

Sony Four-legged Robot League
RoboCup 2003 Padova, Italy
The 7th International RoboCup Conference and Competitions
July 2-11, 2003

TEAM Griffith
4-LEGGED ROBOT TEAM



Application

Team Information

TEAM NAME:	TEAM GRIFFITH
TEAM WEB PAGE:	http://gucis.cit.gu.edu.au/~mi-pal/
Team Leader:	Estivill-Castro, Vladimir, Assoc. Prof.
Deputy Team Leader:	Thornton, John, Dr.
Affiliation:	School of Computing and Information Technology (CIT) & School of Information Technology (SIT) - Griffith University
Address:	Brisbane, Queensland 4111, AUSTRALIA
Email:	v.estivill-castro@cit.gu.edu.au
Phone:	(61-7) 3875-5402
Fax:	(61-7) 3875-5051
Expected number of team	6 members present at Padova, Italy.

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Team Description Paper

Researchers at Griffith University have long been involved in the research and scientific challenges of Robotic Soccer through RoboCupJr, RoboCup 2002 and the 2000/2001/2002 FIRA Cups. Currently, Griffith's academics also have research projects involving the Sony AIBO platform for fielding robots and Intelligent Human-Computer Interfaces. Team Griffith includes participants with the University of Newcastle RoboCup Junior team. That team won the Tertiary Division in 2001 in Seattle and inspired the formation of the Newcastle Robotics Laboratory. They also were members of the NUbots team that finished 3rd both in the challenges and in the soccer competition in 2002. One Chief Investigator has led a team at the FIRA robotic soccer competitions.

This is an application for participation in the 2003 Sony Four-legged Robot League by a new team from Griffith University. As such, it outlines the research interest and track record of team members, the approach to research challenges and the commitment to participate in RoboCup 2003.

Clear statement of research interests

The research interests of the academic team at Griffith University are vision, perception and action, reasoning, and learning for intelligent mobile agents. The development and research for a team participating in the 4-legged league fits within a research program at Griffith that brings various collaborators together into exciting and multidisciplinary projects. In particular, this application complements the following areas of research strength:

1. **The relation of perception and action to coordination.** This research direction is represented by A/Prof. Treffner's recently awarded ARC Discovery grant entitled "*Dynamics of Locomotion: Visualisation in skill acquisition & rehabilitation*" (funding commencing in 2003; CIs Assoc/Prof. P.J. Treffner, Dr. R.S. Barrett, Prof. L. Adams, Dr. J.R. Thornton, and Dr. N. Kim). This is a multidisciplinary project that spans the Schools of Information Technology (INT), Physiotherapy and Exercise Science (PES), and has an international Chief Investigator in Dr. Kim. Also in this direction is current research into how stability of coordinated perception-action constrains mobile systems. This is funded by A/Prof. Treffner's ARC SPIRT on "Biomechanics and dynamics of safe driving" (CIs A/Prof. P. J. Treffner and Dr. R.S. Barrett, and has industry partner in the Holden Performance Driving Centre).
2. **Intelligent systems and reasoning.** Prof. Sattar leads this research direction and involves recently awarded ARC-Discovery grant entitled "*Real-time high-level cognitive robotics controllers*" (funding commencing in 2003; CIs Dr. M. Pagnucco, Prof. C.A. Sammut, Prof. A. Sattar, and Dr. A.C. Nayak). This is also a multidisciplinary project that spans several university departments.
3. **Robotics and algorithms for vision.** The research in this area is coordinated by Dr. Thornton and includes Thornton's successful development and leadership of the Griffith University FIRA robotic soccer team, as well as his joint-ARC with A/Prof. Treffner on the recently awarded Discovery grant, "*Dynamics of Locomotion: Visualisation in skill acquisition & rehabilitation*".
4. **Machine learning and intelligent data analysis** A/Prof. V. Estivill-Castro coordinates the research in this domain. It involves the newly established Machine intelligence and

Pattern Analysis Laboratory (Mi-PAL) and external funding (recently transferred to Griffith) for “*Approximate proximity for applications in data mining and visualization*”, ARC Discovery, 2002-2005 and “*Discrimination of echoes in computer based ultrasonic flaw detection for CAD modelled steel pieces*”, ARC SPIRT, 2001-2003.

The individual research interest of the members of the academic team directly involved in Griffith University 4-legged Sony AIBO soccer team are as follows (in alphabetical order):



Assoc/Prof Vladimir Estivill-Castro: (contact person/team leader): Knowledge Discovery and Data Mining, Machine Learning, Spatial Databases, Geographical Information Systems, Computational Geometry and Algorithms. Dr. Estivill-Castro was team leader of the U. of Newcastle RoboCupJr team that finished World Champion in Seattle 2001. He was an academic member supervising 2 students of the 4-legged team from U. of Newcastle, this team finished 3rd in RoboCup 2002. Estivill-Castro was directly involved in programming in C++, designing the software architecture, the image segmentation methods, team strategies and was even Robot Manipulator in the match Nubots vs. Team Sweden.



Professor Abdul Sattar: Knowledge Representation, Hypothetical Reasoning, Default Logics, Belief Revision, Abductive Reasoning, Constraint Satisfaction, Temporal Reasoning, Intelligent Agents, Logic Programming, Computational Logics, Truth Maintenance, Partial Evaluation, First-order Theorem Proving, Learning Theory. Prof. Sattar has been director of the Knowledge Representation and Reasoning Unit (KRRU); he is a member of the CRC (Cooperative Research Centre) for Smart Internet Technologies.



Dr. Phil Sheridan: Computer Vision, Supervised Machine Learning, Space-Variant Sensing for Robotic Vision. Image transformations on pixel lattices.



Dr. John Thornton: Intelligent Robotics, Robot Vision and Control Architectures, Constraint Satisfaction, Local Search Techniques, Constraint Weighting, Over-constrained Systems, Algorithms for Satisfiability, Intelligent Scheduling, Timetabling and Rostering.

Dr. Thornton has been the coordinator and main developer of the “**RoboCoasters**” (MiroSot Robot Soccer Team) of the FIRA competitions. Griffith University’s RoboCoasters competed in the FIRA Robot World Cups in 2000 (Rockhampton), 2001 (Beijing) and 2002 (Korea), including qualifying in the last 8 teams in the world in the 2002 competition.



Assoc/Prof. Paul Treffner: Dynamical systems models of perception-action, visualisation and virtual reality, motor coordination. multimodal information and gestural communication, complex systems and self-organisation, ecological psychology. Recently co-supervised with J. Thornton the project of the student Joe Leonard. This project used ecological psychology principles of visual perception to implement a very efficient ball-tracking algorithm (see www.int.gu.edu.au/%7Es227447/6215.htm).

Proposed Approach to Address the RoboCup challenge

We propose a software architecture that decomposes the challenge into modules:

- Vision
- Locomotion
- Localization
- Action-State/Intention/Behaviour Control
- Networking
- Team Play

With respect to the Vision module, we are applying a series of techniques from computer vision, machine learning and data mining for image segmentation and image analysis. We have, what we believe are, original and novel methods for colour segmentation and object recognition as well as image partitioning. We have developed a tool that allows capturing a large data set and building a classifier for colour segmentation in the form of very efficient decision lists.

For the locomotion module we will apply the techniques from the UNSW team as well as the techniques from the CMU team. Locomotion is outside the scope of our research interests at the moment. However, we are investigating vision coordination with locomotion. Note that legged leagues poses an interesting challenge with respect to physical robots on wheels. Unless we stop locomotion and assume a posture to grab an image, we typically do not know the position of the camera when images/frames are received. We are actually applying smoothing techniques to localize the ball properly in a sequence of frames in order to allow the goalkeeper to anticipate properly the trajectory of the ball.

We have a new approach to localization that avoids a Kalman filter or a Markov approach. Our distance from those methods is due to the fact that we believe that, in play, robots need to localize sporadically, or at least, they do not need to continuously localize. So, only in specific situations, for example, once a certain proximity of the ball has been achieved, we localize. Our localization actually uses a method based on local search and will be described in a later research paper.

The architecture for behaviour allows prioritising activities such as simple action/state activities (e.g., getting up after falling down) and more complex behaviours (e.g., defense and attack).

The Networking strategy we have in place is based on UDP and not on TCP/IP. Thus, we broadcast to other robots, but we broadcast sporadically. We have a virtual token ring approach where the robot physical proximity to the ball determines the token, and we have a circular token, where robots have a time-slice to broadcast.

Team play is based on the availability of wireless communication. Our robots default to individual behaviours and zone positioning under the failure or lack of wireless communication. For team play, each robot makes a judgement of relevance of the information to forecast and makes decision for team play on the basis of recently broadcasted information and information available to it on its sensors.

Background of Principal Investigator

There are at least two very active principal investigators in Team Griffith. Dr. V. Estivill-Castro (acting as leader) and Dr. John Thornton (acting as deputy leader). These two researchers are supervising (and co-supervising) at least 3 PhD students (Joel Fenwick, Nathan Lovell, and Joe Leonard) and 3 honours students (Shane Anderson, Jeremy Docker, and Stuart Seymon) and two undergraduate students (Daniel Walters and Kris Croker). All this students are actively involved in the research, development, and implementation of the TEAM GRIFFITH platform.

The rationale for this organization is that these two Chief Investigators have several years of experience with RoboCup. Dr. Estivill-Castro with the world-champion team for RoboCupJr in 2001 and the Nubots (3rd place legged league in 2002), while Dr. Thornton had several years of experience with the FIRA robotic soccer competitions.

These two researchers have a strong background in the algorithmic techniques of computer vision for robotic soccer and behaviours like goalkeeper actions. John Thornton algorithms for shape recognition have attracted industrial partners and commercialisation interests.

They both have a strong research profile in techniques from the general area of artificial intelligence In particular, data mining, local search, machine learning, genetic algorithms, spatial data management, computer vision. These two researchers have published specifically in RoboCup topics as follows:

1. **Thornton, J. R., Leonard, J., Wiseby, R. & Lee, Y.** "Shape Recognition and Enhanced Control Systems for Robot Soccer" *Proceedings of the 2002 FIRA Robot World Congress*, Seoul, Korea, p. 670-675 (2002).
2. **Estivill-Castro, V. and Lovell, N.** "Improved Object Recognition – The RoboCup 4-legged league" *Proceedings of the 2003 IDEAL 4th International Conference on Intelligent Data Engineering and Automated Learning*. Hong Kong, Springer Verlag Lecture Notes in Computer Science, to appear (2003).

Description of the team organization and effort spent.

The team has a team leader in Assoc. Prof V. Estivill-Castro and a deputy-team leader in Dr. John Thornton. The other academics involved in the team contribute regularly by participating in fortnightly general meetings of the team and supervision of PhD and honours students involved in specific research and development projects. Students dedicated to the project involve 3 PhD students (Joel Fenwick, Nathan Lovell and Joe Leonard), 4 honours Students (Shane Anderson, Stuart Seymon, Jeremy Docker, David Harris).

The School of Computing and Information Technology awarded two undergraduate summer scholarships to Daniel Walters and Kris Crocker who have been involved in the WEB-site development and the AIBO-networking architecture since last October.

The team is organized along the modules described before with Joel Fenwick acting as Software Coordinator and leader of the development team.

Dr. Phil Sheridan is supervising projects and is focusing on the recently announced technical challenges, as some of these have direct links to computer vision.

Other aspects of team organization have been mentioned in other sections of this application. Here, we emphasize that this constitutes an effort from 3 campuses across Griffith University (Estivill-Castro is based at Logan Campus, Sattar, Thornton and Treffner at the Gold Cost Campus and Sheridan at the Logan campus).

Pointers to relevant publications.

The following is a sample of publications in the areas of computational intelligence, intelligent systems, knowledge discovery, machine learning, machine vision, motor control, perception, robotic soccer, spatial data mining and temporal reasoning.

Amazeen, E., Amazeen, P., **Treffner**, P. J., & Turvey, M. T. Attention and handedness in bimanual coordination dynamics. *Journal of Experimental Psychology: Human Perception and Performance*, **23**, p. 1552-1560 (1997).

Beaumont, M., **Sattar**, A., Maher, M., & **Thornton**, J. R. "Solving Over-Constrained Temporal Reasoning Problems" *Proceedings of the Australian Joint Conference on Artificial Intelligence, AI-2001*, p. 37-49 (2001).

Estivill-Castro, V. and Yang, J. "Fast and Robust General Purpose Clustering Algorithms" *Data Mining and Knowledge Discovery*. In Press. ISSN 1394-5810.

Estivill-Castro, V. and Lee, I. "Multilevel Clustering and its Visualization for Exploratory Data Analysis" *GeoInformatica*, **6**(2): 123-152 (June 2002). ISSN 1384-6175.

Estivill-Castro, V. and Yang, J. "Clustering Web visitors by fast, robust, and convergent algorithms" Special Issue "Mining the Web" of the *International Journal of Foundations of Computer Science*, August No. 4 **13**:497:520 (2002) ISSN 0129-0541.

Estivill-Castro, V. "Collaborative Knowledge Acquisition with a Genetic Algorithm" *Proceedings of the IEEE International Conference on Tools with Artificial Intelligence (ICTAI-97)*. IEEE Press, 270-277, (1997) ISBN 0-8186-8203-5.

- Kravchuk, O., Pullan, W., **Thornton, J. R.** & **Sattar, A.** The Effects of Structure on Properties of Non-Uniform 3-SAT Problems Tested on Adjacency of Variables. *Proceedings of the 15th Australian Joint Conference on Artificial Intelligence, AI-2002*, Canberra, to appear (2002).
- Nagarajan, A. and Goodwin, S.D, and **A. Sattar, A.** “Dual Encoding Using Constraint Covering,” In *Proceedings of PRICAI-2000*, Melbourne, August, pp 457-468 (2000).
- Navarrette, **A. Sattar, R.** Wetprasit and R. Marin, “On point-duration networks for temporal reasoning,” *Artificial Intelligence*, **140**: 39-70, (2002).
- Pujari A. and **A. Sattar** “A New Framework for Reasoning about Points, Intervals and Durations,” In the Proceedings of IJCAI-99, pp 1259-1264 (1999).
- Rao, and **Sattar, A.** “Polynomial-time Learnability of Logic Programs with Local variables from Entailment,” *Theoretical Computer Science — An International Journal TCS*, **268**(2):179-198 (2001).
- Sattar, A.** and R. Goebel “Consistency-motivated reason maintenance system,” In *International Journal New Generation Computing*, Vol. **15** No.2, 1997, pp.163-186.
- Sheridan, P.**, Hintz, T and Alexander, D. “Pseudo-invariant transformations on hexagonal lattice” *Image and Vision Computing* **18** 907-917 (2000).
- Sheridan, P** and Hintz, T. and Alexander, D. “Space-Variant Sensing for Robotic Vision”. 5th International Conference on Mechanisms and Machine Vision in Practice. Nanjing, China, 10th-12th Sep. p. 185-190 (1998).
- Thornton, J. R., & Sattar, A.** “On the Behaviour and Application of Constraint Weighting” *Proceedings of the Fifth International Conference on the Principles and Practice of Constraint Programming, CP’99*, p 446-460 (1999).
- Thornton, J. R., & Sattar, A.** “Dynamic Constraint Weighting for Over-Constrained Problems” *Proceedings of the Fifth Pacific Rim International Conference on Artificial Intelligence, PRICAI’98*, p. 377-388 (1998).
- Thornton, J. R., & Sattar, A.** “Using Arc Weights to Improve Iterative Repair” *Proceedings of the Fifteenth National Conference on Artificial Intelligence, AAAI-98*, p. 367-372 (1998).
- Thornton, J. R., & Sattar, A.** “Applied Partial Constraint Satisfaction Using Weighted Iterative Repair” In A. Sattar (Ed.) *Proceedings of Tenth Australian Joint Conference on Artificial Intelligence, AI’97*. Lecture Notes in Artificial Intelligence 1342, Berlin Heidelberg: Springer-Verlag p. 57-66 (1997).
- Thornton, J. R., Pullan, W. & Terry, J.** “Towards Fewer Parameters for Clause Weighting SAT Algorithms” *Proceedings of the 15th Australian Joint Conference on Artificial Intelligence, AI-2002*, Canberra, to appear (2002).
- Thornton, J. R., Bain, S., Sattar, A. & Pham, D.** “A Two Level Local Search for MAX-SAT Problems with Hard and Soft Constraints”. *Proceedings of the 15th Australian Joint Conference on Artificial Intelligence, AI-2002*, Canberra, to appear (2002).
- Thornton, J. R., Beaumont, M. Sattar, A. & Maher, M.** “Applying Local Search to Temporal Reasoning” *Proceedings of the 9th International Symposium on Temporal Reasoning and Representation, TIME-2002*, p. 94-99 (2002).
- Thornton, J. R., Leonard, J., Wiseby, R. & Lee, Y.** “Shape Recognition and Enhanced Control Systems for Robot Soccer” *Proceedings of the 2002 FIRA Robot World Congress*, Seoul, Korea, p. 670-675 (2002).
- R. Torres-Velazquez, and V. **Estivill-Castro** “A Memetic Algorithm Instantiated with Selection Sort Consistently Finds Global Optima for the Error-Correcting Graph Isomorphism” *Proceedings of the 2002 Congress on Evolutionary Computation CEC-02*, as part of the 2002 IEEE World Congress on Computational Intelligence. Honolulu, Hawaii, May 12-27, 2002. p. 1958-1963 (2002).
- Treffner, P. J., & Kelso, J. A. S.** (1999). Dynamic encounters: Long-memory during functional stabilization. *Ecological Psychology*, **11**, 103-137.
- Treffner, P. J., & Turvey, M. T.** (1993). Resonance constraints on rhythmic movement. *Journal of Experimental Psychology: Human Perception and Performance*, **19**, 1221-1237.
- Treffner, P. J., & Turvey, M. T.** (1995). Handedness and the asymmetric dynamics of bimanual rhythmic coordination. *Journal of Experimental Psychology: Human Perception and Performance*, **21**, 318-333.
- Treffner, P. J., & Turvey, M. T.** (1996). Symmetry, broken symmetry, and the dynamics of bimanual coordination. *Experimental Brain Research*, **107**, 463-478.
- Treffner, P. J., Barrett, R., & Petersen, A. J.** (2002). Stability and skill in driving. *Human Movement Science*, **21**, 749-784.
- Treffner, P. J., & Peter, M.** (2002). Intentional and attentional dynamics of speech-hand coordination. *Human Movement Science*, **21**, 641-697.
- R. Wetprasit and **A. Sattar** “Temporal Reasoning with qualitative and quantitative information about points and durations,” In *Proceedings of the AAAI-98*, pages 656-663, Madison, Wisconsin, (1998).
- R. Wetprasit, **A. Sattar** and L. Khatib “Representation and Reasoning with Multi-Point Events,” *Constraints (an International Journal)*, **5**, pp 211-253, (2000).

Video Submission –

Sample videos will be placed at

<http://gucis.cit.gu.edu.au/~mi-pal/>

Travel support commitment for the team participation in RoboCup 2003

Griffith University has made a strong commitment to participating in RoboCup-2003 legged league as a result of Assoc/Prof V. Estivill-Castro transfer from Newcastle Univ. Two PhD students moved with Dr. Estivill-Castro, in particular, Nathan Lovell (student world champion in RoboCupJr and Software Developer leader for the 2002 NUbots).



Griffith University has funded the equipment necessary for RoboCup-2003. The University has already set up the infrastructure for the research and development effort. Space has been allocated. In particular, the Machine intelligence and Pattern Analysis Laboratory (Lab Room 1.47 Science 2 Building Nathan Campus) has been set up with a recently built soccer field as specified for the legged-league (carpet, boundaries, colours, and lighting) as well as the necessary equipment.



We have purchased one Sony AIBO ERS210/B last September and through regular contact with Ms Yumi Maekawa we purchased 8 ERS-210(A)/Black models.

In particular, Estivill-Castro, Treffner, Sattar, Thornton and Bartlett secured Infrastructure funds from an Internal Infrastructure Grant at Griffith University. A total of \$93,000 Australian dollars were awarded for 2003 under the title of "Perception, Action, Reasoning and Learning for Intelligent Mobile Agents" for infrastructure to support research across 3 schools at Griffith University.



Also, this academics in this team are all members of a recently announced Research Center A for Griffith University. The "Institute for Intelligent and Integrated Systems" will be under the directorship of Prof. A. Sattar and will have

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Robotics as one of its demonstrator programs. The centre brings together over 30 researchers, 15 of them with international reputation. This allows for links in areas like Voice and Pattern Recognition (identified by the laboratory lead by Prof. Kuldip Paliwal) and Autonomous Vehicles (identified by the work with robotic cars by Assoc. Prof. Ljubo Vlacic). Expertise within the Institute exists also on areas like Artificial Neural Networks, Combinatorial Optimisation, Machine Learning and Human-Computer Interaction.

The commitment to participate in RoboCup 2003 is also reflected by TEAM GRIFFITH's commitment to participate remotely at the German Open in early April and at the Australian open in late April. This preliminary competitions will allow our team to fine tune some of the novel ideas and techniques that constitute the core proposals and base of our research.

At least 7 team members will attend RoboCup-2003. Travel and accommodation for Robo-Cup2003 is to be funded from two *Australia Research Council Discovery Projects* held by the Principal Investigators. Also, support is expected from a Griffith University Internal Grant for 2003. Post-Graduate students involved in technical paper to be presented at the RoboCup symposium will also have additional support from the School of Computing and Information Technology. Therefore, it is possible that more members may attend RoboCup-2003.