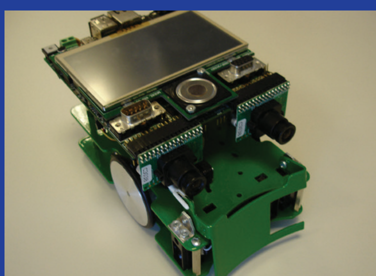
THE UNIVERSITY OF WESTERN AUSTRALIA

Faculty of Engineering, Computing and Mathematics

Computational Intelligence Information Processing Systems

RESEARCH 2016/2017



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Foreword from the Head of CIIPS

The highlight of the past year was the launch of our electric jet ski—the first in Australia and apparently the second in the world. With virtually no noise or water pollution, electric jet skis are pure fun and possibly the future of recreational vessels.

While we see electric drive systems in more and more application areas, including trucks, buses, and even dirt bikes, the commercial take-up of electric vehicles is still lagging behind expections, especially in Australia where we have no incentives for EVs. The fantastic take-up rates in Norway and California show what is possible in the right political climate. The rest of the world is waiting for cheaper batteries, which will eventually make EVs financially more attractive than combustion cars—this will be the tipping point for electromobility and will happen over the next 10 years. So it is important to not delay and put charging infrastructure and grid reinforcements in place now. Fleet charging management as well as home energy management systems remain therefore important research areas for us.

Worldwide automotive research in 2016 seemed to concentrate on a single topic: driverless cars. Most automotive OEMs seem to have made this their goal and spend billions of dollars in R&D funds towards this goal, which includes processing hardware, software, new sensors as well as high definition maps for roads and environments. In CIIPS and REV, we have worked for many years on autonomous robots as well as on driverless cars, so these topics are now coming together. With our semi-autonomous BMW X5 and our fully driverless SAE car we are in an excellent position to continue on this research path.

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, Windows and Macintosh 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 EVs 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 mobile robot simulation to Autonomous Underwater Vehicles (AUV).

The group maintains seven research vehicles 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
- Electric Jet Ski
- Electric Scooter

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.

Members of CIIPS

Academic Staff

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

Dr Adrian Boeing
BE, PhD, MIEEE
Robotics; Automation; Physics Simulations; Computer Graphics; Computer Vision
adrian.boeing@uwa.edu.au

Mr Chris Croft
BE, MBA, MIEAust, MGMA
Engineering Management; Project Planning
chris.croft@uwa.edu.au

Professor David Harries
BSc, DipEd, MEnvStud, PhD
Smart Grids; Renewable Energy; Photovoltaics; Elektromobility
dharries@gmail.com

Professor Terry Woodings
BSc, DipComp, PhD, FACS, FQSA
Software Engineering; Software Metrics
terry.woodings@uwa.edu.au

Technical and Professional Staff

Mr Ivan Neubronner
Senior Technician
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Ms Linda Barbour
CIIPS Administrative Secretary
linda.barbour@uwa.edu.au

Mr Marcus Pham
REV Student Manager
rev@ee.uwa.edu.au

International Visitors

Mr Hannes Wind, University of Stuttgart, Germany

Mr Frank Bender, University of Stuttgart (Endeavour Research Fellowship), Germany

Mr Julian Beilhack, TU München, Germany

Mr Siyao (Scott) Meng, USTC, China (Australia–China Research Training Program)

Ms Ke Feng, USTC, China (Australia–China Research Training Program)

Ms Fexuan (Fay) Wang, USTC, China (Australia–China Research Training Program)

Contact Details

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Fax: +61 (8) 6488 1168
Website: http://ciips.ee.uwa.edu.au/

Doctor of Philosophy (PhD) Students

Current PhD Students

Mr Thomas Drage
Environmental Perception and Navigation Control Systems for an Autonomous Performance Vehicle
Professor Thomas Bräunl, Dr Adrian Boeing

Mr Franco Hidalgo
Navigation system for an autonomous underwater vehicle for turbulence monitoring
Professor Thomas Bräunl, Dr Adrian Boeing

Mr Kai Li Lim
Visual Odometry and Place Recognition for Embedded Autonomous Ground Robots
Professor Thomas Bräunl, Professor Victor Sreeram

Mr John Pearce
Renewable Energy Systems
Professor Thomas Bräunl, Professor David Harries

Mr Stuart Speidel
Electric Vehicle Charging Systems
Professor Thomas Bräunl, Professor David Harries, Emeritus Professor John Taplin

Mr Guido Wager
Energy Efficiency of Electric Vehicles and Recharging Technologies under Consideration of Usage Profiles
Professor Thomas Bräunl, Dr Jonathan Whale (Murdoch), Professor David Harries

Completed PhD Students (2016)

Mr Robert Reid
Large-Scale Simultaneous Localization and Mapping for Teams of Mobile Robots
Professor Thomas Bräunl, Dr Adrian Boeing

Ms Saufiah Abdul Rahim
A Genetically Evolved Neural Network for an Action Selection Mechanism in Behaviour-Based Systems
Professor Thomas Bräunl

Submitted and under review

Ms Fakhra Jabeen
The Adoption of Electric Vehicles: Behavioural and Technological Factors
Associate Professor Doina Olaru, Emeritus Professor John Taplin, Professor Thomas Bräunl

Final Year and Master of Professional Engineering (MPE) Project Students

Electrical, Electronic and Computer Engineering

Christopher Blignaut BE
Thomas Churack BE
Zisu Ding MPE
Timothy Ha BE
Joshua Knight MPE
Sonia Miranda MPE
Manish Mohanty BE
Travis Overington MPE

Software Engineering

Tim Raphael MPE
Jeethan Rodrigues BE

Mechatronics Engineering

Richard Allen BE
Brett Downing BE
Andrew Henson BE/BArts
Robert Hortin BSc/BE
Tim Lander BSc/BE
Jeremy Tan BE
Hannes Wind, Visiting Scholar

Mechanical Engineering

Claye Jensen BE
Shu (Eric) Low BE UWA
Michael Stott BE
Xiachuan Zhou MPE

Research Activities

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

Robotics and Automation Lab

Professor Thomas Bräunl, Dr Adrian Boeing and Mr Chris Croft
Intelligent mobile robots; embedded systems; image processing; simulation.
Location: EECE 3.13

High Integrity Computer Systems Lab

Professor Terry Woodings
High-performance, high-reliability and high-quality computer hardware and software systems; design methodologies and management.
Location: EECE 3.11

Smart Grids 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



Automotive Lab

Professor Thomas Bräunl

The Automotive Lab was established in 2008 and is dedicated to research on driving economy, such as plug-in electric vehicles, as well as active driving safety, such as driver-assistance systems.

The Faculty of Engineering, Computing and Mathematics' Renewable Energy Vehicle Project (REV) operates in this lab.

Details can be found at: http://robotics.ee.uwa.edu.au/automotive.html and http://REVproject.com

REV Vehicles

The following vehicles were built and/or modified by REV:

REV Eco

Electric conversion of Hyundai Getz
DC drive system, 28kW, 144V, 13kWh, 80km range

REV Racer

Electric conversion of Lotus Elise S2
3-phase DC drive, 75kW, 266V, 16kWh, 100km range

Formula SAE Electric car

4-wheel drive system with torque vectoring, 60kW, 52V, 8kWh

Autonomous SAE Electric car

Two DC drive motors, 13kW, 48 V, 4.3kWh drive-by-wire, laser scanner, GPS, IMU, camera

Scooter

36V 750W 14-inch hub motor, top speed of 32km/h, Battery—12cells of 10Ah 3.2V LiFePO4, total of 38.4V, 15km range

REVski

Electric conversion of Jet Ski, Sea-Doo 4-TEC
96V, 50kW, 7.6kWh, 30min. drive-time

Autonomous BMW X5

Drive-by-wire, laser scanner, GPS, IMU, camera

Electric Jet Ski

One of the highlights was the long awaited completion of the REV Electric Jet Ski, which received enormous media attention. The electric jet ski provides all the fun of riding a jet ski but without its negative aspects, which are excessive noise and substantial pollution of air and water. The jet ski is as easy to ride as a petrol-based version and all you hear is the splashing of the water.

The electric jet ski was launched by UWA's Vice-Chancellor, Professor Paul Johnson in presence of all students and sponsors. Senator Linda Reynolds later visited REV to get first hand information on the electric jet ski as well as on the electric cars.

We based our system on a Sea Doo jet ski shell with a 50kW AC motor—developed and donated by Submersible Motor Engineering (SME) Perth, a Curtis controller, and high-current headway Li-Ion battery cells. A total of 240 battery cells, organised in 30 sets in a series of eight parallel battery strands each, enclosed in waterproof PVC tubes. This gives the jet ski an overall voltage of 96V and a total capacity of 7.6kWh. Larger battery packs are an option which we are looking to explore when conducting a first trial with several electric jet skis in a real application environment.

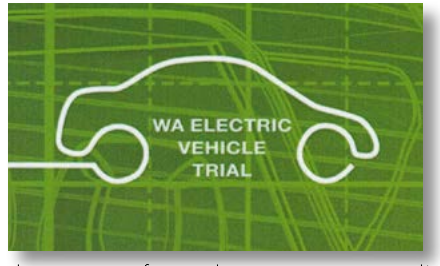
The REV Project team would like to thank its sponsors:

- Submersible Motor Engineering and Dick Haffenden, Maddington (motor sponsor)
- Total Marine Technologies and especially Brett Manners, Bibra Lake, (Engineering advice)
- Altronics, Northbridge (electronics parts)
- Australian Medical Association (sponsor)
- NVIDIA (sponsor)

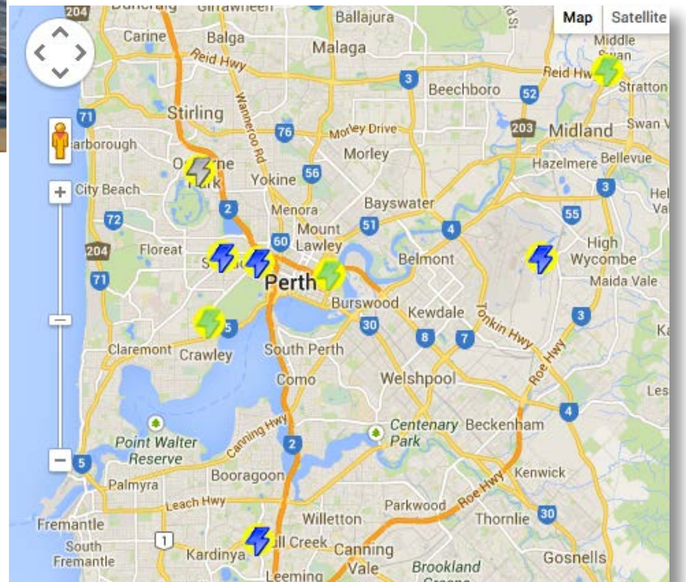
Senator Linda Reynolds examines the REV Electric Jet Ski

REV EV Charging Network

The REV Project continues to monitor electric vehicle charging behaviour as ongoing PhD research projects from its network of EV charging stations established for the WA Electric Vehicle Trial (2010–2014). Public participation in the charging trial is steadily being taken up by Perth locals who own converted or commercial electric vehicles.



The Report from the Western Australian Electric Vehicle Trial is still available from: http://REVproject.com/trialreport.pdf



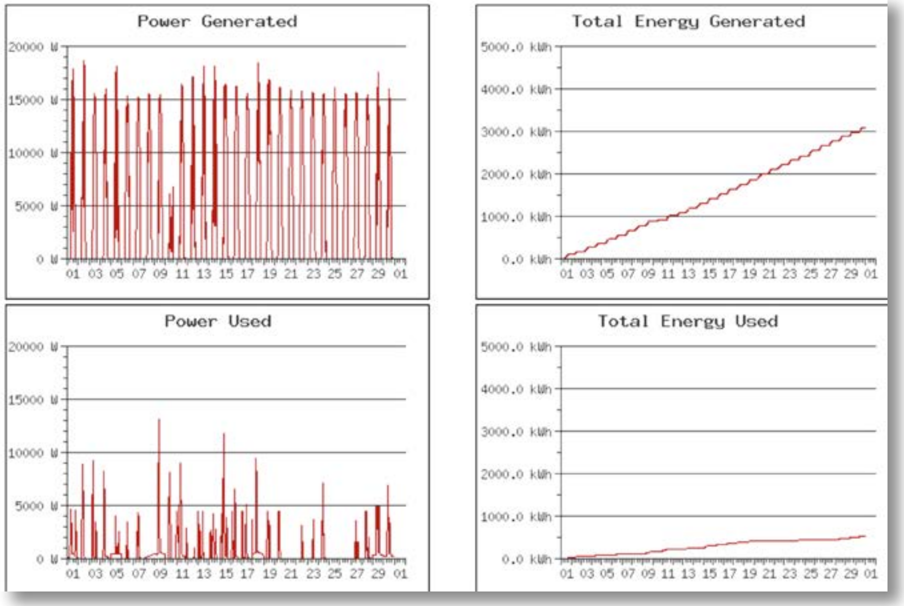
REV Project EV charging station locations are shown on this map.

- UWA University Club
- UWA Engineering
- Murdoch University CREST
- City of Subiaco
- City of Cockburn
- City of Swan
- City of Fremantle
- West Australian Newspaper
- RAC DTEC Centre, Airport
- Mainroads WA
- Perth Transport Authority

Perth's EV Community—gathering of Tesla drivers at Barbagallo Raceway, Wanneroo (Image courtesy of David Lloyd, WA Tesla Community Group).

Energy Monitoring

REV closely monitors the energy used for charging EVs as well as the energy created from on-campus rooftop solar PVs. As our studies have shown, most EV charging happens during sunshine hours, so the energy required for charging can almost directly come from our existing solar PV systems. Very little grid support is required.



REV Vehicle GUI and Instrumentation

Students in the Automotive Lab worked on the design of the Renewable Energy Vehicles' (REV) Graphical User Interface (GUI) and Instrumentation. The focus of the project is on creating a more robust and improved version of the Graphical User Interface (GUI) in the two Renewable Energy Vehicles—the REV Eco (Getz) and the REV Racer (Lotus). The new interface predominantly aims to 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, and thereby reduce costs and benefit the environment. This task will involve the addition of new features as well as removing redundant and unrequired features to maintain ease of use.

Marcus Pham

GUI of REV Racer Lotus Elise

Autonomous Driving

We are operating two autonomous research vehicles in REV. One is the semi-autonomous BMW X5 (donated by BMW Group), which we use for driver-assistance functions, the other one is the fully autonomous Formula-SAE-Electric car that was originally built and later modified at UWA.

Both cars use a similar sensor setup with GPS, Xsens IMU (Inertial Measurement Unit), IBEO-Lux Lidar, digital camera, and wheel odometry. The drive-by-wire actuation is also similar. Both cars use a DC motor to turn the steering wheel and a powerful servo to push down the brake pedal. The SAE car also has an electronic multiplexer for the accelerator, while the BMW always requires a human driver to push the accelerator.

We conduct research in autonomous driving in different scenarios, using "Deep Learning" approaches to classify sensor input and fuse information from different sensor types for generating a driving path. For on-board signal processing we are using an Nvidia Jetson processor board, for offline learning we are using an Nvidia Titan X GPU board (donated by Nvidia).

Right from top:

The autonomous Formula-SAE-electric racecar; the BMW's embedded driver assistance system; and the brake-pedal electric servo in the BMW

Below left to right:

The BMW steers autonomously around a stationery vehicle

Home Energy Management

We have developed a tool that allows planning and optimizing of solar PV and home energy storage systems, see: http://revproject.com/energy/energy.php

(1) The system starts with the typical daily energy usage distribution for Perth. The usage can be adjusted to match an individual home.

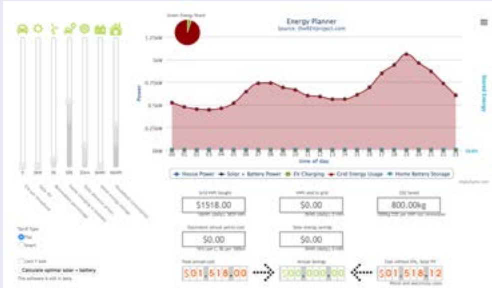
(2) The addition of solar PVs completely offset the energy usage during the daylight hours, but obviously cannot reduce energy consumption in the early morning hours or later afternoon/evening hours. All excess energy goes back to the grid for a relatively low financial compensation. The figures at the bottom of the graph calculate the annual savings of the selected configuration.

(3) With the addition of home energy storage, we can store the excess energy produced by the solar PV during sunshine hours and use it for all other hours in the day. Pressing the "optimal" button will calculate the best setting for solar PC and energy storage sizing to not require any energy from the grid for the "average day", bringing the annual energy cost close to zero. Unfortunately these settings are not sufficient to go completely "off the grid", as a much larger energy storage would be required to overcome a few rainy/cloudy days in a row.

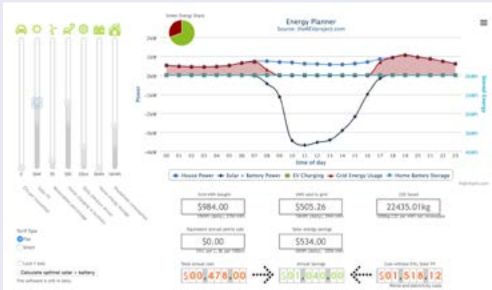
(4) Finally, EVs can be introduced into the household with their average daily driven distances and the effect on the solar/storage configuration be observed and again optimized.

Thomas Bräunl and Stuart Speidel

(1)



(2)



(3)

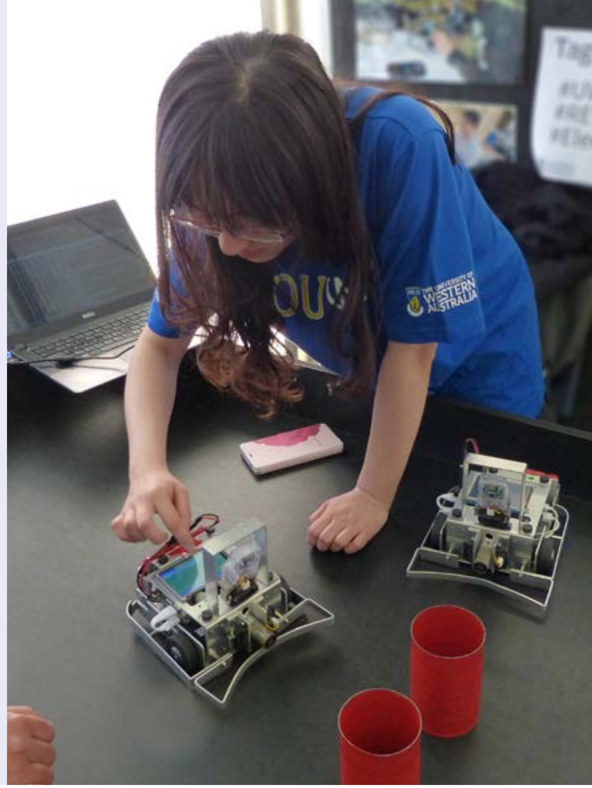
(4)

Robotics and Automation Lab

Professor Thomas Bräunl,
Dr Adrian Boeing and Mr Chris Croft

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: http://robotics.ee.uwa.edu.au

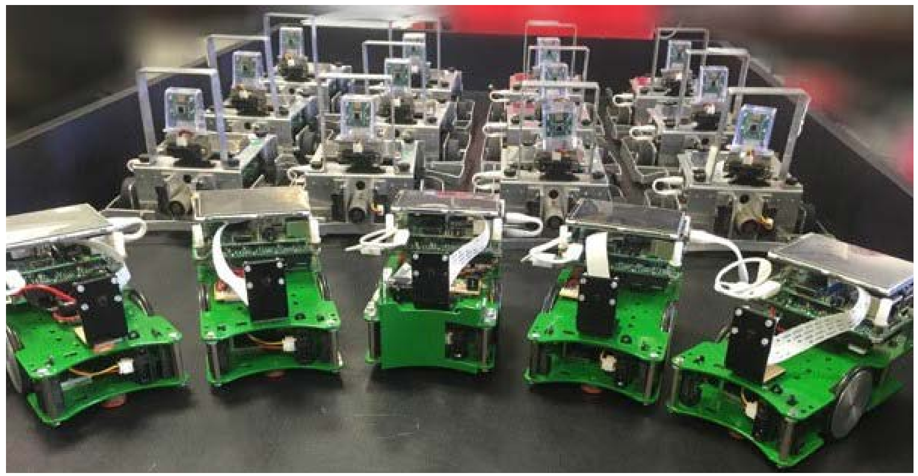
The Systems Engineering Analysis Management Project (SEAM) operates within this lab.



Above: obstacle avoidance through optical flow

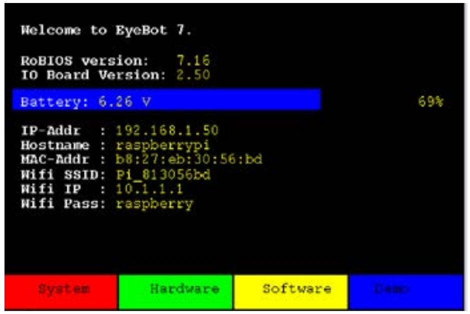
Mobile Robots

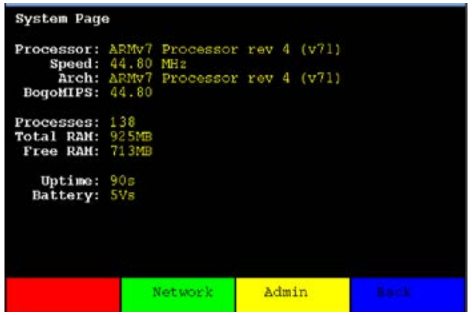
All of our small, embedded mobile robots are now based on Raspberry PI-3 controllers, which give us at least one magnitude of higher computational performance, compared with the previous generation based on ARM + FPGA. This is especially required for our applications in real-time image processing and learning algorithms.

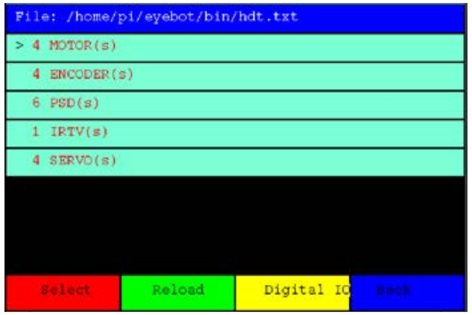


We have completed new hardware, in the form of an interface board for all sensors and actuators of our mobile robots, as well as a new version of our robot operating system, RoBIOS-7, which now runs as an application on top of Linux.

Typical application programs include object detection, learning, path planning, swarm behavior, and cooperative work.







Autonomous Hexacopter (SEAM)

Within the Robotics and Automation lab, the SEAM Project (Systems Engineering Analysis Management) undertakes a wide range of differing projects, usually in conjunction with other groups or researchers. SEAM has two major areas of interest—the management of systems in crisis and the development of automated control of remotely piloted vehicles.

A hexacopter multi-rotor unmanned aerial vehicle (UAV) has been designed and built. This autonomous vehicle is controlled by a modified Raspberry Pi controller and can perform preconfigured GPS way-point paths as well as tracking color-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.

Chris Croft

Autonomous Submarines

Above: the blue MAKO and yellow USAL AUVs

Underwater robots are broadly used in oil and gas industries, environmental surveys, search and rescue and other areas due to their capabilities of remote operation, data logging and manoeuvring, and can perform autonomous operations, navigating long distances at deep depths for monitoring and even carrying actuators such as robot arms.

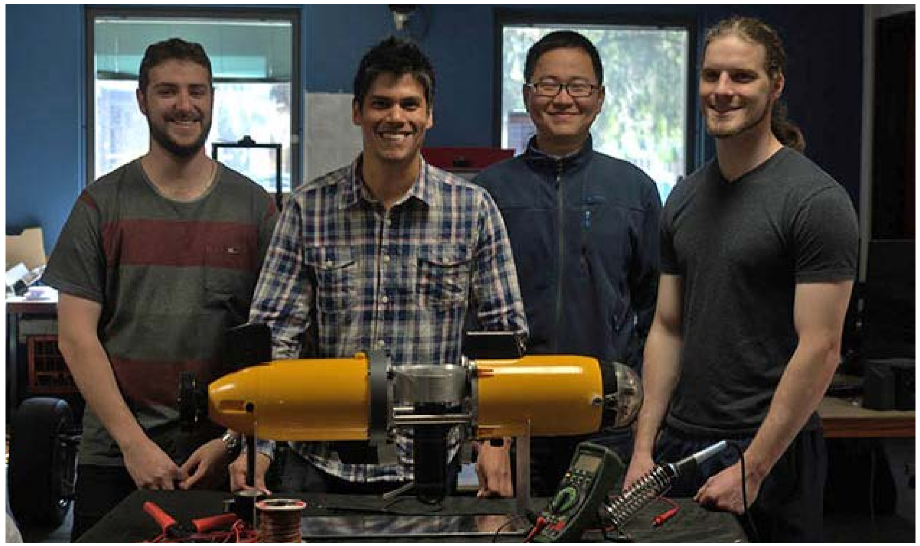
A major challenge is to make autonomous robots aware of their surroundings and location, particularly in underwater scenarios without GPS and with positioning sensor errors. Simultaneous Localisation and Mapping (SLAM) is an approach that integrates data for positioning and map generation in order to estimate the current position of the robot in an online build map. The final goal is to develop and test different SLAM algorithms for low-cost robot applications.

In the last year, two underwater vehicles of the Robotics and Automation lab have been upgraded: the MAKO and USAL. Both robots have propellers to generate thrust but have a different configuration for turning. The USAL utilises a rudder for performing curves whereas the MAKO has a set of thrusters for rotating and curve. In terms of sensors, the robots have cameras for mapping and positioning sensors such as Inertial Measurement Units, distance, depth and velocity sensors.

The software architecture is being upgraded to ROS (Robot Operative System) which allows a modular and flexible programming framework. The architecture inherently can be integrated into a simulation environment set with hydrodynamics and physics laws for testing. The hardware structure is abstracted in this environment having virtual sensors and actuators.

The robots and the simulation environment will be the research platform for developing and testing SLAM algorithms that will provide more tools for autonomous navigation for underwater robots.

Franco Hidalgo



Above: The AUV team—Tim Raphael, Franco Hidalgo, Xiaochuan Zhou and Robert Hortin

High Integrity Computer Systems Lab

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.

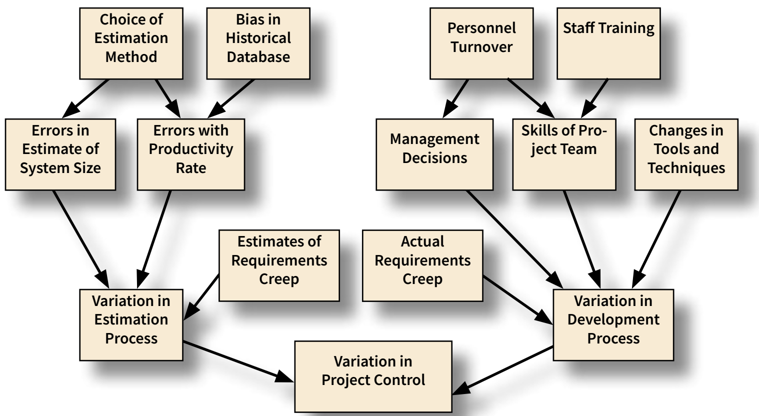
Now in his 50th year at the University of Western Australia, Terry continues to research, teach and supervise higher degree students in the area of Software Engineering.

The departure of Professor Gary Bundell from the group has led to a decrease in the activities of the High Integrity Computer Systems Lab. However, Terry was involved with Professor Melinda Hodkiewicz and members of the School of Computer Science and Software Engineering (CS&SE) in consulting to a large mining company on the application of Artificial Intelligence to key process controls.

Terry continues to have significant teaching roles in units on Software Quality, the Software Process and the Risk, Reliability and Safety of Engineering Systems.

He also has supervised a number of student projects including Sam Hall's development of a diagnostic system for problems in software project estimation. In 2015, Omar Al-Bataineh successfully completed his doctoral thesis on 'Verifying Real-time Systems Using Dense-time Model Checking Technology'. This work was supervised by Terry in conjunction with Professor Mark Reynolds and Dr Tim French of CS&SE.

In 2015, Terry became chairman of the Software Engineering Forum, a joint initiative of the Institute of Engineers Australia and the Australian Computer Society. This group meets monthly to disseminate new ideas and results to software professionals in government, industry and academia.



Sources of variations in software projects

Above: Figure from Sam Hall's dissertation on numerically partitioning the variation in project control into sets of changes to the estimation and actual development processes.

Smart Grids Lab

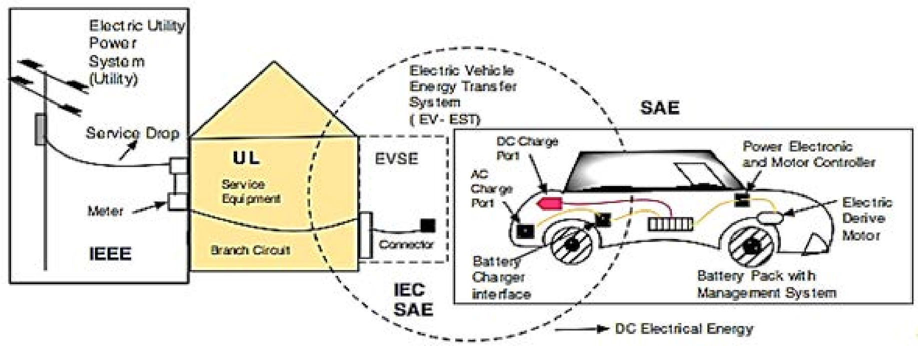
Professor David Harries

The Smart Grids Lab is currently involved in investigating electric vehicles (EVs). This work includes The University of Western Australia's Renewable Electric Vehicle (REV) Project on analysis and modelling of EV charging behaviour.

During the past year David collaborated on a PhD research project assessing the combined impacts of distributed solar PV systems, battery energy storage systems and electric vehicle (EV) recharging on a local distribution network. High penetrations of distributed solar PV systems can result in voltage rise and frequency drops in the grid (instability). The project used a real distribution network to simulate the instability impact using the Power Factory power supply system simulation software. The modelling was then repeated with increasing levels of battery energy storage capacity over a period to 2030. To analyse the impacts of increasing EV penetration levels, a model of a typical low-voltage distribution grid was developed under three different future scenarios (2030). The results explored the consequences of high penetration rates of EVs as well as high penetration rates of PV systems and utilising Energy Storage Systems (ESS). An optimal charging pattern for energy management was developed based on the outcomes of the analysis. This study concluded that a control strategy for EV charging based on peak demand shaving, combined with high levels of solar PV penetration and relatively moderate levels of energy storage capacity would have benefits for the local network in terms of reducing demand, reducing peak loads, improving the voltage profile and minimising power losses.

A second project that David collaborated with was an Honours research project focusing on the differences and similarities in stated motivations, perceptions and attitudes towards EVs between industry groups and the Western Australian public. A second purpose was to understand what these different groups believed would be the optimal public policy measures to encourage EV uptake. A qualitative survey was used to survey members of the Australian general public and industry groups, including Sustainable Energy Now (SEN) and the Western Australian chapter of the Australian Electric Vehicle Association (AEVA). The survey responses revealed a strong case for policy to be based on evidence, rather than on public or populist opinion.

David also worked on a paper modelling the likely sale value depreciation rates of electric vehicles with Professor Thomas Bräunl (School of Electrical, Electronic and Computer Engineering) and Professor John Taplin (UWA Business School).



Above: Electricity transfer for electric vehicle recharging

Student Activities

UWA Endurance Vehicle Team

Shell Eco-Marathon, Manila

A team of 15 UWA undergraduate students represented Western Australia in the February 2015 Shell Eco-Marathon in Manila, The Philippines.

Over a period of six months the UWA Endurance Vehicle (EnVe) Team planned, designed and constructed the competition racer for the ultra-high-efficiency challenge. For most members, this was the first practical outlet for the skills they had learned in their classes, and was an opportunity to gain an intensive understanding of the design and manufacturing processes they will use throughout their careers. The team's Technical Director Rowan Heinrich, decided they would experiment with highly advanced technology such as vacuum-infused carbon fibre composites and in-house built electrical systems, as this expertise would better prepare members of the team for careers in engineering.

The UWA EnVe Team alongside the team from Deakin University were the first Australian teams ever to travel to the Shell Eco-Marathon, a series of endurance races designed to challenge vehicles of energy types including Hydrogen Fuel Cell, LPG, Petrol and Battery-Electric. The 10-day tour was also the first international competition for a UWA team since 2009.

Shell Global, who invited the team to participate, also hosted over 120 other international teams spanning a region from Egypt to Japan. The incredible scale of the event meant that even the racetrack and buildings for the event had to be planned for more than a year before the actual races.

The vehicle, featuring a full carbon fibre monocoque, 750W (1HP) electric motor, custom-built 48V LiFePO4 battery, adjustable gear system and hydraulic disk brakes managed to endure both a battery system malfunction and a transmission failure before being withdrawn from the race.

The team would like to thank sponsors for joining us on our competition journey.

The next competition for the team is anticipated to be the World Solar Challenge 2017 from Adelaide to Darwin.

Carl P-Conquilla

ITC Global EV Challenge

Following the Shell Eco-Marathon in February 2015, the UWA EnVe team was invited to participate in the 2015 ITC Global EV Challenge in Wundowie, Western Australia.

The competition is open to secondary and tertiary student teams, as well as privately entered teams with a focus on energy efficiency and cost-effectiveness. The entirely carbon-fibre monocoque construction of the 2015 EnVe racer, competed in the dynamic events.

Since the competition is aimed at significantly lower budget vehicles than the UWA entry, the team decided to experiment with some of the more advanced technologies such as heavier steering mechanism, overdriven motor controller, driver-selectable gear ratio and a stiffer rear brake assembly.

Carl P-Conquilla

EnVe 2015 Technical Specifications	
Weight:	62kg
Propulsion:	Rear wheel driven via chain and adjustable ratio sprocket, 750W brushed geared DC motor
Chassis:	Vacuum infused carbon fibre, with foam core, steel front and rear roll hoops, polycarbonate windows
Energy Storage:	12x LiFePO4 cells, 48Wh, 38.4V nominal
Suspension:	Carbon wing cantilever flexure beam, front only
Safety Features:	Five-point harness, fully encapsulating steel roll structure, carbon fibre impact structure front/sides/floor, firewall insulation between electrical systems and driver, rapid escape system (less than 3 seconds escape time), fire extinguisher and emergency shutdown interlock internal and external.

Large-Scale Simultaneous Localization and Mapping for Teams of Mobile Robots

Robert G. Reid

Supervised by Professor Thomas Bräunl, and Dr Adrian Boeing

Localisation and mapping are core requirements for teams of mobile robots to cooperate autonomously in everyday environments. From emergency search and rescue, to precision agriculture and space exploration, there are many applications where it is advantageous to deploy teams of robots without relying on external localization or a priori maps, and instead using on-board sensors only. This problem, called Simultaneous Localization And Mapping (SLAM), has been well-studied for individual robots. While many single-robot SLAM solutions have been adapted to teams of robots, highly-centralized architectures are typically proposed that fail to address real-world problems such as intermittent and lossy communications, and particularly in the case of large-scale deployments.

For robust deployments of autonomous teams of robots, a decentralized multi-robot SLAM (MR-SLAM) solution is required; one that allows teams of robots to operate for extended periods independent of a central server by sharing SLAM data and performing loop closures on-board. Several decentralized architectures have been described in the literature, however none have demonstrated MR-SLAM with the mapping fidelity required for both indoor and outdoor deployments at large scales. State-of-the-art large-scale MR-SLAM systems have demonstrated up to 15 robots exploring a 500×500 meter urban environment at the 2010 Multi Autonomous Ground-robotic International Challenge (MAGIC). While these systems were centralized, their Decoupled Centralized Architectures (DCA) allowed individual robots brief periods of limited autonomy. Without the ability to share SLAM data or close loops on-board, however, architectures like DCA are unable to provide teams of robots with extended operations or high-level autonomy independent of a central server.

This thesis contributes in three areas:

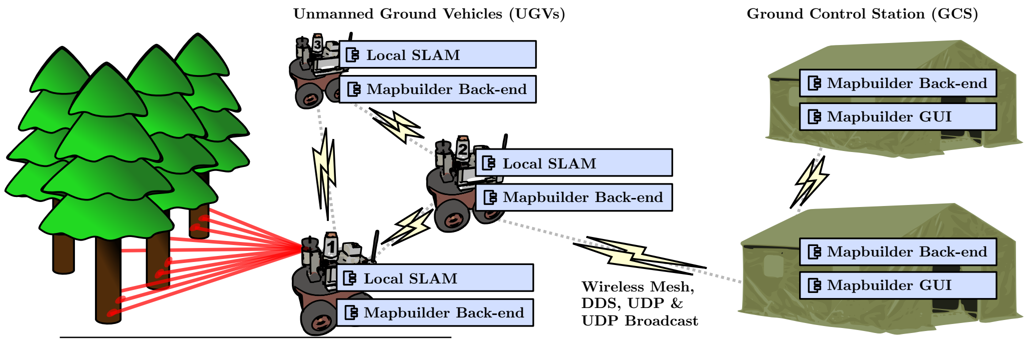
1) The design of a MR-SLAM architecture that combines a novel hybrid-decentralized pose-graph SLAM technique with a unique submap-based approach; this architecture distributes pose graph optimization and global map building across all robots, enabling decentralized teams to operate autonomously for extended periods.

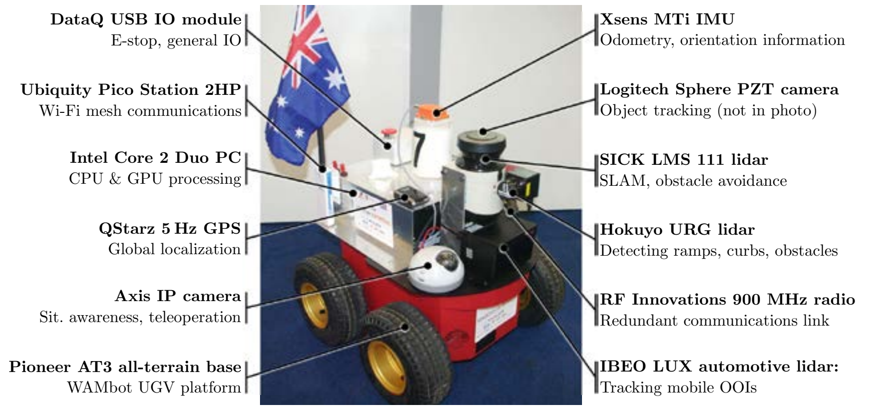
2) Highly-parallelized algorithms that enable efficient global occupancy gridmap fusion and efficient submap correlations that generate multimodal constraints; together these algorithms allow the proposed architecture to be realized on commodity hardware.

3) Continuous Mode Blending Optimization (COMBO), a novel technique that enables pose graphs with multimodal constraints to be optimized using traditional nonlinear least squares; this allows complex environments and effects such as perceptual aliasing to be modeled more accurately.

These contributions were demonstrated on-line at the MAGIC challenge, and more recently with three merged challenge datasets replayed in real-time—these are the largest multi-robot datasets described in the literature, with heterogeneous teams of 10, 14 and 23 robots exploring over 3.1 km, 6.1 km and 8.3 km of total odometry, respectively. Results include global occupancy gridmap fusion at over 20 Hz, with globally-referenced mapping accuracies of ±0.27 m, ±0.62 m and ±0.35 m, without using Global Positioning System (GPS) sensors. The proposed submapping technique compresses sensor data approximately 50 fold, reducing communications bandwidth requirements to averages of 1.2 KB/s, 2.2 KB/s and 2.4 KB/s. Submap constraints with multimodal Gaussian distributions are generated in real-time and desirable convergence properties are demonstrated using COMBO. The total computation, storage and communications requirements are shown to scale linearly, enabling future deployments orders of magnitude larger.

By distributing the MR-SLAM back-end so that all robots are able to build their own copies of the global gridmap, the proposed architecture enables teams of robots to operate autonomously without continuous communications to a centralized server. This distributed approach is highly scalable, since each robot includes the computational resources it requires to process its own sensor data and maintain its own registration to the global pose graph. The proposed hybrid-decentralized and distributed MR-SLAM architecture provides robust localization and mapping capabilities for large-scale deployments of autonomous robots in real-world conditions. This approach enables many applications where teams of robots need to cooperate in GPS-denied environments, with imperfect communications and without a priori maps.





Energy Efficiency of Electric Vehicles and Recharging Technologies

Guido Wäger

Supervised by Professor Thomas Bräunl, Dr Jonathan Whale and Professor David Harries

Transportation in our developed world is a complex system and a major component of the world economy. However, the unsustainable use and air pollution caused by the use of conventional motor vehicles and their dependency on fossil fuels are a major concern. Although electric vehicles (EVs) are feasible solutions to reduce current transport issues EVs face market uptake barriers in particular due to limited range as well as efficiency and recharging issues. Although many major car manufacturers offer EVs there are knowledge gaps in efficient use and operation of these vehicles. This project will identify and analyse inefficiencies from the charging infrastructure to the vehicle operation and use and will offer potential solutions.

Firstly the project has investigated energy efficiency improvements by synchronising auxiliary air-conditioning (AC) with the vehicle drive train on a real road driving cycle pattern. The research findings are applicable to EVs, internal combustion engine (ICE) vehicles, and hybrids. An EV-converted Ford Focus was configured to operate the AC compressor solely from kinetic energy recovered from the drive train when coasting or slowing down. Test drives with the Ford Focus with standard AC operation increased the energy consumption by 11.6% compared to AC off, yet when the vehicle was synchronised with the drive train the energy consumption increased by only 5.8% compared to AC off, an energy saving of 8.1Wh km-1. The configuration maintained comfortable cabin conditions (temperature and humidity) similar to driving with a standard AC system configuration. In vehicles with an interconnected automatic AC and engine management system data-bus, this efficiency improvement may require a software update only. The second part of the project investigated driving of electric vehicles at highway speeds. Fast-DC charging significantly reduces the recharging time and can be used to make longer EV trips possible, e.g. on highways between cities. Although some EV and hybrid car studies have been conducted that separately address issues such as limited drivable ranges, charge stations, impact from auxiliary loads on vehicle energy consumption and emissions, there is currently limited research on the impact on drivable range from the combination of driving EVs at highway speeds, using auxiliary loads such as heating or air conditioning (AC), and reduced charge capacity from fast-DC charging and discharge safety margins. In this study we investigate these parameters and their impact on energy consumption and drivable range of EVs. Our results show a significantly reduced range under conditions relevant for highway driving and significant deviation from driving ranges published by EV manufacturers. The results and outcomes of this project are critical for the efficient design and implementation of so-called ‘Electric Highways’. To prevent stranded cars and a possible negative perception of EVs, drivers and charging infrastructure planners need be aware of how EV energy and recharging demands can significantly change under different loads and driving patterns.

Further studies are planned for 2017 investigating efficient acceleration and decelerations (Smart Braking) of electric vehicles.

Autonomous Visual Navigation for Ground Robots and Vehicles

Kai Li Lim

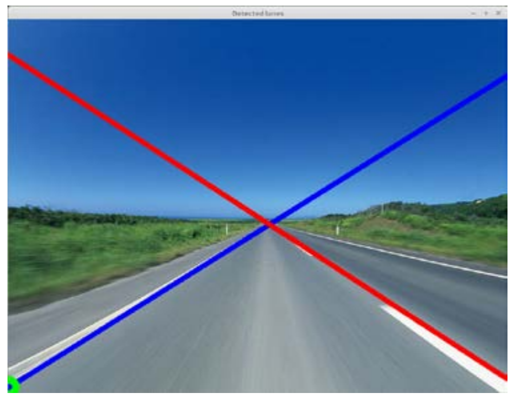
Supervised by Professor Thomas Bräunl

Above: Pedestrian detection using OpenCV. Based on the pedestrian’s position in the frame, the vehicle is able to react and steer away from the pedestrian.

Autonomous mobile robotics is a popular research field in recent times, as they are becoming increasingly indispensable for tasks that require the exploration of uncharted areas, reconnaissance and search-and-rescue operations. Likewise, the advent of visual and high-performance computing such as General-purpose computing on graphics processing units (GPGPU) is seeing the solving of computer vision problems at unprecedented speeds and accuracy. This research project works on a holistic visual navigation solution for autonomous ground robots and vehicles. This solution combines visual odometry and scene recognition to achieve navigation and localisation.

Visual odometry is an alternative to wheel odometry that is commonly used in mobile ground robots, its application is most beneficial for the solving of wheel slip—an odometric error that commonly occurs in varying terrains that accumulate during navigation. Using visual odometry also enables the robot to perform obstacle detection and avoidance, whereby the algorithm will be capable of estimating the distances between the robot and the obstacles through motion perception.

Visual scene recognition supplements visual odometry to achieve positioning and localisation using the camera, without the need for additional sensors or environmental fixtures. This is achieved by associating and recognising objects and features that are unique to a certain location. The recognition of these objects also enables obstacles to be tracked and classified, supplementing the results from optical flow on applications such as pedestrian detection and tracking. Additionally, using scene recognition enables the segmentation of ground areas into traversable and nontraversable areas; an example of this is the detection of kerbs and lane markers on roads. While visual odometry and place recognition is widely researched independently, works that combine both elements with optical flow are few. This project’s execution will be done in two parts, where algorithms will first be tested on a Raspberry Pi-controlled mobile robot for prototyping before it is ported onto an electric vehicle for final testings. The finished product will incorporate state-of-the-art visual navigation techniques such as deep learning and classification on a dedicated hardware platform for autonomous driving.

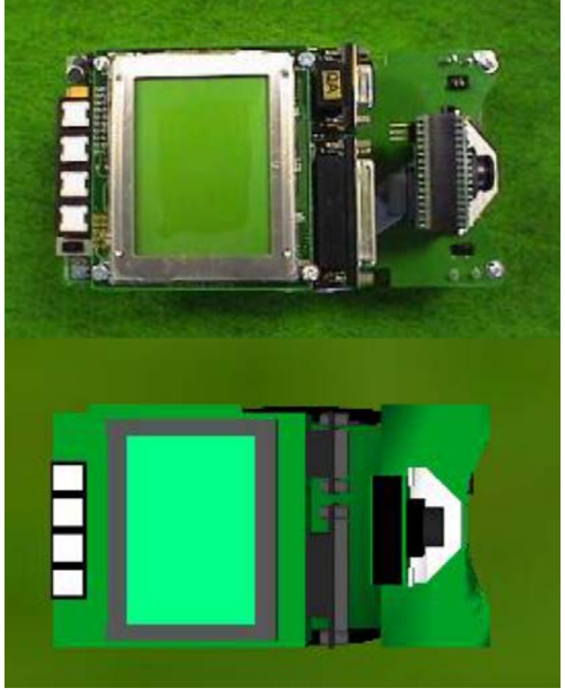


Visual road lane detection using Hough transform. These lines mark the left and right lane boundaries, guiding the vehicle’s trajectory (image: public domain).

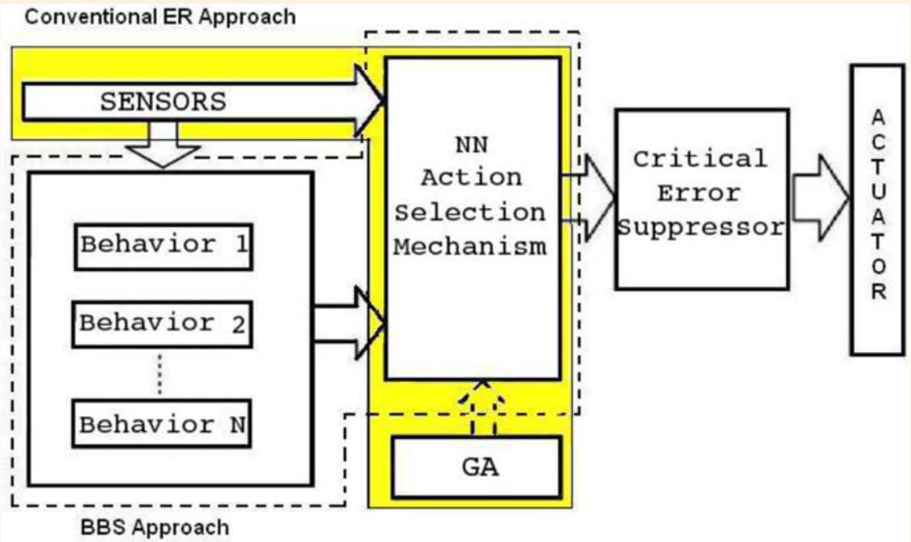
A Genetically Evolved Neural Network for an Action Selection Mechanism in Behavior-based Systems

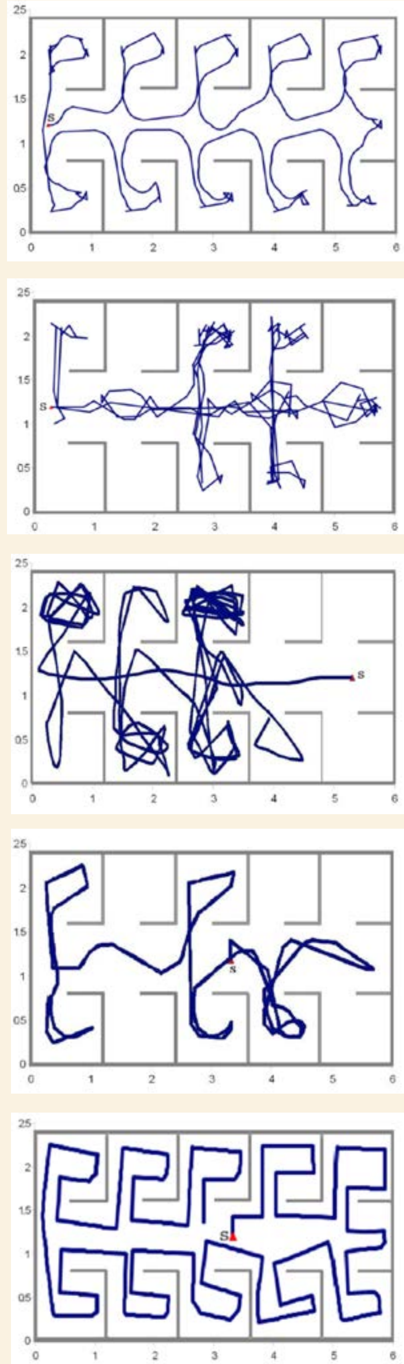
Dr Saufiah Abdul Rahim
Supervised by Professor Thomas Bräunl

The world of robotics has grown so much that it has reached a state where it can be trusted with many real-world applications, especially those that involve a high safety risk for human effort. From its 'humble' beginnings operating in a static and controlled environment, robot platforms are now required to operate in dynamic and unknown environments, which traditionally require human intelligence for real-time decision making. Development of a control system for a robot platform to handle such a scenario can be very demanding. The system requires complex decision making capabilities in order to be sufficiently robust and responsive to the dynamics of its environment. One possible approach is to implement a behavior-based system, which 'reacts' to its environment rather than using pre-programmed rules of engagement. However, other than the accuracy of its sensors, the success of a behavior-based system relies largely on its Action Selection Mechanism (ASM) module, which is basically a behavior coordination method. Common implementations of behavior coordination method can be categorised into two: arbitration and command fusion. Consequently, deciding on a suitable coordination method for a particular task in an unknown environment presents a similar complex issue. To handle this, the more popular approach is to use Artificial Intelligence (AI) in the development of ASM modules. In this thesis, a Genetic Algorithm (GA) has been used to evolve a neural network engine that is used as an ASM module for a behavior-based system. The proposed control architecture implements a basic GA to train the synaptic weights of a simple Multi-Layered Perceptron (MLP) feed-forward Artificial Neural Network (ANN) in identifying a suitable formulation of ASM. A simple, yet found to be adequate, fitness function has been formulated in order to ensure the effectiveness of a GA in evolving the system. The proposed fitness function is defined as such that it can be generalised and applied to any robot control tasks. The proposed system has been tested using simulation software in two common robot mission scenarios involving unknown environments: search and exploration, and target tracking. Simulation results show that the proposed Genetically Evolved ASM (GEASM) can dynamically manage the behavior coordination method that enables the system to achieve mission objectives in both test scenarios. For the search and exploration mission, the GEASM managed to achieve a 93% success rate compared to other architectures, with the nearest competitor at 67%. As for the target tracking mission, the GEASM achieved a stunning 100% success rate, compared to the next best at 75%. Since the test environment is actually different from the one used in training the proposed system, it can be projected that the GEASM can actually enable a system to perform in an unknown environment with a significantly high probability of success.



Real and simulated robot





Media Reports

Television Reports and Interviews

Channel 9, ***The first electric jet ski to hit Australian waters***, National Nine News, Tim McMillan and Emmy Kubainski, 23 October 2015 18:46

ABC TV News, ***WA's EV Charging Network***, Claire Moodie, 22 January 2015, 17:17 and 19:21

Print Media

The Western Independent, ***Australia's eco jet ski***, vol. 21, no. 4, November 2015

Subiaco Post, ***Top tech award for UWA student***, 17 January 2015, p. 69 (1)

UWA News, ***Quick charge at the Club***, Lindy Brophy, December 2014, vol. 33, no. 10, pp. 8 (1)

Radio Interviews

6PR, ***Australia's First Electric Personal Watercraft***, Interview, 23 October 2015, 12:45

720 ABC Radio, ***Electric Jet Ski***, 23 October 2015, 14:03
Also broadcast from: ABC Goldfields WA (Kalgoorlie), ABC Great Southern (Albany), ABC Kimberley (Broome), ABC Midwest and Wheatbelt (Geraldton), ABC North WA (Karratha); ABC South West WA (Bunbury).

ABC Radio Australia, ***Mahasiswa Australia Ciptakan Jet Ski***, by Nicolas Perpitch, 23 October 2015, 15:35

6PR Radio, Perth Tonight, ***Fast-DC Charging at UWA***, interview with Chris Ilsley, 12 December 2014, 20:00

Online and Other

Electronics News Australia, ***WA students build battery-powered jet ski***, 26 October 2015
http://www.electronicsnews.com.au/news/wa-students-build-battery-powered-jet-ski

Gas2, ***Electric Jet Ski is zero emissions fun***, 24 October 2015
http://gas2.org/2015/10/24/electric-jet-ski-is-zero-emissions-fun/

Gizmodo Australia, ***Watch Australia's First Electric Jet Ski in Action***, 24 October 2015
http://www.gizmodo.com.au/2015/10/watch-australias-first-electric-jet-ski-in-action/

WA today, ***Perth's UWA shows off Australia's first electric jet ski***, 28 October 2015
http://www.watoday.com.au/wa-news/perths-uwa-shows-off-australias-first-electric-jet-ski-20151028-gkklky.html

Inside EVs, ***UWA Floats Electric Jet Ski***, 28 October 2015
http://insideevs.com/uwa-floats-electric-jet-ski/

Professional Activities

Invited Talks

Thomas Bräunl

23 September 2016
Invited Talk: *From Silicon Valley to Automotive Valley*, Department of Transport, Perth Transit Authority, East Perth

22 July 2016
Seminar Presentation: *Automotive Valley*, UWA/EECE Sabbatical

24 June 2016
ChargeForward and HEMS-EV Integration, BMW Group Technology Office, Mountain View CA

9 February 2016
Presentation: *REV Lab,* at BMW Group Technology Office, Mountain View CA

20 December 2015
Keynote Address together with Reinhard Klette (AUT, NZ): *Smart Vehicles for a Smart City*, 2015 IEEE International Conference on Smart City, Chengdu, China

4 December 2015
Invited Talk: *Autonomous Vehicle Research*, for Innovation Autonomous Vehicles Round-table, PriceWaterhouseCoopers, Perth

3 September 2015
Invited Talk: *Electric Vehicle Research in Western Australia*, AEVA Annual Meeting, Fremantle

11 August 2015
Invited Talk: *From Mobile Robots to Autonomous Vehicles*, UWA Engineering Seminar, Perth

23 July 2015
Keynote Address: *Autonomous Vehicles—The Future of Mobility*, Australian Institute of Traffic Planning and Management (AITPM), Self-Driving Vehicles Technical Forum, Perth

17 February 2015
Keynote Address: *From Electric Cars to Autonomous Vehicles*, The 6th International Conference on Automation, Robotics and Applications (ICARA 2015), Queenstown, New Zealand

David Harries

August 2016
Invited Talk: *The role of Distributed Generation in Australia's future electricity supply system*, Allans Linklater forum on Energy, Perth.

October 2016
Invited Talk: *Towards a sustainable electricity supply system,* National Environmental Law Association Conference, Perth.

Semester 2 2016
Guest Lecturer: *Geothermal Energy and Biomass Energy,* for the Renewable Energy Unit (GENG5506) in the Master of Professional Engineering at UWA.

Professional Committees

Thomas Bräunl

- Member of the Board of Governors (BoG) of the IEEE Intelligent Transportation Systems Society (ITSS), 1 January 2014 to 31 December 2016

David Harries

- Cockburn Sound Management Committee.
- President, Conservation Council of Western Australia.

Conference Chairs

Thomas Bräunl

IEEE Pacific-Rim Symposium on Image and Video Technology (PSIVT)

- Program Co-Chair, 2015 Auckland NZ

International Conference on Autonomous Robots and Agents (ICARA)

- Keynote Presenter, Steering Committee and Program Committee, 2015 Queenstown, NZ.

IEEE International Conference on Robotics and Automation (ICRA)

- Associate Editor 2015, Seattle WA
- Associate Editor 2016, Stockholm, Sweden

19th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems (KES)

- International Program Committee, Singapore 2015

IEEE 18th International Conference on Intelligent Transportation Systems (ITSC)

- Associate Editor, Gran Canaria Spain, 2015

Australasian Conference on Artificial Life and Computational Intelligence (ACALCI 2015)

- Program Committee, 2015 Newcastle, Australia

Terry Woodings

- Chairman of the Software Engineering Forum, a joint initiative of the Institute of Engineers Australia and the Australian Computer Society

Publications

Books

Urmee, T., Harries, D., Holtorf, H.
Photovoltaics for Rural Electrification in Developing Countries
Springer International Publishing, Switzerland, 2016

Bräunl, T., McCane, B., Rivera, M., Yu, X. (Eds.)
Image and Video Technology
7th Pacific-Rim Symposium, PSIVT 2015, Nov. 25–27, 2015, Auckland, New Zealand, Revised Selected Papers Series: Lecture Notes in Computer Science, Vol. 9431, Subseries: Image Processing, Computer Vision, Pattern Recognition, and Graphics, Springer, Heidelberg, 2016

Book Chapter

Boeing, A., Bräunl, T.
Dynamic Balancing of Mobile Robots in Simulation and Real Environments
In: Dynamic Balancing of Mechanisms and Synthesizing of Parallel Robots, Zhang, D., Wei, B. (Eds.), Springer International, Cham Switzerland, Dec. 2015, pp. 457–474 (18)

Journals

Speidel, S., Bräunl, T.
Leaving the Grid—The Effect of Combining Home Energy Storage with Renewable Energy Generation
Renewable & Sustainable Energy Reviews, 2016

Wäger, G., Whale, J., Bräunl, T.
Driving Electric Vehicles at Highway Speeds—The effect of higher driving speeds on energy consumption and driving range for electric vehicles in Australia
Renewable & Sustainable Energy Reviews, 2016

Oakley, J., McHenry, M., Bräunl, T.
Limitations of testing standards for battery electric vehicles: accessories, energy usage, and range
IET Electrical Systems in Transportation, 2016, pp. (17)

Azadfar, E., Sreeram, V., Harries, D.N.
The investigation of the major factors influencing plug-in electric vehicle driving patterns and charging behaviour
Renewable and Sustainable Energy Reviews, 42: 2015 pp. 1065–1076

Boeing, A., Baltes, J., Bräunl, T.
Using Modelling and Simulation to Improve Dynamic Balancing of Biped Mobile Robots
Int. Journal of Mechanisms and Robotic Systems, vol. 2, no. 3/4, 2015

Conferences

Teoh, S., Bräunl, T.
Performance Evaluation of HOG and Gabor Features for Vision-based Vehicle Detection
5th IEEE Intl. Conf. on Control System, Computing and Engineering (ICCSCE 2015), 27–29 Nov. 2015, Penang Malaysia, pp. 72–77 (6). Best Paper Award.

Hidalgo, F., Mendoza, J., Cuéllar, F.
ROV-based acquisition system for water quality measuring
OCEANS 2015, 19–22 Oct. 2015, Washington D.C.

Drage, T., Churack, T., Bräunl, T.
LIDAR Road Edge Detection by Heuristic Evaluation of Many Linear Regressions
18th IEEE Intl. Conf. on Intelligent Transportation Systems, ITSC 2015, Sep. 15–18, 2015, Gran Canaria, pp. (6)

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

Abstracts of Final Year and MPE Project Dissertations

Richard Allen

Supervisors: Thomas Bräunl and Chris Croft

Autonomous UAV Collision Avoidance

Unmanned aerial vehicles are at the forefront of human-robot interaction. There is an explosion currently undergoing in the popularity of commercial products and hobbyist projects. Their use in fields such as search and rescue, delivery, photography, and scientific study is becoming more commonplace. As this trend continues, we can expect both more reliance on UAVs' autonomous behaviours, as well as more incursion into human spaces.

The project uses a multirotor platform entailing an Ardupilot flight computer, laser range-finder, and a raspberry pi computer and camera. It has been made capable of user-directed waypoint navigation, avoidance of user-determined obstacles, computer vision in tracking and following objects, and image data collection. This report is on our work in the field of object avoidance and environmental mapping.

Christopher C. Blignaut

Supervisor: Thomas Bräunl

Methods for Improving the Absolute Localisation of an Autonomous SAE Vehicle

In 2013, UWA developed an autonomous high level control system on a Formula SAE race car, enabling the vehicle to autonomously drive along paths defined by GPS waypoints. This provided a foundation platform for further research and in 2015 the REV Project's Autonomous SAE Team set out to improve aspects of the functionality and robustness of the vehicle. It was determined that a limiting factor in the vehicle's performance, ease of use and advanced obstacle avoidance, was its poor localisation. Localisation is the vehicle's ability to accurately determine its position in either an absolute (global) frame, or its relative position from its initialized position.

This report outlines the design and implementation of a unique, low-cost real-time kinematic (RTK) GPS solution, integrated into the SAE vehicle's localisation scheme. This integration is adapted to the current controller and configured to enable survey-grade absolute positioning during times of GPS availability. Tests on the RTK implementation indicated significant improvements in the accuracy of absolute position, with a slight compromise in reliability. Of significance, the capacity for the vehicle to localize accurately, identified masked problems in the vehicle control, and thus allowed for progression towards a better functioning autonomous vehicle.

Whilst implementation of the RTK GPS was successful, it highlighted the need for the vehicle to be able to operate in times of a loss of GPS availability. For a complete localisation solution, methods of dead-reckoning and filter driven interpolation between GPS corrections were investigated.

The report also describes the design and partial implementation of a tightly coupled recursive Extended Kalman Filter into a sensor fusion scheme using odometry as the main element of positioning, and outlines all possible issues that might arise in the full implementation and testing.

Thomas Churack

Supervisor: Thomas Bräunl

Improved Road-Edge Detection and Path-Planning for an Autonomous SAE Electric Race Car

This paper describes the development and implementation of several improvements made to the UWA REV Autonomous SAE Electric Race Car, specifically with respect to its road-edge detection capabilities and path-planning intelligence.

The road-edge detection capability of the vehicle has been extended to allow the vehicle to make use of all the layers of incoming LiDAR scan data provided by the IBEO laser scanner and this data is also now adjusted in real time, so as to compensate for any variations in vehicular attitude. One application for road-edge detection—the ability to map traversed roadways—is explored to test the efficacy of these improvements in practice. The vehicle's road-edge detection capability sees further additional applications through the exploration and implementation of its integration in to the vehicle's path-planning subroutines, so as to facilitate the vehicle being able to autonomously remain on road while driving, rather than being manually instructed to follow curves through dense way-pointing. A lane-keeping algorithm is also proposed to further extend the vehicle's path-planning ability with a view towards making the vehicle practical to operate in an urban environment.

Results are demonstrated through simulations showing the successful integration of real-time road-edge avoidance, thus achieving the goal of the project.

Zisu Ding

Supervisor: Thomas Bräunl

Motor Comparison and Selection for Electric Jet Ski

Jet skis, traditionally powered by diesel or petrol engines, have good performance but at the expense of emitting pollutants and producing noise. The REV Project aims to convert a traditional petrol-powered Jet ski to a fully electricity-powered one, eradicating pollution to the environment while maintaining good performance. The motor, regardless of type, is one of the most important components of any electric vehicle. It is responsible for delivering mechanical energy by using electric energy as a power source.

For this project, the battery-powered motor is designed to drive the impeller connected to it. With several motors available on the market, an asynchronous motor, synchronous motor and two types of DC motors have been investigated in a theoretical point of view as well as real context, i.e, the electric Jet ski.

Meanwhile, commercially available motors of each type are selected in order for further practical comparison by taking into account several practical factors. Though limited in motor types and specific models, the investigation and comparison together are expected to provide both justification for the Jet ski motor selection and reference work for future similar projects.

Brett Downing

Supervisors: Chris Croft, Thomas Bräunl

Computer Vision Driven Object Tracking for Low-Cost UAVs

Multirotors are here to stay, and may soon be expected to interact in a human environment. Commodity Quadcopters are advertising capabilities to act as chase-cams and turn-key mapping solutions, but none of the current generation commodity UAV offerings feature computer vision driven or even assisted flight modes to improve tracking, image framing or obstacle avoidance. Such vision-assisted routines would also apply to autonomous or semi-autonomous inspection tasks for fixtures in remote or hazardous environments.

In this project, we build on the results of previous year groups and implement turn-key waypoint navigation and fail-safe methods using the Ardupilot software stack, and develop robust object tracking, data collection behaviours and exclusion zones on a computationally starved platform with an aim to integrate vision-assisted behaviours in low-cost, lightweight UAVs.

Timothy Ha

Supervisor: Thomas Bräunl

Development of a Motor Controller for an Energy Efficient Electric Vehicle

The Shell Eco-Marathon held in Manila is an annual competition aimed at sparking innovation in the development of efficient automotives and attracts over 130 teams from universities across the Asia-pacific region. The UWA Endurance Vehicle team aims to enter a vehicle in the battery electric category of the competition in 2016. The rules state that for vehicles in this category, a custom motor controller must be designed and built for the competition by its respective team.

This project aims to develop a motor controller that is suitable for this vehicle with a focus on efficiency, reliability and safety. After considering different types of motors, it has been decided that the vehicle's propulsion method will be in the form of a brushed DC motor. The motor controller takes a throttle input from a potentiometer that is adjustable by the driver and uses a microcontroller to produce a PWM signal with the corresponding duty cycle. This signal is then used to drive a power MOSFET to control the current flow to the motor. A gate driver has been employed to maximise gate voltage swing, thereby reducing the MOSFET transition time, which reduces losses from heat and improves its lifespan. Various designs have been assessed to determine their efficacy in relation to our requirements. Based on the results of this testing, a prototype motor controller has been developed and assembled into a package where critical components can easily be inspected and replaced. In addition, expandability and improvements in system reliability have also been considered.

Andrew Henson

Supervisor: Thomas Bräunl

Development of Battery System for an Energy-Efficient Electric Vehicle

This project is concerned with the design, construction and implementation of a battery system for EnVe; an energy-efficient all-electric vehicle which is due to compete in the Shell Eco-Marathon in Manila, 2016. Due to significant issues with the 2015 EnVe battery system, a complete redesign was needed to ensure reliability and performance of the 2016 vehicle.

Accordingly, the objectives of this project are to design a battery system which is functional, reliable, efficient, and viable (given available monetary and material resources). Work undertaken includes—selection of battery cells; design, construction and implementation of a lithium-ion battery management system (BMS); and design, construction and implementation of a battery box. The BMS forms the bulk of the thesis, and in particular its novel "live battery swap" function. Testing has already revealed fulfilment of the above stated objectives.

Mr Robert Hortin

Supervisor: Thomas Bräunl

Automating the USAL and MAKO Robots: Development and Implementation of Sensors and Mapping Algorithms

Autonomous Underwater Vehicles (AUVs) represents a rapidly expanding research field in engineering. Underwater mapping is an important application, and one in which AUV technologies can have a substantial impact. Existing solutions to achieve autonomous underwater mapping are limited and highly expensive. Thus, the development of a reliable, low cost, task specific system is required. This project aims to provide two custom built, underwater vehicles with autonomous mapping functionality through the creation of control software and implementation of low cost sensor systems.

Specific focus is applied to automating the USAL and MAKO robots, which are custom built, low-cost underwater vehicles constructed at UWA. Automation of two tasks are programmed for the robots: area patrolling (mapping) by wall detection; and line following. Area patrolling by wall detection involves the robot autonomously pathing around an area limited by walls that are detectable by infrared sensors, and is achieved through the implementation of a low cost, infrared distance measuring sensor suite. Line following involves the robot identifying a line and following the line to its endpoint and is achieved through implementation of a low cost, on board camera. Combining these tasks allows the robot to patrol certain areas limited by walls that can be detected by infrared sensors and generate a map from predefined landmarks from video.

Results from this project will help to inform future researchers about the extensions and capabilities of using low cost, infrared distance measuring sensors and cameras in an underwater mapping application, as well as provide guidance in programming control algorithms for tasks relating to the USAL and MAKO robots.

Claye Jensen

Supervisor: Thomas Bräunl

Design and Installation of Mounting Systems for an Electric Personal Watercraft

As part of the REV Project, the REVski is a personal watercraft which is being converted to electric drive. The unique nature of the project and unusual layout of the internal surfaces and hard points, makes mounting and protecting the key electrical components of the drive system difficult.

For this project, the design requirements of the mounting system were identified by using the applicable Guidelines and Standards for electric vehicles and watercraft, as well as the corrosion resistance, fatigue life, cost and functional requirements agreed upon by the project team. After several iterations of design, the final mounting system was selected based upon maximising mounting space and minimising electric cable length. The strength of the design and likely fatigue characteristics were estimated through computer simulations and found to meet the design requirements. Component layout, cable routing and waterproofing were planned and the entire system was installed and is being utilised successfully.

The REVski is now operational and undergoing testing.

Joshua Knight

Supervisor: Thomas Bräunl

REVSki—Electric Jet Ski Electrical safety Compliance of LV and ELV Systems in a Maritime Setting

The concept of electric vehicles has been around for many years now, but has been mainly confined to the automotive market, while application to the boating arena is far less developed. Companies have released concepts of electric versions of personal water craft (jet skis), but are yet to release prototypes.

The REVSki project aimed to convert a petrol-powered jet ski to electric drive, whilst complying with Australian Standards. The vehicle used was a SeaDoo GTI130, originally with a 97kW (130hp) rotary petrol engine. This motor was replaced with a fully submersible 50kW (67Hp) continuous rated three-phase AC induction motor, constructed by Submersible Motors Engineering Pty Ltd (SME), powered through a motor controller with an 80Ah pack of Lithium Iron Phosphate batteries delivering a nominal voltage of 96V DC. From this battery pack the motor controller generates 96V Three-Phase AC power to drive the motor. To ensure the REVSki is safe and Australian Standards compliant, these two 96V systems were designed and implemented with electrical safety systems to meet or exceed the standards, included an earth-fault protection system, overcurrent protection systems and protection against direct contact. Electrical safety procedures were also implemented in the construction, operation and maintenance, so the REVSki is constructed safely without incident.

The REVSki has been successfully operated for a number of tests and at time of writing is in the process of being tuned to increase its performance. As currently configured, the vessel travels at roughly 40km/h and the battery lasts for around 30 minutes on 3.5 hours of charge. While vehicle performance is not yet comparable to the original petrol-powered variant, performance should continue to improve with further testing. As a result of the work of the 2015 group of students, the vehicle concept has been successfully proven and a working prototype, the REVSki, has been constructed that is compliant to Australian Standards.

Tim Lander

Supervisor: Thomas Bräunl

Training a Convolutional Neural Network for Object Recognition

In this project, training is done on a conventional desktop computer, object recognition is done in (relatively) real time on a Raspberry Pi 3. Images are captured from a single front facing camera mounted on a Raspberry Pi 3 powered Eyebot.

Compared to traditional object recognition techniques, such as feature detection, training a neural network is a much less involved process. It is not necessary to hand craft features which represent an object. Simply running the training program over a series of images featuring the object is enough to train the system to recognise an object. The end goal is a system which can identify a variable number of objects with relatively high accuracy in near real time. The Eyebot could then drive around and announce whenever a known object comes into range of the camera.

The main technology used is Google's TensorFlow. Nvidia's CUDA and cuDNN are used to significantly accelerate training time.

Eric Low

Supervisor: Professor Thomas Bräunl

Retrofitted Jet Ski Stability Assessment

Metacentric height and the curves of stability are usually determined during the design stages of a watercraft. Due to installations of various new components and an electric motor, the new location of the centre of gravity of the REVski is unknown and needs to be determined to ensure that adequate buoyancy is provided to remain upright when loaded with riders. Hence, the main objective is to assess and analyse stability of the REVski.

For this report, stability of the retrofitted REVski will be first assessed according to AS1799.1 to check whether it is in compliance with the standard. Also, the inclining experiment will be conducted to determine the weight and centre of gravity of the watercraft. Methods of improving stability will be sought if required.

Sonia Miranda

Supervisor: Thomas Bräunl

Electrical Circuit Design with Wheel Speed Control and Documentation

Electronics play an essential part in vehicle driving. The key interaction of intricate electrical systems ensure error-free function and increased safety. Sensors enable critical data communication required in the vehicle's electronics and computer microcontrollers control electrical changes and then take suitable actions. These technologies have opened the door for computers to enhance human judgment.

The aim of this project is to provide an electronic system for improving both the stability and performance of the REV SAE vehicle. Developments include: power control and steering capabilities for sensing and high-performance processing for driver assistance and autonomous vehicle operation and a comprehensive electrical system documentation for the vehicle. A highly integrated circuit is implemented on a printed circuit board to meet the required low level control of the vehicle. Along with these developments are calibration of the battery monitor system and wheel-speed sensor integration to give computers control over driving. Also brake servo/brake reservoirs for overcurrent protection are implemented that prevent servo failure. The wheel-slip control system is developed to achieve superior braking performance and maintain vehicle stability. Real-time data such as the wheel braking power at each wheel is required.

Much research is being conducted to improve the accuracy and simplify the systems that are being implemented on various platforms. Advanced vehicular safety and navigation systems using LiDARs and GPUs deliver the most capable solution for real–time object detection, tracking, recognition and classification.

Manish Mohanty

Supervisors: Thomas Bräunl and Chris Croft

Environmental Mapping in 2D/3D with the use of a Multirotor Unmanned Aerial Vehicle

In recent years, unmanned autonomously flying helicopters, airplanes, and multirotor copters have gained popularity due to extensive use in fields not limited to: defence, emergency response, live streaming events, mining and agriculture. To be able have a system that can fly autonomously and execute actions, simplifies human need for contribution, increasing its potential uses exponentially.

Through the use of a mini computer (Raspberry pi 2), distance sensor (Lidar) and a Picam (Raspberry branded mono-lens camera) on board the UAV system, users are able to fly autonomously, capture images and store them in the memory of the raspberry pi 2. Later, stored images are extracted and tilled together to create panoramic 2D images with the use of an offline stitching software. Users are also able to create 3D models of any large object by capturing multiple shots covering a 360 degrees' field of view with varying altitudes, and model it offline by using a 3D modelling software.

The main focus of this paper is on 3D modelling, by acquiring photogrammetric data and processing it through several modelling software. It includes several examples of the 2D offline stitching achieved by using AutoStitch (offline software) and 3D modelling done by two offline 3D modelling software known as PhotoScan and 123 Autodesk, allowing us to compare capabilities and performance whilst highlighting restrictions. All the testing is conducted in autonomous mode, achieved by simply flicking a switch on a remote controller. Through utilizing its autonomous flying and image capturing capabilities, the Hexacopter at The University of Western Australia can perform many intelligent mapping operations.

Travis Overington

Supervisor: Thomas Braunl

UWA 2016 Endurance Vehicle (EnVe) Project—Electrical Protection and Safety Systems

Climate change is influencing an ever increasing interest in the development of electric vehicles. As a consideration of this process, the safety of these electrical vehicles must be investigated. This paper will investigate and design the general safety of the UWA Endurance Vehicle (EnVe) Project.

In all electrical designs, the ratings of the elements in the system must be chosen correctly to ensure the system can withstand the nominal voltage and current levels. This includes the cables, connectors and protective fuses. The electrical grounding is also an important consideration when investigating the safety of electrical systems. This design must protect the driver and crew from any electrically charged surfaces due to broken cables in the system.

The final aspect of safety designed in this paper are the individual safety circuits, which will be used to interpret the measurements of sensors inserted around the vehicle. This safety system will be connected to an indication system which will display the status of the systems to the driver and crew.

Tim Raphael

Supervisor: Thomas Bräunl

A Modular Control System Architecture for Autonomous Underwater Vehicles (AUVs)

The Robotics and Automation Lab at UWA aims to renew the Autonomous Underwater Vehicle (AUV) platform to perform unmanned missions. The existing vehicles (MAKO and USAL) built in early 2004 have been redeveloped with new controllers under a new software architecture to allow advanced sensing of location and pose to perform unmanned mission objectives.

This project aims to evaluate the current state of autonomous robot architecture and implement a platform for UWA to continue its AUV objectives. Firstly, for the redevelopment of autonomous operation, a middleware platform was chosen to form the core around which navigation, sensing and operational capability can be built. Middleware is software which sits on top of a low-level system (an Operating System) and provides services to higher level applications. This project selected the Open Source platform "ROS—Robot Operating System". Secondly, a software architecture was constructed around ROS to enable seamless integration with a 3-D simulation environment to perform high-fidelity testing involving advanced underwater dynamics and realistic mission scenarios. Next a modular software architecture was designed, built and tested around the custom hardware used by the lab. A basic controller was deployed to hardware and tested in a real-world environment. To test the flexibility of the software architecture, the same controller was connected to the simulator, with the purpose of emulating the custom hardware, to compare the results. The new software architecture provides reusable templates and modules for ongoing development of the AUV platform.

Future development of autonomous vehicle control software can now be accelerated due to the ability to rapidly test the same code base on both simulator and hardware. Undergraduates and researchers working alongside the Robotics and Automation Lab can now develop control software more efficiently by testing through simulation to identify key issues before performing costly field trials.

Jeethan Rodrigues

Supervisor: Thomas Bräunl

REView—Online Monitoring of Charging Stations for Electric vehicles

Dwindling fossil fuel reserves and climate change issues have led to exploration and development of systems to help combat these problems. One such project is the UWA REV Project with the vision of creating commercially viable zero-emission vehicles powered from renewable energy resources. In 2011 several AC charging stations were established in Perth by REV and in 2014 on the UWA campus, the first ever commercial DC fast-charging station that charges an EV to 80 per cent in 20 minutes—seven times faster than AC and 25 times faster than charging at home.

This thesis aims to monitor and analyse the effectiveness of DC charging by designing a robust online web-based user interface. Thereafter, a comparison will be made between the effectiveness of AC and DC charging stations. For this purpose, a web-based software package called REView portal will be used that has a collection of statistical data obtained from EV trackers, charging stations and renewable energy resources. The portal presents results in a meaningful way to motivate people to shift to zero-emission transport. It automatically evaluates the data statistically, allowing station users/drivers and charging stations owners to monitor the efficiency, effectiveness, energy use and expenses of their EV and charge stations respectively. For ease of availability, users can access the data by means of mobile phone web apps, desktop web apps and can also export and print.

The REView portal already monitors the AC charging data of EVs so the focus will be on collecting DC charging data via our designed web-user interface. The results of number of charges consumed per day, number of charges consumed per week, time taken per charge, energy consumed per time of day and number of charges as per connector ID (Chademo/CSS) will be graphically represented (bar and pie charts). To compare the AC and DC charging, parameters like charge frequency and energy frequency per time of day and time of week will be used. Lastly, Veefil station data (DC charger) will be integrated into the REView system.

Michael Stott

Supervisor: Thomas Bräunl

Design and Construction of Closed Loop Cooling Systems for Electric Personal Water Craft

The UWA Renewable Energy Vehicle (REV) Jet Ski project, is a team whose objective is to design and build an electric jet ski that is safe and meets relevant standards to operate in WA.

This project aimed to design, build and test a closed loop cooling system for the electric motor and motor controller. The system will transfer heat dissipated from the electric motor and motor controller to the body of water on which the jet ski is ridden.

Research and testing were conducted to design and select components for the construction of the cooling system. Pump selection, cooling plate design and fitting selection were carefully considered when calculating the heat dissipation rate required. Recommendations include redesign of the cooling plate and selection of enlarged fittings to reduce dynamic head loss and decrease pump size.

Jeremy Tan

Supervisors: Chris Croft, Thomas Bräunl

Real-time Point of Interest Identification on a Multirotor Unmanned Aerial Vehicle

The proliferation of unmanned aerial vehicles (UAVs) such as remote-controlled aeroplanes, helicopters and multirotors highlights their potential use, particularly in the field of automation. Technological advancements have led to the possibility of complete automation in a low-cost, functional manner. A common task in aerial imaging is the detection of points of interest, such as location markers, objects and buildings, for purposes including localisation, object tracking, and mapping. However, this is commonly performed off-line, and is not fully autonomous.

We present a fully autonomous, real-time point of interest ID system controlling a hexacopter. Various search patterns and image processing techniques are explored and compared for accuracy and speed. GPU processing is also explored to maximise utility of the embedded system. Furthermore, we present a modern web interface to visualise and oversee the autonomous control of the hexacopter.

Hannes Wind

Supervisors: Thomas Bräunl (UWA); Oliver Sawodny and Florian Morlock (University of Stuttgart)

Review of Formation Control Approaches and their Implementation Considering a Realistic Model of Mobile Robots

This work investigates the formation control applied on real mobile robots. Therefore, a literature research regarding the formation controller for mobile robots is conducted. Several formation controllers are investigated concerning the ability of implementing them on the real robots. In order to perform these simulations, a dynamic model of the robot is considered. To obtain the parameter of the dynamic model, a model identification is accomplished. Furthermore, several extensions to this model are added, in order to achieve a more realistic model of the robot and the whole system. Once a suitable formation controller is chosen, the implementation on the real robots is carried out.

The results of this implementation are highlighted and some practical aspects are discussed. In addition to that, an obstacle avoidance controller is proposed. In order to verify this controller, simulations are performed and to be able to validate the collision avoidance controller, further experiments are carried out.

Xiaochuan Zhou

Supervisor: Thomas Bräunl and Adrian Boeing

A Study on the Simulation Environment for MAKO and USAL

The Computational Intelligence—Information Processing Systems (CIIPS) group at UWA has long-established research on Autonomous Underwater Vehicles (AUVs) in its Robotics and Automation lab. MAKO, the lab's first AUV, was designed in 2004. Two years later, another submarine called USAL, based on the commercial AUV C'Cat, was released. It was much lighter and presented a different motor configuration.

Along with these two robots, a simulation environment named Subsim was developed specifically for the two AUVs. It has been updated and maintained till 2009. In the following years, researchers and students in UWA continued updating these two submarines by adding sensors and other equipment like cameras and controllers.

This part of the project aims to update the simulation environment to a ROS compatible environment. Robot Operating System (ROS) is an open source software framework, which includes various libraries and tools for robot development. Two open source simulators named Gazebo and UWSim were used in this project. Gazebo is known as a general purpose robot simulator with high extensibility and no built-in package for the underwater environment, while UWSim is specifically for underwater vehicles. Compared with Gazebo, UWSim is easier to use with built-in libraries and packages for the marine environment.

The first step is to identify the structure of the robots which includes identifying the links of the submarines, the local coordinate system for each link, the joints and types of motion. The next step is building the visual model for each link in Solidworks, a powerful solid modeling computer-aided design (CAD) tool. The visual model will then be edited and rendered in Blender and Meshlab. After that, The link and joint information of the submarines (including parameters) are defined in Gazebo and UWSim separately since they are using different model file format. The underwater environment is simulated using plugins in physical libraries. After that, ROS is used to control both simulators by sending commands and inputs. Outputs from the simulators can also be collected in ROS. Finally, once the physical models are built, the dynamic parameters for the simulation are tuned according to the real robots. In this way, the simulated robot behaves as the existing submarines.

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