THE UNIVERSITY OF WESTERN AUSTRALIA
Achieving International Excellence

Computational Intelligence Information Processing Systems
School of Electrical, Electronic and Computer Engineering
Faculty of Engineering, Computing and Mathematics

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REF: LB CIIPS 2012/13 Research Report

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Engineering, Computing and Mathematics

Computational Intelligence Information Processing Systems

Research Report 2012/2013

Contents

Foreword from the Head of CIIPS

Electric Vehicles and EV Charging remain two of the central research topics in the CIIPS Group. Besides our two own EV conversions, Hyundai Getz and Lotus Elise in the Renewable Energy Vehicle Project (REV), we are now conducting the first Australian EV Trial with 11 locally converted Ford Focus (EV Works) on the road, as well as 23 Level-2 fast-charging stations (Elektromotive) in the first Australian EV Charging Trial, funded by industrial partners and the Commonwealth through an ARC Linkage project.

Not being an electric vehicle, our petrol-driven BMW X5, donated by the BMW Group, has now been equipped with fully-functional drive-by-wire steering and braking. The effectiveness of our vision-based collision avoidance driver-assistance-system was demonstrated at the RAC DTEC test track and filmed by a Channel Seven News team.

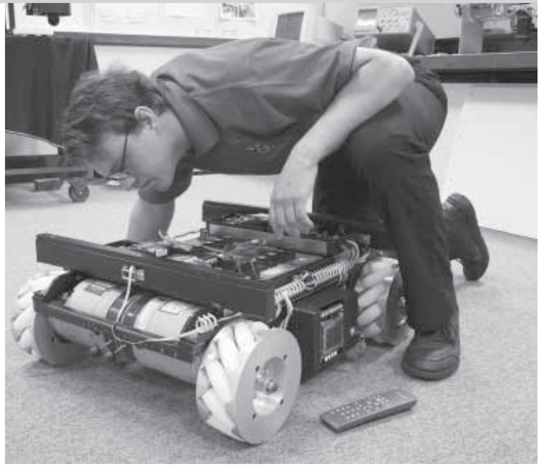
Finally, our 2012 Formula SAE-Electric car is taking shape. This is our second vehicle development in this category, following our Formula SAE-E 2010 car with a twin rear engine design. For 2012, we will be using four individual wheel hub motors, linked through an electronic control system.

As every year, CIIPS has had a number of international visitors and we are excited to see them contribute to our research projects. We will continue our CIIPS policy of an open student exchange policy wherever possible.

Professor Thomas Bräunl

Head
Computational Intelligence Information Processing Systems (CIIPS)

Introduction to CIIPS



The Computational Intelligence Information Processing Systems Group (CIIPS) has evolved from the Centre for Intelligent Information Processing Systems which was established in November 1991 as a 'Category A' Centre within the then Department of Electrical and Electronic Engineering at The University of Western Australia. Formerly existing as the Digital Signal Processing Research Group within the Department, it developed into a multidisciplinary research centre bringing together researchers from engineering, science, mathematics and medicine.

The group combines an active teaching program with pure and applied research to provide an environment in which innovative theoretical developments can be rapidly turned into technologies that provide solutions to a range of real-world problems. CIIPS runs the MEICT (Master of Engineering Information and Communications Technology) and the DEICT (Doctor of Engineering Information and Communications Technology) programs within the School of Electrical, Electronic and Computer Engineering.

The group is active in the areas of artificial neural networks, embedded systems, digital signal processing, image processing, mobile robots, parallel and reconfigurable computing, pattern recognition, electromobility and automotive systems.

Strong and successful collaboration between the group and industry is a key element in its operation. Joint research and development projects with a number of Australian companies have been undertaken, as well as contract research for industry, government and other bodies.

Equipment

The group is well equipped for the research that it undertakes. It has a network of Linux and Windows workstations. Various forms of data acquisition, including speech and image capture, are supported by a variety of peripherals. Sophisticated equipment for the support of hardware design and testing is also available, in particular, software and hardware for the design and programming of field-programmable gate arrays (FPGAs). The group also provides about thirty autonomous mobile robot systems in its Robotics and Automation Lab and five research cars in the REV Automotive Lab.

A number of systems have been developed and constructed for research and teaching purposes, including a reconfigurable parallel computing system using FPGAs and simulation systems for various areas ranging from embedded systems to mobile robot simulation.

The group currently has five research cars for various aspects of automotive research:

- BMW X5 (Drive-by-wire)
- Hyundai Getz (Electric conversion)
- Lotus Elise S2 (Electric conversion)
- 2010 Formula SAE—Electric Race Car
- 2012 Formula SAE—Electric Race Car

Capabilities

The capabilities of the group encompass both hardware and software development. Special-purpose devices and circuits can be designed and constructed. Sophisticated software for signal and image processing and pattern recognition can be developed, using adaptive filtering, artificial neural networks and other digital signal processing techniques.

The group is well placed to do pure research, applied research, research and development and contract research.

Contact Details

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Members of CIIPS

Academic Staff

Professor Thomas Bräunl (Head of CIIPS)
Dipl.-Inform., MS, PhD, Habil., SMIEEE, MDHV, MSAE
Electromobility; Automotive Systems; Robotics; Image Processing; Concurrency; Embedded Systems
thomas.braunl@uwa.edu.au

Dr Adrian Boeing
BE, PhD, MIEEE
Robotics; Automation; Physics Simulations; Computer Graphics; Computer Vision
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Professor Gary Bundell
BE, MEngSc, PhD, MIEAust, CPEng, SMIEEE, MIET, CEng
Real-time and Distributed Computer Systems; Computational Modelling; Software Safety Systems
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Mr Chris Croft
BE, MBA, MIEAust, MGMA
Engineering Management; Project Planning
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Professor David Harries
BSc, DipEd, MEnvStud, PhD
Smart Grids; Renewable Energy; Photovoltaics; Elektromobility
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Research Associate Professor Kevin Vinsen
Strategic Planning Systems; Surveillance Systems; Unmanned Vehicles
Research Associate Professor, International Centre for Radio Astronomy Research (ICRAR)
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Professor Terry Woodings,
BSc, DipComp, PhD, FACS, FQSA
Software Engineering; Software Metrics
terry.woodings@uwa.edu.au

Professor Anthony Zaknich,
BE, MESc, PhD, BSc, BA, SMIEEE, MAES
Artificial Neural Nets; Signal Processing and Pattern Recognition
anthony.zaknich@uwa.edu.au

Technical and Professional Staff

Mr Ivan Neubronner
Senior Technician
ivan@ee.uwa.edu.au

Ms Linda Barbour
CIIPS Administrative Secretary
linda.barbour@uwa.edu.au

Volunteers

Mr John Mullan

Mr Stephen Whitely

Mr Brendan Waterman

Visitors

Mr Arnaud Delevacque
École Centrale Paris, France

Mr Valentin Falkenhahn,
University of Stuttgart, Germany

Mr Ibrahim Halfaoui
Technical University Munich (TUM), Germany

Mr Alex Scherer
Technical University Munich (TUM), Germany

CIIPS Research Labs

Automotive Lab

Professor Thomas Bräunl

REV–Eco (Electric Hyundai Getz); REV–Racer (Electric Lotus Elise); SAE–2010 (Electric Formula SAE); SAE–2012 (Electric Formula SAE); BMW X5 Drive-by-Wire.

Location: EECE G.50

High Integrity Computer Systems Lab

Professor Gary Bundell, Professor Terry Woodings

High-performance, high-reliability and high-quality computer hardware and software systems, design methodologies and management.

Location: EECE 3.11

Integrated Sensory Intelligent Systems Lab

Professor Anthony Zaknich

Adaptive self-learning systems; intelligent signal processing; audio and underwater applications.

Location: EECE 3.11

Robotics and Automation Lab

Professor Thomas Bräunl, Dr Adrian Boeing

Intelligent mobile robots; embedded systems; image processing; simulation.

Location: EECE 3.13

Smart Grid Lab

Professor David Harries

Smart grids; distributed generation technologies; thermochemical energy storage systems; impact of electrical vehicles on electricity supply systems.

Location: EECE 3.11

Systems Engineering Analysis Management Lab

Mr Chris Croft

Applied engineering projects; project planning and management.

Location: EECE 3.11

Students 2011/2012

Doctor of Philosophy (PhD)

Mr Yuxuan Bai
Formula SAE Motor Control Design
(T. Bräunl)

Mr Omar Al-Bataineh
Verifying Real-time Systems Using
Dense-time Model Checking Technology
(M. Reynolds,T. French, T. Woodings)

Ms Elham Azadfar
Smart Grid Infrastructure Requirements
for Electric Car Charging
(T. Bräunl, D. Harries)

Mr Dariush Farrokhi
Speech Enhancement of Non-stationary Noises
(R. Togneri, A. Zaknich)

Ms Fakhra Jabeen
Automotive Charging and Customer Choice
(J. Taplin, T. Bräunl)

Mr Jithin Sankaran Kutty
SIMD Vision
(T. Bräunl)

Mr Robert Reid
Embedded Vision
(D. Huynh, T. Bräunl)

Mr Stuart Speidel
Analysis and Modeling of Driving Patterns
for Range Limited Electric Vehicles
(T. Bräunl, J. Taplin, D. Harries)

Mr Soo Siang Teoh
Development of Robust Vision-based Vehicle
Detection and Tracking Algorithms for Driver
Assistance Application
(T. Bräunl)

Mr Weiqun Zheng
Model-based Software Component Testing
(G.Bundell)

Master of Engineering Science (MSc)

Mr Ian Fergus Hooper
Development of In-wheel Motor Systems
for Formula SAE Electric Vehicles
(T. Bräunl)

Doctor of Engineering (DEICT)

Mrs Sujatha Bulandran
An Exploration of Assumptions in
Requirements Engineering.
(T. Woodings)

Final Year Electrical, Computer, Mechanical and Mechatronics Engineering Project Students

Mr Andrew Adamson (2012)
Ms Naomi Altman (2012/2013)
Mr Alexandros Andronis (2011)
Mr Russell Bennett (2012)
Mr Timothy Black (2012)
Mr Zachery Brandstater (2011)
Mr Lochlan Brown (2012)
Mr James Cohen (2012)
Mr Jonathan Eng (2011)
Mr Marcin Kiszko (2011)
Mr Sean Klimek (2012)
Mr Nicholas (Yongxing) Lee (2012)
Mr Zev Jonathan Levi (2012)
Mr Warren Lionnet (2012)
Mr Calum Meiklejohn (2012)
Mr Matthew Michalek (2012)
Mr David Ogilvy (2012)
Mr Scott Richards (2011)
Mr Jacob I. Salter (2011)
Mr Jeon Singh (2011)
Mr Thomas Skevington (2011)
Mr Davip Susanto (2012)
Mr Beau Trepp (2011)
Mr Matthew Tyler (2011)
Mr Brendan J. Waterman (2011)

Automotive Lab

Professor Thomas Bräunl

The Automotive Lab was established in 2008 and is dedicated to research on driving economy, such as plug-in electric vehicles, as well as active driving safety, such as driver assistance systems. The Automotive Lab currently houses five vehicles, a BMW X5, a Hyundai Getz, a Lotus Elise S2, and two Formula SAE race cars. The Engineering Faculty's REV Project (Renewable Energy Vehicle) runs in this lab. Details can be found at: http://robotics.ee.uwa.edu.au/automotive.html and http://theREVproject.com.

Adjusting the Embedded Driver Assistance System

Driver Assistance Systems

Our BMW X5, donated by BMW Group, was the star of a Channel Seven, Today Tonight report in the series 'The Clever Country'. The BMW has been converted to drive-by wire by UWA workshops staff and students, allowing it to steer and brake through digital signals from an embedded computer system. For this, an electric motor has been mounted to actuate the steering column, still giving the driver the ability to override the signal by moving the steering wheel manually. A powerful electric servo is being used to press down the brake pedal from behind, leaving enough room for the driver's foot to also operate the pedal. The accelerator pedal has not been actuated for safety reasons.

EyeBot controller

An EyeBot V6 advanced embedded controller is mounted with a suction cup on the BMW's windscreen combining a digital camera with the image processing hardware in one module. Software developed by students using the OpenCV image processing library uses a classifier system based on image symmetry to detect other cars as potential obstacles. If the system detects a possible collision with a car in front, it will warn the driver acoustically and then either conduct an emergency braking or alternatively take evasive action by actively steering the car around the obstacle while also braking. For testing, a realistic looking inflatable copy of the REV Hyundai Getz is being used as the obstacle car.

The autonomous BMW and the inflatable Getz

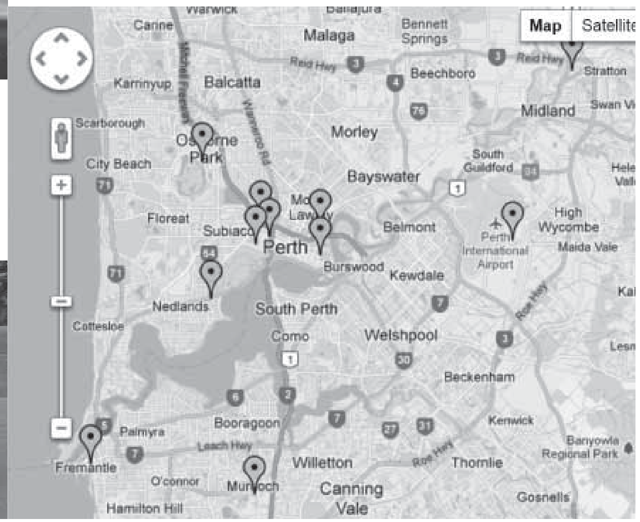
The final project demonstration for this project was conducted in July 2011 at the RAC DTEC Driving Centre near Perth Airport and was broadcast by Channel Seven's Today Tonight, Australia.

Also in the focus of a TV report from Channel Seven were our electric REV Eco (converted Hyundai Getz) and REV Racer (converted Lotus Elise), performing acceleration measurements at the RAC DTEC Driving Centre. Test results as well as an interview were recorded and broadcast in June 2011 by Channel Seven's Today Tonight, Australia.

Electromobility

Our two first Australian trials on EVs and on EV charging are now well underway with 11 locally-converted Ford Focus EVs on the road and 23 charging stations in the ground. All cars and all stations are equipped with GSM data loggers, plus GPS modules and additional sensors for the cars. With this, we are able to construct complete movement profiles of the electric fleet cars and we are able to collect comprehensive data on EV charging behaviour. Of special interest are *where* (home/office/station) and *when* (daytime/day-of-week) charging occurs. These questions can only be answered by collecting and evaluating relevant user data, as we are doing in this project.

WA EV Trial car



EV charging station locations in Perth

The follow-up question is—what effect can daytime dependent tariffs have in influencing people's charging behaviour, in order to avoid additional power demand peaks? This is a million-dollar question, which we are analysing very carefully.

The Formula SAE-Electric is a new student competition category for single-seater electric race cars, designed and built by students. While our REV Formula SAE-E-2010 car was a conversion of an older vehicle from UWA Motorsport, we are now designing and building our 2012 car from scratch as a pure electric vehicle.

For the 2010 car, we used a twin rear engine design that let us experiment with multiple motor designs. For the 2012 car, we are now using four individual wheel hub motors, linked through an electronic control system. The challenges are in the mechanical design of packaging motor and gearing into the small available wheel hub space, as well as in the sensor-based electrical/computing control and coordination of the four motors in different driving situations.

We were finally able to confirm exact energy consumption for our REV Lotus and the electric Ford Focus. In a project in cooperation with Murdoch University, the electric Lotus and manual and automatic versions of the electric Focus were tested on a calibrated dynamometer at Orbital Engines. The cars were driven according to the speed profiles for urban and extra-urban cycles, required by the Australian Design Rules. Typically dynamometer testing gives more repeatable and comparable results, but also more favourable values (i.e. lower consumption and therefore longer range), as compared to real road testing, which we conducted previously.

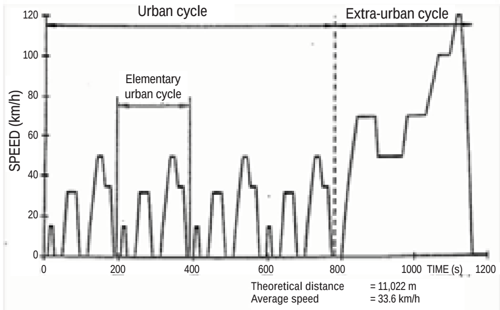
REV would like to express its appreciation for the support of its 2011/2012 sponsors:

- Swan Energy
- Galaxy Resources
- WA Department of Transport
- BMW Group
- EV Works
- Altronics
- Huber + Suhner
- UWA School of Physics

In 2011/2012 the Automotive Lab hosted the following visitors:

Alex Scherer, TU Munchen, Germany;
Valentin Falkenhahn, Uni Stuttgart, Germany.

Members of the UWA REV Team with the SAE EV and Ford Focus EV at the Perth Sun Fair



Australian Design Rules speed profile

The EV Lotus Elise is tested on Orbital Engines' dynamometer

High Integrity Computer Systems Lab

Professor Gary Bundell, Professor Terry Woodings

The aim of the Laboratory is to engage in research into the engineering of high-integrity information and software systems. Such research requires the development of tools and methodologies to aid the design of these systems; performance analysis, measurement and benchmarking of these systems; and evaluation of the organisational and environmental context in which these systems need to operate. As such, it is very much a multidisciplinary endeavour that requires an understanding of the underlying information and communications technology, robust engineering design principles and practices, and extensive knowledge of current and potential applications for these types of systems.

Research conducted has been in safety critical embedded systems for the resources industry, specifically in two rail and automation control applications for MRX Technologies. This has involved research into embedded systems development to the various IEC 61508/61511/62278/62279 standards, and development of specific software subsystems for the on-board equipment replacing the train driver.

Professor Terry Woodings (third from left) and Dr Sabrina Ahmad (far right) with delegates at the SE 2011 UTeM Conference, Malaysia

Another important thread of research was undertaken in the software engineering area, concerned with software project and process metrics, including studies on the requirements engineering of systems with the allocation of priorities, when there are insufficient resources, based on the measurement of value and effort. Project risk was studied with reference to assumptions made in the requirements definition process. The work explored techniques for systematic process improvement based on a reduction in variation in the estimation of relevant project parameters. As a result of this research, Dr Sujatha Bulandran, supervised by Terry, became the first Doctor of Engineering in ICT at UWA. Sujatha had her thesis passed at the end of 2011 and graduated at the April 2012 ceremony. Her thesis is entitled, 'An Exploration of Assumptions in Requirements Engineering'.

Terry has been appointed Visiting Professor at the Universiti Teknikal Malaysia Melaka and made the first of his annual visits there in October 2011. While there, he delivered the keynote address at the SE 2011 UTeM conference on Software Engineering. The talk was entitled, 'Quality Software Implies Quality Knowledge'.

In cooperation with the School of Computer Science and Software Engineering, UWA, Terry is continuing with research in knowledge engineering and software metrics. He is jointly supervising one doctoral and two Masters students in that school—Mrs Sabrina Ahmad, Miss Lesley Lu Zhang and Mrs Wan Junidin, all of whom have had their theses passed and graduateD in September 2012.

In 2011, Terry taught three undergraduate courses—Software Requirements and Project Management; Software Quality and Measurement; and Software Engineering Industry Project Leadership, as well as one postgraduate course—Software Process: Principles, Implementation and Improvement.

As a member of CIIPS and in conjunction with Professor Mark Reynolds and Assistant Professor Tim French, Terry is supervising a PhD student, Mr Omar Al-Bataineh. The subject of his research is, 'Verifying Real-time Systems Using Dense-time Model Checking Technology'. Two papers have been accepted for publication.

Gary's PhD student Mr Weiqun Zheng completed his research on linking software component specification and design information to earlier work on software component testing. His thesis entitled 'Model-based Software Component Testing' was submitted for examination in early 2012.

Integrated Sensory Intelligent Systems Lab

Professor Anthony Zaknich

The Lab's activities are related to the philosophy, theory and applications of intelligent signal processing, including; learning theory; self-learning systems; artificial neural networks; adaptive systems; time-frequency filters and signal analysis; time delay spectrometry; adaptive space–time frequency signal processing; audio and Hi-Fi; and underwater acoustic communications.

A number of audio DSP projects are in progress leading towards the development methods of accurate measurement of loudspeaker responses in non-anechoic environments, 3-D loudspeaker frequency response models and efficient loudspeaker equalisation filters.

This work is the basis of a new book in progress, 'Loudspeaker response testing, modelling and equalization: Including a complete design and testing project example'. There are very few published books on this topic so it will fill a hole in the market by providing a valuable research and application resource on the topic.

2012 also saw the completion of PhD student, Mr Dariush Farrokhi. Jointly supervised by Professor Zaknich and Associate Professor Roberto Togneri, his thesis entitled 'Single Channel Speech Enhancement in Severe Noise Conditions' was passed in April.

Robotics and Automation Lab

Professor Thomas Bräunl, Dr Adrian Boeing

The Robotics and Automation Lab was established in 1998 and is dedicated to research in intelligent autonomous mobile systems. Using embedded systems, over 50 mobile robots have been designed and built in the lab, while the development of simulation systems also plays a major role in the lab's research efforts. Details can be found at: http://robotics.ee.uwa.edu.au

Following the success in the MAGIC2010 Robot Competition in Adelaide, we now have a new student generation working on getting our mobile robot team to the next level. The task is to let a team of mobile robots autonomously explore an unknown area and have them cooperatively generate a map of the environment without human intervention.

We are using a group of five Pioneer AT outdoor robots for this task, which have been equipped with several sensor systems, including two laser scanners, an inertial measurement unit, a GPS system and a digital camera.

The robots are able to communicate wirelessly with each other as well as with a dual (redundant) base station. The new software backbone of the overall system will be the newly developed ROS robot operating system. Our research partners at Edith Cowan University are developing a robotics software simulation environment for an identical robot hardware setup.

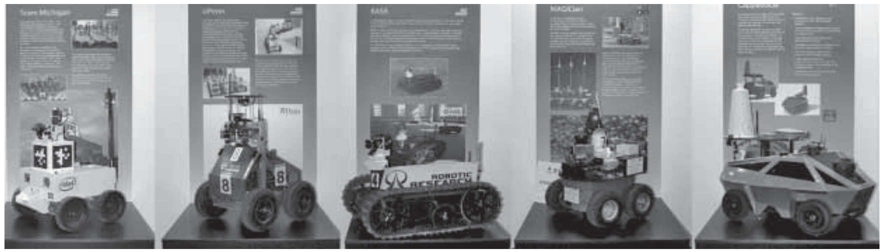
RAM Shed Challenge

In an embedded robotics project, we are looking at a next generation digital image sensor module with built-in massively parallel image processing hardware. Every pixel has associated with it an SIMD processing element, all of which are centrally controlled. This will make it possible to immediately pre-process a captured image on the sensor chip before it is even transferred to the CPU. This approach will greatly reduce the computational effort for image processing required on the CPU, freeing it for other tasks in a robotics or a general embedded environment.

In 2012 the Robotics and Automation Lab hosted the following visitors:

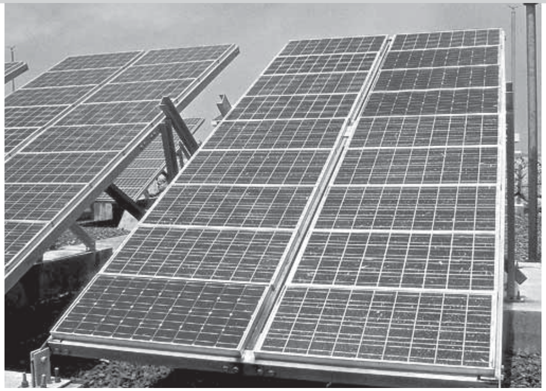
Arnaud Delevacque, École Centrale Paris;

Ibrahim Halfaoui, Technical University Munich.



Magic 2010 Awards

Smart Grids Lab

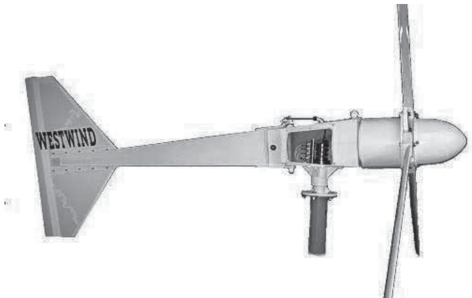


Professor David Harries

The Smart Grids Lab is currently involved in investigating electric vehicles and the potential impacts that recharging of EVs may have on electricity supply systems; battery technologies; distributed generation technologies; the integration of high penetrations of renewable generation systems such as solar PVs and wind systems in urban and rural grids; and the development of monitoring and control systems for managing the variability of output from solar PV systems.

Before joining the UWA CIIPS group, Professor David Harries was the inaugural director of the Research Institute for Sustainable Energy (RISE) at Murdoch University, the inaugural director of the Centre for Research on Sustainable Transport Fuels (CREST) at Murdoch University and Curtin University of Technology, the inaugural Executive Director of the Government of Western Australia's Sustainable Energy Development Office (SEDO) and the Assistant Director of the Government of Tasmania's Office of Energy Planning and Conservation. His involvement in the energy sector (electricity, gas, renewable energy and energy efficiency) over the past 32 years has included academic teaching, research, policy and planning, consulting (including to the governments of Saudi Arabia and Brunei Darussalam) and the representation of government on high-level-national energy-policy-making bodies. David was Chair of the Tasmanian Electricity Network Planning and Reliability Panel and the Tasmanian Electricity Code Change Panel. He was also a member of the working group set up by the Prime Minister to develop a legislative framework for a third party access regime to natural gas pipelines in Australia and the working group established to develop a mechanism for implementing the national renewable energy target.

Currently David is Technical Director at Energy Made Clean Ltd and the Vice President (formerly President) of the Conservation Council of Western Australia.



Picture courtesy of Westwind

Systems Engineering Analysis Management Lab

Mr C. Croft

SEAM was established as a vehicle to undertake a wide range of differing projects, usually in conjunction with other groups or researchers. The group has two major areas of interest, the management of systems in crisis and the development of automated control of remotely piloted vehicles.

The group investigates of a number of issues relating to the use of virtual reality environments to control cameras on remote controlled helicopters and aircraft. This research is focused on simulator sickness and the representation of virtual worlds using minimal graphic elements.

The group's key research areas cover three major groups. The first relates to the management of systems under stress and focuses on the methods in which management is undertaken in unpredictable systems. The second is the ongoing development of auto piloted flight in small aircraft. With the move into virtual reality, the group is currently building the tools to undertake research into the depiction of non visual virtual environments, for example the futures markets or concentration of pollutants in a vessel.

Publications 2011/2012

Research Book

Bräunl, T. *Embedded Robotics—Mobile Robot Design and Applications with Embedded Systems*, (Chinese transl.), Xi'an Jiaotong University Press, P. R. China, June 2012

Journal Articles

Haque, S., Togneri, R., Zaknich, A. *An Auditory Motivated Asymmetric Compression Technique for Speech Recognition*, IEEE Trans. Audio, Speech and Language Processing, vol.19, no.7, July 2011

Mullan, J., Whitely, S., Harries, D., Bräunl, T. *Modelling the Impacts of Electric Vehicle Recharging on the Western Australian Electricity Supply System*, J. Energy Policy, vol.39, no.7, July 2011

Lim, C., Mamat, R., Bräunl,T. *Impact of Ambulance Dispatch Policies on Performance of Emergency Medical Services*, IEEE Trans. Intell. Transportation Systems, 2011

Al-Bataineh, O., French, T., Reynolds, M., Woodings, T.L. *Verifying Real-time Commit Protocols Using Dense-time Model Checking Technology*, arXiv.org CS, 2012

Bräunl,T. *Synthetic Engine Noise Generation for Improving Electric Vehicle Safety*, Int. J. Vehicle Safety, 6(1), pp1–8, 2012

Mullan, J., Harries, D., Bräunl, T., Whitely, S. *The Technical, Economic and Commercial Viability of the Vehicle-to-grid Concept*, J. Energy Policy, June 2012

Boeing, A. et al. *WAMbot: Team MAGICian's Entry to the Multi Autonomous Ground-robotic International Challenge 2010*, J. Field Robotics, 29(5) pp707–728, 2012

Teoh, S., Bräunl, T. *Symmetry-based Monocular Vehicle Detection System*, J. Machine Vision and Applications, 23(4), pp. 831–842, July 2012

Conference Papers

Lopes, S., Frisch, B., Boeing, A., Vinsen, K., Bräunl, T. *Autonomous Exploration of Unknown Terrain for Groups of Mobile Robots*, IEEE Intelligent Vehicles Symposium (IV'11), Baden-Baden, June 2011

Boeing, A., Bräunl, T., Reid, R., Morgan, A., Vinsen, K. *Cooperative Multi-robot Navigation and Mapping of Unknown Terrain*, 5th IEEE Int. Conf. on Robotics, Automation and Mechatronics, RAM 2011, Qingdao, China, Sept. 2011

Reid, R., Bräunl, T. *Large-scale Multi-robot Mapping in MAGIC*, 5th IEEE Int. Conf. on Robotics, Automation and Mechatronics, RAM 2011, Qingdao, China, Sept. 2011

Al-Bataineh, O.I., French, M., Woodings, T.L. *Formal Modeling and Analysis of a Distributed Transaction Protocol in UPPAAL*, 19th Int. Symp. on Temporal Representation and Reasoning (TIME 2012), Leicester, UK, Sept. 12–14, 2012

Boeing, A., Pangeni, S., Bräunl, T., Lee, C. *Real-time Tactical Motion Planning and Obstacle Avoidance for Multi-robot Cooperative Reconnaissance*, IEEE Int. Conf. Systems, Man, & Cybernetics, Seoul Korea, Oct. 2012

Boeing, A., Bräunl, T. *Leveraging Multiple Simulators for Crossing the Reality Gap*, 12th Int. Conf. on Control, Automation, Robotics and Vision, ICARCV 2012, Guangzhou, China, Dec. 2012

Teoh, S., Bräunl, T. *A Reliability Point and Kalman Filter-based Vehicle Tracking Technique*, 33rd Int.l Conf. on Information Systems (ICIS'12), Penang, Malaysia, Dec, 6–7, 2012

Professional Activities and Research Grants

Conference Chairs and Programme Committees

Bräunl, T.

- MASCOTS 2011, Singapore
- IASTED Robotics and Applications (RA 2011), Vancouver, Canada, June 1–3, 2011
- ICINCO 2011, Noordwijkerhout NL, July 28–31, 2011
- ICINCO 2012, Rome, Italy, June 28–July 2, 2012
- IEEE Intl Conf on Robotics, Automation and Mechatronics (RAM), Qingdao, China, Sept. 17–19, 2012
- ICARA, Wellington, NZ, Dec. 6–8, 2012
- Australasian Joint Conference on Artificial Intelligence, Murdoch/Perth, Australia, Dec. 5–8, 2012
- Australasian Joint Conference on Artificial Intelligence, Sydney, Australia, Dec. 4–7, 2012
- ICARCV 2012, Guangzhou, China, Dec. 5–7, 2012

Research Grants

Bräunl, T., Taplin, J., Harries, D.
Western Australian State Electric Vehicle Trial: Analysis and modeling of driving patterns for limited-range electric vehicles
ARC Linkage Project 2010–2012—$803,000
Industry Partners—Department of Transport; CO2 Smart; and AEVA.

Journal Editorial Boards and Advisory Boards

Bräunl, T.

- International Journal of Social Robotics (Springer-Verlag), Associate Editor and Member of the Editorial Board.
- International Journal of Advanced Robotic Systems, Editorial Advisory Board Member.
- International Journal of Simulation Modelling, Editorial Board Member.
- IEEE Computer Society's Technical Committee on Parallel Processing Member.
- IEEE Robotics and Automation Society's Technical Committee on Marine Robotics Member.
- Australian Research Council (ARC) Expert of International Standing, Assessor of research project proposals.

Invited Talks and Project Demonstrations

Invited Talks

Bräunl, T.

April 20, 2012 'Electromobility Meets Robotics', UWA Faculty of Engineering, Computing and Mathematics

March 16, 2012 'Safety Aspects of EV Charging', Steering Committee of WA Electric Vehicle Trial

March 13, 2012 'Future of EV Charging', Australian Electric Vehicle Association

February 29, 2012 'Electric Vehicle Charging Trends', ARC Linkage Meeting on EV Charging, UWA

February 8, 2012 'Electric Vehicle Charging', Solar Seminar, Peel Development Commission, Mandurah

May 19, 2011 'The Electric Vehicle Revolution', WaterCorp, Perth

May 12, 2011 'Electrification of Personal Transport in Western Australia', Western Power, Perth

April 14, 2011 'The Electric Vehicle Revolution', Centre for Water Research, Perth

March 25, 2011 'Is Western Australia Ready for Electric Cars?', Energising South East Asia, Perth Convention Centre

February 17, 2011 'Electric Vehicles in Western Australia', Australian Fleet Managers Association, Perth

Project Demonstrations

Bräunl, T.

May 2, 2012 REV vehicle and charging station demonstration for international agents at UWA

April 26, 2012 REV vehicle exhibition and demonstration, Elektrokhana, RAC-DTEC Driving Centre, Perth Airport

April 22, 2012 REV vehicle exhibition at Electric Fair, Northbridge

April 18, 2012 REV student project demonstrations for UWA Media Unit

April 1, 2012 REV SAE-Electric Car exhibition at Perth Sun Fair

March 26, 2012 REV vehicle demonstration for delegation from Anna University, India

February 23, 2012 REV demonstration for Heilongjiang Province student delegation (China)

February 23, 2012 Robotics demonstration for Heilongjiang Province student delegation (China)

July 19, 2011 REV Racer Lotus demonstration for 'A day in the life of a uni student', UWA

July 19, 2011 REV Racer Lotus demonstration for Yanchep Beach Development Project

June 30, 2011 REV demonstration for IIT Kharagpur

June 30, 2011 Robotics and Automation demonstration for IIT Kharagpur

May 30, 2011 Photo shoot of REV Lotus for 'Dark Matter'

July 11–18, 2011 REV Eco Getz exhibition at Gravity Discovery Centre, Gingin

May 6, 2011 REV Racer Lotus demonstration for Beilby, East Perth

April 13, 2011 REV Lotus and Getz demonstration for international agents, UWA

April 10, 2011 REV Lotus exhibition at Perth Sun Fair

March 22–26, 2011 REV Lotus exhibition at Energising South East Asia Conference and Exhibition, Perth Convention Centre

Postgraduate Degrees Completed 2011/2012

Doctor of Philosophy (PhD)

Dr Dariush David Farrokhi
Single Channel Speech Enhancement In Severe Noise Conditions
Supervisors: Anthony Zaknich, Roberto Togneri
Admitted to the Degree of Doctor of Philosophy on 19 September 2012

Dr Soo Siang Teoh
Development of a Robust Monocular-based Vehicle Detection and Tracking System
Supervisor:Thomas Bräunl
Admitted to the Degree of Doctor of Philosophy on 19 September 2012

Mr Weiqun Zheng
Model-based Software Component Testing
Supervisor: Gary Bundell
Thesis submitted for examination April 2012

Dr Sujatha Bulandran and Professor Terry Woodings at the 2012 Autumn Graduation ceremony at UWA

Master of Engineering Science (MEngSc)

Mr Ian Fergus Hooper
Development of In-wheel Motor Systems for Formula SAE Electric Vehicles
Supervisor: Thomas Bräunl
Admitted to the Degree of Master of Engineering Science on 23 July 2012

Doctor of Engineering (DEICT)

Dr Sujatha Bulandran
An Exploration of Assumptions in Requirements Engineering
Supervisor: Terry Woodings
Admitted to the Degree of Doctor of Engineering in Information and Communications Technology on 29 March 2012

Abstracts of Postgraduate Dissertations

Sujatha Bulandran

DEICT

Supervisor: Terry Woodings

An Exploration of Assumptions in Requirements Engineering

The aim of this thesis is to explore the issue of assumptions made during Requirements Engineering (RE). As the initiating phase of a software development process, RE involves activities which are expected to fulfil the needs of the user. The defects which originate during RE are particularly expensive to rectify when uncovered in the later stages of development. Assumptions made in RE, particularly during requirements analysis, are a significant source of defects and contribute to the total rework cost of the software. Therefore, there is a need to make visible and verify these assumptions in order to reduce the overall development cost.

This research examines the adaptation of a standard defect detection technique for revealing assumptions during requirements analysis. This is an extension of the previous literature which largely emphasises the importance of detecting assumptions in software projects via automated tools. A process model for the research, termed the Exploration of Assumptions in Requirements Engineering (EAiRE) has been constructed by defining assumptions in the context of RE. In support, there was a need for a Taxonomy of Assumptions in Requirements Engineering (TARE) to enhance this investigation. Several important principles for detecting and inserting artificial assumptions are defined and explained. Further, two experimental trials were designed (a Scenario Based Experiment and an Assumptions Seeding Experiment).

The results of the experiments demonstrated that assumptions can be detected using the suggested approach. The number of the assumptions detected, particularly in relation to the size of the requirements documents used in this study, exceeded expectations. It is clear that it is worth investing greater effort on the detection and measurement of assumptions in RE since this is where many defects originate. The discovery of assumptions at this initial stage of system development has the potential of significantly enhancing the quality of the delivered software.

Dariush David Farrokhi

PhD

Supervisors: Anthony Zaknich, Roberto Togneri

Single Channel Speech Enhancement In Severe Noise Conditions

Single Channel Non Stationary Noise Speech Enhancement (SCNSNSE) algorithms can be used in many applications including enhancement of pre-recorded speech, hearing aids devices, speech recognition and telecommunication equipment. Many organisations such as medical, aviation and law enforcement are interested in having access to algorithms that can improve the quality of noisy speech signals.

A combined set of existing and new algorithms were uniquely put together to produce a SCNSNSE system architecture. This novel system architecture produced improved speech enhancement at low SNR (below 0 dB SNR). This SCNSNSE architecture contains novel algorithms at pre- and post-processing stages and enhances the speech signal which is contaminated with highly non-stationary noise.

Ian Hooper

MEngSc

Supervisor: Thomas Bräunl

Development of In-wheel Motor Systems for Formula SAE Electric Vehicles

With the threat of anthropogenic climate change and humanity's dependence on non-renewable petroleum, the need for a transition to zero-emission transport is widely acknowledged. Battery electric vehicles represent the most promising solution for urban transport, being the most efficient technology which can be powered from renewable energy sources.

As of 2011, most major automobile manufacturers have either released or announced development of EVs, and it is clear that they are going to play a big role in our future transport needs. To date, all such vehicles employ a conventional drivetrain with a single motor, driving the wheels through a transmission and differential.

In contrast, many small EVs such as bicycles and scooters have employed in-wheel motor systems (also known as hub motors)— where the electric motor is contained within the wheel hub itself. In-wheel motor systems offer many advantages over conventional drivetrains including fewer moving parts, lower transmission losses, and space savings. However the performance requirements of road-going automobiles has so far precluded the use of in-wheel motor systems.

This thesis reviews electric motor technology and recent academic research on in-wheel motor systems to determine the most promising candidates. A design for a direct-drive wheel motor is proposed and optimised through magnetostatic Finite Element Analysis (FEA) experiments. Finally the development of an in-wheel motor system for a Formula SAE EV is presented, based on a high-speed motor with reduction drive, and its performance is compared with direct-drive solution.

Formula SAE is an international competition which challenges university students to construct and race Formula-style vehicles. The competition was started in 1978 for petroleum-powered vehicles. In response to growing interest in sustainable transport and electric vehicles, in 2007 many universities began developing electric FSAE vehicles. The competition represents a valuable arena for electric vehicle research and evaluation.

Soo Siang Teoh

PhD

Supervisor: Thomas Bräunl

Development of a Robust Monocular-based Vehicle Detection and Tracking System

This dissertation investigates the techniques for monocular-based vehicle detection. A novel system that can robustly detect and track the movement of vehicles in the video frames is proposed. The system consists of three major modules: a symmetry based object detector for vehicle cueing, a two-class support vector machine (SVM) classifier for vehicle verification and a Kalman filter based vehicle tracker.

For the cueing stage, a technique for rapid detection of all possible vehicles in the image is proposed. The technique exploits the fact that most vehicles' front and rear views are highly symmetrical in the horizontal axis. First, it extracts the symmetric regions and the high symmetry points in the image using a multi-sized symmetry search window. The high symmetry points are then clustered and the mean locations of each cluster are used to hypothesise the locations of potential vehicles. From the research, it was found that a sparse symmetry search along several scan lines on a scaled-down image can significantly reduce the processing time without sacrificing the detection rate.

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Vehicle verification is needed to eliminate the false detections picked up by the cueing stage. Several verification techniques based on template matching and image classification were investigated. The performance for different combinations of image features and classifiers were also evaluated. Based on the results, it was found that the Histogram of Oriented Gradient (HOG) feature trained on the SVM classifier gave the best performance with reasonable processing time.

The final stage of the system is vehicle tracking. A tracking function based on the Kalman filter and a reliability point system is proposed in this research. The function tracks the movement and the changes in size of the detected vehicles in consecutive video frames.

The proposed system is formed by the integration of the above three modules. The system provides a novel solution to the monocular-based vehicle detection. Experimental results have shown that the system can effectively detect multiple vehicles on the highway and complex urban roads under varying weather conditions.

Weiqun Zheng

PhD

Supervisor: Gary Bundell

Model-based Software Component Testing

Software component testing (SCT) is a proven software engineering approach to evaluating, improving and demonstrating component reliability and quality for producing trusted software components, which is critical to support the success of component-based software engineering. Model-based testing (MBT) of software components enables the utilisation of a consistent model-based approach and specification (e.g. UML models) for effective component development and testing. However, advancing from model-based development to MBT poses certain crucial challenging problems that remain unresolved and hamper the utilisation of SCT/MBT, and further research is thus required to address those problems to achieve the goal of desirable SCT/MBT effectiveness.

The thesis systematically reviewed the important concepts, principles, characteristics and techniques of SCT/MBT in the literature to provide a solid foundation for this research and introduced the following new concepts and definitions to form the first major part of the work's original contribution: (1) In software components and SCT—a new comprehensive taxonomy of software component characteristics; a new software component definition; a new definition of software component testing; a useful taxonomy of software component testing techniques; and a practical taxonomy of component testability improvement approaches. (2) In MBT and UML-based testing—a study of model-based tests; a new definition of MBT; a new test model definition; a new definition of UML-based testing; a core UML subset for SCT; and a study and review of use-case-driven testing and scenario-based testing.

The principal original contribution of this thesis is to introduce a novel hybrid SCT methodology, called Model-Based Software Component Testing (MBSCT), which consists of five major methodological components, a three-phase testing framework, six main methodological features and six core testing capabilities.

Alexandros Andronis

Supervisor: Thomas Bräunl

On-board Instrumentation for an Electric Formula SAE Race car

With increasing petrol prices, researchers are constantly finding new ways of increasing the quality and efficiency of electric vehicles. The UWA REV Project has the objective of building EVs that are viable for the commercial market. A recent project is an Electric SAE race-car built as an alternative to petrol-engine FSAE race-cars.

The focus of this dissertation is the electrical instrumentation—an essential component of the overall vehicle design. It involves the design and implementation of a system used to gather real-time information about the vehicle used for two main purposes: traction control and performance analysis. This work is split into three sections: Electrical design, hardware design and software design.

The Electrical design section focuses on the electronics used to interconnect the system with an external power source, sensors and I/O devices, including noise filtering and circuit protection. A major component of the electrical system is the design and implementation of a Printed Circuit Board (PCB). The PCB and enclosure were designed to be Electro Magnetic Compatibility (EMC) compliant.

The hardware design component focuses on the design and implementation of external sensors used in this vehicle. Three main sensors were developed as part of the instrumentation system—Pedal position sensors determine the position of the accelerator and brake pedals; a rotary sensor detects the angle of the steering wheel; and an accelerometer/gyroscope IMU characterises the motion of the vehicle. The sensors are connected to a microcontroller used to process raw data into useful information.

The software design section details the software framework used to interface these sensors with the system's microcontroller. This framework includes software for communicating with analog and digital sensors as well as communication protocols for communicating data to other I/O devices such as the traction control AVR (used for motor control) and an X-Bee transmitter, which is capable of transmitting data wirelessly to an on-site computer (for performance analysis).

Zachery Brandstater

Supervisor: Thomas Bräunl

Traction Control and Torque Vectoring with Wheel Hub Motors

Internal Combustion Engines have dominated the transport and motor vehicle industry for the majority of the last century. However, powering vehicles with renewable energy sources provides ecological, economical and sustainable benefits. In particular, Electric Vehicles have proven to be far more cost effective per kilometre driven than their petrol powered counterparts. There are also other benefits to using electric motors such as significantly improved torque response from the motors, more accurate control over motor output and greater flexibility in motor design.

This project aims to combine all of the benefits of electric motors to produce an electronic stability system that improves both the stability and performance of a vehicle. This will be achieved through the design and construction of an open-wheel racer specifically tailored to incorporate individual motors in all four wheels. The system will incorporate driver input and vehicle feedback to individually control the motors in an all-wheel-drive setup. This allows us to predict torque requirements and limitations in real-time. This, in turn, can enable maximum performance during safe operation.

Jonathan Eng

Supervisor: Thomas Bräunl

Implementation of an Embedded System For Vehicle Avoidance For a BMW X5 System

This project successfully fully implemented stage one of the vehicle detection algorithm onto the Eyebot M6 embedded controller designed by the Automation Computing and Energy Research Group (ACE Group). It involved construction of a serial RS232-to-TTL converter so that the Eyebot M6 would be able to send the signals to the Arduino microcontroller that controls the braking and steering motors on the BMW X5 vehicle. A simple user interface was specifically designed which gave the driver the ability to choose between two modes of resolution and the option of activating the steering avoidance system and deciding which direction to turn.

The whole programming aspect of the Eyebot M6 was done using Microsoft Visual Studio 2008, and the entire code revolved around the symmetry based detection algorithm that stage one of the vehicle detection algorithm is centred on. For the signals to be sent out to the Arduino controller, work was carried out in conjuction with a mechatronics student who designed and implemented the braking and steering systems on the BMW X5. A solution had to be devised to send the command signals to the Arduino board from the Eyebot M6, that also had the capability of handling glitches in the commands as well as to be noise resistant when sending out commands in the channel. The Eyebot M6 could not send the signals out using the USB port as it was faulty but was able to send the signals via the serial port, however the Arduino board had no serial RS232 ports but had TTL ports. To overcome this, an RS232–to–TTL converter was constructed to convert the signals so that the Arduino board could processes the commands.

The braking protocols used when a vehicle/object was deemed to be too close to the vehicle without any other inputs other than the camera, was that if said vehicle/object's base was below a set row on the image, the vehicle would start braking. The same concept is also followed by the steering protocols.

Without stage two of the vehicle detection algorithm, the system can only assume that the detected object is a vehicle, as stage two checks the detections from stage one with a database of known vehicles. As such the system treats all detected objects within the region of interest to be a valid vehicle.

Marcin Kiszko

Supervisors: Adam Wittek, Thomas Bräunl

REV 2011 Formula SAE Electric—Suspension Design

This thesis covers the suspension and steering design process for REV's entirely new 2011 Formula SAE electric race vehicle. The team intends to utilise four wheel-hub motors endowing the vehicle with all-wheel-drive and extraordinary control over torque vectoring. The design objectives were to create a cost-effective, easy-to-manufacture and simple race suspension that would act as a predictable development base for the pioneering power train. The ubiquitous unequal-length, double-wishbone suspension with pull-rod spring damper actuation was chosen as the underlying set up.

The design was based largely on UWA Motorsport's 2001–2003 vehicles as none of the team members or supervisors had previous FSAE experience and because the resource constraints were similar and preceded the complex Kinetics suspension system.

The kinematic design of the wishbones and steering was completed on graph paper while design of the components including FE analysis

was carried out in SolidWorks. The spring and dampers where set up for pure roll, steady-state conditions. The major hurdle during design was overcoming the conflicting dimension of the electric wheelhub motor and pull-rod. Most of the suspension components are to be made from Chrome Molybdenum steel (AISI 4130).

Scott Richards

Supervisors: Chris Croft, Thomas Bräunl

Real Time Analysis of Music to Determine Chord Progressions

This study focused on sound analysis techniques to determine the musical chords used by an artist. It is the first of what is beginning to appear as a series of projects, and thus contains more of a focus on preliminary studies and results rather than a complete program.

Mathworks MATLAB was the program of choice due to its relatively simple coding language, availability, and ability to give an output in a ready-to-use format. In conjunction with Mathworks Signal Processing Toolbox, a free toolbox created by members of the Finnish Centre of Excellence in Interdisciplinary Music Research was utilised. While extremely detailed in several areas of musical information retrieval, it was found that the toolbox could use much improvement in the chord analysis area.

The Music Information Retrieval (MIR) toolbox is used in this study purely to gather the musical data. The data is output in a matrix format of normalised strengths of musical pitches and then compared against several matrices to determine what chord types are present in the input data.

Also investigated in this paper were several possible methods of beat analysis. MIR toolbox, MixMeister BPM analyser and another MATLAB code entitled Beat Tracking by Dynamic Programming (BTBDP) were compared against a manually calculated result. As this paper serves as somewhat of a preliminary study, no program was selected outright.

The code that this study has produced can accurately pick out guitar chords of several types in a musical setting (drums, bass and vocals included). While the real-time aspect of this project has not been thoroughly examined due to its strong dependence on hardware rather than software, it is believed that the results gained from this study will assist future students greatly in their investigations. Further study would see more chords added into the programs vocabulary, possible altering of the chord matrices and the inclusion of probability to yield more accurate results.

Jeon Singh

Supervisor: Thomas Bräunl

Hardware Redesign of an Experimental Embedded Platform

Embedded systems are increasingly being utilised in processes and systems automating much of what used to be carried out by users. Reasons for this include the idea that computers are able to work more efficiently, accurately and reliably than humans. The EyeBot has been an embedded system developed by a group of engineers and students led by Professor Thomas Bräunl. The last incarnation, the EyeBot M6, was created in 2006 and in 2011 was in need of an upgrade. This project describes a new design, intended as a replacement for the EyeBot M6, containing at least the same functionality with increased performance and simpler application development.

The EyeBot M6 was primarily designed for use in image processing applications, particularly being utilised in obstacle detection for vehicles. The system's two fundamental components

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are the CPU and FPGA. Over the years since 2006 these two components have been succeeded by newer, faster devices with more features. This combined with the flaws of the EyeBot M6 favoured a redesign of the system. This new EyeBot is designed around the Gumstix Overo Fire COM, utilising the TI OMAP 3530 processor and the Xilinx Spartan 6 FPGA. The Gumstix COM handles all general processing including display, user input and external device interfacing, while the FPGA is a dedicated soft core dealing with processing images from two cameras and passing information back to the processor. The intention of this design project is to create a leading edge embedded system purposed for stereo image processing, while considering other applications by university students. Emphasis is placed on simple hardware design and robustness to aid in it's implementation as an experimental embedded platform.

Jacob I. Salter

Supervisors: Adam Wittek, Thomas Bräunl

Design, Analysis and Manufacture of 2011 REV Formula SAE Vehicle Chassis

Torsional stiffness and weight are the two most important quantifiable aspects to the chassis of any race car. Thus, the first aim of this project is to design a chassis of which the trade-off between high torsional stiffness and low weight is balanced to achieve high vehicle performance across the various competition events. The chassis will have to comply with the specification in the Society of Automotive Engineers (SAE) 2011 Formula SAE Rules. The car, that is to be an electrically power vehicle with four hub motors has a differing set of major component than the traditional combustion engine cars in the FSAE, namely the presences of two large battery boxes and the lack of a solid engine block. The second objective is use a finite element analysis and computer aided design software, to calculate the mechanical chassis properties of weight and torsional stiffness, then comparing them against values measured from the fully fabricated chassis. To eliminate possible sources of error in the modelled values, mechanical testing of materials used in the construction will be conducted.

Thomas Skevington

Supervisor: Thomas Bräunl

Design and Implementation of a Network Enabled Power Measurement System

Domestic power meters have been shown to have a significant effect in the area of demand-side energy management. The information they provide is of great use to a homeowner in helping to identify areas in which reductions in energy consumption can be made.

The aim of this project is to design and implement a network enabled power meter which would allow the data collected to be collated in a central location, reducing the user interaction required to retrieve meaningful data from a group of meters.

The implemented system uses a client-server architecture with all devices connected to the server via a common Ethernet network. Two client controllers were looked at, one as a demonstrator, and a second low-cost, low-power controller suitable for embedding into devices. The collected data is made available via HTTP request to the server and can be accessed via any network enabled device on the network.

Beau Trepp

Supervisor: Thomas Bräunl

Design of an Embedded Data Acquisition and Display System Using a Modular Approach

The topic of electric vehicles is becoming increasingly popular due to rising fuel costs and growing concern over emissions. Despite this attention, most electric vehicles have little or no telemetry systems, making many aspects of their operation and efficiency a mystery.

The aim of this project was to develop an extendable system in order to capture various data-points that can be available in a vehicle, as well as an interface to display this data inside the car. The design developed differs from traditional embedded systems by being completely modular. It uses existing network protocols to allow the system to be distributed between various smaller embedded components. This will enable it to be easily extended, should the need for more data-points arise, and allows the use of many smaller systems to be implemented incrementally, rather than one expensive monolithic design.

In order to help facilitate robustness and code re-use, a windowing toolkit was also developed. This provides a common platform for user interaction, and defines pre-built components in order to speed up the design and implementations of the user interface.

By exposing and recording more data, deeper analysis can be done on the efficiency of the car, and help justify different technological improvements to the vehicle. The higher granularity of data acquired can also be used to analyse the economy of the vehicle in different conditions.

Matthew Tyler

Supervisor: Thomas Bräunl

REV Performance Vehicle Instrumentation

The REV Project is a multidisciplinary effort to design, build and evaluate electric vehicles with the goal of demonstrating the viability of renewable energy vehicles for personal transport. The following project outlines changes and additions to the REV Lotus instrumentation systems for the 2011 period.

Changes have been made to the core GPS and BMS programs, allowing for more robust operation. The telemetry module has been rewritten to cooperate with the now running electric vehicle trial. A more informative battery-monitoring panel has been added, in line with a need for more detailed battery analysis. The Engine Audio Replication System (EARS) has been reviewed and implemented into the user interface. A new panel has been implemented using the twitter API for relaying traffic data from Main Roads.

A new CAN-SPY device is introduced, which lays groundwork for implementing CAN based sensors and actuators, offering a more flexible and responsive platform for sending and receiving information across the vehicle. This simultaneously offers an expansive and high-speed platform for future work. This first device is used to obtain feedback from the motor controller.

The problems with estimating battery capacity for the REV Lotus are introduced. Current methods of estimation both in production and in research are discussed. A new method is tested offering performance with an average error of approximately 10% through use of a combined neural network, coulomb count and Kalman filter approach.

Brendan J. Waterman

Supervisors: Adam Wittek, Thomas Bräunl

Design and Construction of a Space-frame Chassis

The purpose of this project is to design and build a space-frame chassis for a race car to compete in the FSAE-A competition as part of the UWA REV team. The FSAE competition is a competition for university students to design, build and race their own open-wheeled race cars, there are also a number of static design events in the competition.

The 2011 REV FSAE car will be powered by four electric motors with one mounted to each wheels' upright. This is a new configuration for a FSAE car and as such requires an entirely new chassis design that both supports the loads placed on it but also weighs as little as possible. The chassis design implements structural battery boxes which have the dual purpose of protecting the driver from the batteries and adding strength to the frame, this has not previously been used in any other FSAE car. Using these stressed battery boxes gives the chassis excellent torsional stiffness, yet the entire frame still weighs just over 40kg.