on shape-based computer vision and optimisation, his works on machine vision with a focus on geometric methods.
- *Madison Flannery* is a 3rd year Computer Science undergraduate currently working on improving the detection of field objects in the NUbots vision system.

- *Jake Fountain* is a fourth year undergraduate student studying a combined degree in mathematics and science, with his main interests lying 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 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' configuration system to consolidate system parameters.
- *Peter Turner* is technical staff in the School of Electrical Engineering and Computer Science. He is an expert on robot hardware and electronics and familiar with the Darwin-OP.

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:

- *David Budden* is a recent Computer Engineering and Computer Science graduate, who completed his Honours thesis on colour-based computer vision and bipedal robotic locomotion.
- *Dr. Alexandre Mendes* is deputy head of the Newcastle Robotics Lab. He is a Senior Lecturer in Computer Science and Software Engineering. He joined the group in September 2011 and his research areas are algorithms and optimisation.
- *Steven Nicklin* is studying for a Doctor of Philosophy in the robotics lab. He has been working on localisation and modelling of the robot. Steve has been NUbots team leader several times and was member of the world champion teams in 2006 and 2008.

5 Hardware and Software Overview

The NUbots use the DARWIN-OP robot with footsensors. The team has four of these robots that are of the standard design with the exception of a reduced footsize which currently is introduced.

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 [16] and is covered under the GPL. This includes associated toolkits for optimisation and learning on the robots. Our software platform is designed to work on multiple robotic platforms, and all of the individual modules have been designed with this in mind. The sensors and actuators are accessed using a standard format, regardless of the robot running the software [21].

The software is broken into a number of modules. The primary modules are: vision, localisation, behaviour, and motion. An overview of our software structure can be seen in Figure 1. The research areas applied to each of these modules are described in the research section.

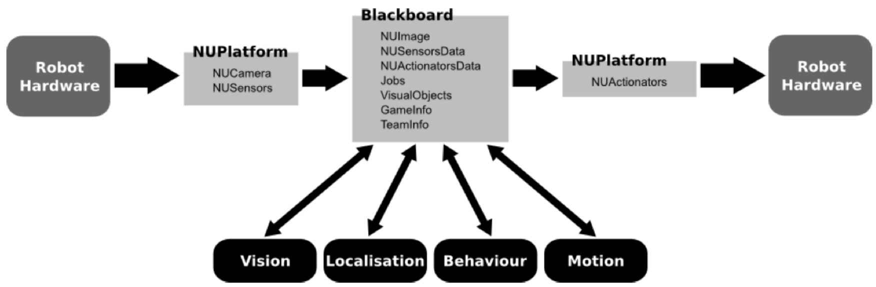

Fig. 1. An overview of the software framework, and the transfer of information between the hardware and software modules via the blackboard [21].

6 Acknowledgement of Use of Code

The NUbots Darwin-OP robots use a walk engine ported from the B-Human NAO robot walk engine [10]. We acknowledge the source of this code and have made changes only in the areas that allow it to inter-operate with our multi-platform framework.

7 Enhancements since RoboCup 2012

Since Robocup 2012, improvements have been made in the area of vision, with improved accuracy of ball detection [2], more accurate goalpost detection, and RANSAC based field-line detection. In connection with this, localisation performance has also been improved and will better deal with the challenges of same-coloured goals.

A new reinforcement learning framework has been introduced into the NUbots codebase. This framework currently governs the robot's head movement strategy, aiming to optimise localisation information. We hope to expand on this work in the future, extending our framework to solving other tasks.

The foot length of the Darwin-OP robots has also been reduced slightly in order to align with the 2013 maximum foot area rules. This is particularly relevant to locomotion and physical actions as learning systems must aim for a relatively smaller set of possible stable solutions.

Locomotion has been improved in the areas of both speed and stability thanks to the development of a new walk optimisation framework and associated new local optimisation algorithms. Embodiment in learning is also an important concept as it allows stability improvement learning at the RoboCup venue, using only the robot's senses as feedback.

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 since 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, [18, 19, 17]. 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 [20, 22] 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.

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. Concepts 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 parameter consolidation, development of a web-based online visualisation and debugging utility and the application of software architectural principles in the area of machine vision. Some of this work is currently still in progress as part of the 2012/2013 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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