THE UNIVERSITY OF WESTERN AUSTRALIA

Achieve International Excellence

FACULTY OF ENGINEERING, COMPUTING AND MATHEMATICS

Computational Intelligence Information Processing Systems

RESEARCH 2014/2015

Contents

Foreword from the Head of CIIPS

The new wave of high-performance low-cost embedded systems has made an impact to our research and teaching work. Embedded controllers that used to cost over $1,000 can now be purchased for less than $50. As a consequence, we have replaced high-end embedded controllers and automotive PCs with new low-cost controllers in all of our electric research cars and research robots and we have changed over to a new generation of low-cost embedded controllers in our undergraduate teaching labs.

On the Electromobility side, we have successfully completed the WA Electric Vehicle Trial, the first EV trial conducted in Australia. It ran from 2010 to 2013 with 11 locally converted Ford Focus cars and 23 charging outlets from an ongoing ARC Linkage project.

With manufacturer-built (OEM) cars now available in Australia, our focus will shift from building EVs to charging and management of EVs. Our software suite REView covers vehicle tracking, charging monitoring, billing, statistical analysis as well as smartphone apps.

Our REV Formula-SAE Electric student team made its first appearance at the Melbourne FASE competition and our Robotics student team participated in the Autonomous Ground Vehicle Competition (AGCV), both in Melbourne at the end of 2013. These events are annual competitions, so we will build on this experience and are looking forward to the next round.

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.

Activities

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.

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)
- Driverless Formula SAE—Electric Race Car
- 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.

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Members of CIIPS

Academic Staff

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Volunteers

Mr Luke Frewer, BPhil student

Mr Andrew Pham, BPhil student

Mr Rohan Mehra, BPhil student

Visitors

Mr Wei Tang
Jiangsu University of Technology, China

Mr Alex Evers
RWTH University, Germany

Mr Rémi Keat
École Centrale Lyon, France

Mr Huri Ma
Zhejiang University, China

Mr Yuanlai Liu
University of Science and Technology of China

Doctor of Philosophy (PhD) Students

Ms Saufiah Abdul Rahim
Genetic Robot Algorithms
(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
Modelling the Impacts of a Large-scale Penetration of Electric Vehicles on Electricity Networks
(D. Harries, I. Khanna, V. Sreeram)

Mr Thomas Drage
Control System for Autonomous Performance Driving
(T. Bräunl)

Mr Franco Hidalgo
Visual Simultaneous Localisation and Mapping (SLAM) for an AUV (Autonomous Underwater Vehicle) in shallow water
(T. Bräunl)

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

Mr Andreas Kostler
Modelling of Electric Vehicle Energy Consumption and Home Energy Management Systems
(T. Bräunl)

Mr Robert Reid
Multi-Robot SLAM
(A. Boeing, T. Bräunl)

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

Mr Guido Wager
Energy Efficiency of Electric Vehicles and Recharging Technologies under Consideration of Usage Profiles
(T. Bräunl, D. Harries, J. Whale)

Final Year Project Students

Electrical, Electronic and Computer Engineering

Mr Michael Baxter (2014)
Mr Alex Beckley (2013)
Mr Lochlan Brown (2013)
Mr Merrick Cloete (2014)
Mr Thomas Drage (2013)
Mr Timothy Forrest (2014)
Mr Martin French (2014)
Mr Ross Green (2014)
Mr Jordan Kalinowski (2013)
Mr Don Madappuli (2013)
Mr Rory O'Connor (2013)
Mr Garrick Paskos (2014)
Mr Marcus Pham (2014)
Mr Cody Zhinqiang Qiu (2013)
Mr Thomas Smith (2014)
Ms Tushara Teegala (2014)
Mr Daniel Throssell (2013)
Mr Chris Venables (2013)
Mr Qing Zhou (2014)

Mechanical Engineering

Mr Rowan Clark (2013)
Mr Christopher Corke (2014)
Mr Alex Hildebrand (2014)
Mr William Jacobs (2013)
Mr Rajinda Jayamanna (2013)
Mr Graham Lionnet (2013)
Mr Man Ho Ma (2013)
Mr Michael Storey (2014)
Mr Nicholas Ward (2014)
Mr Jameson Wedge (2013

Mechatronics Engineering

Mr Jessen Beinart (2014)
Mr Gabriel Feng (2013)
Mr Jake Galiano (2014)
Mr Samuel Gribble (2014)
Mr Stuart Howard (2014)
Mr Alexander Mazur (2014)
Mr Enda McCauley (2013)
Mr Ruvan Muthu-Krishna (2014)
Mr Carl Pantos-Conquilla (2014)
Mr Liam Poli (2013)
Mr Omid Targhagh (2014)
Mr Riley White (2013)
Mr Luke Thomas Wilson (2014)
Mr Richard Hang Yang (2014)
Mr Calvin Yapp (2013)

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

Automotive Lab

Professor Thomas Bräunl

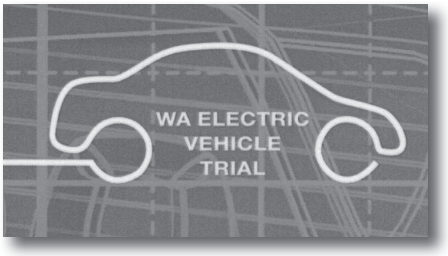
The Automotive Lab was established in 2008 and is dedicated to the research on driving economy, such as plug-in electric vehicles, as well as driving safety, such as driver-assistance systems. The Automotive Lab currently houses five vehicles, a BMW X5, a Hyundai Getz and a Lotus Elise S2, a Formula SAE-Electric race car and an autonomous FSAE-Electric race car. The Faculty of Engineering, Computing and Mathematics' Renewable Energy Vehicle Project (REV) is running in this lab. Details can be found at:
robotics.ee.uwa.edu.au/automotive.html **and** ***REVproject.com***

Professor Thomas Bräunl and Hon. Senator Christine Milne, Leader of the Australian Greens at the UWA charging station

The WA Electric Vehicle Trial 2010–2013 has been completed and the trial report can be downloaded from:

REVproject.com/trialreport.pdf

Eleven locally converted Ford Focus have been monitored via 3G-enabled black boxes. This allows us to monitor their driving, parking and charging behaviour.



Cumulating EV movements over two years allows us to highlight driving patterns and preferred charging locations.

Having completed the REV Eco and REV Racer EV conversions in the previous years, our activities have now concentrated on monitoring and charging of EVs. As part of the ARC-funded Linkage project, we have established one of the largest EV charging networks in Australia with 23 charging outlets. We can monitor the live status of each station and we can give users feedback on their EV charging status via a smartphone app.

A significant finding of the two interwoven EV projects is customer behaviour at public charging stations. Most charging events are happening during daytime hours,

so an EV charging station can be ideally offset or even directly fed by a rooftop solar PV system, as can be seen in the diagram (black—charging; grey—maintaining charge after completion of charging).

Charging times do not match parking times: as the diagram demonstrates, cars occupy a charging bay much longer than actually required for charging. This is because a standard charging time of four hours is too long for staying with the car and in general, parking appears to be at a higher premium than charging.

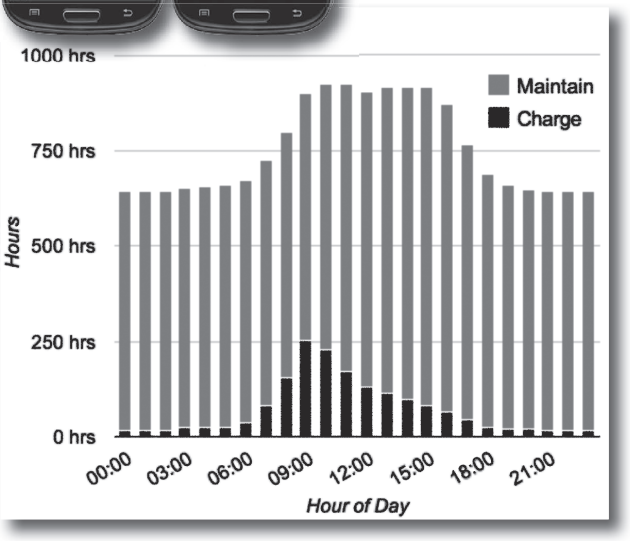
As a result of these outcomes, we do not propose further increase of the existing network of fast-AC chargers (7kW), but instead advocate to establish a smaller network of fast-DC chargers (50kW). On these systems a typical charge time is 20–30 minutes (for 80 per cent charge) and the driver is expected to stay with the vehicle and remove the vehicle after charging. This will effectively decouple charging from parking and allow a much more efficient use of charging stations.

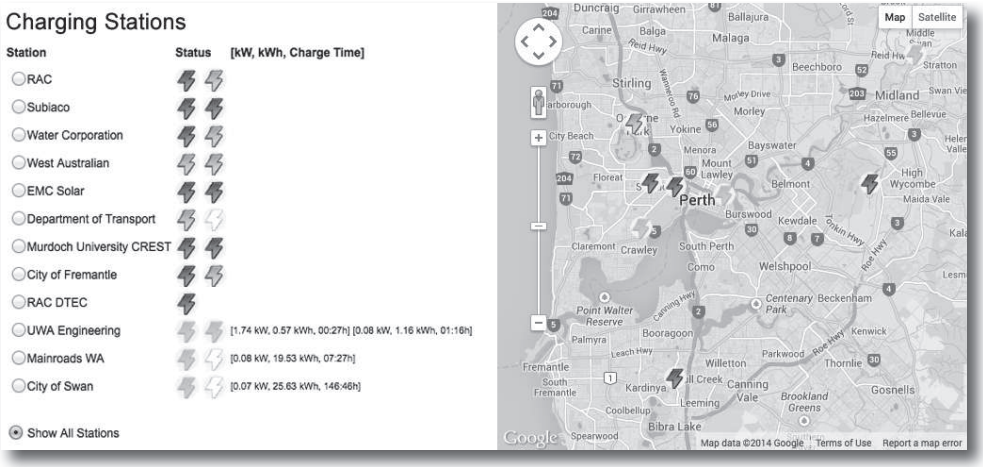
Indeed, one of the final achievements of the ARC Linkage project on Electric Vehicle (EV) charging was the installation in November 2014 of Australia's first commercial Combo-CCS charging station. This station type can charge an EV in only 30 minutes from empty to an 80 per cent charge level, so it is about seven times faster than the medium–fast Level-2 charging station used in all other locations of this project and about 25 times faster than regular home charging.

Above: EV driving heat map

Left: Smartphone app

Below: Time spent for charging and maintaining charge





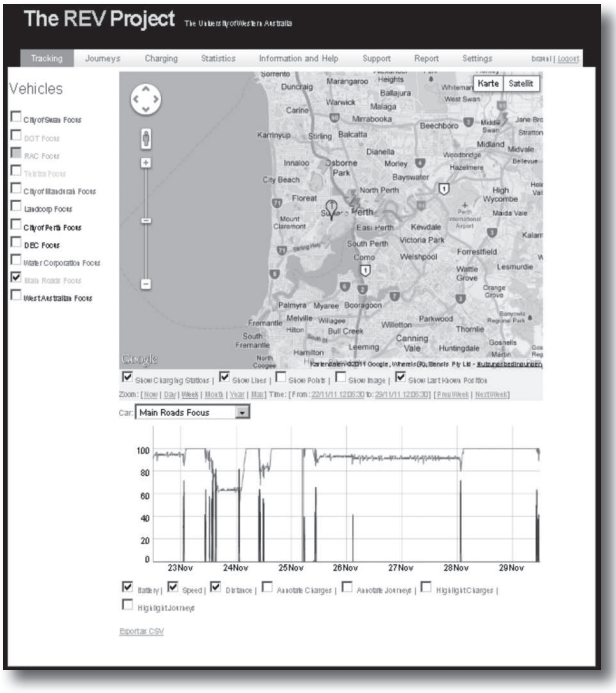
Above: Charging station activity

It can charge an EV with either the Combo CCS-1 or the CHAdeMO standard, in order to cover almost all fast-charge capable EVs from the USA/Europe (CCS) and Japan (CHAdeMO).

With 50kW DC charge power, the charger location had to be carefully considered. The selected bay next to the University Club has the advantage of sufficient power reserves of a large building and the driver can get a cup of coffee in one of the many cafes nearby while their car completes a fast charge.

Fast-charging stations will change the game for EVs, as they decouple parking from charging. During the ARC Linkage project we observed many cases of charging stations being used more for parking than for charging. This cannot happen with fast-DC stations, as the allowed usage time is limited to 30 minutes, after which the driver has to remove his/her EV and either drive it away or park it like a conventional vehicle. Fast-DC stations may also make

Below: Vehicle tracking and EV charging station locations in Perth



Above: An iMiEV charges at the new fast-DC charging station

commercial charging networks profitable, as they have a much higher customer throughput per day and offer a premium charging service for EV owners. From a research perspective, we are investigating the differences in energy efficiency between slow home charging, medium–fast AC charging, and fast-DC charging. We also plan to investigate the effect of repeated fast charging on battery life.

The new DC charging station is located off Hackett Drive in UWA's car park 3 next to the University Club and is open for use by the general public. For the time being, power is free and no parking fees apply.

The station was generously donated to the REV Project by a private Perth individual and was officially launched on 12 December 2014 by the Minister for Finance, Hon. Bill Marmion and by the Vice-Chancellor of UWA, Professor Paul Johnson.

Mr Paul Eddington and Professor Thomas Bräunl promoting the Electric Highway Project to Local Government Minister Hon. Tony Simpson on 11 September 2014 at Parliament House

ARC Linkage Project Partners

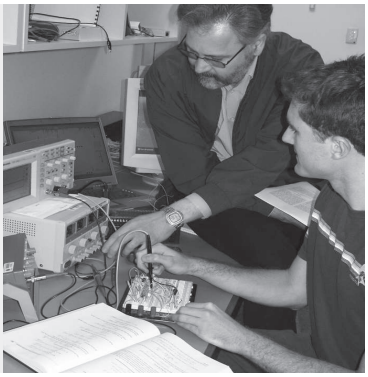
- WA Department of Transport
- C02 Smart
- AEVA
- Murdoch University
- Gull Petroleum
- UWA Business School
- UWA Faculty of Engineering, Computing and Mathematics

Sponsors:

ALTRONICS EV WORKS Swan Energy Telstra GALAXY SME HUBER+SUHNER

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/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.

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 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.

High Integrity Computer Systems Lab

Professor Gary Bundell, Professor Terry Woodings

The HICS lab engages in research into the engineering of high-integrity information and software systems. This requires development of tools and methodologies to aid the design, performance analysis, measurement and benchmarking of these systems and evaluation of the organisational and environmental context in which these systems need to operate. It is 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.

Dr Weiqun Zheng, Prof. Terry Woodings and Linda Barbour

Research has been in safety critical embedded systems for the resources industry, specifically in two rail and automation control applications for MRX Technologies. This 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.

Another thread of software engineering research is in software project and process metrics, involving 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. This research resulted in the DEng thesis entitled, 'An Exploration of Assumptions in Requirements Engineering' by Dr Sujatha Bulandran.

Terry has been a Visiting Professor at the Universiti Teknikal Malaysia Melaka since 2011. He assists in advising on teaching and laboratory facilities. 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 a number of masters students. Of particular interest is Mr Declan Chester who is researching the generation through software of the sounds of a quality violin. In 2014, Terry taught two Masters level courses—Software Testing and Quality Assurance; The 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'. A number of papers have been accepted for publication

Dr Weiqun Zheng was admitted to the degree of Doctor of Philosophy on 20 March, 2013. His thesis is entitled 'Model-based Software Component Testing'. Professor Terry Woodings and Linda Barbour attended his graduation ceremony.

Automotive Simulation System

Robotics and Automation Lab

Professor Thomas Bräunl, Dr Adrian Boeing

The Robotics and Automation Lab was established in 1998 and is dedicated to the research on 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: *robotics.ee.uwa.edu.au*

Autonomous Hexacopter

Our Pioneer mobile robot fleet has been upgraded to the ROS open source operating system and OpenCV computer vision library. With the many software packages available, this has given a productivity increase in developing mobile robot application programs.

A hexacopter multi-rotor unmanned aerial vehicle (UAV) has been designed and built in cooperation with the SEAM lab (Chris Croft). This autonomous vehicle is controlled by a modified Raspberry Pi controller and can perform pre-configured GPS way-point paths as well as tracking colour-coded objects on the ground. With the huge potential of these multi-rotor systems and their large range of application areas, we are trying to get a larger group of interdisciplinary researchers at UWA together to do cooperative research work in this area.

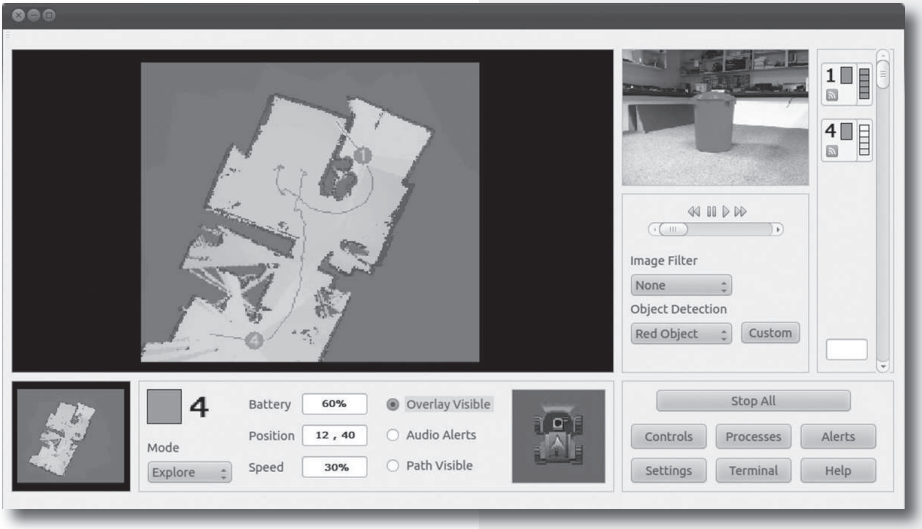
A project in between Electromobility and Robotics is our autonomous or driverless electric race car. This EV has a full drive-by-wire system with motor-driven steering, brake servo and an electronic accelerator pedal. A high-level control program uses a predefined path of GPS waypoints in combination with input from a Sick laser scanner, an Xsens IMU, a GPS and a camera to find a collision-free driving course for this car.

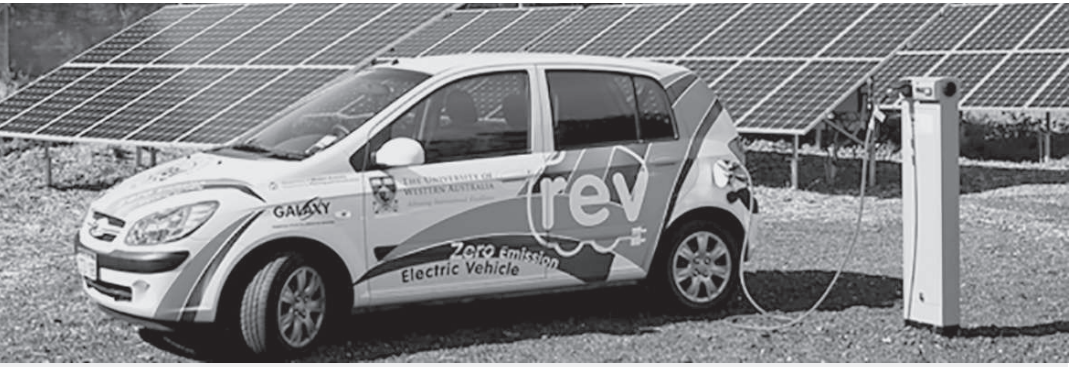
In 2013 and 2014 the Robotics and Automation lab hosted the following visitors:

- **Mr Wei Tang**
  Jiangsu University of Technology, China
- **Mr Alex Evers**
  RWTH University, Germany
- **Mr Rémi Keat**
  École Centrale Lyon, France
- **Mr Huri Ma**
  Zhejiang University, China
- **Mr Yuanlai Liu**
  University of Science and Technology of China

Autonomous SAE car

Simultaneous Localisation and Mapping (SLAM)





Smart Grids Lab

Professor David Harries

The Smart Grids Lab is currently involved in investigating electric vehicles (EVs). This work includes the University's Renewable Electric Vehicle (REV) Project and an ARC Industry Linkage Grant project for which Professor Bräunl is the Lead Researcher.

The ARC Linkage research project has two major components: a study of the potential impacts that recharging of EVs on electricity supply systems, and a socio-economic study of the factors influencing electric vehicle purchase decisions. The former component involves an assessment of recharging behaviour using a number of recharging stations installed as a part of the project in various locations in the greater Perth metropolitan area. This forms the basis of a PhD research project being undertaken by Stuart Speidel from the School of Electrical, Electronic and Computer Engineering, The recharging of each of the participating electric vehicles is recorded in real time, including the state of charge (SOC) of the battery before and after recharging, the location of the recharging station, the time and duration of the recharging. The participating EVs include members of the Electric Vehicle Association of WA, the University's electric vehicles and eleven Ford Focus vehicles being used in the first trial of electric vehicles in Australia. Driver preference for different types of recharging stations is also being tested and the results will inform decision makers about the optimal types and locations of recharging stations to maximise the take-up rate of EVs and to manage the potential impacts of EV recharging contributing to growth in peak electricity loads. A fast charging station has been installed at UWA in the University Club car park. The future work that the Smart Grids Lab group is planning to undertake includes research of charging efficiency in a variety of stations, cars and conditions.

The socio-economic study of the factors influencing electric vehicle purchase decisions includes a major survey of householders in Perth using a mail out survey to identify the reasons behind consumer vehicle purchase decisions, including purchase costs, cost per kilometre, vehicle range and vehicle noise. The study forms the basis of a PhD research project being undertaken by Fakhra Jabeen

from the UWA Business School. The results of the revealed preference survey will provide useful information on the likely take up rates of EVs under different fuel price and under technology improvement scenarios, which will assist decision makers in planning for the increasing percentage of the vehicle fleet comprising EVs. (See p20 for the student's summary).

The related work being undertaken by the Smart Grids Group includes studies of different battery technologies, the potential capacity of EVs to provide benefits for management of the electricity grid, such as providing a new large interruptible load, and the combined impacts of EVs and distributed generation technologies, including 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 35 years has included academic teaching, research, policy and planning, consulting (including to the governments of Saudi Arabia and Brunei Darussalam) and the representation of governments 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, and a member of two working groups set up by the Prime Minister: The Gas Reform Implementation Group that charged with developing a legislative framework for a third party access regime to natural gas pipelines in Australia, and the National Renewable Energy Target Working Group that was established to develop a mechanism for implementing a national commitment to increase the proportion of electricity supplied in Australia from renewable energy sources.

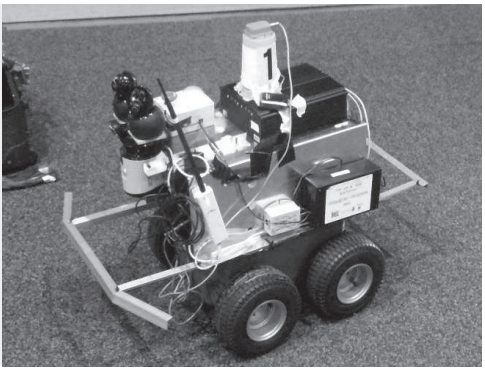
Currently David is a director of two companies, EMC Ltd and Solar Farm Carnarvon Pty Ltd. He is also an executive director of EMC Solar Construction Pty Ltd, where he is employed full time as the Technical Director. David is also currently the President of the Conservation Council of Western Australia.

Electric vehicle enthusiast Joseph Law charges up at the UWA charging station

Student Group Activities

Autonomous Ground Vehicle Competition (AGVC)

Robotics Student Team



In 2013, students Stuart Speidel and Thomas Smith represented UWA in the Australian Defence Science and Technology Organisation's Autonomous Ground Vehicle Competition (AGVC) hosted by Deakin University from 28 November to 1 December 2013. The competition requires competitors to develop autonomous robotic vehicles to successfully navigate through an outdoor obstacle course within a certain time limit. To complete the challenge competitors must: (1) navigate autonomously within the marked lanes; (2) maintain minimum/maximum speed between 1.6–16 km/h and (3) negotiate flags and obstacles and locate multiple navigation waypoints. Even as one of the smallest teams with a very low budget the UWA students passed both the technical inspection and the qualifying navigation course allowing them to compete, where they went on to travel the 8th greatest distance of 12 teams. None of the teams completed the competition's challenge, leaving the current rules and grand prize unchanged for the next year. The UWA Robotics Team is competing again in December 2014.

Formula SAE Competition

UWA Formula REV Team

The UWA Formula REV Team represented Western Australian electric vehicle development, achieving Third Place in the Electric Vehicle category of the 2013 Formula SAE-Australasia competition in Melbourne.

The annual competition, held in December, was an opportunity for 22 teams from Australian and international universities to showcase their student engineers and technical achievements.

The students of The Renewable Energy Vehicle Project strive to explore electromechanical drivetrains like no other university racing team, thanks to our sponsors Swan Energy, and our new sponsor Tesla Forum WA.

This was our first entry into the prestigious competition and it was great to see so much enthusiasm towards our concept. Our long awaited four-wheel-drive race car was praised for its innovation and ambition by design judges, and there was plenty of room for further innovations within the same concept.

We were very proud to represent UWA alongside the prestigious UWA Motorsport Team, and to produce two racecars in one year from UWA for the very first time.

The 2014 Project anticipates a strong effort this year, with more students and a revised concept based on the lessons learned from this car.

The REV Project operates upon the diligence of motivated students, and through the support of a wide range of industries. For more information see: *www.REVproject.com*.

REV '13 Technical Specifications:

- Propulsion: 4x 15kW (peak) Brushless Direct Current Motors, mounted in four symmetrical hub assemblies.
- Energy Storage: 2x 26V (52V total), 6.4kWh LiFePO4 Accumulators, mounted either side of driver.
- Wheels: Hoosier tyres, 13" wheel rim size.
- Chassis: Custom steel space-frame chassis.
- Mass: 275kg, 50-50 distributed.
- Range and endurance: To be determined.
- Safety features: Forward impact attenuator, side impact structure, Insulation Monitoring Device (IMD), Safety interlock circuit.

Household Survey of EV Purchase and EV Charging

Conducted by Fakhra Jabeen

Supervised by Professor John Taplin, Professor Brett Smith, Dr Doina Olaru and Professor Thomas Bräunl

The household survey provided a total of 450 complete responses through a mail-out questionnaire, and 305 respondents through PureProfile panel data.

The mail-out sample showed an average of 1.85 vehicles per household, similar to an average of 1.8 vehicles per household for Perth residents. A comparison of the number of vehicles owned by mail-out and PureProfile samples was performed by using a t-test that is: $t(8)=2.3$; $p=0.99$, indicating that in this respect the two samples are not significantly different; approximately 60% of respondents had at least two or more cars in both the mail-out and PureProfile samples.

In the mail out-survey responses there was a large variety of car brands. The most common was Toyota (18%) followed by Holden (11%). A small proportion (4%) of vehicles had an engine size greater than 4 litres, and 91% of vehicle fuel costs were paid by households. Another observation is that 33% of respondents indicated that it is 'somewhat likely'/'likely' that they will purchase an electric vehicle in the next five years. Looking at the fuels already used by households: petrol was the most common at 84%; 12% were Diesel, while 1% had EV/Hybrid vehicles. Comparing this with the Australia-wide data, petrol-powered vehicle registrations make 79.9% of the total vehicle fleet, while diesel-powered vehicle registration (including heavy vehicles) make 17.2%, and the rest are LPG, dual fuel and electric vehicles (ABS, 2013).

More than half of the respondents in both the mail-out and PureProfile samples expect to buy a new car in the next three years. When requested to indicate the amount that they were willing to spend to purchase their next car, 8.7% of the mail-out sample reported above $50K, 21.3% between $35K and $50K, 42.3% between $20K and $35K, with the remainder (27.7%) willing to spend less than $20K. The proportions in the PureProfile sample differed considerably; a larger part (39.7%) of the sample were willing to spend less than $20K, with 38.7% between $20K and $35K, 16.7% between $35K and $50K, and approximately 5% of sample reported above $50K as the amount they are willing to spend for their next vehicle.

In terms of spatial coverage, the mail-out sample did not represent all suburbs of Perth. There were more respondents in the southern part of the city and they were more clustered along the main railway line compared to the north of the city. The online PureProfile sample uniformly covers metropolitan areas of Perth with almost an equal spread of respondents across the north and south of Swan River.

Findings from this study suggest that households from metropolitan areas of Perth are sensitive to purchase and running cost of vehicles. Households preferred short charging times for their vehicles, low noise and low emissions. A large number of respondents were concerned about environment. Another interesting finding from one of the household sample indicated that respondents had a strong preference for large number of charging stations. This reflects a requirement for establishment of charging infrastructure in Perth.

Range remains a barrier in the EV uptake. In the focus group conducted in November 2011 in the WA EV trial, drivers were concerned about the range of an EV and they clearly indicated in their discussions that they would pick EV if either the range is extended or there is availability of fast charging stations. This is confirmed through findings from the household study.

Awards and Prizes

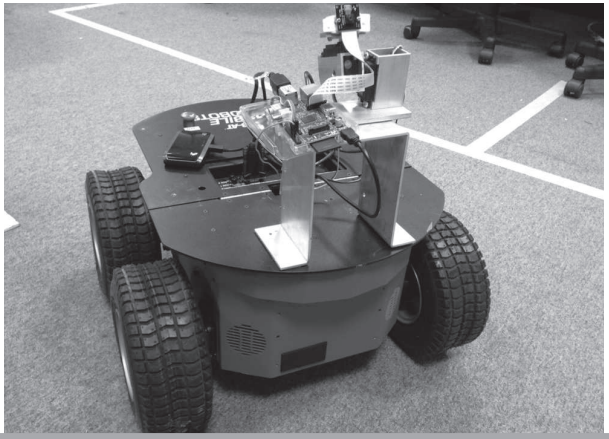
APICTA
Asia Pacific ICT Alliance
AWARDS

2014
iAWARDS

THE
INCITE
AWARDS

PhD student Stuart Speidel won the Asia–Pacific ICT Alliance (APICTA) Awards for the entire Asia–Pacific region. He was awarded the prize in Jakarta on 30 November 2014. Stuart won this award in the Sustainability and Environmental Technology category for the REView project, a web-based portal software package that collects statistics from electronic vehicle trackers, vehicle charging stations, and on usage of renewable energy resources. REView will enable drivers, fleet managers and charging station operators to make more effective business decisions.

This win follows on the heels of his winning the 2014 iAwards National Postgraduate Tertiary Student category on 29 August in Melbourne, recognising the most outstanding project or research undertaken by a postgraduate student or group of students during either coursework or research Masters, Doctoral or Post-Doctoral programs and also the 2014 WAiTTA Incite and Peter Fillery award in the Student Domain (WA IT Award) awarded on 30 June in Perth.



TELSTRA M2M
UNIVERSITY CHALLENGE

A CIIPS student team with team leader Marcus Pham was finalist in the 2014 Telstra M2M (Machine-to-Machine) University Challenge with project HAZbot, supervised by Thomas Bräunl. The team was one of the top eight finalists out of 23 entries.

Publications

Conference Papers

Drage, T., Kalinowski, J. and Bräunl, T. *Development of an Autonomous Formula SAE Car with Laser Scanner and GPS*: 19th World Congress of the International Federation of Automatic Control, IFAC'14, Aug. 2014, Cape Town, South Africa

Hidalgo, F. and Bräunl, T. *Review of Underwater SLAM Techniques*: ICARA 2015, Queenstown NZ, Feb. 2015)

Jacobs, W., Hodkiewicz, M. and Bräunl, T. *A cost-benefit analysis of electric loaders to reduce diesel emissions in underground hard rock mines*: IEEE IAS 2014 Annual Meeting, 5–9 Oct. 2014, Vancouver Canada

Jabeen, F., Olaru, D., Smith, B., Braunl, T. and Speidel, S. *Electric Vehicle Battery Charging Behaviour: Findings from a Driver Survey*: Australasian Transport Research Forum, 2–4 Oct. 2013, Brisbane

Kalinowski, J., Drage, T. and Bräunl, T. *Drive-By-Wire for an Autonomous Formula SAE Car*: 19th World Congress of the International Federation of Automatic Control, IFAC'14, Aug. 2014, Cape Town, South Africa

Masek, M., Ophelders, F., Pangeni, S., Boeing, A. and Bräunl, T. *WAMbot: Simulation and Modelling of a Team of Autonomous Mobile Robots*: IEEE Tencon, Xi'an China, Oct. 2013

Reid, R., Cann, A., Meiklejohn, C., Poli, L. and Bräunl, T. *Cooperative Multi-Robot Navigation, Exploration, Mapping and Object Detection with ROS*: IEEE Intelligent Vehicles Symposium, Gold Coast Australia, June 2013

Journal Articles

Drage, T., Kalinowski, J. and Bräunl, T. *Integration of Drive-by-Wire with Navigation Control for a Driverless Electric Race Car*: IEEE Transactions on Intelligent Transportation Systems, Oct. 2014)

Jacobs, W., Hodkiewicz, M. and Bräunl, T. *A cost-benefit analysis of electric loaders to reduce diesel emissions in underground hard rock mines*: IEEE Transactions on Industry Applications, 2014

Jacobs, W., Bräunl, T. and Hodkiewicz, M. *The diesel-electric debate for underground mines—health and economic perspectives*: Australian Resources & Investment Magazine, ARIM, vol.8, no.1, Mar. 2014

Rahim, S., Yusof, A. and Bräunl, T. *Genetically evolved action selection mechanism in a behaviour-based system for target tracking*: Neurocomputing, 2014)

Speidel, S. and Bräunl, T. *Driving and charging patterns of electric vehicles for energy usage*: Renewable and Sustainable Energy Reviews, vol.40, Aug. 2014

Wäger, G., McHenry, M., Whale, D. and Bräunl, T. *Enhanced EV and ICE vehicle energy efficiency through drive cycle synchronisation of deferred auxiliary loads*: Intl. J. of Electric and Hybrid Vehicles (IJEHV), Oct. 2014

Wäger, G., McHenry, M., Whale, J. and Bräunl, T. *Testing energy efficiency and driving range of electric vehicles in relation to gear selection*: Renewable Energy, Elsevier, no.62, Feb. 2014

Book

Bräunl, T.
Embedded Robotics—Mobile Robot Design and Applications with Embedded Systems: Russian translation, Izhevsk Institute of Computer Science with Springer-Verlag, 2012

Reports

Pandey, R., Pham, M., White, J. and Bräunl, T. *Road Testing the Holden Volt Extended Range Electric Vehicle November 2013–February 2014*: UWA, Apr. 2014, pp (17)

Mader, T. and Bräunl, T. *Western Australian Electric Vehicle Trial—Final Report*: WA EV Trial Consortium, UWA, June 2013, pp. (56)

Magazines and Online

Bräunl, T.
Costly, toxic and slow to charge? Busting electric car myths: The Conversation, Melbourne Australia, article no.21321, 20 Feb. 2014

Bräunl, T.
Trial complete: electric vehicles can work in Australia: The Conversation, Melbourne Australia, article no. 118843, 2 Dec. 2013, Republished by the Science Network Western Australia on 5 Dec. 2013

Bräunl, T.
Setting the standard: Australia must choose an electric car charging norm, The Conversation, Melbourne Australia, article no. 16277, 16 Sep. 2013, Melbourne Australia, Republished by the Science Network Western Australia on 19 Sep. 2013

Research Grants

Professor Thomas Bräunl, Professor John Taplin and Professor David Harries
WA Electric Vehicle Trial: Analysis and modeling of driving patterns for limited-range electric vehicles.
ARC Linkage Project 2010–2015: $803,000
Industry Partners: WA Department of Transport, CO2 Smart and AEVA.

Assistant Professor Pejman Rowshan Farzad, Professor Martin Ebert, Professor Sean Bydder, Dr Colin Tang, Professor Thomas Bräunl and Associate Professor Du Huynh
More Accurate Prostate Radiotherapy Treatments.
Cancer Council of WA—Suzanne Cavanagh ECI Grant—Safety and Quality: $35,000
Duration: 1/1/2015–31/12/2015

Professional Activities

Journal Editorial Boards and Technical 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.
- Member of to the Board of Governors (BoG) of the IEEE Intelligent Transportation Systems Society (ITSS), 1 January 2014–31 December 2016.
- Member EL-054 Standards Australia. *Demand response for electric vehicle supply equipment (EVSE) intended for residential installations*: Department of industry Working Group 4

Conference Chairs and Program Committees

Bräunl, T.

- Program Committee, Australasian Conference on Artificial Life and Computational Intelligence (ACALCI 2015), Newcastle, Australia
- Associate Editor 2015, IEEE International Conference on Robotics and Automation (ICRA), 2015 Seattle, WA
- International Program Committee, 19th International Conference on Knowledge-Based and Intelligent Information and Engineering Systems (KES), 2015 Singapore
- Program Committee, International Conference on Autonomous Robots and Agents (ICARA), 2015 Queenstown, NZ
- Steering Committee, IEEE Pacific-Rim Symposium on Image and Video Technology (PSIVT), 2015 Auckland, NZ
- Steering Committee, International Workshop on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (MASCOTS), 2015 Atlanta, GA
- Steering Committee, International Workshop on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (MASCOTS), 2014 Paris
- Steering Committee, International Workshop on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (MASCOTS), 2013 San Francisco, CA
- Technical Director, WA Electric Vehicle Trial, 2010-2013
- Intl. Environmental Co-operation Forum and Exhibition MIECF, 21–23 March, Macao, China
- E-Mobilia World, 26–27 March, Kuala Lumpur, Malaysia
- IFAC Symposium on Intelligent Autonomous Vehicles IAV 2013, 26–28 June, Brisbane, Australia
- ICINCO 2013, 29–31 July, Reykjavik, Iceland
- Program Co-Chair for Pacific-Rim Symposium on Image and Video Technology (PSIVT) 2015

Woodings, T.

- Chair of the Australian Computer Society annual distinguished lecture award—Dennis Moore Distinguished Oration

Project Demonstrations

Bräunl, T.

21–28 November 2014 REV Lotus Exhibition at Sustainability Week, Scitech, Perth

13 October 2014 Robotics and REV lab visit and demonstrations for Christ Church Grammar School

10 October 2014 Robotics and REV lab visit and demonstrations for University Teknologi, Mara, Malaysia

10 August 2014 REV Autonomous EV Demonstrations, UWA Open Day

10 August 2014 Hexacopter Robotics Demonstrations, UWA Open Day

1 April 2014 REV EV Demonstrations at Environfest, UWA, Perth

8 March 2014 REV Racer Electric Lotus Demonstration at Elektrokhana, DTEC Driving Centre, Perth Airport

12–16 December 2013 Formula SAE-Australasia Electric Competition, Victoria University, Melbourne

28 November–3 December 2013 AGVC Robotics Competition, Deakin University, Melbourne

7 November 2013 REV and Robotics Demonstrations, for Scotch College High School

6 November 2013 Robotics Lab and REV Demonstrations for Engineering Delegation from University Teknologi Malaysia (UTM)

4 November 2013 Robotics Demonstration at Our Lady of Mercy Primary School, Girrawheen

30 October 2013 Robotics Demonstrations at the Our Lady of Mercy Primary School

25 October 2013 REV Electric Vehicle Exhibition at the Model Solar Car and Boat Challenge

16 August 2013 REV Lotus Presentation at Lynwood High School

11 August 2013 REV Demonstration of Electric Lotus and Electric Getz and Autonomous SAE Car Demonstration for UWA Open Day

11 August 2013 Robotics Demonstration of Autonomous Hexacopter for UWA Open Day

31 July 2013 Autonomous SAE Car Demonstration for Japanese High School, Perth

1 May 2013 REV Project Demonstration for International Agents at UWA

10 April 2013 REV Demonstrations for Leadership WA Meeting, Perth

23 March 2013 REV Demonstrations for Earth Hour, Perth

19 March 2013 REV Demonstration at EnviroFest, Perth

10 March 2013 REV Demonstrations of REV Racer, REV Eco, REV-SAE 201 and REV SAE-2013 at Electrokhana, RAC DTEC Driving Centre, Perth Airport

15 January 2013 REV Demonstration for Scitech/CSIRO, Perth

11 December 2012 REV Demonstration at Mount Lawley Senior High School

16 November 2012 REV and Robotics Demonstrations for Bosch Investments, China

2 November 2012 REV EV Trial Presentation at Kapinara Primary School

25–26 October 2012 REV Exhibition for Model Solar Car Challenge, Perth

19 September 2012 REV SAE-Electric Exhibition at the UWA Postgrad Expo

19 September 2012 Representing REV and Perth's EV charging station network at the Sustainability Innovation Think Tank, Fremantle

7 September 2012 Charging Station demonstration for Senator Christine Milne, Australian Greens Leader, UWA

17 August 2012 REV Demonstration, Lynwood Senior High School, Parkwood

12 August 2012 REV Demonstrations and Robotics and Automation Lab Demonstrations, UWA Open Day

3 August 2012 REV Demonstration for representatives of University of Notre Dame, Illinois

17 July 2012 REV Demonstrations for "A Day in the Life of an Engineering Student", UWA

Invited Talks

Bräunl, T.

17 February 2015 Keynote Address: *Robot SImulation: The Good, The Bad, and The Ugly*, The 6th International Conference on Automation, Robotics and Applications (ICARA 2015), Queenstown, New Zealand

10 August 2014 Keynote Address: *The Electric Vehicle Revolution—Lessons learned form the Western Australian EV Trial*, TUM Expert Seminar on Electromobility in Tropical Megacities, Singapore

29 November 2013: *Australia's First Electric Vehicle Trial*, Sustainable Energy Association SEA, Perth

25 October 2013: *Electric Vehicles*, Building Better Schools Conference, Perth

17 Aug 2013: *The Electric Car Revolution*, University of the 3rd Age, Melville

26 Mar 2013 Keynote Address: *Electric Vehicle Trial in Western Australia*, E-mobilia World, Kuala Lumpur

21 Mar 2013 Keynote Address: *Electric Vehicle Charging Future*, MIECF Intl. Environmental Co-operation Forum, Macao

8 Oct 2012: *Electric Vehicles*, Public Works Training Week, Esplanade Hotel, Fremantle

31 July 2012 Keynote Address: *From Robotics to Automotive Research*, An Evening with Young Australian of the Year, Marita Cheng, Perth

Media Reports

TV

SBS, *Australia's first Combo fast-DC charging station*, 24 November 2014

Channel 11, Scope, Student Science, *REV Autonomous SAE Car*, 23. Oct. 2014

ABC Catalyst, *REV Racer Electric Lotus and EV Trial Ford Focus*, 7 February 2013

Channel 10, *EV Charging Network*, Nick Way, 2 September 2012

Channel 7, Today Tonight, *Clever Cars–Obstacle avoiding BMW X5*, report and interview, Clever Country, Monica Cos, 6 July 2011, 18:30

Channel 7, Today Tonight, *Electric Vehicle Trial and Acceleration Tests*, 10 June 2011, 18:30

ABC TV, Catalyst, *Robot Wars*, 24 February 2011, 20:00, Science Magazine

Radio

ABC 702 Sydney, *Western Australian Electric Vehicle Trial*, interview with Dominic Knight, 2 December 2013, 17:00

ABC Radio Tasmania, *Introduction of Electric Cars as Fleet Cars in Tasmania*, Daniel Brown, 14 October 2013, 16:00

ABC Radio, *Electric Vehicle Trial in Perth*, with Robyn Williams, 12 November 2012, aired 6 April 2013 12:05

JJJ Radio, *Electric Vehicles in Australia*, with Stuart Speidel, Kaitlyn Sawrey, 28 March 2012 14:15

Electronic Media

Science WA, *Manual surpasses auto in electric test*, Interview with Nic White, 8 October 2013 *http://sciencewa.net.au/topics/technology-a-innovation/item/2441-man*

RAC, *Western Australia's electric vehicle trial*, 26 April 2013 *http://rac.com.au/About-Us/Community/Environment/What-the-RAC-is-doing.aspx*

RAC, *Advocacy for environmental sustainability*, 24 April 2013 *http://rac.com.au/About-Us/Community/Environment/What-the-RAC-is-doing.aspx*

The Sydney Morning Herald, Digital Life, *No more lonely nights: romantic robots get the look of love*, Interview with Elle Mitaros, 28 March 2013 *http://www.smh.com.au/digital-life/digital-life-news/no-more-lonely-nights-romantic-robots-get-the-look-of-love-20130327-2guj3.html*

WA Today, *No more lonely nights: romantic robots get the look of love*, Interview with Elle Mitaros, 28 March 2013 *http://www.watoday.com.au/digital-life/digital-life-news/no-more-lonely-nights-romantic-robots-get-the-look-of-love-20130327-2guj3.html*

Robots Podcast, *The Wambots Team*, Interview, with Ron Vanderkley, 30 November 2012 *http://www.robotspodcast.com/podcast/mp3/robots-20121130-episode118.mp3*

Electronics News, *WA electric vehicle trials yield valuable data*, Isaac Leung, 10 July 2012 *http://www.electronicsnews.com.au/news/wa-electric-vehicle-trials-yield-valuable-data*

Print Media

Auto Engineer, 2013 *Formula SAE-Australia*, issue 50, December 2013, pp 13 (1)

Subiaco Post, *Rev heads get charged up in Subiaco*, interview on new charging station installation in Subiaco, vol 40, no 48, 30 November 2013, pp 4 (1)

RAC Horizons, *All electric*, Ruth Callaghan, October/November 2013, pp 39–40 (2)

RAC Horizons, *Power up*, October/November 2013, pp 41 (1)

RAC Horizons, *Where to charge*, October/November 2013, pp 41 (1)

The West Australian, WestWheels, *The power rangers*, interview with Karl Peskett on owning an EV and charging station placements in Perth, 13 July 2013, p 1–4 (4)

Subiaco Post, *Subi leads charge*, report on electric vehicle charging station plans in Subiaco by Lloyd Gorman, 13 July 2013, p 15 (1)

Sunday Times, *Adaptable living space for a wireless future—One home fits all,* interview with Claire Bickers, 9 June 2013, p 30 (1)

UWA News, *What drives FM staff? Something clean, quiet and low-carbon*, no 4, June 2013, p 16 (1)

Sunday Times, *Adaptable living space for a wireless future—One home fits all*, Interview with Claire Bickers, p 30 (1)

UWA News, *Time to give back 100*, April 2013, no 2, pp 12-13 (2)

The West Australian, *Energising WA, Fast-charging network trial*, 22 March 2013, p 20 (1)

The West Australian, *Energising WA*, Less emissions mission, 22 March 2013, p 10 (1)

The West Australian, *Free treat for WA's motorsport purists*, Adrian Chambers, 6 February 2013, p 18 (1)

Business News Perth, *Electric cars may plug into solar patterns*, Mark Pownalt, 31 January 2013, p 27 (1)

Scoop, National, *Electrifying research*, on WA Electric Vehicle Trial and plans for Electric Highway, 1 January 2013, pp 40 (1)

Sunday Times, *Word on the street*, Greg Thomson on the electric car charging network, 30 September 2012, pp 50 (1)

Stirling Times, *New network set to spark interest in electric cars*, based on interview, 25 September 2012, pp 4 (1)

UWA News, *Filling up with green energy*, report on the visit of Senator Christine Milne, Australian Greens Leader, pp 13 (1)

Subiaco Post, *Network to recharge Perth's electric cars*, based on interview, 15 September 2012, pp 52 (1)

Computerworld, CIO, Techworld, *Military Use of Robots*, Interview with Stephanie McDonald, 29 August 2012

UWA News, *No queues at this 'refuelling' station*, Lindy Brophy, 20 August 2012, pp 3 (1)

Capital City Daily and West Australian, *Electric future—The three-year electric vehicle trial continues with The University of Western Australia (UWA) at the forefront*, Energising WA, 16 March 2012, pp 22 (2)

Mandurah Coastal Times, *Experts on Solar*, General News, 8 February 2012, pp 4 (1)

RAC Horizon, *RAC Ford Focus electric patrol vehicle*, issue 28 February–March 2012, pp 43 (1)

Abstracts of Final Year Project Dissertations

Michael Baxter

Supervisor: Professor Thomas Bräunl

Development of a hexacopter mid-level control system

Multirotor unmanned aerial vehicles (UAVs) such as quadcopters and hexacopters have quickly become popular platforms for aerial autonomy research in recent years. The UWA Hexacopter group explores the capabilities of a Raspberry Pi computer on a hexacopter in on-board autonomous control and navigation. This research is geared towards agricultural surveying and inspection applications.

This project is focused on the development of a mid-level system, providing a user library for control over the hexacopter. This builds on from last year's work, complimenting the hardware with a suitable software system. Programs were written to interface with the hexacopter's flight board as well as to gather data from sensors including: GPS, IMU and camera. Applications of the system were explored in both GPS and camera-based navigation. GPS-based navigation was achieved using feedback control and path-planning algorithms. Camera-based navigation involved tracking a coloured object using centre of mass and cam shift algorithms.

Alexander Beckley

Supervisor: Professor Thomas Bräunl

Drive Train for an Electric Jet Ski Conversion

The jet ski is a small watercraft designed to carry one or two people for short distances on water, first commercially released in 1973, and commonly associated with water sports and family recreation. Although not as common as the motorcar or motorbike, Jet skis have never been considered an environmentally friendly vehicle due to their high level of noise and environmental pollution. Similar to small cars and motorbikes, they typically use 4-stroke petrol engines with capacity around 1500cc, and with petrol tanks up to 78 Litres.

The RevSki project is the first of its kind in Australia as it will test the performance characteristics of an entirely electric powered jet ski against a conventional petrol powered jet ski. The aim is to determine if an environmentally friendly, low emission electric jet ski can be competitive with petrol powered jet skis in the modern market. This thesis documents the design of the electric drive train including an in-depth analysis of all key design decisions as well as the selection key components, made throughout the design phase of the REVSki Project. The electric drive train includes the battery system, high and low voltage wiring, the motor, safety systems and control systems.

Jessen Beinart

Supervisor: Professor Thomas Bräunl

Advanced Embedded Systems

The Advanced Embedded Systems project's goal is to update the EyeBot hardware and software. EyeSim is the Eyebot's simulator; a multiple mobile robot simulator that runs Eyebot programs and models a robot's movement and sensors.

The purpose of this project involves the porting of the EyeSim simulator from Windows to Mac Operating Systems. A brief overview of simulators, their history and operation will be covered. An in-depth look at the workings of the EyeSim simulator is presented. The author has provided the porting process, including version control, the installation of the latest versions of open source libraries, bugs and their solutions and debugging methods. The final results are presented, along with suggestions for further work for the updating of EyeSim.

Lochlan Brown

Supervisor: Professor Thomas Bräunl

Improving Performance Using Torque Vectoring on an Electric All-Wheel-Drive Formula SAE Race Car

Various forms of electronic stability, traction and launch control have existed for over two decades, improving safety, sports performance and off-road capabilities of vehicles. These technologies involve individual control of each wheel's drive torque or braking force in response to the dynamics of the driving conditions and the driver's intentions. With the exception of launch control, applications of these electronic handling-improvement systems are rarely seen on the Formula SAE platform. This is mostly due to the limitations of a combustion engine and conventional drivetrain; individual control of torque to each wheel requires additional mechanical systems adding unjustifiable weight and complexity for the resulting gains. However, an all-wheel-drive electric Formula SAE vehicle with four individual hub motors has the potential for experiments with torque vectoring via electronic means, with minimal additional mechanical systems.

The University of Western Australia's Renewable Energy Vehicle (REV) group has been designing such a vehicle for the 2013 Formula SAE competition in Melbourne. Processing driver inputs such as steering angle, throttle and brake position in addition to the actual dynamic state of the vehicle observed through wheel speeds, three axes of acceleration and angular velocities, a torque vectoring algorithm has been designed and implemented on an ARM Cortex M3 microcontroller and has achieved significant improvements in cornering performance.

Rowan D. Clark

Supervisors: Professor Thomas Bräunl and Dr Roshun Paurabolly

REVski—Electric Jet Ski Project investigation and proposal of thermal management system and auxiliary mounting assembly

The REV project is a UWA initiative aiming to design and develop environmentally sustainable technologies for future transportation. The REVski project involves the electric conversion of a personal watercraft to demonstrate the possibilities of renewable energy use in recreational watercraft. This particular project focuses on the thermal management system and auxiliary supporting structure for various components of the REVski. Various constraints and considerations, namely cost, time, materials and interfaces, have influenced the steps taken during the process and ultimately shaped the final result. A thermal management system has been proposed and certain features of the system have been designed to cool the motor and motor controller. An assembly for mounting various auxiliary components within the REVski has also been designed adhering to the same constraints and considerations as the design process for the thermal management system. Future works and recommendations on further study in the related field are also proposed.

Merrick Cloete

Supervisor: Professor Thomas Bräunl

Integrated Image Processing , Object Tracking and GPS recording on a Hexacopter system

In this project image processing and object tracking for a mobile Hexacopter system have been implemented to allow for the detection,

tracking and GPS recording of red objects. A connected components algorithm is implemented to detect multiple objects and determine how many are within the camera's current field of view as well as their respective centre of masses with respect to the image. A CAMshift algorithm is implemented to track red objects as they move or as the Hexacopter moves which can maintain tracking on objects even when the range or depth of the objects is dynamically changing. Furthermore, GPS locations of objects are able to be recorded utilising the Hexacopter's on-board GPS. Tracking of multiple objects at once and recording of their location using GPS has applications for surveying—in particular the ability to combine the GPS, IMU and image processing techniques to generate on-the-fly GPS coordinates of objects without flying by them allows for faster surveying and data collection with Hexacopter drones.

Christopher Corke

Supervisors: Professor Adam Wittek
and Professor Thomas Bräunl

Conversion of Petrol Powered Watercraft to Electric Featuring an Investigation into the Battery Mounting System and its Compatibility

The renewable energy vehicle (REV) jet ski electric personal watercraft is an initiative being undertaken by the REV project at the University of Western Australia. The aim of this project is to convert a commercial personal watercraft from being powered by petrol in an internal combustion engine to an electric driven craft. While this dissertation starts off containing information that is important to the success of the project as a whole its primary focus is on the battery restraint system. Previously a design had been proposed and procured. However it was found to be unsuitable for the task. This dissertation attempts to rectify this through modifications, however, when it becomes apparent that the design is inadequate a completely new approach is taken. The design process focused on how to design a restraint that would fit into the difficult hull geometry while fulfilling the necessary requirements of sealing in a marine environment. The final design also takes into account the possible future heat dissipating requirements. The battery system as a whole is a significant component to be added to the original personal watercraft. It is therefore important that its effect to the mass of the craft and its centre of mass is investigated. It is estimated that the mass has increased by between about 69.2 kg to159.2 kg compared to the original fully fuelled Sea-Doo which would also decrease the carrying capacity by the same amount. It was also estimated that although the centre of mass was changed it was somewhat insignificant.

Thomas H. Drage

Supervisor: Professor Thomas Bräunl

Development of a Navigation Control System for an Autonomous Formula SAE-Electric Race Car

This dissertation describes the development of a high level control system for an autonomous Formula SAE race car featuring fusion of a 6-DOF IMU, a consumer grade GPS and an automotive LIDAR. Formula SAE is an annual competition organised by the Society of Automotive Engineers which has recently introduced the new class SAE Electric. The aim of the Autonomous SAE car developed in this project is to provide UWA with a platform for research into driverless performance cars. The car features electric motors driving each of the two rear wheels via independent controllers and has full drive-by-wire control of the throttle, steering and (hydraulic) braking system. The project consists of the design and implementation of a navigation control system which uses a Linux PC to interface with a range of sensors as well as the drive-by-wire system, safety systems and a base station. The navigation control system is implemented as a multi-threaded C++ program featuring asynchronous communication with hardware outputs, sensor inputs and user interfaces. The Autonomous SAE car can drive

following a map consisting of “waypoints” and “fence posts” which are recorded by either driving the course manually or through a GoogleMaps based web interface. Mapped driving is augmented by the use of a LIDAR scanner for detection of obstacles including road edges for which a novel algorithm is presented. GPS is used as the primary navigation aid, however sensor fusion algorithms have been implemented in order to improve upon the measurement of the car’s position and orientation through the use of a 6-DOF Inertial Measurement Unit. Attention to safety is essential in such a project as the car weighs in excess of 250kg and is capable of driving at a speed of 80km/h. Safety systems are implemented as part of the navigation controller as well as through independent hardware. Facilities for remote intervention and emergency stopping are provided through a wireless link to the base station as well as through hard-wired systems on the car itself. Measurements derived from autonomous test driving as well as the sensor fusion and road-edge detection algorithms are presented as well as an overview of the future potential of the platform as a research tool.

Gabriel Feng

Supervisor: Professor Thomas Bräunl

Renewable Energy Vehicles’ User Interface: Implementation of a Raspberry Pi and Engine Audio Replication System

In this time when vehicles are getting more and more sophisticated, and information is abundant, there are many sources of distraction for a driver. A vehicle’s user interface can be a major contributor if poorly designed. Time taken to complete a task on the user interface and the ergonomics of the action are two factors to consider in the design.

In this project the existing system in both Renewable Energy Vehicles are moved to a new platform and improved upon to provide a safer and more functional user interface. A comparison will also be done between the touchscreen interface in the Lotus Elise, and a one dimensional scroll wheel in the Hyundai Getz. The previous Engine Audio Replicating System will also be re-implemented.

Timothy Forrest

Supervisor: Professor Thomas Bräunl

SIMD Microprocessor for Image Processing

Digital images are merely matrices, with each element representing a single pixel. There are many image processing routines that consist of performing the same operation on each pixel of an image, such as brightness adjustments and edge detection. Performing the same operation on large sets of data is exactly what parallel processing is great for, allowing huge increases in performance.

This project examined the use of a Single Instruction Multiple Data (SIMD) microprocessor for the parallel processing of images. The SIMD microprocessor as the name suggests is designed to perform a single instruction on any amount of data (for each pixel in this case) in a single operation cycle. The design and preliminary simulation of the SIMD microprocessor was done using Retro, a graphical circuit design tool. Retro had to first be further developed and improved to allow the simulation of an SIMD microprocessor. The circuit was then developed and simulated, a number of image processing routines were simulated to show the performance gains over a non-parallelised processor. Retro was also extended to allow the generation of VHDL from the graphical circuit. VHDL stands for VHSIC Hardware Description Language and is a coding language used for electronics design. The VHDL for a single Processing Element has been generated and tested, however the VHDL generation for the entire SIMD system still requires further work. Once the VHDL generation is complete the full circuit can be synthesised and simulated and finally implemented on a field-programmable gate array (FPGA) in the future.

Martin French

Supervisor: Professor Thomas Bräunl

Advanced Path Planning for an Autonomous SAE Electric Race Car

The UWA Autonomous SAE Electric Race Car was built in 2013 as a student project to provide a platform for learning in the field of Autonomous Vehicles and Driverless Performance Cars. The car was provided with the necessary hardware and primitive control software for autonomous driving. As such, this project is concerned with the implementation of an advanced path planning algorithm with a primary goal of obstacle avoidance. The implemented path planning algorithm will accept a set of waypoints entered on the cars control software, build an arc-length parameterised cubic spline, localise the position of the car on the base frame, build a set of possible paths and finally generate an associated 'cost'. From this set of possible paths, the ideal path is the one associated with the least 'cost', which is further passed as a set of refined waypoints to the upper level control systems. Parameters affecting the calculation of the ideal path such as path 'smoothness', path safety, path consistency and distance from base frame will also be discussed. As a result of practical issues, time constraints and parallel projects, the control software was paired with a simulator to collect results. Measurements from these results will be presented as well as an overview of further testing and future improvements of the path planning algorithm.

Jake Galiano

Supervisor: Professor Thomas Bräunl

Design, Modelling and Analysis of a Front Bumper for the Formula SAE Autonomous Electric Car

For the second year of the Formula SAE autonomous electric car project, improvements and modifications were made to the car with the goal of achieving more accurate and precise performance, as well as the ability to safely and reliably traverse a race track. A front bumper was designed for the car in order to protect the car's systems and front wheels in the event of a head-on crash, as well as to improve the aerodynamics of the car. Stress, strain and kinetic energy transfer tests were simulated on a CAD model of the bumper. The car was also modelled in order to be used in future vehicle dynamics simulations, to assist with improving the car's safety at high speed. A protective cover was also designed and modelled to encase the car's motors and controllers at the rear, as well as protective wheel chain guards.

Ross Green

Supervisor: Professor Thomas Bräunl

Lane detection for autonomous ground robotic vehicles

The Autonomous Ground Vehicle Competition (AGVC) is an annual event that aims to stimulate robotics related research in Australian tertiary institutions. Entrants develop autonomous robotic vehicles which can successfully negotiate an outdoor obstacle course under a prescribed time. The robot must stay within the boundaries marked by painted white lines, locate multiple navigation waypoints marked by GPS coordinates and avoid obstacles placed throughout the course. This project covers the design, implementation and testing of the vision processing software used for UWA's entry into the upcoming 2014 AGVC. The software must reliably and robustly detect the course boundaries marked by painted white lines on a grass oval, then treat these lanes as boundaries in the robot's world map so as not to cross the boundaries as it navigates the course. This task is complicated by the outdoor environment, as the software must be robust to changes in both lighting and grass conditions.

The system is implemented on the open source Robot Operating System (ROS) and uses a number of existing OpenCV image processing functions. The system is currently undergoing testing in the expected course conditions for the 2014 competition.

Samuel Gribble

Supervisor: Professor Thomas Bräunl

Design of the Battery Restraint System and Battery Safety System for the REV Jet Ski

The UWA REV Project is a staff and student body working together to design and construct zero emission vehicles due to the need for a renewable alternative to the combustion engine. Two years ago there was a goal set to convert a jet ski to electric drive and compare its performance to a petrol powered jet ski. The progress of this project has been stalled due to complications with the design and safety of the battery box. The battery box has been through numerous designs and now has one that will safely house and monitor the temperature and charge of the batteries. Aspects from the previous works have been used in the design as well as a more effective configuration to minimise the weight and space used within the hull. The completed design and construction allowed for the water testing to commence.

Alexander Hildebrand

Supervisor: Professor Thomas Bräunl

Conversion of a Personal Watercraft from an Internal Combustion Engine to an Electric Drive System

In the past decade the personal watercraft industry has undergone a dramatic change by replacing traditional two-stroke engines with more environmentally friendly four-stroke motors. The UWA REV project hopes to take this one step further by replacing the combustion engine with an electric drive system. Though the automotive industry has made considerable advances in electric drive systems, the recreational watercraft industry has seen no real progress in this respect. This project hopes to investigate the feasibility of this concept.

Primarily the focus of this work is the redesign of the battery restraining system which has hampered the timeline of the project since the beginning because of the tight and odd shaped Jet Ski hull. This design, if finished and built in time, will mean the Jet Ski components can be assembled and the most important stage, testing, can finally begin.

Stuart Howard

Supervisor: Professor Thomas Bräunl

Development of the EyeBot Controller Library Functions and RoBIOS interface

The latest generation of EyeBots is being developed at UWA and is being run off the raspberry Pi. This requires an updating of the current EyeBot functions and RoBIOS interface so that it is compatible with the new hardware. This project presents the processes taken to update the EyeBot library functions and the RoBIOS interface. It also goes through some of the challenges encountered and overcome and recommendations for any future work on the EyeBots.

William Jacobs

Supervisors: Professor Thomas Bräunl and Professor Melinda Hodkiewicz

Electric LHDs in Underground Hard Rock Mining: A Cost/Benefit Analysis

With recent developments in the adverse health effects of diesel particulate matter and growing emphasis on sustainability, zero-emission electric vehicles are becoming an increasingly common option in underground mining systems. As exposure regulations become stricter, and with potential savings in the cost of ventilation, fuel and consumables, there is also economic incentive to consider alternatives to diesel machinery. As a result, the diesel/electric debate is fundamental to any underground mining company's triple bottom line. Diesel fueled load haul dump units (LHDs) operate in fleets underground for long hours, and as such are of particular significance. The main objective of this study is to conduct a cost/benefit analysis of the implementation of electric LHDs (eLHDs) in Western Australian underground

hard rock mines. This was achieved through a comprehensive review of the issues affecting the diesel/electric LHD debate, as well as through the development of a parametric life cycle cost model.

The results indicated that eLHDs are not yet a universal solution to all underground mining systems. It was found that while eLHDs can offer lower operating costs and do contribute many qualitative benefits, they also have a range of drawbacks, primarily due to their trailing cables. Nevertheless, with a suitable mine design, electric load haul dump units are a viable option and could pave the way for zero-emission electric machinery in the Australian mining industry.

Rajinda Jayamanna

Supervisor: Professor Thomas Bräunl

Design of the Battery Restraining System and Motor Mounting System for the REV Jet Ski

With increasing awareness of global warming, and its effects on the environment, there is a great need to develop renewable energy technology and demonstrate its viability to the general public. Australia's heavy dependence on gasoline-based transportation produces large amounts of greenhouse gases, thus an alternative must be provided through research and promotion of electric drive technology.

This project is responsible for the design, construction and placement of the battery restraining system and the motor mounting system for the REV Jet Ski. Design and placement is dependent upon many factors such as weight distribution, available space and cost constraints. The design of the battery restraining system and the motor mounting system follows relevant standards and regulations. The design of these components is aided by the Solid Works design package and ANSYS Workbench. Upon successfully completing the design and stress analysis the battery restraining system and the motor mounting system will be fabricated and assembled through the mechanical engineering workshop or the physics workshop. This project also evaluates g-forces that a Jet Ski experiences at peak performance. This is achieved by attaching a USB accelerometer in the hull of the REV Jet Ski. The data obtained from the experiment provides crucial information in moving forward with the battery restraining system and the motor mounting.

Jordan Kalinowski

Supervisor: Professor Thomas Bräunl

Conversion of a Formula SAE Vehicle to Full Drive-by-Wire Capability

The automotive industry is increasingly using electrical control systems in order to assist the driver of a vehicle or to automate certain manoeuvres.

This project describes the conversion of a Formula SAE car into a vehicle with autonomous drive-by-wire capability. This includes control over the braking, steering and throttle functions of the vehicle. By installing a servomotor and mechanical linkage, the vehicle is capable of braking via an electronic command. Control over the vehicle's acceleration is achieved through replication of the vehicle's original throttle hall sensor output voltage. A DC motor was used to actuate the steering of the vehicle by use of a belt drive on the steering column. The setup of the low-level controller and the aforementioned actuators are discussed. The design process of the systems used to convert the vehicle to drive-by-wire acceleration, braking and steering are documented along with details of the low-level controller and safety systems. The end result is a vehicle which is capable of being controlled by a high-level system for research into autonomous control algorithms.

Graham N. Lionnet

Supervisors: Professor Adam Wittek
and Professor Thomas Bräunl

Drive line design and implementation for REV Formula SAE electric vehicle

This thesis project outlines the design of a drive line system for the formula SAE (Society of Automotive Engineers) competition. The vehicle is to participate in an event scheduled by the formula SAE in Melbourne in December 2013. The car must have a reliable drive line in order to complete the race weekend. After an initial failure of the drive line implemented in the car in 2012, the system needs to be evaluated to identify which components must be redesigned, manufactured and implemented into the existing system. The designs must adhere to the regulations distributed by the FSAE, while being cost effective and competitive.

The designs in this thesis are machined and implemented into the existing 2013 REV (Renewable Energy Vehicle) FSAE vehicle at the University of Western Australia.

Man Ho Ma

Supervisors: Professor Adam Wittek
and Professor Thomas Bräunl

Weight reduction of the 2011 space-frame chassis

This work presents an introduction to Formula SAE (FSAE) frame design based on the experience of the 2011 space-frame chassis.

The basic theories and methodologies for designing these systems are presented so that new teams will have a baseline for their new FSAE design. Comparison between 2011 space-frame chassis and the new design will be given.

Don Madappuli

Supervisor: Professor Thomas Braunl

Design and Implementation of a Battery Management System REV Jet Ski

The 21st century has seen growing concern for environmental degradation resulting from carbon emission. As a result, pressure from global interests groups has led all industries to adopt an ecofriendly approach to both their manufacturing processes as well as the end product provided to the consumer. The Renewable Energy Vehicle Project by UWA has seen the development of numerous road vehicles such as the REV Racer (2009 Lotus Elise) and REV Eco (Hyundai Getz) which aim to create electric plug-in vehicles as a viable option in place of the traditional petrol engine. In 2013 the focus will be on utilising technologies embedded within the aforementioned vehicles into traditional petrol powered water sports vehicles.

Design and implementation of an efficient battery power source is the main focus of this research project, with the objective of attaining comparative performance figures to traditional petrol engine jet skis. Furthermore, research into a suitable battery management system and charging method will be undertaken to maximise performance during its usage in water activities. Numerous forms of battery sources are available currently on the market for similar road vehicle electric conversion projects. However, due to the fact that such a vehicle will be used on water, consideration must be made to the suitability of these different power sources. It is paramount that implementing a particular battery and charging system will allow the vehicle to ultimately meet all safety and design standards governed by the relevant authorities. The end goal of conducting such a research project will be to not only produce a working electric jet ski, but to also prove its viability to both the consumer and its possibility to be marketed as a product.

Alexander Mazur

Supervisors: Professor Thomas Braunl
and Mr Chris Croft

Autonomous Operation and Control of a Multirotor UAV through 4G LTE Using Onboard GPS and Image Processing

Through utilising modern telecommunication networks, we present a 'hexacopter' capable of intelligent remote waypoint navigation and image processing. Through the use of a web interface employing mapping software, users are able to specify remote waypoints for the hexacopter to navigate to. The hexacopter maintains an internet connection through 4G LTE (or 3G if necessary), allowing monitoring and control within regions of no WiFi or radio reception. The hexacopter is controlled through a Raspberry Pi, employing GPS and 4G modules, along with a suite of sensors including a 5-megapixel camera. Utilising various image processing algorithms for object detection, the hexacopter can coordinate flight patterns to perform tasks such as object tracking and surveillance. Through utilising GPS and image processing techniques in tandem, the hexacopter can perform intelligent searching operations.

Enda McCauley

Supervisor: Professor Thomas Bräunl

Multi-Robot Mapping and Localisation

The use of multiple robots is becoming increasingly common in the real world though applications in search and rescue, exploration and the military. The advantages of such an approach include redundancy, robustness and greater speed at mapping a large area compared to a single robot. In practice utilising multi-robots is difficult to achieve because the map from each robot needs to be combined into one. This is a difficult task with many possible solutions. One such solution, dubbed Mapbuilder utilised the power of a discrete GPU to combine submaps from five robots into one large map. It worked successfully and the team that built it placed fourth in the MAGIC2010 competition in South Australia. Since then the Mapbuilder algorithm has been modified to run under the open source ROS system and no longer produces maps of acceptable quality.

This project aims to identify the reasons for Mapbuilder's newfound problems and, once identified, attempt to fix them. The final solution describes a new ROS-based robot localisation system using sensor fusion with an Extended Kalman Filter. This final solution includes SLAM-based position information and an Inertial Measurement Unit to provide accurate orientation. This system was experimentally compared to the existing system and was found to provide significant improvements to both map quality and reliability. At the same time new GPU technology should provide a performance boost if leveraged correctly. An attempt was made to optimise and improve the matching process used as part of Mapbuilder. Three methods, ranging from simple configuration modifications to detailed code changes were identified and experimentally evaluated. All methods provided large gains on a single robot map but only the last method was found as having any effect on map quality in a large multi-robot map. It is recommended that this last method should become standard practice in the future. The other poor results where unexpected and although the reason was identified at a high level finding the exact reason was beyond the scope of this project.

Ruvan Muthu-Krishna

Supervisor: Professor Thomas Bräunl

Autonomous SAE Car—Real-time Kinematic GPS Integration and Passenger Feedback

The UWA Autonomous SAE Car is an ex-Formula SAE car that has since been converted to a fully electric drive-by-wire vehicle with all essential systems for autonomous driving. This dissertation surrounds the design and

implementation of systems within the car that will allow it to adequately sense and map its racetrack environment such that the car can then attempt to drive a path laid along it. It also details added functionality of the user interface that provides the co-driver a means of monitoring the cars operation whilst driving autonomously. Results of testing carried out on the cars various subsystems are presented as well as proposed future work to meet the goal of a turn-key autonomous race car.

Rory O'Connor

Supervisors: Professor Thomas Braunl and Mr Chris Croft

Developing a Multicopter UAV Platform to Carry Out Research Into Autonomous Behaviours, Using On-board Image Processing Techniques

In conjunction with CIIPS and fellow students, a hexacopter UAV was developed to carry out practical semi-autonomous on-board image processing functions. In this project, the process of developing the platform, for research and development of autonomous UAV applications is investigated and the findings are reported.

Using off-the-shelf components, the research focuses on utilising a Raspberry Pi computer to process live image data captured from an on-board camera, to identify and isolate nearby objects of interest. The position and inertial data of the UAV is also measured in real time, to provide a reference for interpreting the image data. Furthermore, the Raspberry Pi was programmed to generate intelligent flight responses in reaction to the data recovered from the camera and other sensors. This process controls the desired reaction of the UAV to the objects identified in the nearby environment. By incorporating these algorithms together with autonomously controlled flight trajectories, the UAV was successfully programmed to carry out simple track-and-follow tasks in a robust manner without operator assistance or interference. The results of this image-based feedback control can be used to assist further development of a wide variety of functions that may be implemented into other UAV platforms. In turn, these functions can be tailored to suit a host of relevant real world applications, depending on the requirements of the operator.

This thesis gives insight into the autonomous capabilities of modern UAV platforms. The results achieved will serve as a robust system to further study. UWA engineering students in honours research next year have arranged to continue the work that began as part of this thesis.

Carl Pantos-Conquilla

Supervisor: Professor Thomas Bräunl

Design of a UWA Electric Racecar

The University of Western Australia (UWA) Motorsport Team has been developing performance racecars for the Formula SAE competition since 2001. In this time the team has won numerous awards and is well-regarded internationally for their innovative designs. In 2009 the UWA Formula Renewable Energy Vehicle (REV) Student Project began developing a second series of competition-specific racecars to meet the growth of technology into electric propulsion vehicles.

The Formula SAE opportunity enriches student experiences for more than 500 university teams internationally, a challenge that kick-starts their mastery of professional engineering skills. Design decisions are inclined on the availability of industrial sponsorship and yields some of the freshest applications of electric propulsion technology in Australia. Resources gathered for use in this work are varied but most notably, the availability of past UWA-designed racecars of both combustion and electric propulsion will be the basis of which this work is unique and novel.

Garrick Alexander Paskos

Supervisor: Professor Thomas Bräunl

Navigation solutions for the 2014 AGVC

The Autonomous Ground Vehicle Competition (AGVC) is an annual Australian interuniversity competition intended to "stimulate robotics related research in Australian tertiary institutions", facilitated by the Defence Science and Technology Organisation (DSTO). The 2014 AGVC poses the problem of autonomous navigation of a wheeled robot (holonomic or differential drive) within a 2-dimensional plane, constrained by visual boundaries, discrete obstacles and time.

This work presents a partial solution to the problem posed by the 2014 AGVC—employing the required sensors and robot base, accessed by a notebook computer running Ubuntu Linux and the Robot Operating System (ROS) robotics middleware.The use of ROS provides a concrete interface to hardware and functional software components, facilitating the division of the problem into smaller, less dependent "project tasks". Additionally, the collaborative nature of the ROS project provides the employment of existing software solutions to common robotics problems that would otherwise be outside the technical scope of the project.

This work is mainly concerned with the navigation components of the project and secondarily, their integration with other components (such as visual obstacle detection and filtered odometry sources).It has been found that the employment of existing Rao-Blackwellised particle filter based simultaneous localisation and mapping (SLAM) software is sufficient to localise the robot within an environment consisting of sparse landmarks and slippery terrain. Additionally, the use of existing "costmap" based navigation software provides reliable and optimal navigation to arbitrary poses within the frame of reference provided by the SLAM components.

Marcus Pham

Supervisor: Professor Thomas Bräunl

Redesign and Implementation of REV Vehicle GUI and Instrumentation and Road Testing of Holden Volt

The UWA Renewable Energy Vehicle Project (REV) is a project that aims to 'revolutionise personal transport' by building zero emission vehicles to combat the growing concerns of carbon emissions due to internal combustion engine vehicles. UWA currently has two road-legal, fully electrical vehicles that provide a possible solution to these environmental issues. In any vehicle, the first point of human-to-machine interaction is to the instrumentation inside of the vehicle's cockpit. Instrumentation is particularly important in an electric vehicle, as a user will need to receive information to gauge the current state of the vehicle whilst not overloading the driver with information and causing a distraction to the actual driving of the vehicle.

This project focuses on creating a more robust and improved version of the Graphical User Interface inside of the two REV vehicles. The new interface will predominantly aim to satisfy the likely users of electric vehicles. As such, it will give the user what is most likely to be the main reason behind their choice of an electric vehicle over an internal combustion vehicle—efficiency. Improvements will enable users to measure and see their driving efficiency and compare this with previous trips in real time. This will encourage drivers to more effectively reduce energy use, reducing cost and benefiting the environment. This task involves the addition of new features as well as removing redundant and unrequired features to maintain ease of use.

Liam Poli

Supervisor: Professor Thomas Bräunl

User Interface for a Group of Mobile Robots

The field of robotics has progressed significantly over the past decade. New robust systems can now be used in challenging applications such as military reconnaissance, hazardous environment exploration and search and rescue. Current technology is based around the teleoperation approach which requires at least one human controller to monitor each robot. This approach however cannot be extended to multi-robot control. For a single operator to effectively control multiple robots, an increase in robot autonomy and an advanced multi-robot interface is required. State of the art robotic systems use multiple robots to complete complex and challenging missions that would not be possible with single robot systems.

This project covers the design, construction and testing of a multi-robot user interface. The system design was based on modern Real Time Strategy (RTS) video games. A large emphasis was placed on creating a user friendly system centred on a user experience based design. The system built provided a single user an effective means of controlling multiple robots; with high compatibility with ROS (Robot Operating System), the current standard robotic operating system used by the majority of research institutions. ROS compatibility will allow the product to be easily integrated into other robotic systems. Evaluation was carried out by user testing and heuristic evaluation. The results show that for a single robot users had far superior control using the interface when compared to a simple teleoperation system. Effective multiple robot control was demonstrated by users for two robots through exploration of an unknown environment. The project results were used to develop a set of design guidelines to be used for future multi-robot interface design.

Cody Zhiqiang Qiu

Supervisor: Professor Thomas Bräunl

A SIMD microprocessor for image processing

The aim of this project is to design a Single Instruction Multiple Data (SIMD) microprocessor for image processing. The project focuses on the development of a SIMD image processor using software simulation. It takes a three step approach. The first step is to improve and further develop our circuit simulation software, Retro. Retro is a powerful circuit design tool with built-in real time graphical simulation. A number of improvements have been made to Retro to fulfil our design requirements. The second step is to design the actual SIMD circuit using Retro software. Tasks include designing the internal circuit of each Process Element (PE), internal circuit of the Sequencer CPU, interconnections between PEs and the instruction set of this SIMD image processor. The final step is to verify the correctness of the design by simulating the SIMD circuit in Retro using a number of image processing applications. We should expect a simple and highly efficient image microprocessor available for embedded systems in foreseeable future.

Thomas Smith

Supervisors: Professor Thomas Bräunl and Mr Chris Croft

Advanced Embedded Systems

The EyeBot is a robotics platform used at the University of Western Australia to teach students about embedded systems, with a particular focus on embedded computer vision. To keep up with modern embedded applications and CPU intensive algorithms, an upgrade to the underlying hardware was required. The Raspberry Pi was selected to be the core of the next generation of EyeBots as it offered excellent performance

for both its size and price. However, in order to interface the Raspberry Pi with the numerous sensors and actuators available on the EyeBot, a low level I/O board was needed. An Expansion Board was designed and built over the course of the year that provides the link between the Raspberry Pi and the low level hardware by means of USB serial communication. The use of a standardised communications method such as USB will allow future performance upgrades to be both cheaper and easier as only the Raspberry Pi needs to be swapped out for a more powerful board. The Expansion Board is currently on its second prototype with testing underway to determine if the current design will meet the requirements to be used as a teaching and research tool in the future.

Michael Storey

Supervisors: Mr Geoffrey Drake-Brockman (Pixel Enterprises), Asst Professor Andrew Guzzomi and Professor Thomas Bräunl

Mechanical Design of a Kinetic Art Sculpture—The Signal

Mechanical design has been undertaken for a Kinetic Art Sculpture based on a concept design developed by an external artist, Geoffrey Drake-Brockman. The work entitled 'The Signal' is proposed for the entrance of Meridian Park, an industrial estate in Perth, Western Australia. The purpose of the artwork is to create a centrepoint for the estate and become part of its 'identity'. The artwork consists of a cantilevered array of 28 aluminium rectangular prisms (boxes) mounted on roller tracks at a height of six metres that will each exhibit individually controlled lateral translation. These movements will be reactive to their environment via a control system sensing cars, people and weather. The steel frame underneath the array must support the boxes and their actuators whilst remaining hidden from observers. This will maintain the illusion that the boxes are floating, an aesthetically important feature of the sculpture. Visits to other artworks and construction experience provided the foundation for the design. The majority of modelling has been completed in SolidWorks, with MATLAB assisting with pattern generation and Multiframe for static analysis. The completed design has been engineered to satisfy environmental, fatigue, tribological, buckling and yielding conditions. The artwork is to be installed in 2015.

Omid Targhagh

Supervisors: Professor Thomas Bräunl and Mr Chris Croft

Autonomous Control of Unmanned Aerial Vehicles

Recently, there has been a lot of interest in the application of autonomous flight with small unmanned aerial vehicles (UAV's). The Robotics and Automation research group at the University of Western Australia has investigated this topic by getting a team of final year students to experiment with a Hexacopter UAV. Using pre-existing components, a system was developed capable of autonomously mapping an outdoor area and returning information to the user about any interesting features. As there were several students doing this work, the task was divided up into different areas of interest and my focus was on the capabilities of autonomous navigation. In order to achieve intelligent autonomous flight, a large quantity of data had to be collected and fed back to the Hexacopter. This data was then processed and analysed on-board, allowing the system to be fully independent.

Tushara Teegala

Supervisor: Professor Thomas Bräunl

Electric Mines of the Future

An analysis of all types of renewable energy sources indicates that solar and wind energy are the most widely available and at levels attractive for power generation in Australia. It is evident from solar and wind maps that the optimal locations to install renewable energy sources for

Western Australia is near the mines, where the temperatures are generally high for solar and there is a vast area of open land for installation of wind power as well as optimal rated wind speeds. The energy produced in these locations can be used to power the nearby mining operations. Due to the high capital costs, maximising the output energy for any given installation of renewable energy sources is of vital importance.

This project presents a research model which utilises performance calculations for Solar PV and Wind power to investigate the economic impacts of implementing different mounting systems in conditions applicable to a mine site. The hypothesis is that, due to the high variability in output power produced for solar and wind energy, a higher penetration rate can be achieved with a combination of solar and wind power generation than using one major type of renewable energy source. Important conclusions as to the impacts of different mounting systems and implementing a greater combination of renewable energy sources are drawn from the performance calculations and the data that was obtained from various research papers.

Daniel Throssell

Supervisors: Professor Thomas Bräunl and Mr Chris Croft

A Psychoacoustically Motivated Technique for the Automatic Transcription of Chords from Musical Audio

All music, and especially pop music, is based upon 'chords'—structured combinations of musical notes that harmonise when sounded together. However, because of the presence of inharmonic spectral peaks known as 'upper partials' within most musical sounds, current techniques for automatically transcribing chords from musical audio suffer from varying degrees of inaccuracy as these upper partials obscure the actual perceived sound during computerised analysis. Since different musical instruments exhibit different upper partial signatures, blending multiple elements in a mix worsens this effect due to their interference with one another. In this thesis a psychoacoustically motivated technique for processing audio is simulated to evaluate its effectiveness upon chord transcription. The human auditory system is imitated by taking four 'streams' from songs—individual tracks corresponding to the bass, vocals, drums and other instrumentation—and mixing these in various proportions to determine whether, by reducing the interference of these streams with one another, better chord recognition performance can be achieved with a subset of them. A total of 434 audio files corresponding to 62 individual chords are analysed using an algorithmic technique for automatic chord estimation. It is demonstrated that the best chord recognition performance over the sample set is achieved by partial removal of the drums, vocals and bass, whilst leaving other instrumentation at full signal level. This achieves a significant 40.33% increase in chord transcription accuracy compared to the original unseparated chord samples, showing that it is theoretically possible to improve chord recognition performance by separating audio streams within a song. This result assists the development of more accurate chord recognition techniques in fields such as music information retrieval and also provides some insight into the principles behind human music perception.

Christopher Venables

Supervisors: Professor Thomas Bräunl and Mr Chris Croft

Multirotor UAV Autonomous Operation in an Industrial Environment using On-board Image Processing

This project aimed to expand on multirotor unmanned aerial vehicle autonomous capabilities through the use of on-board image processing, in outdoor, unmapped environments. This capability would simplify multirotor unmanned aerial vehicle operation and expand on the commercial

applications within industrial environments. A multirotor unmanned aerial vehicle was assembled and algorithms and programs were successfully implemented allowing autonomous navigation of GPS waypoints and coloured object tracking using on-board image processing. A remote browser interface was also developed to allow new mission data to be uploaded to the vehicle while carrying out autonomous objectives. The multirotor unmanned aerial vehicle was successfully able to detect and autonomously track a target object by using on-board image processing. Due to the on-board computational limitations enforced by a limited payload, the complete autonomous target object tracking program operates at an average frame rate of 2.85 fps and is capable of reliably tracking a person moving at speeds of up to 10 m/s.

This project has demonstrated the validity of on-board image processing for autonomous multirotor unmanned aerial vehicle control with a robust system that is capable of successfully operating in an outdoor, industrial environment. With increased computational power and by modifying the image processing algorithms for the desired tracking target, this system may be suitable for commercial applications including search and rescue, security and policing, data collection and aerial photography and filmography.

Nicholas Ward

Supervisor: Professor Thomas Bräunl

Effects of Torque from Electric Motors on Personal Watercraft Performance

The effect of supplying an excessive amount of torque to a centrifugal pump results in cavitation of water increasing wear and reducing or stalling propulsion. The differing power and torque characteristics between internal combustion and electric motors have necessitated research into the effects on personal watercraft drivetrains. Drawing on the author's and experts' experience on existing jet propulsion hardware for effective use following power unit alterations, this work considered the value in redesigning or altering the impeller and driveshaft of a personal watercraft resulting from the retro fitment of an electric motor. The options available for performance improvement based on their effects and viability in relation to the projects goals and constraints were investigated. Concluding with the methods chosen by the REV Jet Ski team to improve the jet pump performance.

Jameson Wedge

Supervisors: Professor Adam Wittek and Professor Thomas Bräunl

Redesign of a Steering System for the University of Western Australia Electric Formula SAE Car

This thesis covers the redesign of the steering system for the Renewable Energy Vehicle team's 2013 Formula SAE Electric vehicle for use in the 2013 Formula-SAE competition. The chassis and suspension of the vehicle had already been designed and manufactured. The original steering system incorporated on the vehicle did not allow the car to turn when in motion and therefore had to be redesigned. Successful completion of this project resulted in the REV vehicle being entered in the 2013 Formula SAE competition where it's redesigned steering mechanism allowed it to compete in both the static and dynamic events.

Through research into current steering systems employed on both road going cars and similar open wheel race cars, similar to the REV's vehicle, a design was formulated and was agreed upon by the team to as the best possible solution. Through modelling in SolidWorks, various component designs could be evaluated to ensure adherence with the strict rules of the competition as well as allowing Finite Element Analysis to determine potential failure points. With this new design, a new steering system could be produced and installed on the car so that it could be entered in the competition.

Riley White

Supervisor: Professor Thomas Bräunl

REV Electric Jet Ski Safety Systems

The aim for this project was to design the safety systems for an electric-powered jet ski. The REV project in the past has converted several petrol powered cars to electric power, but this is the first time a water vehicle has been attempted. There are obvious reasons for converting from fossil fuel to electric power, such as lower emissions, less noise pollution and lower running costs.

Although the idea is similar to previous REV projects, converting a petrol powered vehicle to electric power, a water craft has its own unique challenges. The REV jet ski will be exposed to water in its operating environment, and so extra care must be taken to ensure waterproofing of the critical components, to which water exposure would be damaging. Water leakage sensing is one aspect this project deals with, in addition to temperature sensing, battery management, a deadman's switch and safe charging. An important consideration is adaptability—taking into account future work. At the present time the REV jet ski is not complete, and so the safety requirements may grow to incorporate unforseen needs as the project develops. With this in mind, it was necessary to design a safety system that could be added to as required, and be easy to understand for future students who are new to the project.

A modular design that is easy to troubleshoot and modify has been developed, using off-the-shelf, relatively inexpensive, standard parts from local vendors. This ensures that future additions in the form of additional modules will be easy to construct, cost effective and fit uniformly with existing safety modules.

Luke Wilson

Supervisor: Professor Thomas Bräunl

Electric Mines of the Future—a Multiple Criteria Selection Process for a Remote Mine Site Energy Storage Solution

This project involved the generation and validation of an easy-to-use, first-look-at renewable energy storage selection model, which provides those in the mining industry with a process to utilise in initial inspection rounds of possible energy storage solutions for their mine site. The available technologies in the energy storage market place were assessed and analysed in order to generate a subset of viable options that could be implemented as part of a solution. Multiple criteria decision models were also assessed in order to find an optimal method to deal with the many criteria and alternatives that are involved with such a decision. An analytical hierarchy process approach was employed, as well as a decision tree diagram, in order to provide a number of solution sets dependent on the level of information available. The AHP model was carried out with four criteria, and with four specific scenarios; each scenario specifying one criteria as a priority. As such four predetermined recommendations are provided dealing with these scenarios. The decision tree diagram utilises the same four criteria, but expands upon them by assigning varying ranges to them. This allows for a higher level of specificity by the user, with the result being a more tailored energy storage solution subset. The process has yet to have its recommendations compared to example mine sites that have either already deployed energy storage technologies specific to their needs, or have had established engineering companies tender possible solutions. This step will validate whether its recommendations are meaningful and match those currently being deployed within the industry.

Hang Yang (Richard)

Supervisors: Professor Thomas Bräunl and Mr Chris Croft

Design and Implementation of Unmanned Aerial Vehicle—Hexacopter

Unmanned aerial vehicles (UAVs) are a fast-growing field of the robotics and multirotor aircraft industry. Hexacopters are an application of UAVs with the advantages of: small volume; low cost; convenience of use; low requirements for operational environment; and accuracy and efficiency on reconnaissance and interference. The aim of this project is to design the hexacopter and improve the UAV autonomous capabilities using on-board image processing in the unmapped outdoor environment and also expand on the commercial applications within industrial environments. In this project, the hexacopter was assembled and programs were implemented through the Raspberry Pi controller to allow autonomous navigation of GPS waypoints. Also, a Telstra 4G network dongle was used to implement and expand on the commercial applications.

Calvin Wen-Loong Yapp

Supervisor: Professor Thomas Bräunl

Autonomous SAE Car—Drive By Platoon System

Traffic congestion is an issue on our roads and is steadily worsening. A possible solution is introducing a system called drive by platoon in which cars autonomously follow each other allowing drivers to perform other tasks while in traffic. This project aims to implement a drive by platoon on the autonomous SAE car allowing the car to follow an object, person or vehicle driving in front of it. This is achieved using the IBEO LUX sensor that can detect objects using the time of flight principle. The data received from the sensor is analysed and processed to create a plot of points obtained and an algorithm is used to identify the objects present in front of the autonomous SAE car. The object detection algorithm is able to detect objects to within six centimetres laterally and 24 centimetres longitudinally. Using this data, the object is tracked, and commands including acceleration, brake and steering are sent to the control unit of the autonomous car. A program has been written that incorporates the object detection algorithm, the plotting of objects and communication to the autonomous SAE allowing it to track and follow a person walking in front of the car.

Qing Zhou

Supervisor: Professor Thomas Bräunl

An Investigation of Robot Localisation and Goal Planning for AGVC

The Autonomous Ground Vehicle Competition (AGVC) sources Australian Universities for the next generation of autonomous ground robotic vehicles. Robot localisation and goal planning are fundamental components for a robotic vehicle to move autonomously. Accurate and reliable robot localisation requires sensor fusion, which is fusing the data from different types of sensors to obtain better odometry than using those sensors individually. The robotic vehicle in this project runs on Ubuntu 14.04 and ROS indigo and the hardware involved for localisation are an Xsens MTi IMU, a P3-AT robot base and a GPS receiver. Each of the sensors acquires the robot's position in different ways and provides different forms of data, therefore it is necessary to standardise them to estimate the best result. Extended Kalman filter (EKF) is used for estimation and a few sensor data conversion programs are written or obtained from free ROS packages. The goal planning is to manage a few given waypoints in AGVC and the core issues are to decide where the next goal is and whether any waypoint is achieved or aborted. The algorithm is set to choose the closest waypoint as the current goal and to abort the task after trying without success for a certain period. Overall, this project demonstrates how to fuse different sensors to obtain reliable and accurate robot localisation and make the goal planning based on this and given waypoints.

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CRICOS Provider Code: 00126G

REF: LB CIIPS 2014/15 Research