Team rUNSWift
University of New South Wales, Australia

RoboCup 2011
Standard Platform League

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Abstract. RoboCup continues to inspire and motivate our research interests in cognitive robotics and machine learning, including vision, state-estimation, locomotion, layered hybrid architectures, and high-level programming languages. The 2011 rUNSWift team consist almost entirely of final year undergraduate students under the supervision of leaders who have been involved in RoboCup for many years. In 2010 we revamped the entire code-base. Following our good performance in Singapore last year (first place in the challenges and second in the competition) our research and development is continuing in 2011 with innovations in vision, localisation, bipedal walking, and the supporting software infrastructure and tools.

1   The Team

The RoboCup Standard Platform League (SPL) has been and continues to be excellent training for the undergraduates who also make a significant contribution towards research. The UNSW SPL teams (and previously the four-legged teams) have almost entirely been made up of final-year undergraduate students, supported by faculty and research students. The 2011 rUNSWift team includes undergraduate students: David Claridge, Brock White, Carl Chatfield, Sean Harris, Belinda Teh, Jimmy Kurniawan, Yongki Yusmanthia, Youssef Hunter,

Fig. 1. *The 2011 rUNSWift Team. Top: Claude Sammut, Bernhard Hengst, Carl Chatfield, Brad Hall, Maurice Pagnucco. Middle: Jayen Ashar, David Claridge, Brock White, Jimmy Kurniawan, Youssef Hunter. Bottom: Sean Harris, Belinda Teh, Yongki Yusmanthia, Hung Nguyen.*

Yiming Deng, Manuel Lange, Hung Nguyen, Jarupat Jisarojito, and Benjamin Vance; postgraduate students Jayen Ashar and Hung Nguyen; faculty staff: Bernhard Hengst, Maurice Pagnucco and Claude Sammut; and Development Manager Brad Hall. Some of the team members are a pictured in Figure 1.

The team has the financial support of the School of Computer Science and Engineering at the University of New South Wales. The School also provides a great deal of organisational support for travel. We have a competition standard field and a wealth of experience from our participation in the four-legged league, simulation, and rescue competitions. Our sponsors include Atlassian Pty Ltd.

A UNSW 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. The 2010 team report, code and videos are available – see http://cgi.cse.unsw.edu.au/ robocup/2010site/.

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.

We are interested in how Cognitive Robotics can contribute to the specification of flexible behaviours. Languages such as Golog (see Levesque and Pagnucco, 2000 for an application of Golog), allow the programmer to create highly reactive behaviours and the language incorporates a planner that can be invoked if the programmer wishes to be less specific about the implementation of a behaviour. At lower levels in the task-hierarchy we are exploring the application of hierarchical reinforcement learning to learn more reactive behaviours.

Traditional programming languages applied to robotics require the programmer to solve all parts of the problem and results in the programmer scripting all aspects of the robot behaviour. There is no facility for planning or deliberation. As a result programs tend to be complex, unwieldy and not portable to other platforms. High level robotic languages provide a layer of abstraction that allows for a variety of programming styles from deliberative constructs that resort to AI planning in order to achieve user goals through to scripted behaviours when time critical tasks need to be completed.

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   rUNSWift 2011 Robotic Architecture

The rUNSWift robotic architecture [1] is a task-hierarchy for a multi-agent team of four 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 walk generators execute temporally extended

walk phases that invoke primitive state transitions constituting the motion of the robot as it transitions between poses 100 times each second.
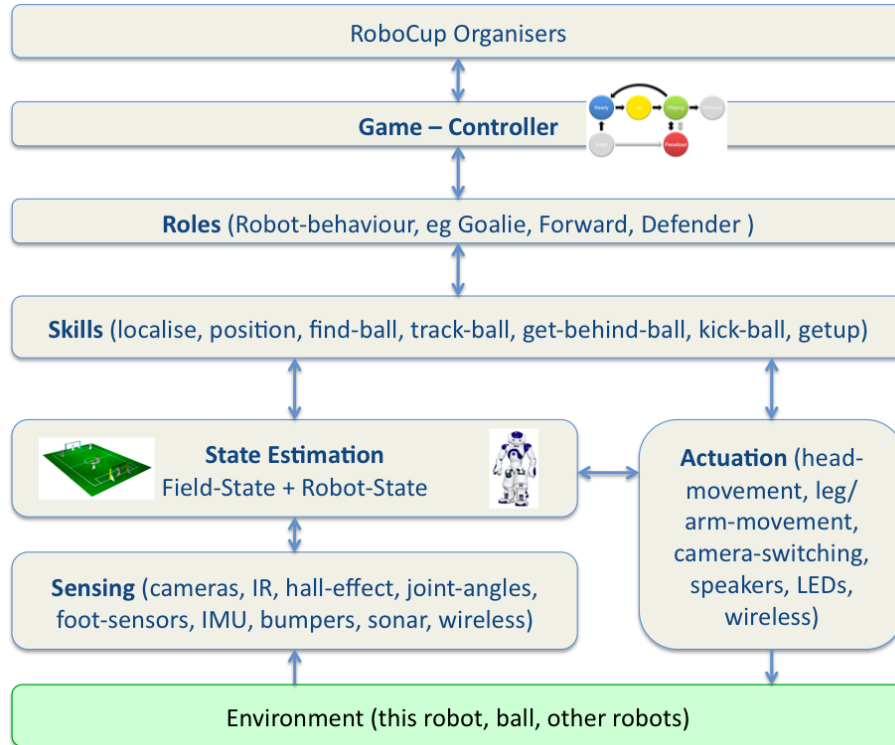

Fig. 2. The 2011 UNSW SPL robotic architecture.

3.1 Vision

Our vision system evolved significantly over our eight years in the four-legged league. 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. This turned out to be very important since the lighting we encountered at the competition was very different from our lab and our previous vision system was not able to cope. Also in 2000, our vision system became good enough to use robot recognition to avoid team mates (Sammut & Hengst, 2003).

In recent years, we updated the vision system to recognise field-markings and to rely less on colour by using edge-features. We are currently researching

foveated vision and virtual saccades to maximise the scare computational resources available on the Nao. For field-lines and field-edges we are developing a sensor model that will provide multiple hypotheses for the new localisation module. A new regression testing frame-work will be exercised as vision modules are upgraded.

Localisation The 2000 competition also saw the initial use of a Kalman filter-based localisation method that continued to evolve in subsequent years (Pham et al, 2002). In the 2000 competition, advantages in localisation and locomotion meant that the team never scored less than 10 goals in every game and only one goal was scored against it in the entire competition. Starting from a simple Kalman filter in 2000, 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.

Including more and more robots in the one Kalman filter does not scale because the number of modes grows exponentially. Instead we are experimenting with multi-robot-multi-modal Kalman filtering and researching the application of loopy belief revision to achieve similar benefits, but more efficiently, with larger teams.

Locomotion In 2000, we introduced the UNSW walk, which became the standard across the league (Hengst et al, 2002). The key insight was to describe the trajectory of the paws by a simple geometric figure that was parameterised. This made experimentation with unusual configurations relatively easy. As a result, we were able to devise a gait that was much faster and more stable than any other team. Since then, almost all the other teams in the league have 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. Starting from the parameterised locomotion representation, the robots are able to measure their speed and adjust the gait parameters according to an optimisation algorithm.

Bipedal locomotion research in our group includes applications 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.

Our current research is attempting to learn versatile bipedal locomotion controllers using hierarchical reinforcement learning. It is well known that learning by sheer enumeration of problem variables does not scale. We are uncovering and exploiting the basic structure of the walking domain to simplify the problem to

learn optimal control solutions. Ongoing research is addressing the application of these techniques to real robotic domains, particularly bipedal locomotion on the Nao and Cycloid II humanoid robots.

Software Engineering and Architecture Throughout the software development of the Aibo 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 in 2010, the upper layers were replaced by Python code. We have also experimented with higher level functions coded in the experimental cognitive robotics language Golog.

One of the key reasons behind the UNSW 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

A UNSW team has taken part in every RoboCup competition since 1999. Details of awards are as follows:

Standard Platform League/Four-legged league: 1999-2006, 2008-2010

- 1st place: 2000, 2001, 2003
- 2nd place: 1999, 2002, 2006, 2010
- 3rd place: 2005
- Quarter-finalists: 2004, 2008
- Challenges: 1st in 1999, 2000, 2001, 2002, 2010
- Challenges: 2nd in 2003

Simulation soccer: 2001 - 2003

- 7th place: 2002

Rescue: 2005 - 2007, 2009-2010

- 3rd overall: 2005
- Semi-finalists and 2nd in autonomous robot challenge: 2006
- Finalists: 2007, 2009.
- Best in class Autonomy: 2009, 2010
- 2nd in Mobility: 2009
- Award for innovative user interfaces: 2009

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2. 2010 Team Report, Code and Videos http://www.cse.unsw.edu.au/ robocup

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