THE UNIVERSITY OF
WESTERN
AUSTRALIA

Faculty of Engineering and
Mathematical Sciences

Computational Intelligence Information Processing Systems

RESEARCH 2018/2019

Contents

Foreword from the Head of CIIPS

A major milestone of the past year was the 10th anniversary of the Renewable Energy Vehicle Project. REV started in 2008 with "REV Eco", the road-licensed electrical conversion of a Hyundai Getz, and the car is still in use today, as a demonstration vehicle for exhibitions, school visits, open days, as well as, quite practically, a pool car for all REV students. Also in 2008, we acquired a used Lotus Elise from the UK and started its EV conversion, which eventually became our "REV Racer". The rest is history: WA EV Trial with 11 Ford Focus conversions, two Formula-SAE conversions, electric jet ski, Western Australia's first EV charging network, Australia's first CCS–DC charging station, REView EV charging and tracking software, and so on. More details on the REV projects can be found in our REV 10th Anniversary issue from 2018.

As electric vehicles are slowly becoming a standard in the automotive industry, we are concentrating more on autonomous driving, which we have done in CIIPS for over 20 years in the form of Autonomous Robots, and since 2011 with our drive-by-wire BMW X5, and later with the fully autonomous Formula-SAE car. In a sense, our two research directions, Robotics and Automotive are coming together.

We also concentrated on Artificial Intelligence methods for perception and motion planning for both robotics and autonomous vehicles, and we worked on the simulation of these systems, which turned out to be an essential tool, as it allows us to generate an early proof of concept and, in addition, accelerates development and learning outcomes significantly.

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 reconfig-urable computing, pattern recognition, electromobility and automotive systems.

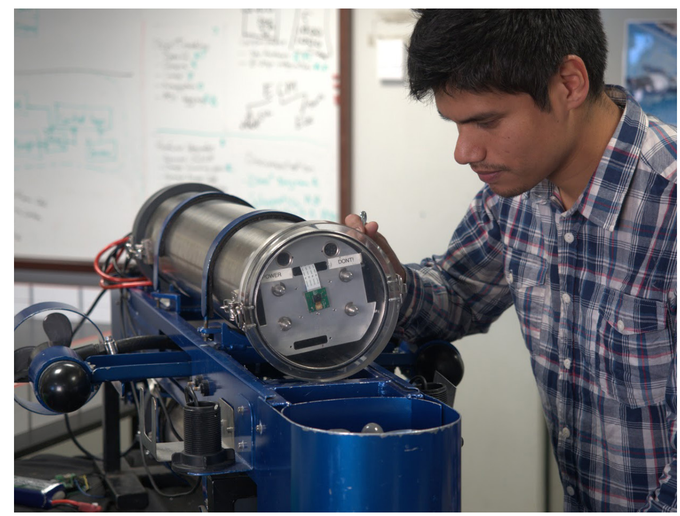
Strong and successful collaboration between the group and industry is a key element in its operation. Joint research and development projects with a number of Australian companies have been undertaken, as well as contract research for industry, government and other bodies.

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 teach-ing 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.

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Members of CIIPS

Academic Staff

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Mr John Francis Akers, University of Washington, USA

Mr Siwei Feng, USTC, China

Mr Chris Kahlefendt, Hamburg University of Technology, Germany

Mr Zihan Lin, USTC, China

Mr Shanqi Liu, Zhejiang University, China

Mr Gabriel Mayer-Lee, Swarthmore College, Pennsylvania, USA

Mr Roman Podolski, Hamburg University of Technology, Germany

Mr Zihan Qiao, Zhejiang University, China

Mr Shuangquan Sun, USTC, China

Ms Yuchen Wang, University of Washington, USA

Mr Yuting Wang, USTC, China

Mr Jingwen Zheng, USTC, China

Students

PhD Students—Current

Mr Razin Ahmed
Development of a Smart Forecasting Algorithm for Power Generation System
Prof. V. Sreeram, Dr Y. Mishra, Prof. T. Bräunl

Mr Thomas Drage
Environmental Perception and Navigation Control Systems for an Autonomous Performance Vehicle
Prof. T. Bräunl, Dr A. Boeing

Mr Kai Li Lim
Visual Odometry and Place Recognition for Embedded Autonomous Ground Robots
Prof. T. Bräunl, Prof. V. Sreeram

PhD Students—Submitted

Mr Franco Hidalgo
Navigation system for an autonomous underwater vehicle for turbulence monitoring
Prof. T. Bräunl, Dr A. Boeing

Mr Stuart Speidel
Energy Usage Patterns for Driving and Charging of Electric Vehicles
Prof. T. Bräunl, Prof. D. Harries, E/Prof. J. Taplin

PhD Students—Completed

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

Ms Fakhra Jabeen
The Adoption of Electric Vehicles: Behavioural and Technological Factors
A/Prof. D. Olaru, E/Prof. J. Taplin, Prof. T. Bräunl

Higher Degree by Research Preliminary—Completed

Mr John Pearce
Providing households with real-time feedback from the monitoring of energy consumption and generation
Prof. T. Bräunl, Prof. D. Harries

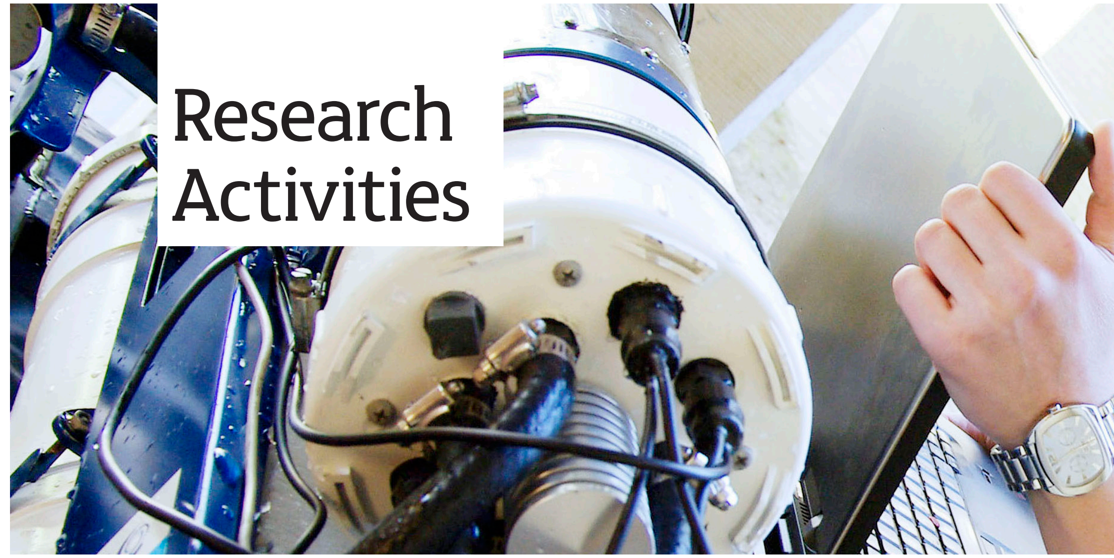
Master of Professional Engineering (MPE) and Final Year (BE) Research Project

2017

Karan Babra, MPE Mech. Eng.
Logan Chau, MPE Mech. Eng.
Jeremy Costin, MPE Mech. Eng.
Jayden Dadleh, MPE Mech. Eng.
Samuel Evans-Thomson, MPE E&E Eng.
John Hodge, BCS/BE E&E Eng.
Fangpeng Li, MPE Software Eng.
Yao-Tsu Lin, MPE E&E Eng.
Yu Liu (Rain), MPE Mech. Eng.
Michael Mollison, BE Mechatronix Eng.
Mitchell Poole, MPE E&E Eng.

2018

Manuchekhr Adina-Zada, MPE Mech. Eng.
Alexander Arnold, MPE Software Eng.
Johnathon Borella, MPE Mech. Eng.
Craig Brogle, MPE Software Eng.
Nicholas Burleigh, MP E&E Eng.
Geoffrey Channon, MPE E&E Eng. (CEED)
Wesley Coleman, MPE E&E Eng.
Aaron Goldsworthy, MPE E&E Eng.
Timothy Kelliher, MPE E&E Eng .
William Lai, MPE E&E Eng.
Dylan Leong, MPE E&E Eng.
Patrick Liddle, MPE E &E Eng .
Ze Lin, MPE E&E Eng.
Lijie Liu, MPE Software Eng.
Mohd Hjariz Mohd Jahis, MPE E&E Eng.
Alexander Morgan, MPE Mech. Eng.
Xiaopqing Ran, MPE E&E Eng.
Tianhao Ren, MPE Mech. Eng.
Morgan Trench, MPE Software Eng.
Maximilian Woloszyn, MPE Mech. Eng.
Tung Leung Wong, MPE E&E Eng.
Chao Zhang, MPE E&E Eng.



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–2013 (Electric Formula SAE); BMW X5 Drive-by-Wire, Electric Jet Ski–2015.
Location: Mech G25

Robotics and Automation Lab

Professor Thomas Bräunl 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 lab currently houses five cars, a BMW X5, a Hyundai Getz and a Lotus Elise S2, a Formula SAE-Electric race car and an autonomous FSAE-Electric race car, plus the electric jet ski and the electric scooter. The Engineering Faculty's Renewable Energy Vehicle Project (REV) is running in this lab.

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

Automotive Lab

The REV Project 10 Year Anniversary

Professor Thomas Bräunl, Mr Colin Smith and Professor John Dell

Thomas Bräunl, Kai Lim and Marcus Pham display superhuman strength lifting the inflatable Getz

REV celebrated its 10th Anniversary in March 2018.

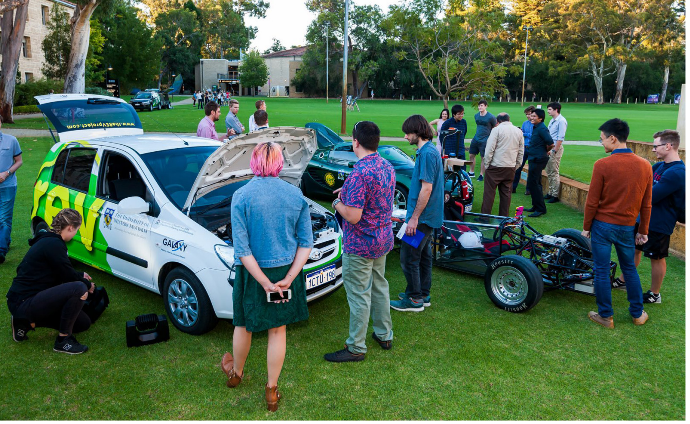
Starting with a Homecoming event in the new REV lab for all students from the past 10 years, the evening continued with presentations from Professor Thomas Bräunl, reflecting on 10 years of REV achievements, and from Mr Colin Smith from energy retailer Synergy on the effect of EVs on the electricity grid.

Professor John Dell, Executive Dean

Professor Thomas Bräunl, Director, The REV Project

The advisory panel takes questions from the audience

Mr Colin Smith, Synergy



Colin Smith with the REV Jet Ski and REV 10 Year Anniversary Booklet

Automotive Lab

2018/2019 Research Focus

Above: William Lai, Timothy Kelliher, Craig Brogle, Chao Zhang and Patrick Liddle

The research focus of REV in 2018/2019 is the advancement of autonomous driving. All sensor equipment has been transferred from the BMW X5 to the autonomous SAE car and two use cases are being considered—

1. Driving along an unknown race-track, outlined by traffic cones.

This scenario is now an international competition, known as “FSG Autonomous”, and may be later adopted by the organizers of the Australian Formula-SAE competition.

REV has been invited to come to the Melbourne competition and showcase their autonomous SAE-Vehicle, the first in Australia

2. Driving along the internal roads of UWA.

In this much more complex and much more realistic scenario, the autonomous car has to use its sensors to detect lane markings, road curbs and other traffic, such as cars, bicycles and pedestrians, as well as general obstacles.

Below: The Autonomous SAE vehicle

Work on the jet ski continued to equip it with numerous sensors, a data logger and a GPS tracker. The new sensors cover the electric drive system, so we can improve the efficiency and range of the jet ski, as well as water quality sensors. With this set-up, we can use the jet ski for monitoring water quality at specific GPS locations for a variety of different applications.

The REV team would like to thank its sponsors—

- Synergy
- Galaxy
- Altronics
- Xsens
- Nvidia
- Australian Medical Association
- Submersible Motor Engineering
- Total Marine Technology

Electric Lotus and Electric Getz

Marcus Pham

The electric Getz and Lotus continue to be used as demonstration vehicles, for exhibitions and educational events such as school visits, open days etc. We also use them for charging efficiency testing.

Over 2018, there have been a few improvements made on the REV Eco (Getz). After 10 years of intermittent use, the original LiFePO4 Winston cells were feeling their age, and not providing sufficient range. Hence, the battery pack has been fully replaced with a brand new set of CALB 72Ah LiFePO4 cells, bringing the driving range back to close to the original range of approximately 80km.

Additionally, whilst the batteries were being replaced, the outdated battery management system was upgraded to the ZEVA EVMS Lite V2, with BMS12 modules providing individual cell status and data over CANBus allowing for future integration with the UWA GUI, or use with the EVMS Monitor V2.

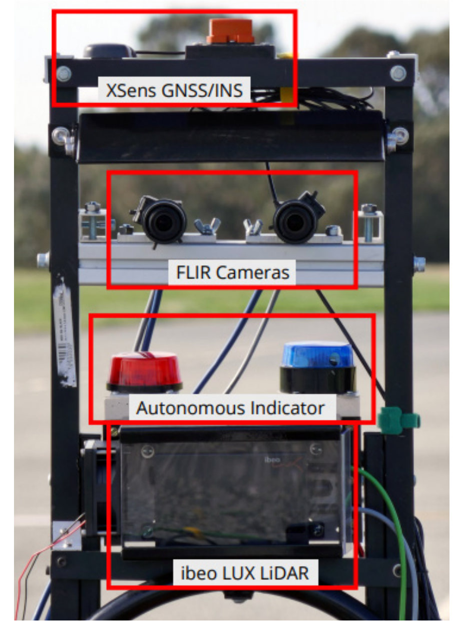
Along with the battery management upgrades, the old DC–DC converter, which was a source of constant maintenance due to being on all the time, was also replaced with a much smaller TDK-Lambda DC–DC for use when the car was running, and a Meanwell AC–DC for charging whilst the vehicle's traction pack is being charged. This allows for the DC–DC coverter to charge the auxiliary battery without draining the traction battery pack.

Finally, alongside the DC–DC upgrade, a ZEVA low-voltage cutoff was installed to protect the auxiliary battery from being over-discharged.

Autonomous Driving

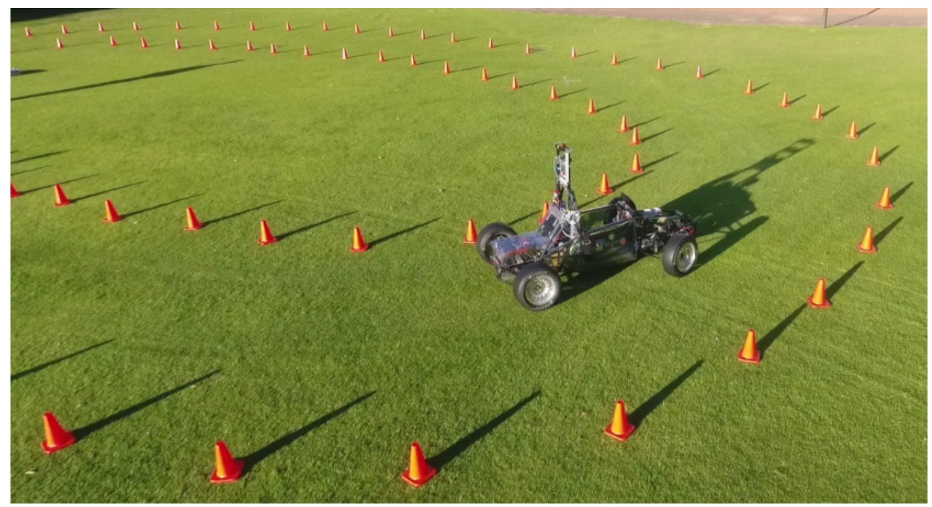
Chao Zhang and Thomas Drage

Software frameworks for autonomous vehicles are required to interface and process data from several different sensors on board the vehicle, in addition to performing navigational processes such as path planning and lane keeping. These can include a combination of cameras, LIDARs, GPS, IMU, and odometric sensors to achieve positioning and localisation for the vehicle and can be challenging to integrate. We utilise a hybrid software framework that combines sensor and navigation processing for autonomous driving. It utilises a modular and scalable approach for interfacing and safety functionality, whilst navigation and sensor interfaces are implemented as nodes in the Robot Operating System (ROS). It is redesigned to replace the existing software on our Formula SAE vehicle, which we use for testing autonomous driving and has been tested and proven to be suitable for use with fully autonomous drives.



Path Planning

- Generates an optimised collision-free path given sensory feedback from cameras and LiDAR.
- The raw sensor readings from cameras and LiDAR are then processed to obtain information about any obstacles in the scene.
- Using a range of the maximum turning circle of the car, of both a left-hand turn and right-hand turn, it then looks at which predicted paths will intersect cones.



- The vehicle dynamics is thus limited during motion planning, whereby the steering angle does not exceed 25°.
- Iterate through all obstacles within the car's range and calculate the best collision-free path to undertake.

Cone Detection

- The histogram of oriented gradients (HOG) descriptor is applied across the image to find and segregate regions of interest (ROIs) that may encompass a cone, to which these regions are used as the input for a support vector machine (SVM) classifier.
- Efforts on further increasing the accuracy of SVM classifier degrades the runtime performance significantly while offering only a minor improvement.
- A convolutional neural network (CNN) is evaluated to provide a flexible feature extraction method to adapt complex variation in enviroment.
- The CNN used in this project consists two convolutional layers and two fully connected layers. It provides better detection accuracies as compared to the SVM approach, while offering similar runtime performance. Moreover, with GPU acceleration, the performance using this network surpasses the SVM approach in terms of introduced latency.

Sensor Fusion

- LiDAR, camera, GPS and IMU each are operated as independent nodes on the TX1 under ROS framework.
- Hall pulse odometry is handled in a low-level controller using Arduino.
- Relevant data from the sensors are encoded as ROS message for path planning/localisation.
- Control program introduces a high-level interface for the vehicle, which communicates with the path planner to combine localisation data with a set of future waypoints.
- Driving instructions are transmitted to specific ROS topic, which in turn are transmitted to a low-level microcontroller by a main control node.
- Localisation is achieved through an EKF-fused IMU and the GPS units combining with wheel encoder odometry.
- The camera and LiDAR are used for road edge and obstacle detection.
- LiDAR provides four layers of depth measurements with a horizontal angle of 85°.
- Road edges are detected through the checking for smoothness and slope.

Deep Learning

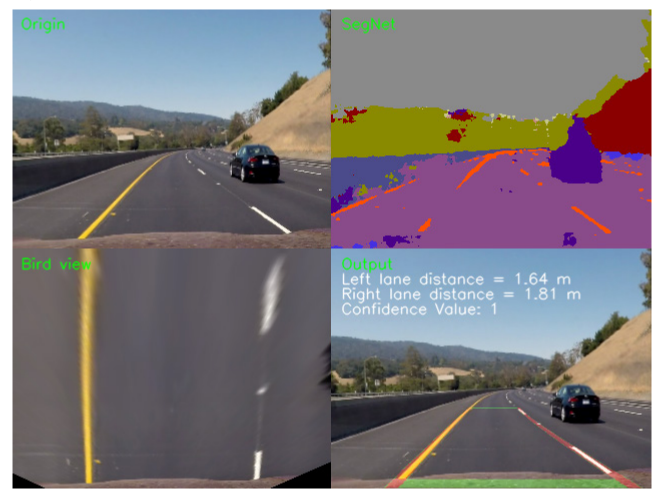
Kai Li Lim

Our autonomous FSAE platform uses deep learning to achieve scene understanding. Using the camera, we train the autonomous driving system to perceive and recognise objects within its field-of-view environment, thereby enabling the vehicle to devise a variety of navigation strategies to react to specific objects. We use this approach to account for the large dynamic found in road scenes, such as moving pedestrians and traffic, as well as variations in road types

Autonomous Bus by Easymile tested by REV during UWA Open Day, August 2018

and markings. Additionally, deep learning introduces higher levels of robustness as compared to conventional image processing techniques, allowing the system to withstand inconsistencies from the camera data, including variations in illumination, seasons, weather and pose, while maintaining high recognition accuracies. To accomplish this, we apply deep learning onto a technique called semantic segmentation, which uses a convolutional neural network (CNN) to classify each pixel on an image frame to constitute an object that it represents.

Semantic segmentation outputs a series of images, each composed from a set of several distinct colours, with each colour representing an object class. Our semantic segmentation method classifies objects into one of the following classes: sky, building, column-pole, road-marking, road, pavement, tree, sign-symbol, fence, vehicle, pedestrian and bicyclist. To cater for the dynamism of road environments, we further classify these objects into static and dynamic objects. Static objects are stationary fixtures such as buildings, roads and vegetation; dynamic objects are often in motion, which include vehicles, pedestrians and bicyclists.



Through the segregation of static and dynamic objects, the system can then apply specific computation methods for different regions within an image frame. For instance, calculations on the road region with lane markers will yield results pertaining to lane keeping, centring the vehicle as it drives. Likewise, calculations on dynamic obstacles such as vehicles will function in tandem with LiDAR measurements, whereby the system will anticipate its trajectory by compensating its velocity against that of the approaching or departing vehicle.

Overall, this incorporation of visual deep learning onto our FSAE platform enables it to achieve a heightened perception of its immediate environment, thereby allowing the system to leverage it and achieve a more intelligent control system.

Automotive Simulation

Craig Brogle

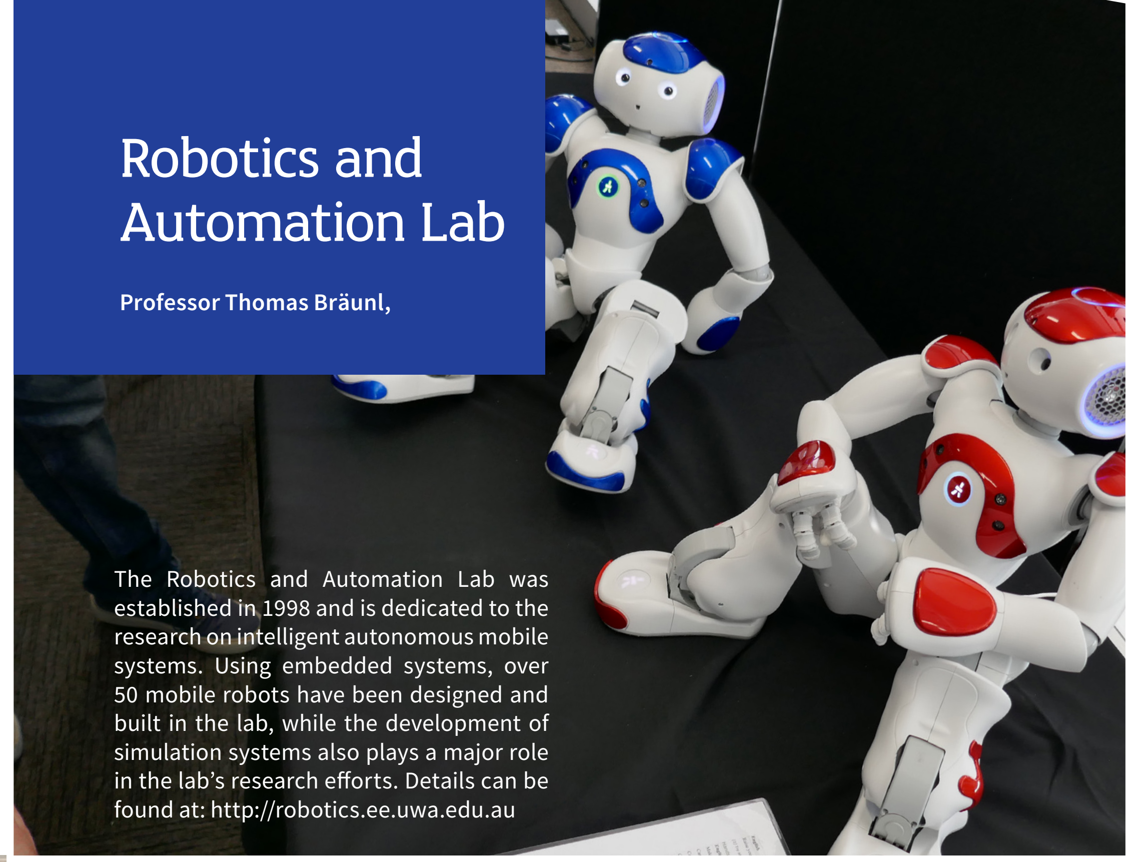
Simulation is a cornerstone for autonomous vehicle testing, allowing high level software such as image processing and path planning to be tested in predefined scenarios on a much faster schedule than is possible with hardware testing. The Automotive Simulation team are working on improving the realism, flexibility and availability of automotive simulations. This allows testing of high-level software (such as path planning and visual navigation) in a range of realistic, reproducible environments without the need to set up suitable physical testing areas.

The Automotive Simulation team have developed a hardware-in-the-loop simulation system, allowing high-level software to be tested with a suite of sensors and compute hardware near-identical to that available on the autonomous Formula SAE vehicle (FSAE). This system consists of a simulation PC, to simulate an environment, sensor suite, manual inputs, low-level controllers, and a Nvidia Jetson TX1 identical to that found on the autonomous FSAE vehicle, allowing identical high-level software to be run within similar hardware constraints.

Simulation of the environment and sensor suites is achieved through the use of the CARLA open source driving simulator. This software provides realistic driving mechanics, along with a configurable suite of sensors, which can include scene, depth map, and semantic segmentation cameras, ray-cast based LiDAR along with the position, orientation and velocity of the simulated vehicle, allowing the FSAE vehicle's sensor suite to be accurately replicated.

Robotics and Automation Lab

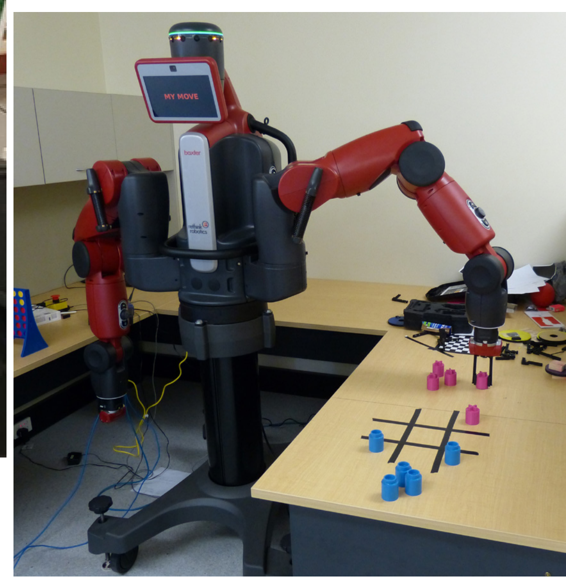
Professor Thomas Bräunl,

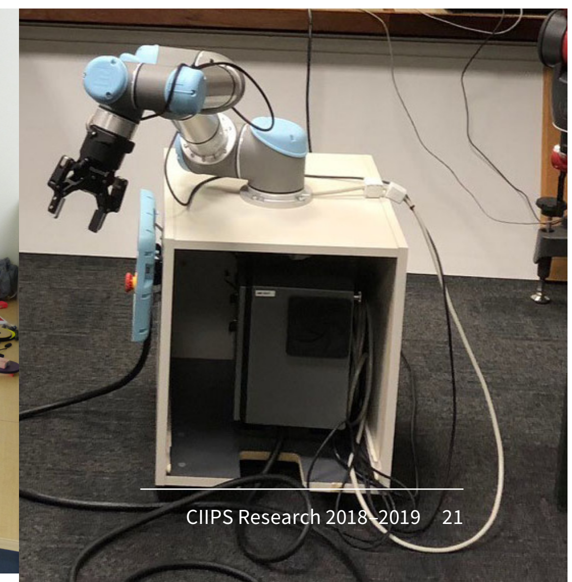


The Robotics and Automation Lab was established in 1998 and is dedicated to the research on intelligent autonomous mobile systems. Using embedded systems, over 50 mobile robots have been designed and built in the lab, while the development of simulation systems also plays a major role in the lab's research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

Robot Manipulators

The lab has a Baxter and a UR5 robot manipulator, which are mainly used for teaching purposes. Students work on group projects for various manipulation tasks with these robots. These include camera sensing, motion planning and task execution.





Humanoid Robots

We are using two Nao robots for teaching and research work. So far implemented tasks include detection of people and other robots, following, detecting and picking up a ball, kicking a ball and goal defending for playing soccer. If we get more Naos, we plan to develop a full robot soccer team.

Automation

A new set-up is our automated production street from Festo. In this teaching equipment, we have five industrial stations, linked by conveyor belts, which can be freely programmed by students. Each station carries out a particular task, from fetching and measuring parts, to assembling and pressing, until finally sorting the finished products.

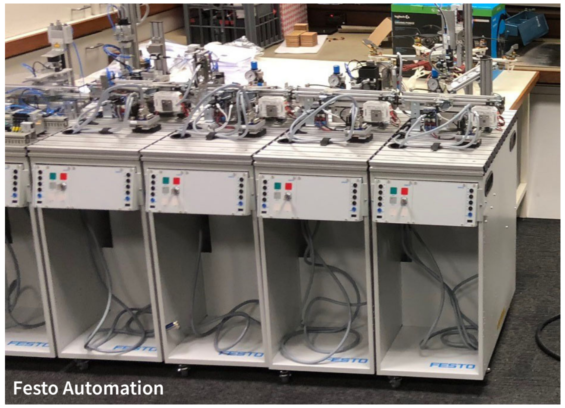
This automation equipment uses standard industrial components and therefore gives students an important industry-relevant experience and skills for their future careers.

Mobile Robots

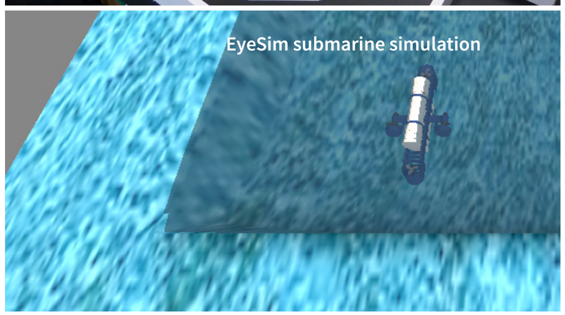
We completed a new generation of our small "EyeBot" mobile robots, which are being used for research in the Robotics Lab, as well as for teaching in the Embedded Systems and Robotics units.

A Raspberry Pi controller is linked via USB to our own embedded IO-board that takes care of motor output and sensor input. Each robot is equipped with a camera sensor, shaft encoders and three infrared distance sensors. Image processing is done on the Raspberry Pi in real-time, while the other sensors are processed on the IO-board.

The main research application task for these robots is now also Autonomous Driving. We are using some variation of the Carolo-Cup and Audi-Cup rules for autonomous vehicles, adapted to our smaller robots.


Festo Automation


Carolo Cup

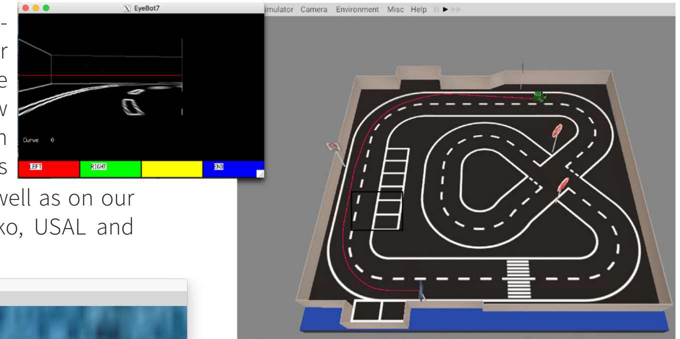

EyeSim submarine simulation

Simulation

Michael Finn and Alexander Arnold

Our EyeSim simulator has been in use for 20 years and has seen four major new developments from scratch. The latest version, EyeSim-VR has been redeveloped based on the physics game engine Unity. This gives us first of all, much more realistic robot movements as compared to older versions. It also gives us native versions on all common platforms, including MAC OS, Windows, Linux, mobile phones, tablets, and even smartwatches. Special virtual reality versions have been developed for Oculus Rift, Oculus Go and HTC Vive.

In a second step, we integrated the functionality of our previous SubSim submarine simulator into EyeSim-VR. Now the same simulation system can be used for driving robots (also on arbitrary terrain) as well as on our autonomous submarines Mako, USAL and BlueROV2.



Above: Carolo Cup in EyeSim Simulator

Left: EyeSim submarine simulation

Below: Underwater SLAM

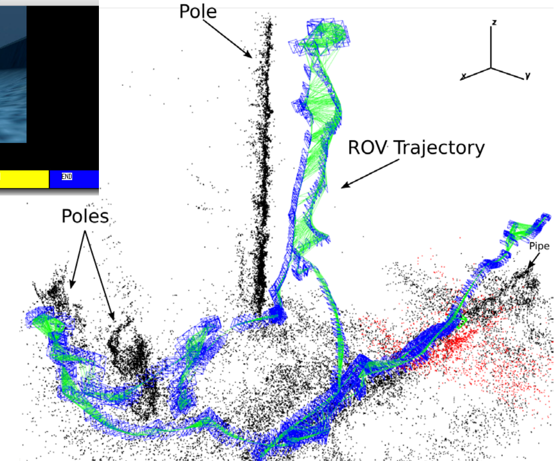
Autonomous Submarine

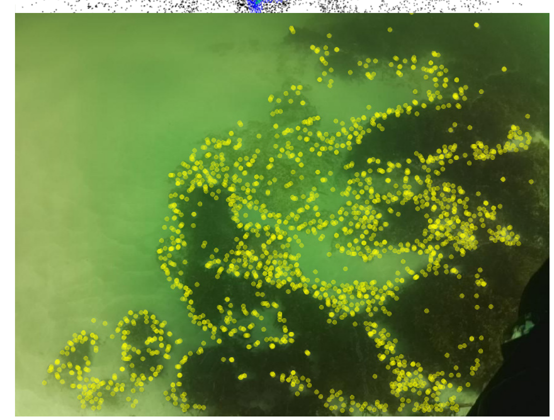
Franco Hidalgo

Experimental evaluation of monocular ORB-SLAM2 applied to underwater scenarios.

For this purpose, we collected more than 40 datasets in different areas and with varying weather conditions. Our results show that the algorithm performs well when given the right conditions in terms of uniform lighting, but struggles with dynamic lighting, as is present in shallow water on sunny days, and monotonous areas, such as large patches of sandy seabed.

The robot started at the ground at about 5.5 meters in an area with three wooden poles covered in coral which stretch from the bottom of the sea to above surface level. Here the ROV moved along a piece of wood which lies on the seabed to where the three standing poles are, and then moved along them.





Events

Greens Visit

A group of fifth year project students was co-supervised by Jonathan Whale (Murdoch University), Thomas Bräunl and Kai Lim (both UWA) to work on an electric vehicle study and a policy brief for EVs.

The focus on this group project was a professional engineering environment to get students ready for future tasks in industry.

It was an invaluable opportunity for students and supervisors to be able to present project findings at the end of the project to a member of state parliament. Visiting UWA Engineering on 24 October, 2018, were the Greens WA MLC, Mr Tim Clifford, and staffer Alison Wright.

The team presented their policy brief “Transition Towards Electric Mobility in WA”, to which Tim Clifford noted that it will definitely help with their work to push for EV uptake in parliament over the following months.

Wiebe Wakker

Wiebe Wakker is a Dutchman who runs the Plug-Me-In Project (plugmeinproject.com). Since March 2016, with the purpose of promoting zero emissions, he has been on a long-distance electric drive from Amsterdam to Sydney in his converted VW Golf, the ‘Blue Bandit’. His trip is funded solely from the offerings of good Samaritans that provide him food, accommodation and of course, a place to charge.

He stayed a few weeks in Perth in August and September 2018, and was invited by the UWA REV Project to charge his Blue Bandit at the REV EV-charging station, UWA.

Media Reports

Television Reports and Interviews

Channel 7 News, *Augmented Reality Glasses in Dentistry*, 27. Apr. 2017

Radio Interviews

Talking Lifestyle Radio Sydney, *Electric trucks and electric jetskis*, interview with Trevor Long, 21. Nov. 2017, 17:20

ABC Triple J Hack, *Electric Vehicles*, 25. Oct. 2018, 14:30, https://www.abc.net.au/triplej/programs/hack/

Print Media

Horizons, *Hydrogen cars to hit Australian roads next year*, interview, June/July 2018, p. 30 (1)

Uniview, *In the frame, Renewable Energy Vehicle Project (REV) 10-year anniversary*, vol. 40, autumn, May 2018, p. 37 (1)

Motor, Motor Trade Association of Western Australia. *The way we move—The future of the automotive industry*, vol. 82, no. 1, March 2017, pp. 4-10 (11)

Online and Other

ABC News, *CSIRO innovation program pushes scientists out of the lab to get ideas ‘into real world’*, Andie Noona, 7. Apr. 2017
http://www.abc.net.au/news/2017-04-07/csiro-program-helps-researchers-get-ideas-to-consumers/8423384

Professional Activities

Professional Committees and Advisory Boards

Thomas Bräunl

- Australian Research Council (ARC), Expert of international standing, Assessor of research project proposals
- Member of IEEE Computer Society’s Technical Committee on Parallel Processing (TCPP)
- Member of IEEE Robotics and Automation Society’s Technical Committee on Marine Robotics
- Member, MainRoads Customer Advisory Council, Western Australia

IEEE 18th International Conference on Intelligent Transportation Systems (ITSC), 2017 Yokohama, Japan

- Associate Editor
- Technical Program Committee

AI World Cup, 2018 Daejeon, South Korea

- Advisory Board Member
- Program Committee

Invited Talks and Project Demonstrations

Thomas Bräunl

Talks

15 March 2019—*Future Automotive Trends*, U3A—South West Metro, Melville, Perth

11 February 2019—*Future Automotive Trends*, U3A—Western Suburbs, Mount Claremont, Perth

7 December 2018—*Automotive Future: Electric and Autonomous Vehicles*, Winston Thought Leadership Lunch, Perth

16 November 2018—*Future Automotive Trends*, U3A—South West Metro, Melville, Perth

9 August 2018—Presentation on Robots and Autonomous Driving for visitor group from Zhejiang University, UWA Oceans Institute

3 April 2018—Invited Talk: *Electric Vehicles*, Micro-grid Workshop, UWA

28 March 2018—Keynote: Renewable Energy Vehicle Project 10 Year Anniversary

14 December 2017—Invited Talk: *Electric Vehicle Future*, Rotary Club, Belmont

27 November 2017—Invited Talk: *Automotive Trends*, Western Power, Perth

19 July 2017—Invited Keynote: *Future Automotive Trends and How They Will Also Change Our Homes*, IEEE Western Australia and Western Power

5 May 2017—Using Robotics in Teaching and Learning, Panel discussion, UWA, Perth

3 May 2017—Invited Talk: *Building Robot Cars*, Robotics Week, UWA Futures Observatory, Perth

20 March 2017—Invited Talk: *Silicon Valley Goes Automotive*, Synergy, Perth

16 February 2017—Invited Talk: *Electric Vehicles*, PACE Seminar Series, UWA

Demonstrations

26 November 2018—Robotics Lab and Automotive Lab demonstrations for Geraldton Senior College students

16 August 2018—REV Lab demonstration for SCUT Sino–Australian College

16 August 2018—Robotics Lab and REV Lab demonstration for Christ Church Grammar School

15 August 2018—Robot Activity course for South West University students, China

12 August 2018—Autonomous Car demonstration and Virtual Robot demonstration for UWA Open Day

9 August 2018—Robotics Lab and REV Automotive Lab demonstrations for visitor group from Zhejiang University

13 June 2018—REV Electric Vehicle Exhibition, Stirling Highway Expo, Scotch College, Perth

1 June 2018—Invited Speaker for Australian Computer Society (ACS) WA State Conference 2018,, Autonomous Vehicles Panel, Perth

4 April 2018—Robotics Lab demonstration for EZONE

Publications

Journals

H. Wind, O. Sawodny, T. Bräunl
Investigation of Formation Control Approaches Considering the Ability of a Mobile Robot, Intl. Journal of Robotics and Automation, June 2018

G. Wäger, J. Whale, T. Bräunl
Smart Accelerating and Braking—Achieving Higher Energy Efficiencies in Electric Vehicles, International Journal of Electric and Hybrid Vehicles, Inderscience, Dec. 2017

F. Bender, Si. Göltz, T. Bräunl, O. Sawodny
Predictive operator modeling for virtual prototyping of hydraulic excavators, Dec 2017, Automation in Construction. 84, 2017, pp. 133-145 (13)

F. Bender, M. Mitschke, T. Bräunl, O. Sawodny
Modeling and Offset-Free Model Predictive Control of a Hydraulic Mini Excavator, Oct. 2017, IEEE Transactions on Automation Science and Engineering, vol. 14, no. 4, pp. 1682–1694 (13)

G. Wäger, J. Whale, T. Bräunl
Performance Evaluation of Regenerative Braking Systems, Journal of Automobile Engineering, Part D, 1-14, Institute of Mechanical Engineers, Nov. 2017, pp. (14).

Conferences

K. Li Lim, T. Drage, R. Podolski, G. Meyer-Lee, S. Evans-Thompson, J. Yao-Tsu Lin, G. Channon, M. Poole, T. Braunl
A Modular Software Framework for Autonomous Vehicles, IEEE Intelligent Vehicles Symposium (IV), June 2018, Chang Shu China, pp. (6)

F. Hidalgo, C. Kahlefendt, T. Bräunl
Monocular ORB SLAM Application in Underwater Scenarios, OCEANS'18, MTS/IEEE, Kobe Japan, 2018

K. Li Lim, T. Drage, T. Bräunl
Implementation of Semantic Segmentation for Road and Lane Detection on an Autonomous Ground Vehicle with LIDAR, 2017 IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems, Nov. 2017, Daegu, Korea

Project Funding, Joint Projects and Sponsorships

Project Funding

Education Futures Scholarship, 2017
Project on Robot Simulation System for In-Class Student Learning

Education Futures Scholarship, 2017
Project on Augmented Reality for Dentistry
Partners: UWA School of Dentistry, UWA Engineering

Synergy Charging Sponsorship, 2017–2019

Galaxy Electric Jet Ski, 2018–2019

Joint Projects/Sponsorship

Synergy: EV Charging Project

Galaxy: Next Generation Electric Jet Ski

MainRoads: EV Charging Infrastructure Study

Nvidia: GPU hardware sponsor

Xsens: IMU sensor sponsor

Altronics: Electronics hardware sponsor

Postgraduate Dissertations

Saufiah Abdul Rahim

Supervisor: Thomas Bräunl

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

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 scenarios 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 behaviour-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 behaviour-based system relies largely on its Action Selection Mechanism (ASM) module, which is basically a behaviour coordination method. Common implementations of behaviour 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 behaviour-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 sufficiently 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 behaviour 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.

Franco Hidalgo

Supervisor: Thomas Bräunl

Simultaneous Localization and Mapping in Underwater Robots.

Water covers more than 70% of the surface of our planet, and there are still areas that remain largely unexplored. Underwater engineering research offers scientists a variety of technologies including robots and specialized instrumentation to explore this environment. Marine robot development faces different challenges from its construction to its control and navigation due to the highly dynamic and harsh conditions of this scenario, limitations in communication, instrumentation, and energy. In this dissertation, we aim to extend the development of underwater robot technologies by investigating and implementing robotics vehicles and, applying and evaluating localization and mapping approaches towards autonomous navigation. This thesis is organized as a collection of research manuscripts based on articles already published or submitted to internationally refereed conferences and journals.

In this dissertation, we research two main challenges in underwater robots. First, we focus on the implementation of underwater robots for scientific studies. We present the implementation of a novel Remotely Operated Vehicle (ROV)-based acquisition system based on current underwater sensors for scientific studies. The design and preliminary tests of the data acquisition are presented. Then we propose a robot framework based on a novel low-level expansion board which applies to underwater robots. We upgrade two underwater robots based on the framework including a simulation environment and ROS integration.

Second, we focus on Simultaneous Localization and Mapping (SLAM) algorithms and their application to underwater scenarios. We review three main SLAM approaches and use them over collected data from a simulation for comparison. Then, we center on visual SLAM, for which, we gathered and made publicly available a collection of datasets from different underwater locations in various illumination conditions. We evaluate the performance of feature detectors and descriptors in matching features over consecutive frames of the datasets. Finally, we apply a visual SLAM method based on ORB features and graph optimization. We present the resulting maps and trajectories generated and evaluate the algorithm over the datasets. We also offer the proper conditions and the challenges for its application.

Fakhra Jabeen

Supervisors: Doina Olaru, Thomas Bräunl

The Adoption of Electric Vehicles: Behavioural and Technological Factors

This research explored the preferences and attitudes towards the adoption of Electric Vehicles (EVs) in Perth, Western Australia (WA).

EVs have distinct properties when compared with Petrol vehicles. EVs have zero tail-pipe emissions and noise, and low running cost compared to the internal combustion engines. This is because EVs use electricity as a transport energy source. However, the limited driving range and the time to recharge the battery (fast-charging stations take 20 to 30 min) are currently considered substantial barriers for adoption. Currently, home charging stations are provided with a new EV, but the public charging infrastructure is limited in WA.

Previous studies either used only consumer behaviour models or discrete choice models for exploring EV adoption, however a few recent studies explored a combination of these two. Using three stages of data collection (driver survey, household mail-out survey and PureProfile online survey, all including revealed and stated preference data) and applying discrete choice modelling with attitudinal constructs, this research explored the potential enablers and barriers of adoption of Plug-in EVs in WA.

The research found the following:

- Drivers of EVs considered the driving experience of an electric vehicle very similar to an internal combustion engine and identified the environmental effect (zero tail pipe emissions) as the main benefit of EVs. Many of them (mainly members of a state EV Association and strong advocates of EV technology) converted their own ICE cars into EVs; they prefer to charge at home for convenience and because many use renewable solar energy, they have a high level of environmental concerns and a marked interest in new technologies;
- The interest they expressed in EVs (perhaps combined with the awareness of a WA EV trial, where 11 organisations purchased EVs and encouraged their employees to use

them) has led to a social desirability predisposition in the household survey; the mail-out household sample indicated bias towards highly educated, older participants, with higher levels of environmental concerns, social norms, and perceived use of EV technology. The initial choice analysis of the data from this sample showed substantial non-trading behaviour and an important sign reversal, for the range parameter of EVs (in contrast to previous studies which indicate that extended driving range increases the utility of an EV). A potential reason for this effect may also have been the substantially different driving range (four to five times larger) between ICE and EV;

- In order to further test the trading behaviour, to minimise the social desirability bias, and obtain a better representation of Perth's population, a second household survey was conducted using an online panel (PureProfile). This latter sample, with equal quotas from the North and South parts of the city, with equal distribution of males and females, and more representative coverage of the population age groups, showed a significantly lower non-trading behaviour, lower scores for environmental concerns, social norms and technology adoption scales, and corrected the negative sign reversal for driving range. The hybrid choice models confirmed the association between preference for EV and higher attitudes for energy conservation, but equally importantly the role of low running cost in the purchase of an EV, as well as the presence of a high-speed EV charging infrastructure.

From the methodological point of view, the research has shown that using the Best–Worst stated choice scenarios (providing the most preferred and least preferred options) is beneficial and provides more reliable parameter estimates. In addition, using experiments with two EVs in the same choice set is more appropriate in situations where technology is largely unknown (not experienced), but there is a positive outlook towards its adoption. Results from mixed logit models confirmed preference heterogeneity within the sample, further distinguishing EV enthusiasts from the population at large.

Robert George Reid

Supervisors: Thomas Bräunl, Adrian Boeing

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

Localization 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 modelled more accurately.

These contributions have been demonstrated online 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.

Stuart Speidel

Supervisors: Thomas Bräunl, David Harries, John Taplin

Energy Usage Patterns for Driving and Charging of Electric Vehicles

Electric vehicles (EVs) are currently a feasible and attractive alternative to their internal combustion engine counterparts. Electric vehicles require access to compatible charging infrastructure, which needs to be safe, secure and available. The stations need to be monitored, have car bays available, be in convenient locations, be spread out appropriately, be in areas where sufficient power is available, and many more other considerations. There are different configurations of stations, which provide various power outputs, use different connector types, different communication protocols, and there are many different international standards. These stations are mostly grid connected, which will create additional loads that need to be considered by electricity providers. Also, the electricity generated from non-renewable resources negates some of the environmental benefits of electric vehicles, and the intermittent nature of certain renewables needs to be optimised with smart charging solutions.

In this thesis, the results of several trials are discussed. As a part of the Western Australian Electric Vehicle Trial, 13 ICE vehicles were converted from petrol to electric, and 23 charging outlets were installed throughout

Western Australia, with usage data recorded over their lifetime. Solar energy data collected at several installations was used in conjunction with energy storage systems to measure the renewables' impact on charging, including data collected from buildings to take into account regular household power usage. The REView portal was created for users to monitor their behaviour, which includes charging stations, vehicles tracking, renewables usage along with billing. Finally, a fast-charging station was installed and monitored at UWA, and its data combined with the data collected from previously installed Level-2 AC charging stations in the Perth metro area.

Combining all this information, this thesis gives an insight into electric vehicle technology, driving/usage/charging patterns of EVs, as well as renewable energy and EV charging infrastructure.

Guido Wager

Supervisors: Thomas Bräunl, Jonathon Whale (Murdoch University), David Harries

Energy Efficiency of Electric Vehicles and Recharging Technologies under Consideration of Usage Profiles

The work performed in this thesis concentrates on studying factors that affect energy efficiencies of electric vehicles (EVs). The studies outlined in the thesis are structured in five sections.

The first study investigates energy recovery on a modified EV driving a typical city stop-and-go scenario. It revealed that by changing the control strategy for large auxiliary loads, such as air conditioner and heaters, sufficient kinetic energy can be recovered and used to maintain comfortable passenger compartment temperature. Implementing this strategy has the potential to increase battery lifespan.

The second study investigates performance tests on regenerative brake systems (RBS). The results showed that the energy recovery system increases the driving range. The results further showed that driving an EV with an energy recovery system also reduces brake maintenance cost.

The third study investigates efficient acceleration and deceleration of an EV. The results showed significant improvements in efficiency of the EV through applying high loads to the vehicle. It was also found that under certain high acceleration rates, energy losses increased, which outweighed the benefits of loading an EV motor to its efficient operating regions.

The fourth study investigates the relatively new fast-DC charging technology and how it affects an EV's battery systems. The experiment showed that the vehicle's battery-management systems were capable of successfully balancing individual cells and hence, maintaining the batteries' charge capacity. The findings suggest that fast-DC charging technology is a feasible option to allow EVs to travel large distances in a day.

The fifth study furthered investigations on the fast-DC charger by researching how fast-DC charging affects the vehicles' range under high-speed travelling. To simulate higher driving speeds, strong head winds or large auxiliary loads, the various components of traction power demand of the cars' batteries were modelled mathematically and the energy consumption of the cars were calculated to estimate the drivable range at these high speeds and loads. The results show a significantly reduced range under conditions relevant for highway driving, and stranded cars, and a possible negative perception of EVs. Drivers and charging infrastructure planners need to be aware of how EV energy and recharging demands can significantly change under different loads and driving patterns.

Final Year and MPE Project Dissertations

Manu Adina-Zada

Autonomous Vehicle Reliability and Localization

Autonomous vehicles need to orientate themselves in the environment to be able to generate manoeuvres to achieve a specific goal. Few sensors exist for this purpose, such as IMU, GPS and odometry. However, these sensors have different precisions and their own advantages and disadvantages. Hence, in this dissertation different configurations of sensor fusion are go explored. Since a standard Kalman filter can't be applied due to the non-linearity of the system model, the sensor fusion was performed by an extended Kalman filter (EKF). Since, odometry and IMU rely on past estimates to determine current position, these sensors become unreliable long term because of the accumulation of past errors. GPS on the other hand, doesn't require past estimates which makes it good for measuring the position long term. However, due to the discrete jumps and high variance of ±1m the estimations from the GPS are poor initially. After applying an EKF, the results have shown that the filter slightly improved the position estimate, due to utilizing the advantages of odometry and IMU.

Alexander Arnold

Object Detection and Classification for Autonomous Robots

With increasing global interest in semi- and fully-autonomous vehicle systems, The University of Western Australia has several research groups continuing to advance the capabilities of autonomous driving vehicles. This research comes with significant cost and risk, so a team was formed to research the effectiveness of embedded robotic vehicles (using the Raspberry Pi-based Eyebot platform) and determine the viability of a multi-robot autonomous driving system on the low-power, low cost hardware. The navigation system of an autonomous robot requires the synthesis of data from a variety of sensors. The camera systems provide a significant amount of information, including the classification and location of objects, though this usually requires running expensive and complex algorithms. Therefore, the purpose of this thesis is to research, design and implement an object detection and classification algorithm that achieves high speed and accuracy while running on the computationally limited Eyebot platform. After researching, testing and comparing several object detection algorithms, it was determined that a mobile-specific neural network implementation would give the best combination of performance and efficiency. This neural network was trained on a relatively small dataset, with impressive accuracy for its speed when compared with other researched algorithms. The solution provides real-time detection of hazards such as other vehicles, as well as the ability to recognise different traffic signs, with speeds approaching real-time detection (approx. 4.5 frames per second).

Julian Beilhack

TU München. Visitor: Sept. 2016–March 2017

ANN-Based Autonomous Navigation for a Mobile Robot Examination in Effective ANN Layout Design and Training

In this thesis ANN layout and training methods for ANN-based autonomous navigation is discussed. ANNs are trained to recognise a set of predefined situations. Movement commands are associated with every situation to achieve autonomous navigation. Experiments were conducted in the EyeSim simulator and with robots of the EyeBot family. Measurements from a laser distance sensor serve as input to the ANNs.

The scenarios examined are autonomous maze and open-world way-point navigation. The process of finding a suitable ANN layout and training procedure is discussed for both scenarios. This includes determining the number of neurons for the input and hidden layer of the ANNs, a suitable stopping condition for the training and the number of training datasets. Further, performance enhancing manipulations on the data fed to the ANNs are discussed. Based on the developed ANNs, autonomous navigation for both scenarios is implemented on the EyeBot robots. The experiments show that ANNs with distance measurements as input can serve as a basis for autonomous navigation in indoor environments. Further it is shown, that economical choices in ANN neurons and training datasets can be made without limiting performance. This can be beneficial for systems with limited computational power and when the availability of training data is limited.

Johnathon Borella

Solar Powered Autonomous Raft (SPAR)

The purpose of this research project was to send a solar-powered boat off the coast of Perth to Rottnest Island autonomously. This crossing is a proof of concept for the more significant problem to cross an ocean. An autonomous marine vessel has never completed an ocean crossing due to the sustainability of the boats. Relevant research has confirmed the suitability of solar panels as a form of sustainable power. Studies have also suggested painting the hull to avoid metal corrosion from seawater. Furthermore, the need for small prototype autonomous models to be tested extensively to fill the lack of current relevant research. This research project began six months after the initial electrical system was designed and built. It takes the perspective of a mechanical engineer to create the physical systems of the SPAR. This report discusses in detail the relevant design considerations around a solar-powered autonomous raft (SPAR). The constructed multihull SPAR has undergone multiple tests in pools and the Swan River to prepare it for its maiden voyage to Rottnest Island. Overall the tests went productively with the majority of the time spent fine tuning the internal electrical and software systems. Long range two-way communication is required before the boat is ready for its maiden voyage to Rottnest Island.

Craig Brogle

Software Architecture and Hardware-in-the-loop Simulation for an Autonomous Formula SAE Vehicle

Simulation is a cornerstone of autonomous driving efforts, allowing testing to occur more rapidly and with significantly less risk than is possible with hardware platforms alone. Simulation systems must be able to emulate a variety of sensors including cameras and LiDARs in order to allow high-level software such as image processing and path planning to be tested. In this paper, we present a hardware-in-the-loop simulation system based on CARLA, which incorporates computer hardware identical to that used on an autonomous vehicle platform in order to provide realistic constraints regarding available processing power along with access to the sensors required to test high-level software. In addition, we explore the Robot Operating System (ROS) based software framework used on the FSAE vehicle. Specifically, we detail how this software framework satisfies the requirements of flexibility, extensibility, and resiliency presented by its use in an autonomous vehicle, along with how its fulfilment of these requirements was beneficial to the development of the hardware-in-the-loop simulation system.

Logan Chau

Modelling and Design of Mounting System for an Electric Personal Watercraft

With rises in petrol prices, increases in demand and issues with pollution, the Renewable Energy Vehicle Project (REV project) at The University of Western Australia have made strides towards a better, cleaner future. The aim for the REVSki project is to showcase the potential of electric powered transports outside of typical vehicles. We hope to expand the concept of electric power and promote research into renewable energy inside the University and wider community. Since 2012, the REVSki project has aspired to create a recreational water vehicle that has similar performance to its petrol powered counterpart, whilst producing zero emission. These vehicles could provide a significant reduction in pollution and emission as they are more efficient to run and significantly quieter. The base vehicle of the REVSki is a 2008 Sea Doo GTI130, with the internal combustion engine being replaced with 50kW continuous rated three-phase AC induction motor and the fuel system replaced with Lithium iron Phosphate batteries arranged to provide a nominal voltage of 96V DC. At the end of 2015, the prototype of the REVSki was functioning, with the majority of the important components installed in order to have a working demo. The vehicle was publically launched, with support being shown from the general public. Since then, the REVSki has been disassembled in order to fix some of the major problems with the demo and apply improvements. A major problem with the balance and stability of the REVSki from the initial demo had to be addressed, as it was observed that the demo was far too front heavy when undergoing water trials. This affected the driver's ability to brake and accelerate, as well as the overall balance of the REVSki. To solve the stability problem, a large scale redesign of the interior components was necessary in order to shift the weight distribution towards the rear of the jet ski. This resulted in a major change in the location of the batteries, motor controller and fuse box , rendering the current method of mounting obsolete. This paper addresses the design, modelling, manufacture and installation of a new mounting system for these interior components. As a result of the work from t he 2017 REV team, the REVSki has been completely rebuilt and installed from the ground up, including a completely revised mounting system. The vehicle concept has been successfully proven, and the REV team hope to improve its performance in order to make it commercially feasible .

Jayden Dadleh

Safety and Battery Management Systems within an Electric Personal Watercraft

The University of Western Australia's Renewable Energy Vehicle (REV) Project is an initiative aimed at revolutionising personal transport. It is run by a team of staff and students focussed on the relationship between transport and long-term sustainability. The fundamental aim of this project is to build vehicles with zero emissions through the conversion of fossil fuel powered engines and motors into units that are powered by renewable electrical energy, through the implementation of grid connected solar panels. Beginning in the second half of 2012, one such project under the REV umbrella has been the REVSki project. An ordinary internal combustion engine jet ski is a large source of emission and noise, therefore, the aim of this particular REV project is to construct an electric jet ski resulting in reduced sound pollution and, more importantly, eliminating emissions. The jet ski, a Sea-Doo GTI130 purchased without a motor or fuel tank, requires certain safety systems to protect both the user and the expensive electrical components that are critical to operation. For the duration of 2017, the end objective had been to install a battery management system to protect the batteries from being damaged by overcharging or by discharging too low. Additionally, the wiring configuration of an existing insulation monitoring module had been reconfigured to work in conjunction with the battery management system, forming a safety system for the user and electrical components. A voltmeter board containing eight voltmeters was used to record the voltage readings of the battery cells over the course of a single charge and discharge cycles. This was both to prove that the battery management system operated as intended and to observe whether voltage drift of the battery cells was significant, which would influence any suggestions on actions for future work. The results that the team acquired has shown that the BMS cuts power when the voltage of the cells reach the lower and upper thresholds. The REVSki Safety System performs as required, however the results have drawn attention to the impact that cost has on the effectiveness of the project, with many leftover batteries showing varying signs of damage and leftover capacity. The REVSki would benefit in future from the addition of temperature and water sensors into the safety system and would greatly benefit from the replacement of all batteries installed prior to 2016 due to their damage

Samuel Evans-Thomson

Environmental Mapping and Software Architecture of an Autonomous SAE Electric Race Car

This dissertation covers the author's work on the development of the control system, software architecture, environmental mapping and visualisation system of an Autonomous Electric SAE car at The University of Western Australia. The UWA REV Autonomous SAE Electric Race Car Project is a platform for students to explore and develop modern electronics and automation systems, and spans multiple disciplines including electronics, power systems, software design, and computer science. This year the project team has been working to extend the autonomous driving functionality of the Electric SAE Race car to be suited to the racing conditions set by Formula Student Germany. This extension involves implementing the ability to autonomously drive through a track delineated by traffic cones. On top of this the team has aimed to improve the platform to facilitate the ease of future developments in part through the author's work in building a modularised software system with the intention of replacing the previous system. The design considerations, implementation processes and test results of this work is discussed.

Aaron Goldsworthy

Remote control of Autonomous Surface Vessels

This thesis concerns two different autonomous surface vehicle (ASV) platforms, the first being the Solar Powered Autonomous Boat (SPAB) constructed as a previous student project at UWA and the second being a Liquid Robotics Wave Glider owned by L3 Oceania. The challenges and approaches involved in both projects differed but the ultimate goal in both was to create and enhance the remote control and automation capability of the two vehicles. Both vehicles are fitted with 3G mobile telecommunications systems, and the WG is additionally fitted with an Iridium satellite communications modem. In the case of the Wave Glider, remote communications are achieved using a control protocol using simple messaging service (SMS) over 3G and Iridium. In the case of the SPAB, autonomous control is done using the mobile data capability of a 3G modem. The SPAB regularly logs telemetry data, retrieves commands and parameters from a remote control server using a Representational State Transfer (REST) application programming interface.

John Hodge

Autonomous Solar Powered Boat

This project is a side-project to the Autonomous Underwater Vehicle project and aims to create an autonomously guided, near-unlimited range water craft from mostly off-the-shelf components. Inspiration for this came from the Sea Charger craft, which was a small team's hobby project to create a solar powered vessel capable of reaching Hawaii from California (which it eventually succeeded at, and almost managed to reach New Zealand before suffering rudder failure). This report covers the process of designing the propulsion, power supply, and control systems for the boat, including the specifics of the design and the various dead ends and stalls that occurred. The final design (as of writing) is a differential-drive three hulled boat made from PVC piping, an aluminium top frame, and propelled by two powerful brushless motor based thruster pods. This design has been tested and can float, propel itself through the water, perform basic navigation between GPS waypoints, and report its position and status via a 3G modem. Due to time constraints (from various delays during development), although the craft can operate semi-autonomously, it still requires work before it can be sent on a multi-day mission (as the 3G telemetry is not rigorously tested, the control logic needs to be tuned for a sea vessel, and the battery failsafe is not yet implemented). This report concludes with a list of future work, both the required work for the craft to be able to run on its own, and optional extensions for data collection and expanded self-monitoring.

Chris Kahlefendt

Implementation and Evaluation of Monocular SLAM for an Underwater Robot

This thesis was created with the goal of finding and evaluating a SLAM algorithm applicable in the underwater environment using only the limited capabilities of the BlueROV2. For the purpose of finding a suitable algorithm an extensive literature review was performed and summarized in the lists at A.1 and A.2. To the best of the author's knowledge these lists present the most complete overview over SLAM algorithms available at the time of writing this thesis.

As a result of this research the ORB SLAM algorithm was picked for testing on the BlueROV2. The thesis provides an in-depth explanation of ORB SLAM explaining the techniques used and the overall structure of the algorithm. The description of the program's internal workings is supported by a detailed diagram visualizing the flow of information in its code. In addition usability functions like logging and easily manipulatable parameters were introduced. All of this allows for an easier introduction into the topic and will make development simpler for anyone working on the topic in the future. For testing the algorithm over 40 different datasets were recorded in varying environments. The evaluation performed on these showed that ORB SLAM can work very well given the right conditions. It does however also show that the algorithm struggles with some of the characteristics of the underwater environment. Especially the highly dynamic lighting and surroundings with lots of moving objects like fish and algae caused ORB SLAM to fail repeatedly.

It was not possible to completely exhaust the potential of the collected data within the time frame of this thesis. For example the recoded IMU data has not been used at all yet. This data could be utilized for testing IMU integration which should be able to significantly improve on discovered problems like the ones encountered in symmetric environments as described in 5.3. The datasets could also be used for testing other enhancements like the introduction of sub maps or tracking of 2D features. But these are not the only direction where future works could be headed. Section 6.2 provides a wide range of other suggestions for improving ORB SLAM in general and with regard to the underwater scenario. One thing this thesis was not able to provide was data with sufficient ground truth. Thisis definitely a large problem and should be a major focus for future works since so far it was only possible to evaluate the algorithm's accuracy in a qualitative way. While the data provided can be utilized to show that enhancements work and improve the result, it is not possible to perform any comparison with other algorithms as long as there is no ground-truth.

In summary this thesis was able to show that SLAM can work well underwater, even when only using a camera. Nonetheless it also demonstrates that there is still a lot of room for improvement. While the explanations and visualisations provided by this thesis allow for a quicker introduction into the topic, the tools, data and insights created and collected can be used as the foundation for the steps that need to be taken to further increase ORB SLAM's performance underwater.

Timothy Kelliher

Real Time Obstacle and Road Edge Detection for an Autonomous Formula SAE-Electric Race Car

The purpose of this research is to develop and implement robust LiDAR perception, including obstacle detection and road edge detection. The goals of this project are to achieve autonomous driving through a track delineated by cones and driving on the internal roads of UWA. The obstacles and road edges are passed to the path planner to achieve the project goals. This project utilises two LiDAR systems for testing. A SICK LMS111-10100, mounted on a low horizontal plane, and an ibeo LUX 4, mounted at an angle below horizontal in order to scan the ground in the distance. The LMS111-10100 scans a single layer while the ibeo LUX 4 scans four layers and completes in-built object detection and tracking. Obstacle detection is achieved by processing the LMS111 10100 data via a Euclidean clustering algorithm. Obstacles are classified as large or small based on the number of points in each cluster. The closest point of an obstacle is reported to path planning. The objective of autonomous driving through a track delineated by cones is met through this perception algorithm. The path ahead is mapping to achieve redrive functionalities on a similar track. Road edge detection is achieved by processing the ibeo LUX 4 data through partial differentiation, statistical analysis and weighted averaging of the results in each layer. Each layer is used to identify a region which is likely a road based on exploitation of the features of a road such as smoothness and continuity of the edges. The road edge detection algorithm is suitable for simplified road driving scenarios but needs improvement in order to achieve application of lane keeping due to errors in the exact position of edges.

Wai Lam William Lai

Autonomous Driving with Dynamic Path Planning

Path planning is one of the crucial elements for autonomous driving. A Hermite spline interpolation algorithm used to ensure smooth manoeuvring in between a series of waypoints is discussed in this paper. Followed by the proposal of a customised algorithm based on graphic-search path planning to achieve the real-time dynamic path planning that avoids static obstacles. Coordinated with sensing devices including odometry from wheel encoders and a single layer LiDAR scanner to detect static obstacles in front, cone following can be achieved without the predefined mapping situation. Cones within detectable distance are evaluated against the limited steering range, the optimal path which is collision-free on the track is constituted from choosing the largest driving range free of obstacles amongst some possible path candidates. The simulation and experimental results of the algorithms demonstrate the potential of practical application for fully autonomous driving. Although Simultaneous Localisation And Mapping (SLAM) technique can aid in the generation of a global map for path planning purposes, it is not, however, within the design project's scope. Skid effects would be an option to consider for maximising the driving speed of the vehicle. However, this mechanical dynamic subject is not within the scope of this paper and hence not being considered.

Fangpeng Li

Renewable Energy Vehicle's User Interface

The Renewable Energy Vehicle project (REV) is dedicated to designing and develop ing environmentally sustainable vehicles. Among the numerous achievements of REV, the REV Eco is a road-licensed plug-in electric commuter car based on a Hyundai Getz, and the REV Racer is an electric sports car based on a Lotus Elise. Embedded controllers for both vehicles were originally designed for replacing vehicle instruments like speedometer and tachometer, and displaying GPS information. After gradual development, modules like media player, battery management system (BMS), and route tracker were integrated into the controller. This thesis focuses on upgrading both software and hardware that concern the user interfaces (UI) on both vehicles to improve the performance and promote the capability. The last modification of the UI was conducted in 2014. Hence the first thing is to upgrade the development environment for the base program, and the operating system allocated on the controllers. During this process, a fair amount of necessary alters and changes were applied to the pre-existing code to eliminate the incompatibility between the previous UI program and the new software environment. Similarly, a hardware of the controllers was changed from Raspberry Pi (RPi) Model B to RPi 3 Model B, the latest product of the Raspberry Pi series of single computer boards. These upgrades are supposed to make the UI adapt to recent techniques and benefit its development in the future.

Yao-Tsu Lin

Autonomous SAE Car—Visual Base Road Detection

This dissertation describes the development of a real-time vision base road detection technique for an autonomous Formula-SAE. Formula-SAE is a long-running annual competition organized by the Society of Automotive Engineers. Recently the SAE-Electric has been introduced. The car in this dissertation is driven by electric motors and controlled via independent controllers. Although the autonomous driving is not including in the Formula-SAE competition, it has been an important research subject over recent years. This project consists of design and implementation of a real-time vision base road detection technique which uses a computation processor board Nvidia Jetson TX1 to interface with a range of sensors. The camera is one of the sensors which provided the processed information for the autonomous driving control system. The camera provides vision-based information then passes it on to image processing and image semantic segmentation methods to detect lane markings or road edges. The image processing method applies OpenCV (Open Source Computer Vision Library) to obtain the images characteristics from the camera input frames then extracts lane markings and calculates the distance between the car and lanes. This road distance information assists the Formula-SAE car to drive in the right position. However, the image processing technique is limited by the lane marking quality, i.e. fading or no marking. Therefore, the image semantic segmentation scheme SegNet is implemented in the system. It handles any low accuracy of the image processing scheme. The semantic segmentation scheme recognizes the edge of the road and provides this information for the autonomous driving control system. This project implements one more image processing method for traffic cones recognition. Because the traffic cones are positioned surrounding the track in competition scenario. This method is HOG (Histogram of Oriented Gradients), used to label a training image set, then create a feature vector. The labelled image set uses linear SVM (Support vector network) classifier for training. The trained data can detect and track traffic cones. This technique assists the autonomous driving control system to control the Formula-SAE car driving in between the road edges. Results are demonstrated through autonomous test driving and simulations showing the success of real-time road edge detection, thus achieving the goal of the project

Lijie Liu

Simulating Autonomous Vehicles

With the development of the economy, the numbers of vehicles in various cities around the world are increasing dramatically. At the same time, problems such as traffic congestion, traffic accidents, air and noise pollution are worsening in urban areas in different countries. Considering the current state of IT technology, the best current solution for most traffic problems is autonomous vehicle technology. The problem to be solved in this research paper is development of a low-cost autonomous vehicle that is suitable for an internal roads environment, for instance, university campuses, industrial areas and large residential areas. This research project uses an open urban driving simulator Carla, which offered an internal roads environment, to train and test an autonomous vehicle. Compared with other autonomous vehicles that are based on high precision map and optical radar, the approaches adopted to develop this low-cost autonomous vehicle are machine learning and computer vision. During the research, a few methods have been tried to identify traffic lanes, traffic lights, vehicles and pedestrians. Eventually, the author chose to ouse AlexNet, one of Convolutional Neural Network (CNN) models for training driving behavior classifier, and used YOLO v3, a real-time object detection system for detecting obstacles, such as other vehicles, traffic lights and pedestrians. Moreover, edge detection and Tesseract OCR have been used for traffic sign detection. At the end of this research project, an autonomous vehicle in Carla simulating environment has been found that achieves human-like self-driving, avoiding obstacles, and detecting traffic indication in real time.

Yu Liu (Rain)

Redesign of REV Jet Ski stability and handling

The UWA REV (renewable energy vehicle) project is dedicated to building zero emission vehicles that are powered by electricity from renewable sources. There have been numerous successful projects such as the electric Lotus Elise and the electric Hyundai Getz that were completed by REV. With its first prototype debut in 2015, the REV Jet Ski (REVski) project aims to convert a conventional petrol engine jet ski into an electrical one, while retaining the jet ski's normal functions. The purpose of this project is to promote the reduction of fossil fuel and noise pollution as a personal water craft (PWC), as well as to ensure the safety of the rider or the environment is not compromised by the conversion. As UWA is the first university in Australia that looks into this electrical conversion, and since there is a big market for water sports and tourism in Australia, it is highly possible that the REVski could be commercialised. However, during the initial on-water test in 2015, it was discovered that the REVski was very 'front-heavy', which means the longitudinal centre of gravity was far too forward. This had led to the jet ski dipping into the water during deceleration, making the jet ski very unsafe to operate on. Moreover, the excessive weight distribution at the front made the set ski very difficult to handle. The above two problems are definitely the disadvantages when considering this project for commercialisation, and to overcome these, the author has conducted a series of designs and testing to improve the REVski's stability and handling, which is the focus of this thesis.

Mohd Hjariz Mohd Jahis

REV Electric Jet Ski

The problem of designing reliable electrical safety systems in a maritime setting is crucial in providing safe operation for personnel and for the protection of internal components within the vehicle. The electrical connections across the systems and installations elsewhere in the vehicle must adhere to the IEC 60092 Standards of Electrical Installation in ships. While the REVski is not a ship, it is a maritime vehicle and the electrical installations made within the REVski must follow these regulations. Additionally, the Australian and New Zealand Electrical Safety Standards must also be followed, as they are intended to protect persons and property from electric shock or fires that may arise from electrical installations (AS/NZS 3004.2:2014). This paper aims to design electrical safety systems in areas of the REVski that may pose a danger to personnel or hinder the performance of the vehicle in the event that a fault occurs. Should a fault occur in any of the areas outlined below, the system is designed to cut power and discontinue the operation of the REVski to prevent any further electrical hazards until they are repaired out of water to a satisfactory level. Safe operating temperatures are considered in the battery tubes, the electric motor and the AC Curtis Motor Control Unit. Protection against high voltage lines is mitigated through the Bender Insulation Monitoring Device by measuring the resistance level of the high voltage lines before they pose a risk to personnel or neighboring equipment. Water leakage in the REVski is managed by the use of Arduino water level sensors. The state of the rechargeable lithium ion batteries housed in PVC tubes is monitored through a battery management system. Future work aims to investigate the use of a graphical user interface to relay the information of the electrical safety system to the user to be viewed from outside the REVski and for data collection. Another area for future research is into the use of depth sensors to monitor the depth at which the REVski is in the water to allow safe navigation and protection of the hull from physical damage. The implementation of mobile water quality testing will also be investigated as a project in the future.

Michael Mollison

High Speed Autonomous Vehicle for Computer Vision Research and Teaching

This thesis presents the development of a rugged, high-speed, low-cost, and highly adaptable autonomous ground vehicle, to serve as an educational tool for future Robotic Engineering students at The University of Western Australia, and enabling future research into Autonomous Navigation and Computer Vision not possible with the University's current fleet of robots. The vehicle was developed with the goal of facilitating future research into Autonomous (car) Driving, and Self Localisation and Mapping (SLAM) techniques, utilising progressively lower cost sensors and hardware than traditionally employed for the purpose, thereby lowering the cost of entry for research into the field. The vehicle was developed around a highly configurable consumer R/C car to ensure stability at high speeds, over varied terrain, both indoors and out, ensuring adaptability to future test conditions, and autonomous and SLAM capabilities utilising a 2D Laser Distance Scanner as it's only sensor were developed as a proof of concept and baseline for future research. The software was developed on top of UWA's RoBIOS software, which provides a touchscreen interface for users to run programs as well as providing a simple API to interact with the robot. As an additional part of this project, improvements and alternatives to RoBIOS were investigated, and functionality, required for the new vehicle, was added to the RoBIOS API, providing a more feature-rich environment for future Robotics students.

Alexander Dale Morgan

Shock and Vibration Isolation for an Electric Jet Ski

Electrical components within a vehicle are designed to fulfil their immediate function and at times, do not account for other aspects such as mechanical shocks or vibrations. Consequently, an additional system needs to be introduced for the purposes of either damping or reducing the vibrations and shocks experienced by the components. The goal of this system is to reduce the transmission of energy and the associated forces experienced by the components. This is for their protection and also to increase the longevity of each component. This is of particular importance for fuses, as mechanical shocks could lead to their failure. In turn, fuses would require frequent replacement which is not ideal in the context of transportation. The Renewable Energy Vehicle PWC (REV Ski) experiences this very situation with its main electrical components. Those that require shock and vibration protection consist of fuse boxes, a DC–DC converter, a MC, and others. These components were bolted to aluminium plates, which were screwed into laminated wood adhered to the REV Ski hull. To effectively design this system, field data was collected through the use of an accelerometer and Arduino Uno. This setup analysed the forces exerted on the MC box, and recorded them to a memory card. Through data processing, the forces and displacements of the system were obtained. This allowed for the appropriate selection of rubber mounts, which were subjected to additional tests to gather empirical knowledge on their performance, and thus suitability as a shock absorber. Future works could involve the researching of active isolation. Should the benefits of which outweigh the disadvantages (monetary costs and power draw from the batteries), students could design a system of sensors and actuators to better isolate the components from shocks and vibrations.

John Philip Pearce

Providing households with real-time feedback from the monitoring of energy consumption and generation

Reducing energy consumption and the use of renewable energy sources have become increasingly important. While the public have been taking steps to reduce energy consumption and switch over to more energy efficient appliances, there is a limit to the possible level of energy reduction using this approach. Making more effective use of the variable generation of renewable energy sources requires a shift in patterns of consumption to more closely follow generation. However, typically occupants are unaware of their energy usage until the end of each billing period. There are a number of commonly used appliances that contribute significantly to household energy consumption and for which time of use could be shifted without significant inconvenience, such as washing machines, dishwashers and tumble dryers. A system capable of monitoring and processing data for household energy consumption, generation and storage in real time could provide useful feedback to occupants leading to a reduction in both overall energy consumption and that from the power grid. This exploratory study focuses on the development of a system to monitor energy consumption and generation for households with roof-top solar photovoltaic (PV) systems and to use that data to drive shifts in energy consumption to better match generation. We present the development of a system to ingest, process and visualise energy consumption and generation data. Using this system we implement a processor to predict, in the short term, periods of lower than usual energy generation and generate notifications for household occupants to suggest deferring using elastic-load appliances. The model of a battery energy storage system created is presented and used to analyse the viability of incorporating battery energy storage into household solar PV systems.

Roman C. Podolski

Implementation of an Iterative Sampling-Based Local Path-Planner

This work presents an implementation of an iterative sampling-based local path planner in the object-oriented programming language C++ with the modern ISO standard of 2014 (C++14). It aims to solve the planning problem for an application in autonomous racing. The targeted hardware is an electronic race car built at The University of Western Australia which is intended to participate in a race similar to the Formula Student Driverless. Since the planner must run efficiently on embedded hardware, this work favors a sampling-based near-optimal solution over a computationally more intensive optimal solution. Further, this thesis introduces a resource economic approach to collision checking. The implementation of the algorithms is required to be performant and easily integrated in the robotic framework of the race car. Therefore, C++14 is used to implement the algorithms, since it provides high-performance and modern language features that integrate well with existing software. Simulation verifies the correct workings and performance of the implementation. The results of the simulation prove that the chosen algorithms find a near-optimal solution to the path planning problem for a scenario like the Formula Student Driverless, while allowing update rates as high as 20 Hz. This work provides the base for a practical application of the provided planner in a robotics framework and integration testing in a real-world scenario.

Mitchell Poole

Improved Localization in UWA REV Autonomous Driving SAE Vehicle Through IMU, GPS, Wheel Encoders and Extended Kalman Filter

The following dissertation describes the improvements developed for the localization system of the Autonomous SAE vehicle at UWA. The main improvements that were applied to the localization system are the addition of odometry to the low level control system, as well as an Extended Kalman Filter, and changes to the low level software, and to the sensor fusion algorithms. Odometry sensing to the SAE vehicle was added in by use of a microcontroller and Hall Effect Sensors. This microcontroller communicated with the microcontroller in charge of steering, braking and acceleration of the vehicle, to provide wheel speed measurements to the main microcontroller into the main processing system. The sensor fusion algorithm attempted to compare and contrast at least three cases; sensor fusion with odometry with a Kalman filter, sensor fusion with odometry using a Kalman Filter, and sensor fusion with odometry and an EKF. A reliable odometry measurement sensor has been obtained, that provides speed for each of the four wheels. The wheel speeds are then captured by the central control unit (an NVidia Jetson TX1 board), which uses the wheel speeds for localization in its control system. Minor calibration will be needed for more accurate wheel speed measurements, outside of this, the odometry is a partially integrated system in the SAE vehicle. The Kalman filter sensor fusion variants and the EKF could not be tested on due to errors in the fusion class, which needs to fully integrated into the system. The addition of the Jetson board allows others to improve the localization of the SAE vehicle by adding in some form of Monte-Carlo algorithms, such as a Particle Filter, or using an Unscented Kalman Filter for localization. The improvements to localization allows for the implementation of a SLAM type control system for the SAE vehicle, or other control system features.

Tianhao Ren

Modeling the Dynamic Behavior of Personal Watercrafts

Under the Renewable Energy Vehicle Project (REV Project), the aim for the REVSki project is to convert a traditional petrol-based jet ski to an electrically powered jet ski. Currently, the first prototype of the electric jet ski is completed , and several on-water field tests have been conducted . However, the electric Jet ski (REVSki) is yet to have the competitive performance to its traditional counterpart. Based on the current model of the electric jet ski, this thesis focuses on the establishment and computation of small personal watercraft's manoeuvering motion model. Firstly, a complete 6-DOF dynamic model of the jet ski is established using commercial CFD software STAR-CCM+. Secondly, a 3-DOF mathematical manoeuvering model for general small personal watercraft is developed based on the linear regression approximation of the hydrodynamic co-efficients. Finally, the mathematical model is simulated using MATLAB and results were compared and analyzed. In the case of hydrodynamic calculation, the method of planar motion mechanism test is used. Firstly, the correctness of the calculation method is verified through the simple geometry of additional mass computation. Then 8 hydrodynamic coefficients related to manoeuvering the "REVski" with 3-DOF under hydrodynamic conditions. In order to simulate the behavior of general small personal watercraft, the method of linear approximation of hydrodynamic coefficients is used. In this way, calculating the hydrodynamic coefficients of a certain small personal watercraft does not require full detail of geometry anymore. The simplified hydrodynamic formulas using linear approximation is used to build up a MATLAB model, and the results are compared with CFD model and actual field test data

Maximilian Jacob Woloszyn

Instrumentation for the REVski; an Electric Personal Watercraft

As with any modern vehicle, it is crucial for the operator to be fully aware of the current state of their vehicle and warned about any system failures that may jeopardize their safety. To do this, sensors or instrumentation are used to measure and monitor important parameters such as the speed of the vehicle and is typically displayed to the operator through a dashboard interface. The instrumentation on board a vehicle depends on several factors but is largely influenced by the type of the vehicle and the environment the vehicle is used in. This thesis focuses on identifying, designing and installing instrumentation required for the REVski, an electric powered jet ski. The REVski is part of the Renewable Energy Vehicle (REV) project and aims to eliminate noise pollution and emissions while providing the same performance as a conventional petrol-powered jet ski. The proposed instrumentation for the REVski will aim to measure and display information relevant to an electric vehicle within a marine environment. This includes battery voltage, state-of-charge, temperature and water level. Capturing this data through an on-board computing system will also allow a logbook of the REVski systems to be created, for which can be used for future design improvements.

Chao Zhang

Integration of Cone Detection, Visual SLAM and Lane Detection for Real-time Autonomous Drive

Image processing is one of the critical components of the software frameworks for autonomous vehicles. Compared with other sensors such as LiDARs, GPS, and IMU, cameras generally provide richer information with a lower unit price. However, the processing of the data is much more complicated and has higher requirements on computation power for real-time application. In this paper, the author presents a high-level integration of visual software solution that combines cone detection, visual SLAM and lane detection for real-time autonomous driving application, with optimisation on architecture for improving runtime performance. This image processing stream is part of the REV SAE autonomous program. The framework is implemented as a node which communicates with other modules in the system under the Robot Operating System (ROS). The testing results are collected from both the simulation system and field driving

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CRICOS Provider Code: 00126G

REF: LB Admin /2018_2019 Research