Team rUNSWift
University of New South Wales, Australia

RoboCup 2017
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 2017 rUNSWift team comprises final year undergraduate honours students, Master and PhD students, past RoboCup students and supervisors who have been involved in RoboCup for over a decade. New developments in 2017 include increased density foveation, a vision architecture change, a new ball and goal classifier, improved localising techniques, and development of both web-based and non-web based testing platforms.

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 SPL team comprises a mix of undergraduate, masters and PhD students, both past and present. 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 2017 rUNSWift team members are Gary Bai, Sean Brady, Kenji Brameld, Amri Chamela, Samuel Collis-Bird, Kirsten Hendriks, Ethan Jones, Alvin Prijatna, Peter Schmidt, Hayden Smith, Liangde Li, Addo Wondo, Victor Wong, Brad Hall, Timothy Wiley, Maurice Pagnucco, and Claude Sammut.

Fig. 1. A subset of the 2017 rUNSWift Team. From left to right, row 1: Claude Sammut, Maurice Pagnucco, Timothy Wiley, Sean Brady, Kenji Bremald, Gary Bai; row 2: Ethan Jones, Bradley Hall, Jeremy Collette, Liangde Li; row 3: Samuel Collis-Bird, Hayden Smith, Kirsten Hendriks, Victor Wong, Amri Chamela.

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 rUNSWift teams in the standard platform league (including the previous 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 the 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. 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 2017 Robotic Architecture

The rUNSWift 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 a 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.

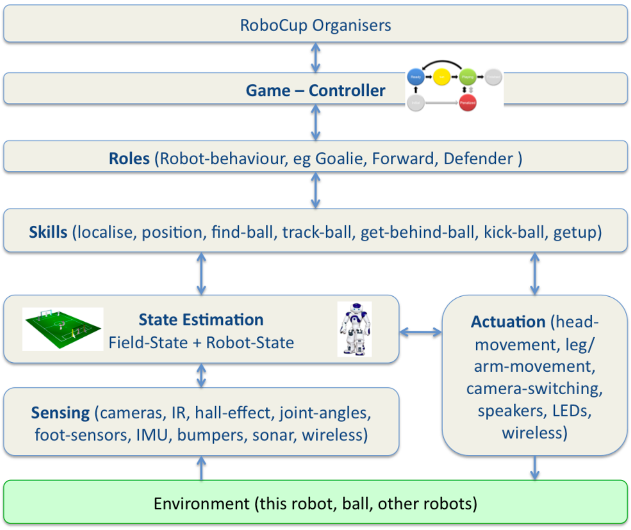

Fig. 2. The 2013 UNSW SPL robotic architecture.

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 teammates (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 scarce computational resources.

The challenges of a new ball in 2016 and dynamic lighting in 2017 have led to a significant restructuring of the vision architecture. Significant efficiency improvements have been implemented in the vision pipeline, allowing us to double the foveated raw image size compared to previous years.

Due to potential dynamic lighting conditions in 2017 and beyond, our offline colour calibration has been automated. Vertical scan lines are used to detect edges that allow classification of green and white for training with a nearest neighbour classifier.

The remainder of our vision operates in two steps: 1) A series of region of interest finders create bounded boxes that are subsets of the full image, and 2) Detectors that determine whether given regions found are certain features on the field. The primary region of interest finder is based on colour, using connected component analysis to find blobs of white pixels.

One of our more developed detectors, the ball detector, uses a number of features found in a given region to classify whether that region is a ball. These features include circle fitting, connected component analysis to detect patches of black and pattern matching to determine the black and white pattern of a ball.

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.

This year we have focused on using distance, orientation, and relative heading to more strongly triangulate the robot's pose. This is based on a principle of localising when we have reliable previous localising estimates.

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 has been adapted in 2015 and 2016 by a number of other teams.

Due to the significant improvements in our locomotion in 2014 only incremental changes have been made in recent years. These include more reliable get-up routines and a faster kicking motion.

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 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, 2008-2019

- 1st place: 2000, 2001, 2003, 2014, 2015
- 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
- Qualifier: 2016

Simulation soccer: 2001 - 2003

- 7th place: 2002

Rescue: 2005 - 2007, 2009-2013

- 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

5 Acknowledgements

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References

RoboCup SPL related publications:

1. Behaviour and motion modifications for a black and white ball in Robocup SPL 2016, Smith, 2016
2. RoboCup SPL 2014 Champion Team paper, Jayen, et.al, 2014
3. Reinforcement Learning of Bipedal Lateral Behaviour and Stability Control with Ankle-Roll Activation, Hengst, CLAWAR, 2013.
4. Fast Monocular Visual Compass for a Computationally Limited Robot, Peter Anderson and Bernhard Hengst, RoboCup Symposium, 2013.
5. An ICP Inspired Unified Sensor Model with Unknown Data Association, Peter Anderson, Youssef Hunter and Bernhard Hengst, ICRA, 2013.
6. 2013 rUNSWift Team Reports and Videos URL: `http://www.cse.unsw.edu.au/about-us/help-resources/for-students/student-projects/robocup/`
7. Robocup Standard Platform League - rUNSWift 2012 Innovations, Sean Harris, Peter Anderson, Belinda Teh, Youssef Hunter, Roger Liu, Bernhard Hengst, Ritwik Roy, Sam Li, Carl Chatfield, Australasian Conference on Robotics and Automation, Dec 2012, New Zealand.
8. 2012 rUNSWift Team Reports and Videos URL: `http://www.cse.unsw.edu.au/about-us/help-resources/for-students/student-projects/robocup/`
9. Robot Localisation Using Natural Landmarks, Peter Anderson, Yongki Yusmanthia, Bernhard Hengst, Arcot Sowmya, RoboCup Symposium, 2012
10. 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
11. Learning Ankle-Tilt and Foot-Placement Control for Flat-footed Bipedal Balancing and Walking, Bernhard Hengst, Manuel Lange, Brock White, Humanoids, Bled, Solovinia, 2011
12. RoboCup Standard Platform League - rUNSWift 2010, Jayen Ashar, David Claridge, Brad Hall, Bernhard Hengst, Hung Nguyen, Maurice Pagnucco, Adrian Ratter, Stuart Robinson, Claude Sammut, Benjamin Vance, Brock White, Yanjin Zhu, Australasian Conference on Robotics and Automation, Dec 1st-3rd Brisbane Australia, 2010

13. 2010 rUNSWift Team Report, Code and Videos following a total rewrite URL:
`http://www.cse.unsw.edu.au/about-us/help-resources/for-students/student-projects/robocup/`
14. 1999–2009 team reports as well as selected code are available at URL:
`http://www.cse.unsw.edu.au/about-us/help-resources/for-students/student-projects/robocup/`
15. Aaron James Soon Beng Tay (2009) Walking Nao Omnidirectional Bipedal Locomotion. UNSW SPL team report.
16. David G. Claridge, Carl Chatfield, Gary Huynh (2009). Software Systems for the Nao Humanoid Robot. UNSW SPL team report.
17. Mitchell Currie (2009) Robocup 2009: Localisation. UNSW SPL team report.
18. Brimo, A. (2008) RoboCup 2008. UNSW RoboCup 2008 Report.
19. Chen, S., Siu, L., Vogelgesang, T., Yik, T. F., Hengst, B., Pham, S. B. and Sammut, C. (2002). The UNSW RoboCup 2001 Sony Legged Robot Leage Team. In A. Birk, S. Coradeschi and S. Tadokoro (Eds.), RoboCup 2001: Robot Soccer World Cup V (pp. 39-48): Springer.
20. Chen, J., Chung, E., Edwards, R. & Wong, N. (2003). Rise of the Aibos III - Aibo RevolutionsI. RoboCup Team Report. http://www.cse.unsw.edu.au/robocup/2003site/report2003.pdf
21. Collien, D. and Huynh, G. (2008). From AIBO to NAO: The Transition from 4-Legged to 2-Legged Robot Soccer, UNSW RoboCup 2008 Report.
22. Hengst, B., Ibbotson, D., Pham, S. B. and Sammut, C. (2000). UNSW RoboCup 2000 Team Report. http://www.cse.unsw.edu.au/ robocup
23. Hengst, B., Ibbotson, D., Pham, S. B., Dalgliesh, J., Lawther, M., Preston, P. and Sammut, C. (2001). The UNSW Robocup 2000 Sony Legged League Team. In P. Stone, T. Balch and G. Kraetzschmar (Eds.), Robocup 2000: Robot Soccer World Cup IV (Vol. 2019, pp. 64-75), Springer.
24. Dalgliesh, J. and Lawther, M. (1999). Playing soccer with quadruped robots. Computer Engineering Thesis, School of Computer Science and Engineering, University of New South Wales.
25. Hengst, B., Pham, S. B., Ibottson, D. and Sammut, C. (2002). Omnidirectional Locomotion for Quadruped Robots. In RoboCup 2001: Robot Soccer World Cup V (pp. 368-373). Berlin: Springer.
26. Kadous, M. W., Sheh, R. and Sammut, C. (2006). Controlling Heterogeneous Semi-autonomous Rescue Robot Teams. In 2006 IEEE International Conference on Systems, Man, and Cybernetic.
27. Kadous, W., Sammut, C. and Sheh, R. (2006). Autonomous Traversal of Rough Terrain Using Behavioural Cloning. In The 3rd International Conference on Autonomous Robots and Agents.
28. Kim, M. S. And Uther, W. (2003). Automatic gait optimisation for quadruped robots. In Australasian Conference on Robotics and Automation. Brisbane.
29. Levesque, H. J., and Pagnucco, M., (2000) Legolog: Inexpensive Experiments in Cognitive Robotics, In Proceedings of the Second International Cognitive Robotics Workshop, Berlin, Germany.

30. Pagnucco, M. and Rajaratnam, D. (2005): Inverse Resolution as Belief Change. IJCAI 2005.545.
31. Pham, K. C. and Sammut, C. (2005). RDRVision - Learning vision recognition with Ripple Down Rules. Proc. Australasian Conference on Robotics and Automation (pp. 7 pages).
32. Pham, S. B., Hengst, B., Sammut, C. and Ibbotson, D. (2002). Stochastic Gradient Descent Localisation in Quadruped Robots. In RoboCup 2001: Robot Soccer World Cup V (pp. 447-452).
33. Nardi, D., Riedmuller, M. and Sammut, C. (Eds.). (2005). Proc of the RoboCup 2004 Symposium.
34. Sammut, C. and Hengst, B. (2003). The Evolution of a Robot Soccer Team. Robotics Research: The Tenth International Conference (pp. 517-529): Springer.
35. Sammut, C. (2003). Robot Soccer: Science or just fun and games? Proceedings of the Australian Joint Conference on Artificial Intelligence (pp. 12-23). Perth: Springer.
36. Sammut, C., Kadous, W., & Sheh, R. (2007). In K. Furukawa (Ed.), Learning to Drive Over Rough Terrain International Symposium on Skill Science, Tokyo.
37. Sheh, R., Kadous, M.W., Sammut, C., & Hengst, B. (2007). In D. Nardi (Ed.), Extracting Terrain Features from Range Images for Autonomous Random Stepfield Traversal. IEEE International Conference on Safety, Security and Rescue Robotics, Rome.
38. Raymond Sheh, Bernhard Hengst (2004). A Fast Vision Sensor Model: Matching Edges with NightOwl Proceedings of the Australasian Conference on Robotics and Automation (ACRA)
39. Tay, A. (2008). Exploration of Nao and its Locomotive Abilities. UNSW RoboCup 2008 Report.
40. Thomas J., Blair, A. & Barnes, A., (2003). Towards an efficient optimal trajectory planner for multiple mobile robots, Proc. 2003 International Conference on Intelligent Robots and Systems.
41. Wyeth, G., Kee, D. and Yik, T. F. (2003). Evolving a Locus Based Gait for a Humanoid Robot. In International Conference on Robotics and Intelligent Systems. Las Vegas.
42. Yik, T. F. (2007). Locomotion of Bipedal Robots: Planning and Learning to Walk. PhD Thesis. School of Computer Science and Engineering, University of New South Wales.
43. Yik, T.F., & Sammut, C. (submitted). In M. Srinivasan & M. Dunbabin (Eds.), Trial-and-Error Learning of a Biped Gait Constrained by Qualitative Reasoning. Australasian Conference on Robotics and Automation, Brisbane.
44. Zheng Wang, Bernhard Hengst, Claude Sammut (2002). Localisation in an Uncertain World with Multiple Agents, MI19.