Team UNSW Australia
University of New South Wales, Australia

RoboCup 2015
Standard Platform League

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Abstract. RoboCup inspires and motivates our research interests in
cognitive robotics and machine learning, especially vision, state-estimation,
locomotion, layered hybrid architectures, and high-level programming
languages. The 2015 UNSW Australia team comprises final year under-
graduate honours students, PhD students, past RoboCup students and
supervisors who have been involved in RoboCup for over a decade. New
developments in 2015 include new goal detection for white goal posts,
integrated whistle detection, improved robot recognition and avoidance,
improved behaviour and low level skills, as well as challenge specific in-
novations.

1 The Team

The RoboCup Standard Platform League (SPL) is an excellent training ground.
Participant team members need to collaborate on the development of a highly
complex software system, deliver it on time, and within budget. This year the
UNSW Australia SPL team comprises a mix of undergraduate, masters and
PhD students, both past and present. Several of our team members have full-
time jobs in industry and have come back to participate in the 2015 competition
by devoting their own time and assisting a new crop of students. By participating
in RoboCup the team is engaged in a unique educational experience and makes a
significant contribution towards research, as is evident from the list of references
at the end of this article.

The 2015 UNSW Australia team members are Kenneth Ng, Luke Pearson,
Peter Schmidt, Ritwik Roy, Roger Liu, Sean Harris, Jayen Ashar, and faculty
members Brad Hall, Bernhard Hengst, Maurice Pagnucco, and Claude Sammut.
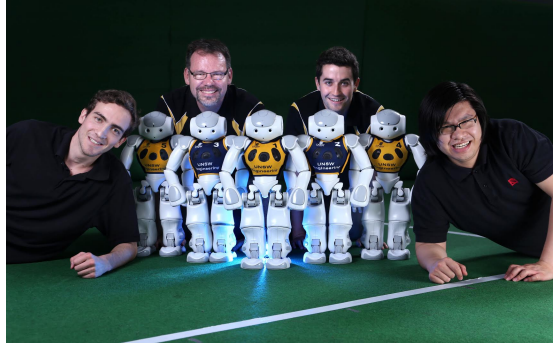
Fig. 1. A subset of the 2015 UNSW Australia Team. From left to right: Luke Pearson, Brad Hall, Sean Harris, Kenneth Ng.

The team has the financial support of the School of Computer Science and Engineering at the University of New South Wales. The School provides considerable organisational support for travel. The team benefits from a wealth of experience and the legacy code from past past UNSW Australia teams in the standard platform league (including the previous Sony four-legged league), simulation, and rescue competitions.

A UNSW Australia team has taken part in every RoboCup competition since 1999. In the following sections we describe our broader research interests and list our contributions over the years. Team reports, code and videos are available at internet address: `http://www.cse.unsw.edu.au/about-us/help-resources/for-students/student-projects/robocup/`.

2   Research Interests

The vision of many robotics researchers is to have machines operate in unstructured, real-world domains. Our long-term aim is to develop general-purpose intelligent systems that can learn and be taught to perform many different tasks autonomously by interacting with their environment. As an approach to this problem, we are interested in how machines can compute abstracted representations of their environment through direct interaction, with and without human assistance, in order to achieve some objective. These future intelligent systems will be goal directed and adaptive, able to program themselves automatically by sensing and acting, and accumulating knowledge over their lifetime.

The School of Computer Science and Engineering at the University of New South Wales is arguably the premiere Australian computing school. Autonomous Systems is a priority research area for UNSW Australia. Our general research focus, of which the RoboCup SPL is a part, is to:

– further develop reasoning methods that incorporate uncertainty and real-time constraints and that integrate with the statistical methods used in SLAM and perception

– develop methods for using estimates of uncertainty to guide future decision making so as to reduce the uncertainty
– extend these methods for multi-robot cooperation
– use symbolic representations as the basis for human-robot interaction
– develop learning algorithms for hybrid systems, such as using knowledge of logical constraints to restrict the search of a trial-and-error learner and learning the constraints
– develop high level symbolic robotic languages that provide abstractions for a large range of deliberation, planning and learning techniques so as to simplify robot programming

3   UNSW Australia 2015 Robotic Architecture

The UNSW Australia robotic architecture shown in Figure 2 is a task-hierarchy for a multi-agent team of five Naos. We use a fault-tolerant network-centric architecture. This means that each robot may have a slightly different view of the world and therefore of its role on the team. The approach has the advantage of providing some redundancy in case individual robots are disqualified or stop working.

Starting at the root-level the game-controller invokes the high-level states for playing soccer. At lower levels, the vision system makes sense of the kaleidoscope of pixel values at 30 frames per second, and the walk generators execute temporally extended walk actions that invoke primitive state transitions as the robot transitions between poses 100 times each second.
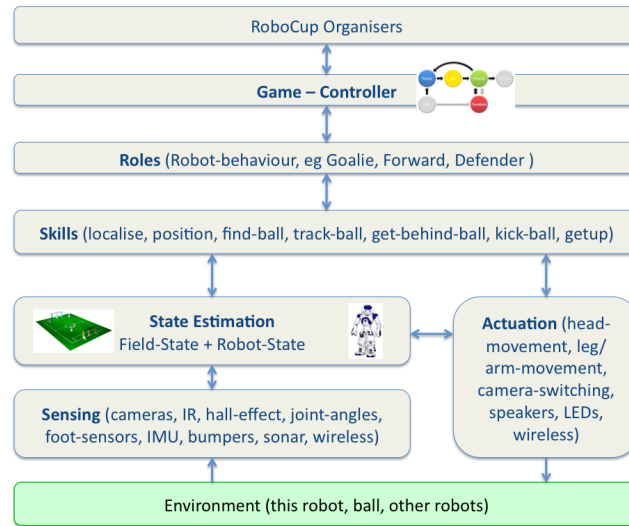
Fig. 2. The 2015 UNSW Australia SPL robotic architecture.

3.1 Vision

Our vision system evolved significantly over the last fifteen years. From the beginning, in 1999, we used a simple learning system to train the colour recognition system. In 2001, we used a standard machine learning program, C4.5, to build a decision tree recogniser. Also in 2000, our vision system became good enough to use robot recognition to avoid team mates (Sammut & Hengst, 2003).

In recent years, we have updated the vision system to recognise the field-boundary, field-markings and to rely less on colour by using edge-features. We have introduced a foveated vision system and virtual saccades to maximise scare computational resources. To disambiguate the symmetric field we introduced a natural landmark recognition algorithm that is able to localise the robot in real-time. This tailored SLAM approach, based on one-dimensional local image features was presented at the 2012 RoboCup Symposium (Anderson, et al, 2012). A spin-off development – a visual compass to help odometric corrections for adjusting for slippage and collisions, was presented at the RoboCup Symposium in 2013 (Anderson and Hengst 2013).

This year we developed a new goal detection module to detect the new white goals. We have also invested research into detecting the ball without using any colour as part of the any ball challenge.

3.2 Localisation

The 2000 competition saw the initial use of a Kalman filter-based localisation method that continued to evolve in subsequent years (Pham et al, 2002). The localisation system evolved to include a multi-modal filter and distributed data fusion across the networked robots. In 2006, we went from treating the robots as individuals sharing information, to treating them as one team with a single calculation spread over multiple robots. This allowed us to handle multiple hypotheses. It also allowed us to use the ball for localisation information.

A significant innovation in 2012 was the use of a variation of the Iterative Closest Point (ICP) algorithm extending previous work on field-line matching (Sheh & Hengst, 2004; Ratter, 2011) to other visual features and objects. This novel algorithm was presented at ICRA (Peter Anderson, Youssef Hunter, Bernhard Hengst, 2013). A summary of innovations for 2012 was presented at ACRA in 2012 (Harris, et al).

In 2014 we ported the 2006 distributed multi-modal Kalman filter localisation innovations developed for the AIBOs to the Naos. We track multiple hypothesis modes for the pose of the robots and ball on the field. Each hypothesis mode consists of the robot pose, ball position and velocity, and the poses of the teammate robots. The robots exchange observations of field lines, goal posts, and the ball with each other over wireless. In this way a robot can incorporate teammate observations into its own filter and improve its localisation accuracy and consistency. This also helps to disambiguate the two symmetric sides of the field.

3.3 Locomotion

In 2000, we introduced the UNSW walk, which became the standard across the four-legged league (Hengst et al, 2002). Almost all the other teams in the 4-legged league at the time adopted a similar style of locomotion, some starting from our code. The flexibility of this representation led to another major innovation in 2003. We were the first team to use Machine Learning to tune the robot's gait, resulting in a much faster walk (Kim & Uther, 2003). In succeeding years, several teams developed their own ML approaches to tuning the walk.

Bipedal locomotion research in our group includes the application of Machine Learning to gaits. PhD student Tak Fai Yik (a member of the champion 2001 four-legged team) collaborated with Gordon Wyeth at the University of Queensland to evolve a walk for the GuRoo robot (Wyeth, et al, 2003), which was entered in the humanoid robot league. We have continued to research bipedal locomotion methodologies and learning strategies (Hengst, et al, Humanoids 2011; Hengst, CLAWAR 2013).

In 2014, machine learning using a Nao physics simulation inspired the development of a new walk and balancing mechanism for use in competition. This walk quickly became noted as one of the big strengths of the team and contributed heavily to our success in 2014.

3.4 Software Engineering and Architecture

Throughout the software development of the AIBO and then Nao code, we have adopted a modular, layered architecture. The lowest layers consist of the basic operations of vision, localisation and locomotion. The behaviours of the robots are also layered, with skills such as ball tracking, go to a location, get behind ball, etc, being at the lowest level of the behaviour hierarchy, with increasingly complex behaviours composed of lower-level skills. Originally, all the behaviours were coded in C/C++ but in 2005 and 2006, as from 2010 onwards the upper layers were replaced by Python code.

One of the key reasons behind the UNSW Australia team's success has been its approach to software engineering. It has always been: keep it simple, make the system work as a whole and refine only what evidence from game play tells us needs work. This practical approach has had a strong effect on our research because it has informed us about which problems are really worth pursuing and which ones are only imagined as being important.

4 Participation and Performance

UNSW Australia has a long and successful history in both the Robocup SPL and other Robocup competitions. Our past results from the Standard Platform League / Four-legged League include:

– 1st place: 2000, 2001, 2003, 2014
– 2nd place: 1999, 2002, 2006, 2010

– 3rd place: 2005, 2012
– 4th place: 2013
– Quarter-finalists: 2004, 2008, 2011
– Challenges: 1st in 1999, 2000, 2001, 2002, 2010
– Challenges: 2nd in 2003, 2012
– Challenges: 3rd in 2011

5   Acknowledgements

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