

**Team rUNSWift**  
**University of New South Wales, Australia**

**RoboCup 2013**  
**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 core 2013 rUNSWift team members are all undergraduate students under the supervision of leaders who have been involved in RoboCup for many years. The team has had a 100% turnover from 2012. We have also started an informal collaboration with the Vietnam National University. Developments for 2013 include automating colour calibration, speeding up field line detection, a new game simulator, better bipedal stability control, improved robot detection and a revamped approach to programming behaviours in Python. We are also upgrading the code-base to work with the larger sized field, new goals, increase in the number of players to 5 per side, new team markers, and other rule changes.

## 1 The Team

The RoboCup Standard Platform League (SPL) has been and continues to be excellent training for the students who also make a significant contribution towards research. The UNSW SPL teams have largely been made up of final-year undergraduate students, supported by faculty and research students.

The core 2013 rUNSWift team members are undergraduate students Beth Crane, Richard Hua, Jack Murray, Dan Padiha, Stephen Sheratt, and Calvin Tam. They are assisted by postgraduate students – Jayen Ashar, Sean Harris, and Alexander Whillas; faculty staff – Bernhard Hengst, Maurice Pagnucco and Claude Sammut; and Development Manager – Brad Hall.

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. This year we totally rebuilt the soccer field in the laboratory to the new 9 by 6 meter competition standard field. The team benefits from a wealth of experience from past participation in the standard platform league (previously Sony four-legged league), simulation, and rescue competitions.

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. Team reports, code and videos are available at internet address: <http://www.cse.unsw.edu.au/help/students/robocup>.

The UNSW and the Vietnam National University have this year started an informal collaboration facilitated by Son Bao Pham. This may lead to forming a future joint SPL team. The students involved include Hy Truong Son, Thai Cong Khanh, Do Duc Kien, Dong Xuan Thuy, and To Ngoc Linh, under the supervision of Ha Le Thanh and Dang Trung Kien.

## 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. UNSW is the only Australian university ranked among the top 100 for Computer Science in the Academic Ranking of World Universities (<http://www.arwu.org>). Autonomous Systems is a priority research area for UNSW. 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 2013 Robotic Architecture

The rUNSWift robotic architecture shown in Figure 1 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 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.

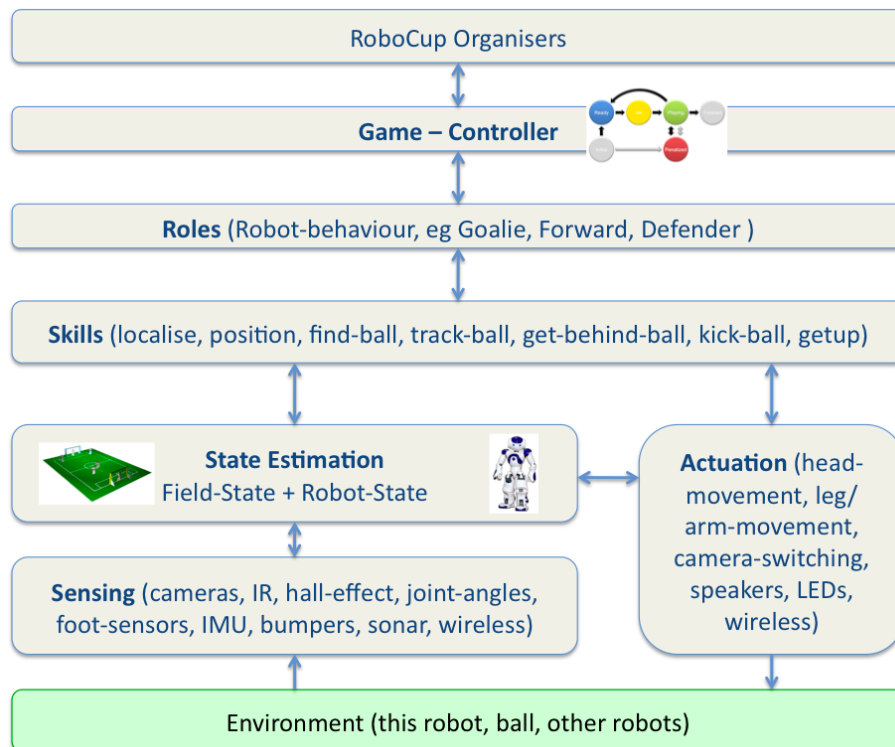


Fig. 1. The 2013 UNSW SPL robotic architecture.

### 3.1 Vision

Our vision system evolved significantly over the last fourteen 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. 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 have updated the vision system to recognise the field-boundary, field-markings and to rely less on colour by using edge-features. We have also introduced a foveated vision system and virtual saccades to maximise scarce computational resources. With the final removal last year of any specified landmark that allows the determination of target goal direction (both goals are now coloured yellow) we 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 last years RoboCup Symposium (Anderson, et al, 2012). A spin-off development – a visual compass to help odometric corrections for adjusting for spillage and collisions, etc – will be presented at the RoboCup Symposium this year (Anderson and Hengst 2013).

Current research and development includes the semi-automation of colour calibration using templates, faster field-line detection using gradient information, improved robot detection, and generally adapting to the new field-dimensions and robot markers.

**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). 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 easily because the number of modes grows exponentially. We experimented with multi-robot-multi-modal Kalman filtering and the application of loopy belief revision to achieve similar benefits more efficiently with larger teams. 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 IRCA (Peter Anderson, Youssef Hunter, Bernhard Hengst, 2013).

**Locomotion** In 2000, we introduced the UNSW walk, which became the standard across the four-legged 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. 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. 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 directed towards learning versatile bipedal locomotion controllers using hierarchical reinforcement learning techniques with continuous states and actions. It is well known that learning by sheer enumeration of problem variables does not scale. We are exploiting the structure of the walking domain to decompose the problem to learn near-optimal control solutions. The team was placed third in the SPL Open Challenge last year, and demonstrated learning of ankle-tilt control for bipedal balancing and walking (Hengst, et al, 2011).

Bipedal locomotion continues to be a research challenge at UNSW learning both coronal (Hengst, CLAWAR, 2013) and sagittal control behaviour.

**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 and 2012 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, 2012
- Quarter-finalists: 2004, 2008, 2011
- Challenges: 1st in 1999, 2000, 2001, 2002, 2010
- Challenges: 2nd in 2003, 2012
- Challenges: 3rd in 2011

### **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, 2011
- 2nd in Mobility: 2009
- Award for innovative user interfaces: 2009

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2. Fast Monocular Visual Compass for a Computationally Limited Robot, Peter Anderson and Bernhard Hengst, RoboCup Symposium, 2013.
3. An ICP Inspired Unified Sensor Model with Unknown Data Association, Peter Anderson, Youssef Hunter and Bernhard Hengst, ICRA, 2013.
4. Robot Localisation Using Natural Landmarks, Peter Anderson, Yongki Yushmanthia, Bernhard Hengst, Arcot Sowmya, RoboCup Symposium, 2012
5. Fast Object Detection with Foveated Imaging and Virtual Saccades on Resource Limited Robots, Adrian Ratter, David Claridge, Jayen Ashar and Bernhard Hengst, The 24th Australasian Joint Conference on Artificial Intelligence (AI2011), 2011

6. Learning Ankle-Tilt and Foot-Placement Control for Flat-footed Bipedal Balancing and Walking, Bernhard Hengst, Manuel Lange, Brock White, Humanoids, Bled, Solovinia, 2011
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