THE UNIVERSITY OF WESTERN AUSTRALIA

Faculty of Engineering and Mathematical Sciences

Computational Intelligence Information Processing Systems

RESEARCH 2020/2021

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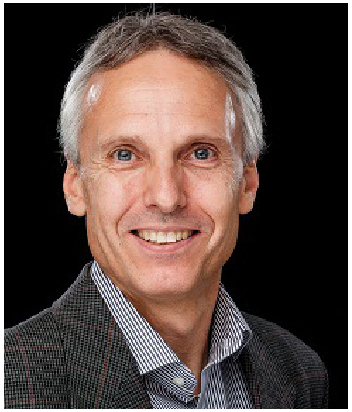
Foreword

from the Head of CIIPS



In the thirteenth year of the Renewable Energy Vehicle Project (REV), we finally added a new vehicle to our collection. We were able to purchase a secondhand electric shuttle bus from ST Engineering in Singapore, where it was previously doing its duties at Gardens by the Bay. The shuttle was built by Ligier in France and includes drive-by-wire functionalities, but had all of its original EasyMile software removed, which is fine by us, as we are adding our own hardware- and software-stack for self driving.

Our new research partner Stealth Technologies is a local start-up company that is made up 100% from CIIPS graduates, including its founder, and does corporate research and development in the autonomous vehicle space. Read more about their activities in this report.

The electric hydrofoil jet-ski is another highlight of our research work, this time in cooperation with local start-up Electro. Aero. Sponsored by Galaxy Resources, we developed a first generation of a hydrofoil personal watercraft with the start-up and are now building an improved second generation within CIIPS/REV.

We have been successful with a major grant in the Automotive Engineering Graduate Program, which is now funding four postgraduate students and provides professional practicum placements for another 24 students over two years. A major industrial project was the development of a state-wide Electric Vehicle charging infrastructure plan for Western Australia, funded by MainRoads and Western Power. Details on this are also published in this report.

We are also looking forward to the new Bachelor's degree in Automation and Robotics, which starts in 2021. This new degree is what UWA calls a "double major" and it combines a great foundation across Mechanical, Electrical and Software Engineering with specialist units in Automation and Robotics. We expect this will be very popular with students and will prepare them well for their future careers.

Professor Thomas Bräunl

Head
Computational Intelligence—
Information Processing Systems
(CIIPS)

Introduction to CIIPS

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

Activities

The group combines an active teaching program with pure and applied research to provide an environment in which innovative theoretical developments can be rapidly turned into technologies that provide solutions to a range of real-world problems.

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

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

Equipment

In the Robotics and Automation Lab, the group operates numerous autonomous mobile robot systems, including about 30 driving robots, five converted model cars, three autonomous underwater vehicles, five walking robots and two drones.

In the REV Automotive lab, the group operates five research vehicles:

- Ligier Shuttle Bus (Autonomous Driving)
- BMW X5 (Advanced Driver Assistance Systems)
- Hyundai Getz (Electric conversion, road-registered)
- Lotus Elise S2 (Electric conversion, road-registered)
- Driverless Formula SAE—Electric Race Car
- Formula SAE—Electric Race Car
- "Conventional" Electric Jet Ski (marine-registered)
- Hydrofoil electric Jet Ski (marine-registered)
- Electric Scooter

Members of CIIPS

Academic Staff

Professor Thomas Bräunl
(Head of CIIPS)
Dipl.-Inform., MS, PhD, Habil., SMIEEE
Electromobility; Automotive Systems; Robotics; Image Processing; Concurrency; Embedded Systems
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Adjunct Professor David Harries
BSc, DipEd, MEnvStud, PhD
Smart Grids; Renewable Energy; Photovoltaics; Elektromobility
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Mr Ivan Neubronner
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Mr Marcus Pham
REV Student Manager
rev@theREVproject.com

International Visitors

Mr Marius Fink
University of Stuttgart, 2019

Mr Felix Wege
TU Hamburg-Harburg, 2020

Contact Details

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Students

PhD Students—Current

Mr Craig Brogle
Automotive Simulation
Prof. T. Bräunl, Prof. F. Boussaid

Mr Jhon Delgado
Autonomous Shuttle Bus Project funded by the Automotive Engineering Graduates Program.
Prof. T. Bräunl, Prof. F. Boussaid

Mr Thomas Drage
Control and Safety Systems for Autonomous Driving
Prof. T. Bräunl, Dr A. Boeing

Mr Khoa LeTrung
Autonomous Shuttle Bus Project funded by the Automotive Engineering Graduates Program.
Prof. T. Bräunl, Prof. F. Boussaid

Mohsen Shokri
Human–Robot Interaction
Prof. T. Bräunl

Mr Chao Zhang
Vision-based Safety System for an Autonomous Vehicle
Prof. T. Bräunl, Prof. F. Boussaid

PhD Students—Completions

Dr Kai Li Lim, 2020
Connected Autonomous Electromobility Visual Navigation and Charging Analytic Frameworks

Dr Stuart Speidel, 2019
Energy Usage Patterns for Driving and Charging of Electric Vehicles

Dr Franco Hidalgo Herencia, 2019
Simultaneous Localization and Mapping in Underwater Robots

Higher Degree by Research Preliminary

Mr Pierre-Louis Constant
Autonomous Boat Design
Prof. T. Bräunl

Mr Machiel van der Stelt
Bicycle Simulation System
Prof. T. Bräunl

MPE Research Project Students

2019

Nicholas Burleigh (EE)
Autonomous Driving on a Model Vehicle

Wesley Coleman (EE)
Solar Powered Autonomous Raft

Marius Fink (EE)
Formation Control of Mobile Robots

Eduardo Guadarrama (EE)
REV Stereo-Detection and SLAM

Junwen Huang (EE)
REV Safety PCB

Jordan King (EE)
Learning Algorithms for Traffic Sign Detection

Dylan Leong (EE)
REVSki Data Transmission, Storage and Visualisation

Marti Leven (EE)
REVski System Architecture & Instrumentation

Ze Lin (Mech)
REVski Instrumentation & Water Quality Sensor

Xiaoqing Ran (Mech)
REVski Safety System and Water Quality Detecting

Jiajian Shao (Mech)
REV Vehicle Path Planner

Morgan Trench (EE)
Web Application to Monitor and Control Solar Boat

Jia Yu (Mech)
REV Sensor Fusion

Tuo Zhang (EE)
REV Segmentation

2020

Farhad Ahmed (EE)
Autonomous Shuttle Bus

Alishan Aziz (EE)
Hydrofoil Jet Ski

Jason Chu (EE)
Autonomous Shuttle Bus

Kyle Crescencio (Mech)
Autonomous Shuttle Bus

Yuchen Du (EE)
Autonomous Shuttle Bus

David Gregory (EE)
Autonomous Shuttle Bus

Jeremy Guo (Mech)
Hydrofoil Jet Ski

Joey Koh (EE)
Autonomous Shuttle Bus

Layla Krishna (Mech)
Hydrofoil Jet Ski

Timothy Masters (EE)
Intelligent Drones (Stealth Tech.)

Nyi Myo Maung (EE)
Mobile Robots

Ben Ness (Mech)
Hydrofoil Jet Ski

Victor Olowodroran (EE)
Standalone Simulator for Articulate Robots

Vladimir Pavkov (Mech)
Hydrofoil Jet Ski

Anthony Ryan (EE)
Vision-based Learning for Autonomous Driving

Vihanga Silva (EE)
Renewable Energy Project

Samuel Tennent (Mech)
Autonomous Painting Robot (CEED)

Daniel Trang (EE)
Autonomous Shuttle Bus

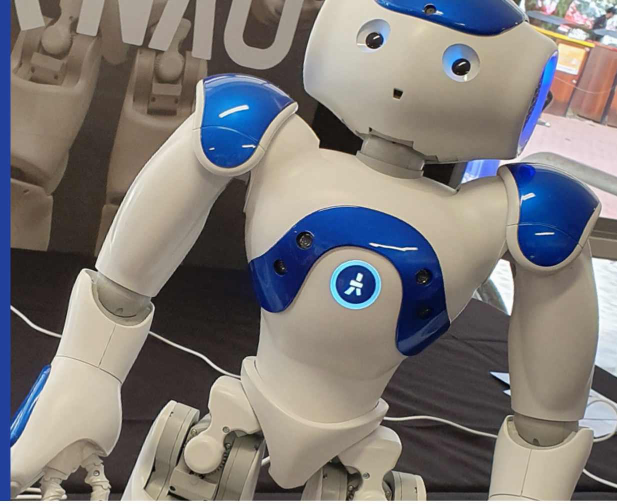
Liyang Leo Xu (Mech)
Hydrofoil Jet Ski

Yingjie Yao (EE)
Renewable Energy Project

Haojin Yu (EE)
Mobile Robots

Yi Zhang (EE)
Renewable Energy Project

Research Activities



CIIPS Research Labs

Automotive Lab

Professor Thomas Bräunl
REV–Eco (Electric Hyundai Getz); REV–Racer (Electric Lotus Elise); Formula–SAE Electric; Formula–SAE Autonomous; BMW X5 Drive-by-Wire, Electric Scooter; Electric Jet Ski; Electric Hydrofoil; Autonomous Electric Shuttle Bus.
Location: Mech G25

Robotics and Automation Lab

Professor Thomas Bräunl
Intelligent mobile robots; embedded systems; image processing; simulation.
Location: EECE 3.13

Smart Grids Lab

Adjunct 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 the research on driving economy, such as plug-in electric vehicles, as well as active driving safety, such as driver-assistance systems. The Automotive Lab currently houses a Ligier electric shuttle bus, BMW X5, Hyundai Getz, Lotus Elise S2, Formula SAE-electric race car, autonomous FSAE-electric race car, a “conventional” electric jet ski, a hydrofoil electric jet ski and an electric scooter. The Engineering Faculty’s Renewable Energy Vehicle Project (REV) is running in this lab.

Details can be found at: http://REVproject.com

Autonomous Electric Shuttle Bus

For a long time, REV has been trying to build a new autonomous vehicle. Finally, we had the chance in a cooperation with the UWA Business School and ST Engineering, Singapore, to purchase a used electric drive-by-wire shuttle bus built by Ligier in France. In its previous life, the shuttle transported visitors to the Singapore Gardens by the Bay as an EasyMile autonomous transporter, however, we only purchased the mechanics and electronics hardware, not EasyMile's software, as our goal always was to develop our own autonomous driving system.

The shuttle is equipped with identical sensor models like we had on our old autonomous Formula-SAE vehicle — only more of them. It has four Sick single-layer Lidar scanners as collision avoidance safety sensors (one at each corner), two Ibeo Lux automotive Lidar scanners on top for navigation (one facing forward and one facing backward) and two Velodyne puck sensors for traffic and pedestrian detection (one in front, one in back).

Our first large task was to identify all system components and get the shuttle driving again with our own software based on ROS (robot operating system) that we already used for our Formula-SAE car. We also updated the battery and charging system to comply with European charging and safety standard (which it did not) and added battery monitoring systems for the drive battery as well as the 12V utility system.

The shuttle can now be charged on any IEC Type-2 EV charging station and display its charging and battery status on an independent LCD.

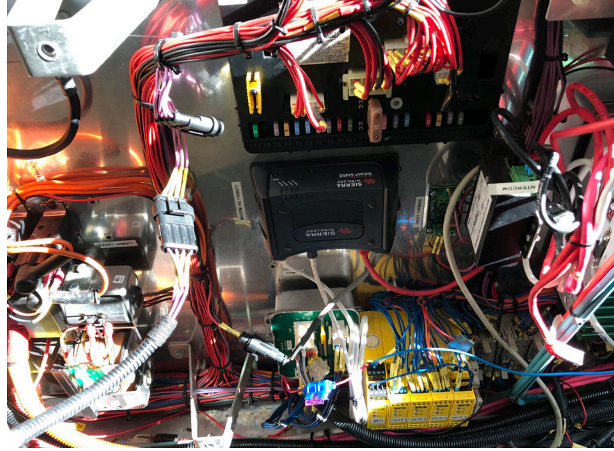
Although we are not the first institution in Perth to operate an autonomous shuttle bus, we are the only one that actually develops their own self-driving system and is not just using some purchased foreign technology. As far as we know, we are the only Australian university developing autonomously driving passenger vehicles.

With the drive-by-wire system now attached to our own computer system and software, we are transferring our software solution from the Formula-SAE car to the shuttle bus and are implementing an intelligent autonomous driving mode. Unlike all commercial autonomous shuttle buses, our system will not just stop and give up if anything — even a parked bicycle or a piece of cardboard — is in its way. Our system will be able to deviate from a fixed preprogrammed path and safely drive a small detour around it.

Later in the year and in cooperation with Doina Olaru and her team at the UWA Business School, we will be offering regular autonomous shuttle bus rides for staff and students along the North–South axis across the university campus. The Business School will evaluate passenger experience and expectations for this technology.

Electric modifications on nUWAy shuttle bus:

- replacement of charging connector to IEC Type 2 “Mennekes”
- addition of ePro current and voltage meter for drive system
- addition of 12V gauge and charging points
- addition of Nvidia Xavier co-processor
- addition of a gigabit switch.



Top and centre: Shuttle bus controls before modifications

Below: Shuttle bus controls after modifications

Electric Hydrofoil WaveFlyer

Together with Perth start-up company Electro.Aero, REV has completed the world's first electric hydrofoil personal watercraft. The WaveFlyer resembles a conventional jet ski, but when in motion, its two hydrofoils lift it out of the water for a completely new cruising experience, softly gliding above the waves. While this smoother ride makes the hydrofoil not necessarily faster than a conventional electric jet ski, it only uses about a quarter of the energy for driving the same distance. So an equivalent hydrofoil can travel four times longer or only requires one quarter of the batteries to cover the same distance.

A team of REV students is currently working on the second generation of the hydrofoil ski in the lead up to forming a new start-up company. The hardest challenge is to design a fly-by-wire system that achieves a sensor-based automatic stabilization for the ski. Because without it, the hydrofoil is very hard to control, especially for novice drivers.

The hydrofoil project has been funded by Galaxy Resources, the UWA School of Engineering and the UWA Innovation Quarter.

The REV Vehicles

Over the 13 years that the REV Project has been running, the following vehicles have been built and/or modified by students.

REV Eco

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

Autonomous BMW X5

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

REVski

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

Autonomous SAE Electric car

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

REV Racer

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

Formula SAE Electric car

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

Scooter

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

EV Charging Infrastructure Report

REV was contracted by MainRoads Western Australia to conduct a study on the "Electric Vehicle Infrastructure Strategic Planning". This study presented a charging network covering all major roads in Western Australia with stations no further than 200km apart and the capacity to handle a 1% EV uptake, which is expected to occur in WA in the year 2025/26 without the introduction of any government incentives.

The 184-page report was written by Prof. Thomas Bräunl, Adjunct Prof. David Harries, Dr Mark McHenry (Murdoch University) and Dr Guido Wager, and contains three EV charging scenarios, considering the availability and strength of the local electricity grid, traffic data from MainRoads, and connection cost from utilities Western Power and Horizon Power. Only DC fast-charging stations between 50kW and 350kW power rating were considered to allow long-distance travel with reasonable charging times.

The recommended charging grid outlined in the map and the table at right comprises a total of 138 fast-DC stations at 61 sites. Its installation, considering station cost, installation cost and grid connection fees/SAPS will come to just $23.6 million for the whole state.

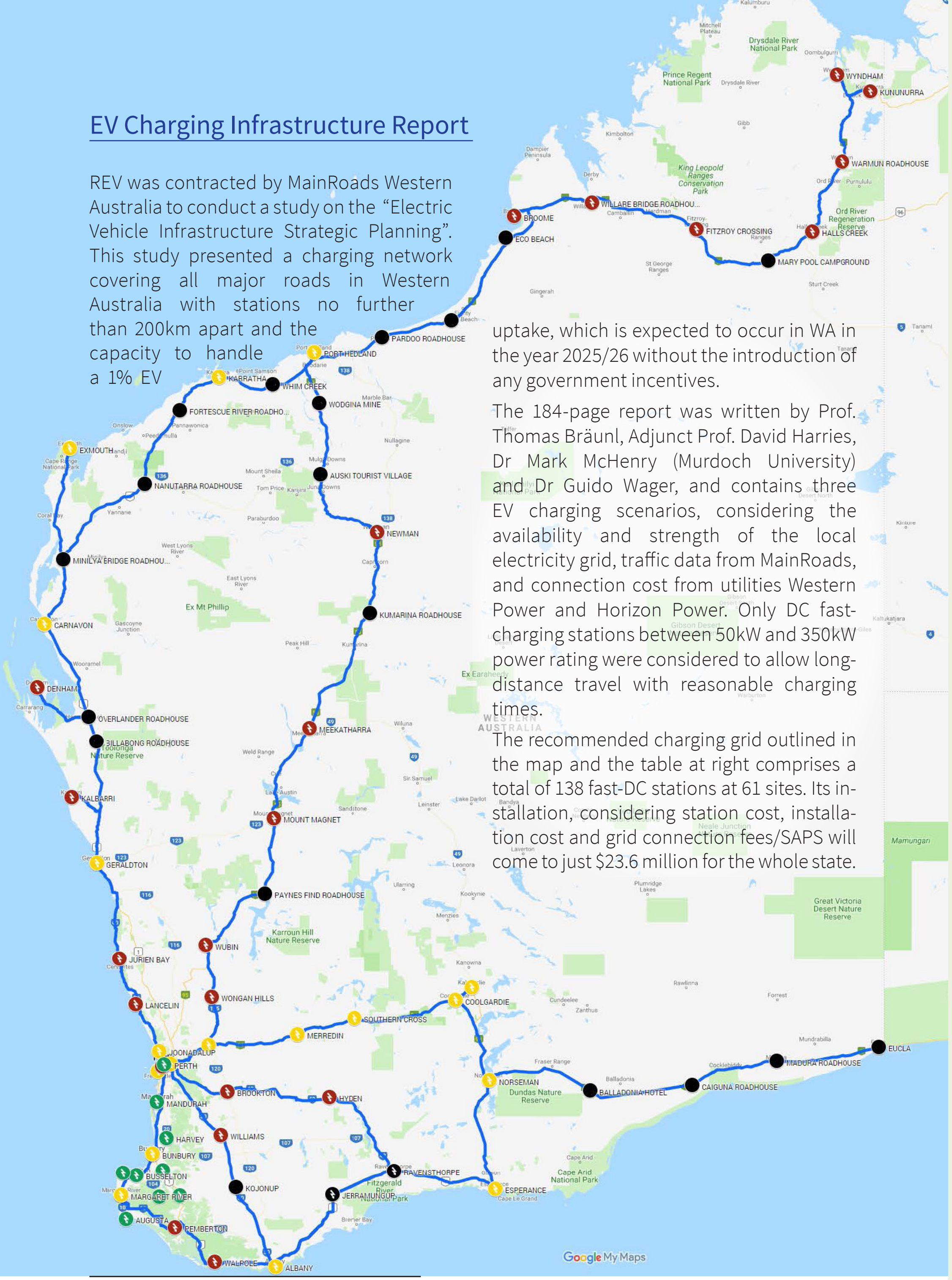


Table 1: Charging infrastructure configuration

PROPOSED				Residents	Residents	Traffic	Total req.	De-rated			Bays	Bays	Bays
			Local Evs at	charging	peak hour	peak hour	peak hour	Installed	Installed	Total	[kW]	[kW]	[kW]
Site	Location	Population	1% uptake	[kWh]	power [kW	power [kW	power [kW]	power [kW]	power [kW	Bays	350	150	50
METRO		*2'300'000*	*14'030*										
1	PERTH / WEST PERTH / LEEDERVILLE	575'000	3'508	3'315	398	100	**498**	**1'470**	2100	6	6		
2	JOONADALUP	575'000	3'508	3'315	398	100	**498**	**1'470**	2100	6	6		
3	FREMANTLE	575'000	3'508	3'315	398	100	**498**	**1'470**	2100	6	6		
4	SOUTH PERTH / VICTORIA PARK	575'000	3'508	3'315	398	100	**498**	**1'470**	2100	6	6		
SOUTH-WEST													
5	BUNBURY	72'403	442	417	50	116	**166**	**490**	700	2	2		
6	MARGARET RIVER	7'654	47	44	5	39	**44**	**490**	700	2	2		
7	PEMBERTON	974	6	6	1	27	**28**	**240**	300	2		2	
8	WALPOLE	439	3	3	0	18	**18**	**240**	300	2		2	
9	ALBANY	29'373	179	169	20	146	**166**	**490**	700	2	2		
10	KOJONUP	1'298	8	7	1	40	**41**	**490**	700	2	2		
11	WILLIAMS	948	6	5	1	83	**84**	**240**	300	2		2	
SOUTH COAST													
12	BROOKTON	756	5	4	1	20	**21**	**240**	300	2		2	
13	HYDEN	377	2	2	0	17	**17**	**240**	300	2		2	
14	RAVENSTHORPE	498	3	3	0	34	**34**	**88**	100	2			2
15	JERRAMUNGUP	356	2	2	0	9	**9**	**88**	100	2			2
16	ESPERANCE	12'107	74	70	8	28	**36**	**490**	700	2	2		
GOLDFIELDS													
17	NORTHAM	6'548	40	38	5	68	**73**	**490**	700	2	2		
18	MERREDIN	2'636	16	15	2	25	**27**	**490**	700	2	2		
19	SOUTHERN CROSS	638	4	4	0	13	**13**	**490**	700	2	2		
20	COOLGARDIE	878	5	5	1	18	**19**	**490**	700	2	2		
21	KALGOORLIE	30'509	186	176	21	9	**30**	**490**	700	2	2		
22	NORSEMAN	581	4	3	0	14	**14**	**490**	700	2	2		
NULLARBOR													
23	BALLADONIA HOTEL	10	0	0	0	11	**11**	**88**	100	2			2
24	CAIGUNA ROADHOUSE	10	0	0	0	14	**14**	**88**	100	2			2
25	MADURA ROADHOUSE	10	0	0	0	10	**10**	**88**	100	2			2
26	EUCLA	53	0	0	0	13	**13**	**88**	100	2			2
MIDWEST													
27	LANCELIN	714	4	4	0	51	**51**	**240**	300	2		2	
28	JURIEN BAY	1'761	11	10	1	64	**65**	**240**	300	2		2	
29	GERALDTON	37'432	228	216	26	77	**103**	**490**	700	2	2		
30	KALBARRI	1'557	9	9	1	10	**11**	**240**	300	2		2	
31	BILLABONG ROADHOUSE	10	0	0	0	27	**27**	**88**	100	2			2
32	OVERLANDER ROADHOUSE	10	0	0	0	6	**6**	**88**	100	2			2
33	DENHAM	754	5	4	1	11	**12**	**240**	300	2		2	
GASCOYNE / PILBARA													
34	CARNAVON	4'426	27	26	3	25	**28**	**490**	700	2	2		
35	MINILYA BRIDGE ROADHOUSE	10	0	0	0	8	**8**	**88**	100	2			2
36	EXMOUTH	2'514	15	14	2	20	**22**	**490**	700	2	2		
37	NANUTARRA ROADHOUSE	10	0	0	0	12	**12**	**88**	100	2			2
38	FORTESCUE RIVER ROADHOUSE	10	0	0	0	16	**16**	**88**	100	2			2
39	KARRATHA	15'828	97	91	11	11	**22**	**490**	700	2	2		
40	WHIM CREEK	32	0	0	0	10	**10**	**88**	100	2			2
41	PORT HEDLAND	13'828	84	80	10	14	**24**	**490**	700	2	2		
KIMBERLEY													
42	PARDOO ROADHOUSE	10	0	0	0	8	**8**	**88**	100	2			2
43	SANDFIRE ROADHOUSE	10	0	0	0	7	**7**	**88**	100	2			2
44	ECO BEACH	10	0	0	0	11	**11**	**88**	100	2			2
45	BROOME	13'984	85	81	10	9	**19**	**240**	300	2		2	
46	WILLARE BRIDGE ROADHOUSE	3'511	21	20	2	21	**23**	**240**	300	2		2	
47	FITZROY CROSSING	1'297	8	7	1	16	**17**	**240**	300	2		2	
48	MARY POOL CAMPGROUND	10	0	0	0	11	**11**	**88**	100	2			2
49	HALLS CREEK	1'499	9	9	1	18	**19**	**240**	300	2		2	
50	WARMUN ROADHOUSE	10	0	0	0	17	**17**	**240**	300	2		2	
51	WYNDHAM	780	5	4	1	10	**11**	**240**	300	2		2	
52	KUNUNURRA	5'308	32	31	4	9	**13**	**240**	300	2		2	
INLAND													
53	WONGAN HILLS	898	5	5	1	10	**11**	**240**	300	2		2	
54	WUBIN	103	1	1	0	4	**4**	**240**	300	2		2	
55	PAYNES FIND ROADHOUSE	10	0	0	0	5	**5**	**88**	100	2			2
56	MOUNT MAGNET	470	3	3	0	10	**10**	**240**	300	2		2	
57	MEEKATHARRA	708	4	4	0	6	**6**	**240**	300	2		2	
58	KUMARINA ROADHOUSE	75	0	0	0	6	**6**	**88**	100	2			2
59	NEWMAN	7'238	44	42	5	7	**12**	**240**	300	2		2	
60	AUSKI TOURIST VILLAGE	10	0	0	0	7	**7**	**88**	100	2			2
61	WODGINA MINE	210	1	1	0	8	**8**	**88**	100	2			2
	Major cities					combined routes			Total power [MW]				
	Major holiday destinations				**1.79**	**1.73**	**3.52**	**20.52**	**27.90**	138	56	42	40

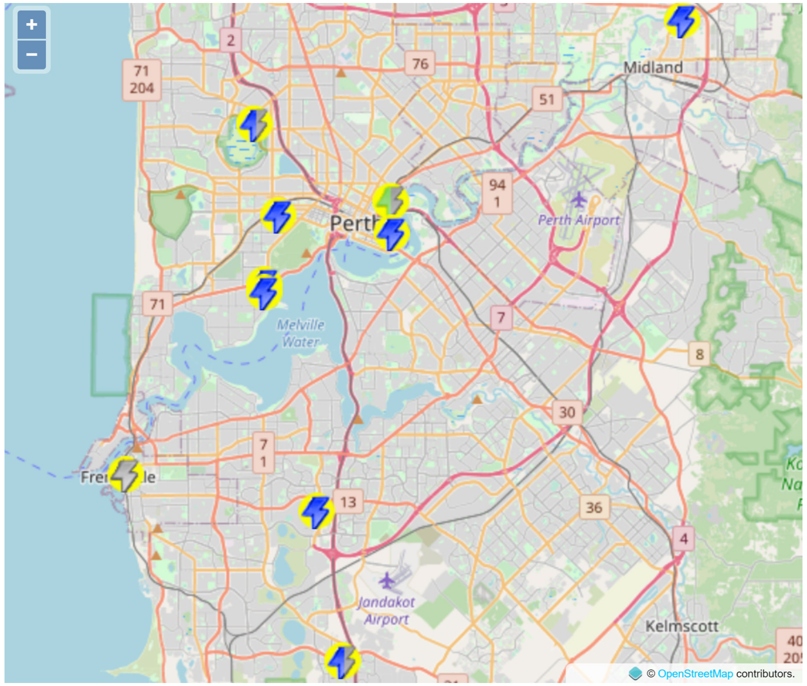
Cloud-based Intelligent Telematics for the Internet of Vehicles

Kai Li Lim

As vehicles are manufactured to be more intelligent, they also become inherently connected. This proliferation of connected vehicles shifts the industrial paradigm as many automotive solutions transition from an engineering to a machine learning approach. When combined with the recent trends surrounding edge computing and the Internet of Things (IoT), the foundation for the Internet of Vehicles (IoV) is established. Some of these solutions evolve into proposals of distributed systems that encompass the field of connected mobility, often incorporating external infrastructures that interconnect through the IoV, catalysed through the recent availability of high speed, low latency 5G mobile networks.

Connected vehicles enable us to effectively monitor, visualise and analyse real-world data that relate to, among others, driving patterns and infrastructure use. This information in turn becomes pivotal, leading to further developments such as in vehicular safety and traffic management. Connected vehicles generate copious amounts of data, and at the crux of any system, before data analytics or visualisation can be performed, is a framework that uses data engineering to collect, consolidate and manage any raw incoming data into valuable, usable, structured data.

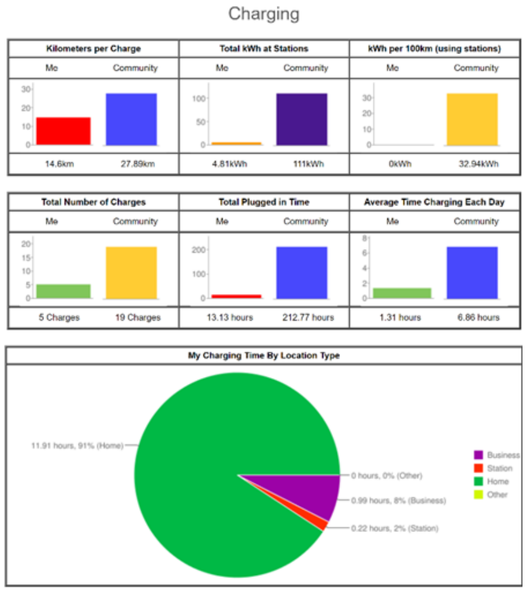
A significant portion of my thesis, “Connected Autonomous Electromobility”, presented such a framework to manage telematic data from our connected vehicles and charging stations around Perth. REView is our intelligent cloud-based telemetry platform developed to automatically receive, analyse and review live and recorded data from electric vehicles and charging stations in real time. It introduces a unified monitoring platform for these infrastructures, currently storing data that dates to the Western Australian Electric Vehicle Trial and the WA Charging Station Trial. REView was developed completely as a full stack, end-to-end web-based platform to be modular and scalable, which uses single-software back end to handle multiple stations from different manufacturers, promoting competition and streamlining the integration of charging technologies into other devices. It currently interfaces with all REV vehicles, as well as our charging station network comprising 23 units of 7 kW AC chargers and one 50 kW DC fast charger, which is also known to be one of the largest networks in Western Australia, and the largest network operated by an academic institution in the country.



REView manages this data across four areas within our ecosystem: charging stations, EV fleet tracking and energy generation, whereby visualisations are presented as a series of interactive charts and tables, often through a time series. Gamification is presented for vehicle tracking to encourage economical driving, and monetisation options are presented as bills to inform users of energy usage in charging stations. Data analytics through REView were summarised as usages pertaining to charging infrastructures and energy generation, as well as heat maps for EV tracking. A forecast of the charging infrastructures’ usage is also presented and analysed as a precursor to predicting Perth’s EV penetration.

In anticipation of an expanding population of EVs and their charging stations around Perth, future REView iterations will see its data management be migrated onto a big data platform such as Apache Hadoop. This accommodates any exponential increase in incoming data volume from these connected infrastructures while preserving real time visualisations. To improve upon its modularity as a cloud service, future improvements on REView such as this will be implemented over a platform as a service (PaaS) computing model, streamlining development efficiency while enhancing the robustness of individual modules. We have since established a working relationship with solution architects at University IT to introduce Microsoft Azure into the REView framework.

	Me	Community
Longest distance driven	**28.1km** from 2012-03-22 12:58:43 to 2012-03-22 13:28:39 Show Analysis	**45.1km** from 2012-03-09 12:39:06 to 2012-03-09 13:36:04 Show Analysis
Longest Driving Time	**00:29:56** from 2012-03-22 12:58:43 to 2012-03-22 13:28:39 Show Analysis	**01:24:24** from 2012-03-21 07:08:53 to 2012-03-21 08:33:17 Show Analysis



Above: Examples of real-time visualisations generated on REView for EV monitoring

Development of an Autonomous and Robotic Security Vehicle

Under the collaboration of the University with Stealth Technologies, UWA Master's degree students in Engineering have participated in the research and development of an autonomous and robotic security vehicle known as the ASV using leading-edge technologies and engineering techniques.

Development of the ASV began with the use case for automation of the regular testing of perimeter intrusion security devices at high-security facilities in addition to patrol and surveillance. The perimeter testing involves guards walking the perimeter multiple times per day to physically test PIDs installed. This is time consuming, mundane and often inconsistent. The vision was to automate this process so that the guards can be freed up to do more value-added tasks. A suitable vehicle base was selected and converted to drive by wire, including installing actuators for steering, braking and safety systems. Additionally, low-level hardware was designed and manufactured to both control drive-by-wire actuators and safety systems.

Development progressed to the sensor suite to provide suitable inputs to the high-level compute that would control the ASV. This included performing functions such as mapping, localisation, path planning and other important tasks, and enabling the ASV to autonomously drive surveillance and patrol missions. In addition, the ASV was equipped with military grade computer vision cameras to enhance its patrol and surveillance capabilities.

The ASV is also equipped with robotic actuators deployed from a hatch in the side of the vehicle. These actuators enable it to pull up to perimeter fences and physically interact with the PIDs sensors on the fence to mimic a cutting or climbing action and trigger the alarm. The ASV is able to talk to the Honeywell EBI system to interrogate alarm points and determine if the alarm was activated successfully. This enables the PIDs to be autonomously tested to ensure that they are working correctly. The vehicle also has a command and control console that enables missions to be configured for it, as well as monitoring its location, status and mission progress together with other important information.

The ASV is a Western Australian initiative imagined, designed, developed and manufactured here. The ASV has been funded through an industry collaboration between the Department of Justice, Honeywell and Stealth Technologies.

STEALTH TECHNOLOGIES

Collaboration between UWA, Stealth Technologies and EV Works

Elliot Nicholls

2020 marked the commencement of the automotive collaboration between the University of Western Australia, Stealth Technologies and EV Works. The collaboration received Commonwealth funding of approximately $500,000 under the Australian Automotive Graduate Engineering Program.

Stealth Technologies is a local Western Australian startup, backed by ASX-listed investment company Strategic Elements Ltd. Stealth Technologies has employed a number of recent and past UWA engineering PhD and Masters graduates.

EV Works is a local company that has specialised in the conversion of vehicles to electric drive and continues to supply state-of-the-art batteries and systems for vehicles and other related applications.

The grant funding is allocated towards upskilling graduate engineers for the Australian automotive and associated industries. To date, the collaboration with Stealth has focused on autonomous and robotic vehicles, with some of the research directed towards commercialising the technology for security-related applications.

Stealth Technologies is also in collaboration with the US$100 billion global giant Honeywell and the Department of Justice to develop autonomous and robotic vehicles.

Both collaborations have provided Stealth with the opportunity to help current UWA Masters engineering students gain valuable commercial exposure and experience. As part of this work, graduate engineers have been exposed to working on leading-edge technologies in emerging engineering fields.

Further automotive and robotics projects are being considered to expand the collaborations.

http://stealthtechnologies.com.au

Sponsors

REV would like to thank its sponsors and private donors for their ongoing support of our project:

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Autonomous Vehicle Simulation

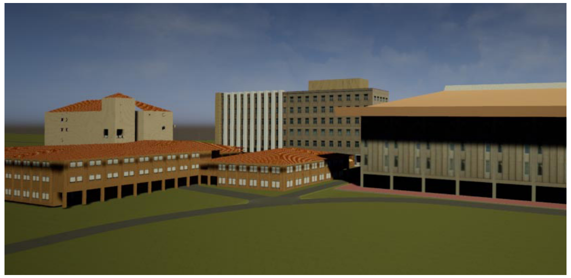
Craig Brogle

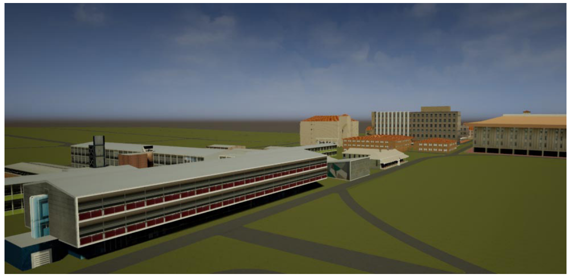
Simulation is a cornerstone of autonomous vehicle testing, allowing high level software such as image processing and path planning to be tested in predefined scenarios on a much faster schedule than is possible with hardware testing. The Automotive Simulation team are working on improving the realism, flexibility and availability of automotive simulations to other CIIPS research groups, allowing for the 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.

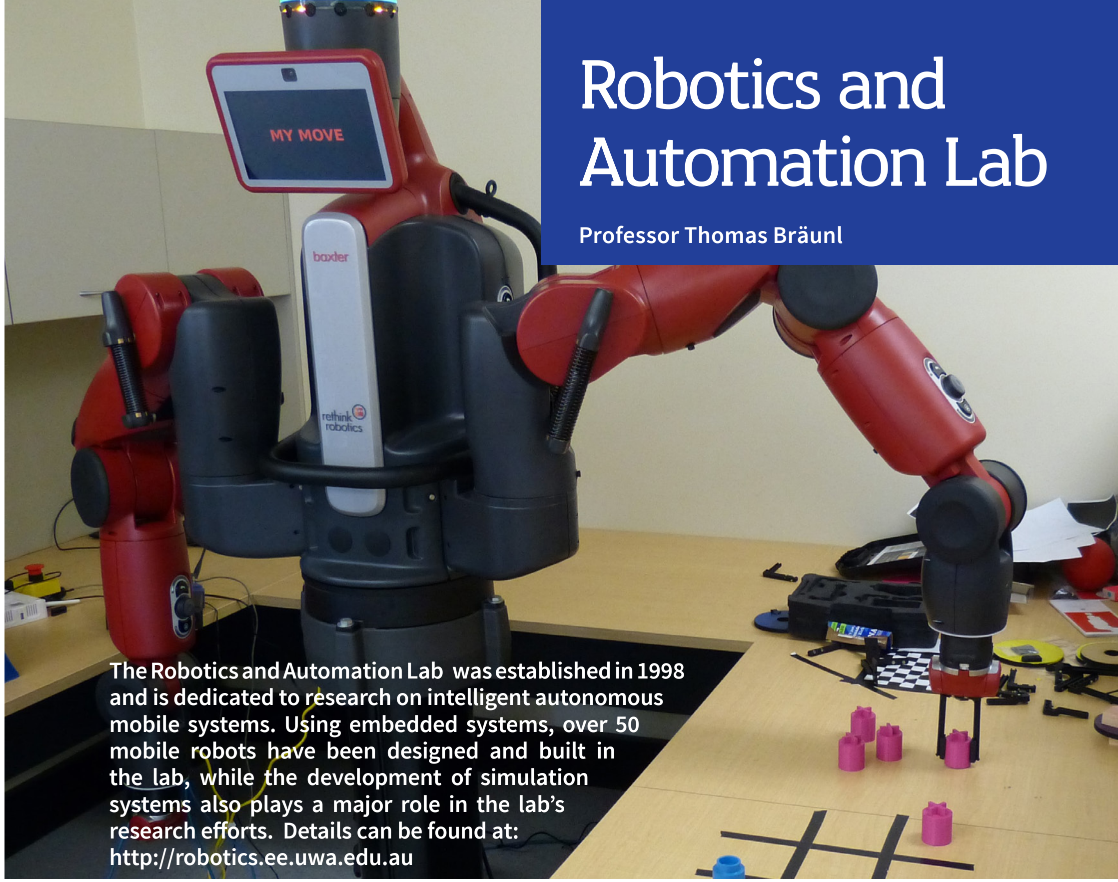
In 2018, the Automotive Simulation team developed a hardware-in-the-loop simulation system, allowing high-level software to be tested with a suite of sensors and compute hardware near-identical to that available on the REV Project's autonomous vehicles. This was achieved largely through the use of CARLA, an open source driving simulator, which provides realistic driving mechanics and a configurable suite of sensors.

Currently, the Automotive Simulation team is focused on extending the range of scenarios and vehicles available within the simulation system. Most important among these is the development of vehicle and sensor models which reflect the newly purchased nUWAy autonomous shuttle. This includes the development of a vehicle model which reflects the unique driving characteristics of the shuttle, such as a symmetric four-wheel steering system, and the accurate placement and configuration of sensors (including LiDARs, cameras, GPS and IMU) to reflect the sensor suite available on the shuttle. Work is also being undertaken to create a realistic model of the UWA campus and surrounding roads, supporting the simulated validation and testing of the vehicle's software in its initial proposed operating environment.

Once the nUWAy shuttle and the UWA campus are available in the simulation system, work on automated testing of software changes will begin. This testing will give increased confidence in the safety and effectiveness of software changes as the shuttle prepares to undertake autonomous routes on campus.







Robotics and Automation Lab

Professor Thomas Bräunl

The Robotics and Automation Lab was established in 1998 and is dedicated to 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

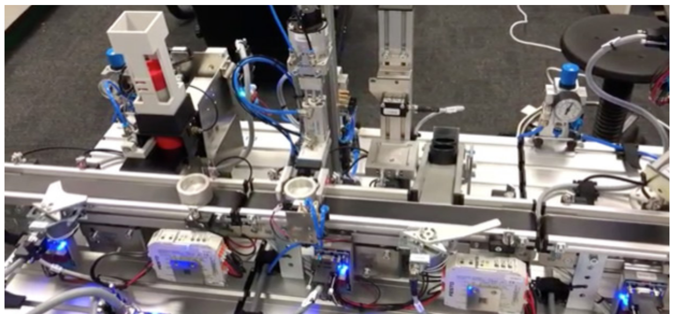
The lab has a Nachi industrial robot, a Baxter and three UR5 robot manipulators, which are mainly used for teaching purposes. Students work on group projects for various manipulation tasks with these robots. These include camera sensing, motion planning and task execution.

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.

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.



Left: The Festo system production street

Human-Robot Interaction (HRI)

Mohsen Shokri

In the past few decades, the application of robotic systems has been mainly limited to industrial production lines where there are HSE issues for humans or a need for high-payload, speed, and accuracy. The focus now is on implementing robot–robot and human–robot cooperation systems that can use the reasoning and planning ability of humans as well as the repeatability and accuracy of robots.

Every robot application has some form of interaction with a human, other robots and environment. A vast number of applications with a significant level of interaction between humans and robots have been introduced in industrial and domestic domains over the past decade. This poses the challenge for robotic researchers and manufacturers to develop a safe environment for humans and robots to coexist and cooperate without compromising the robot system's singular traits of payload capacity, speed and accuracy. Cooperative manipulators can be classified as an intermediate step towards the human–robot interaction system

The problem of cooperative robotic tasks can be defined as a multi-robot coordination problem, which requires an effective control strategy to control the interaction between multiple dynamic systems (robotic arms, environment, and objects). Kinematics and dynamics of robotic manipulators cooperatively manipulating a grasped object can be defined as a closed-loop problem. This can be completed by a mathematical model of contact between robots and the environment.

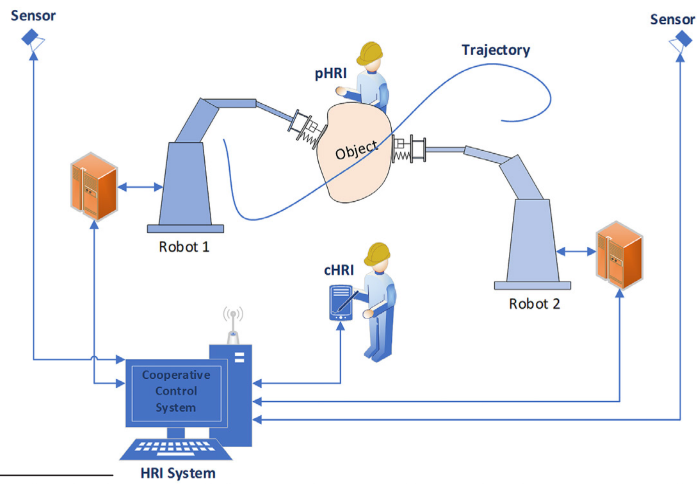
The cooperative manipulators and environment/contact kinematics and dynamics model can be used for developing an effective cooperative control scheme. Similar to a single manipulator control problem, Hybrid Position/Force Control and Impedance Control represent two fundamental approaches for controlling the cooperative robotic arms. A literature survey is being prepared for Cooperative Manipulation Control Schemes in this research program.

This research aims to evaluate and understand HRI issues and explore the current methodology, technology, and algorithms in academic and industrial research. It will seek to further assess intelligent manipulators' characteristics for a safe HRI in a less structured environment. This study intends to assess industrial robot manipulator design, control and operation for safety and dependability as key characteristics of a safe HRI.

The work will be expanded to a case study where two UR5e manipulators will cooperate to build a desired structural shape using hundreds of predefined and identified objects. A cooperative environment and system will be developed where humans and two manipulators can interact and complete the desired task of building a structural feature using identified building blocks.

The results of the research will be verified using UR5e manipulators and a test environment set up in the UWA Robotics and Automation Lab.

Below: Typical Human-Robot interaction



Above: Anthony Ryan demonstrates an autonomous model car

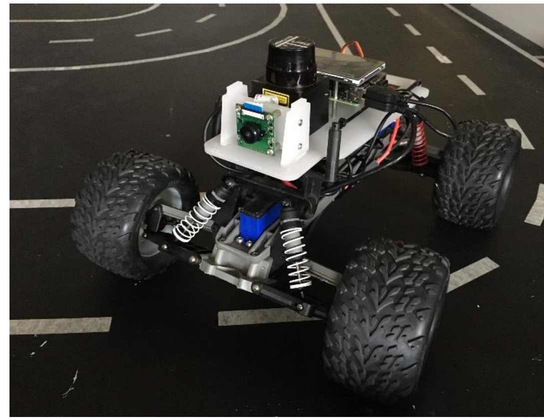
Autonomous Driving Robots

Anthony Ryan

Members from the UWA Robotics Team have been currently experimenting with newer and lower cost implementations for producing autonomous driving robots. The standard approach to solving the challenge of autonomous driving has been to use expensive remote sensors such as LIDAR and RADAR to decompose the problem into several steps such as object and pedestrian detection, lane marking detection, path planning and motor control.

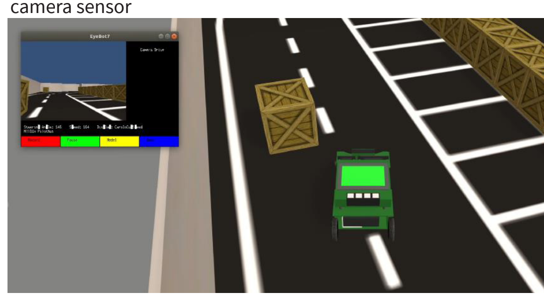
Innovations in the field of machine learning and neural networks have opened up the potential of simplifying the approach to tackling this problem by swapping out these expensive sensors for inexpensive cameras. By training special types of neural networks called Convolutional Neural Networks, robots can now learn to drive by receiving and processing images taken with these cameras in real-time.

Using this end-to-end approach could save time and money in future developments in autonomous robots.



Above: Autonomous model car

Below: simulation of autonomous robot relying only on camera sensor



Autonomous Driving

Few-Shot Learning for Model Car Autonomous Driving

Felix Wege

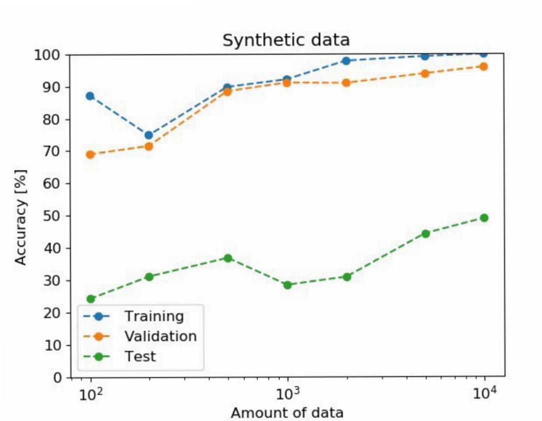
This work implements and compares different approaches to few-shot learning. Few-shot learning is a sub-discipline of machine learning that focuses on training models on small amounts of data. Labeling data from reality is time-consuming and synthetic images do not generalize well as shown in the figure to the right. This work focuses on developing a lane-following algorithm for EyeBots using as little labeled data from reality as possible. It is done by utilizing domain randomization, domain adaptation, and meta-learning.

Domain Randomization

A simple approach to bridge the gap between simulation and reality is domain randomization (DR). Domain randomization generates synthetic images in simulation with randomized parameters. If the variability is high enough a model can be trained to become more robust to changes in appearance and thus better transfer to reality. Randomized parameters include color and texture of objects in simulation and noise to actions. Domain randomization can be done in the absence of labeled data from target domain.

Domain Adaptation

Another approach to creating a model that generalized well is domain adaptation (DA). Domain adaptation seeks to find a model that can perform the desired task and at the same time be invariant to domains. This is often done by introducing additional loss terms that penalize models that discriminate between domains. Domain adaptation can utilize (partially) unlabeled data from target domain combined with labeled data from simulation.



Above: Gap between simulation and reality for learning models.

Meta-Learning

Meta-learning is a technique to train models to learn from few examples, (MAML). The objective is to find parameters that generalize well to new tasks. During meta-training the model is trained to adapt fast to new tasks with small amounts of data. Then, it is fine-tuned on the lane-following task with a small amount of data.

Evaluation

These approaches are compared in two different experiments: 20-shot learning and 0-shot learning, where 20 and 0 refer to the amount of real labeled images per class used for training. Domain randomization is done on 10000 image generated in simulation using patches of random color, size, and orientation as background. Domain adaptation uses a total of 10000 synthetic and 10000 real images, most of which are unlabeled. In addition, a variant of domain adaptation that uses randomized data instead is evaluated. Meta-learning is trained on a subset of ImageNet before being fine-tuned. It is compared with a first-order approxiation FOMAML. All models are evaluated on 500 test images from reality that are held out from training. Lane-following is evaluated on a course set up in the laboratory using an autonomy rating.

Collaborative Design Robotics

Santiago Perez, Thomas Bräunl

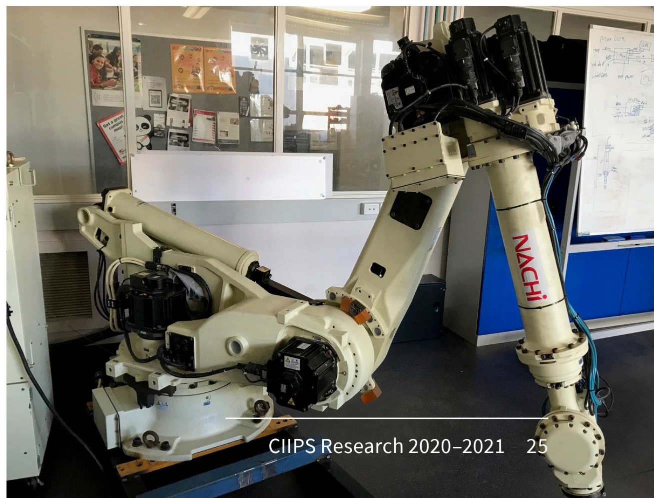
"Design Robotics" is a rapidly expanding field of exploration, now firmly established in many schools of architecture and design around the world. The primary goal of Design Robotics, is to support access to robotic tools for a broad range of research and teaching applications, for those with little or no previous experience with advanced technologies or programming.

The need for a teaching and research environment or platform, supporting students and academic staff without extensive backgrounds in programming or robotics, is essential to maintain a competitive level of engagement with new technologies, across a broad interdisciplinary spectrum.

Thanks to the support we, at the UWA School of Design, have received from our colleagues in Engineering, we have initiated the development of new workflows for Design Robotics, deploying three UR5 collaborative robot arms on loan from the UWA Department of Electrical and Computer Engineering. Our collaboration will extend towards large-scale robotic fabrication research, using the high-payload Nachi industrial robot in the EZONE building. Applications range from concrete printing and, robotic timber Frame assemblages to other large-scale material explorations.

Interdisciplinary student projects have so far been conducted on:

- A custom Clay Extruder for robotic clay 3D printing
- Vacuum Gripper for lightweight material assemblage
- Software for intuitive parametric control of robot arms without the need for manual programming of toolpaths



Smart Grids Lab

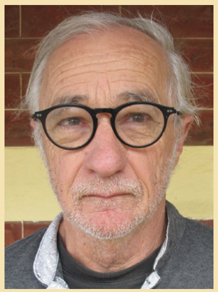
Adjunct Professor David Harries

Image by Vecteezy.com

The Smart Grids Lab is involved in investigating electric vehicles and how they impact energy policy. This work includes the The UWA REV Project on analysis and modelling of EV charging behaviour.

Work over the past year has included contributing to a report on an electric vehicle public fast-charging network for Western Australia. The report identified the optimal locations, charging station types (kW) and numbers of stations per site for roads on the major road network in Western Australia. The work included a timeframe for the roll out of the public EV fast charging network based on forecasts made of future EV take up rates in Western Australia. The work also resulted in the submission of two journal papers.

David Harries



David's research areas include energy policy, the options for curtailing greenhouse gas emissions from the energy sector, techno-economic analyses of emerging renewable energy generation and energy storage technologies, and the assessment of the impacts of distributed energy generation, distributed energy storage and electric vehicle charging on electricity supply grids. He is actively involved in the use of hybrid solar and battery off-grid power supply systems as an alternative to using the electricity network to supply electricity to rural properties.

David has also reviewed a large number of journal papers for different journals such as Renewable and Sustainable Energy Reviews and has been invited to act as guest editor for a special issue of the journal Sustainability on the topic of sustainable transport and electric vehicles.

Invited Talks and Project Demonstrations

Thomas Bräunl

Talks

10 June 2020—Invited Talk: *Electric Vehicles for WA – Increasing Industry Sustainability through the Uptake of Electric Vehicles*, Industry Breakfast, AAPA, Australia, Online

2 May 2020—Invited Talk: *Future and potential of EV for a sustainable WA*, Sustainability Now, Floreat

27 November 2019—Keynote: *Future Cars—Connected, Electric and Autonomous*, KPMG InNovemberation in Future Automotive Trends, Perth

18 November 2019—Keynote Address: *Future Cars: From Zero Emission to Zero Accidents?*, 9th Pacific-Rim Symposium on Image and Video Technology, Sydney

29 October 2019—Invited Talk: *The Next Big Things for Cars*, Raising the Bar Series, Perth

1 August 2019—Invited Speaker and Panel Member: LandCorp Electric Vehicle Panel, Perth

27 June 2019—Invited Talk: *22 and counting*, Univ Stuttgart ISYS, Germany

9 April 2019—Invited Talk: *Electromobility Now!*, Future Transport 2030 Summit, Perth

15 March 2019—Invited Talk: *Future Automotive Trends*, U3A Melville, Perth

11 February 2019—Invited Talk: *Future Automotive Trends*, U3A Western Suburbs, Perth

Demonstrations

5 March 2020—Robotics Workshop for Chuo University, Japan

3 December 2019—Robotics Lab visit and project demonstrations for Coolbinia Primary School and Our Lady of Fatima School

24 October 2019—Robotics and Automotive Lab demonstrations for visitor group from Mount Pleasant Primary School

12 &13 October 2019—Humanoid Robot Demonstration for UWA Theatre Production

16 August 2019—Mobile Robot Workshop for visitor group from South-West University, China

31 July 2019—Launch of the WaveFlyer electric hydrofoil personal watercraft, REV Project with Electro.Aero, Deep Water Point, Mount Pleasant

25 July 2019—Robotics Lab Tour for visitor group from South China University of Technology (SCUT)

25 July 2019—REV Automotive Lab Tour for visitor group from South China University of Technology (SCUT)

18 June 2019—Live autonomous driving demonstration for Honeywell

18 June 2019—Renewable Energy Information Session and REV Lab demonstration for Advanced Manufacturing Growth Centre (AMGC)

13 May 2019—Robotics Lab and Automotive Lab demonstration for members of U3A, Cottesloe

9 May 2019—Mobile Robot Workshop for Girls in Engineering group

10 April 2019—Robotics Lab demonstration for delegates from NEFU University

22 March 2019—Robotics Lab and Automotive Lab demonstration for delegates from Denver University, USA

Professional Activities

Professional Committees and Advisory Boards

Thomas Bräunl

- ICSS International Conference on Smart Science—Editorial Board, Gunma Japan, 2019
- Workshop on Computer Vision for Modern Vehicles, ACPR—Workshop Chair, Auckland NZ, 2019
- Intelligent Vehicles—Associate Editor and Member of the Program Committee, Las Vegas, 2020

Media Reports

Television Reports and Interviews

Network 10 Scope, *National, Electric Hydrofoil Jetski Explained*, Amanda Broomhall, recorded 30 Aug. 2019

ABC News, Sydney, National, *Hydrofoil Jetski*, Michael Tetlow, 3 Aug. 2019, 0:19

ABC Nightly News, Sydney, National, *Hydrofoil Jetski*, Yvonne Yong, 2 Aug. 2019, 23:24

ABC Late Night News, Melbourne, National, *Hydrofoil Jetski*, Michael Tetlow, 2 Aug. 2019, 22:34

ABC News, Perth, *Hydrofoil Jetski*, James McHale, 2 Aug. 2019, 19:29

ABC News Hour, Sydney, National, *Hydrofoil Jetski*, Andrew Geoghegan, 2 Aug. 2019, 18:50

ABC News, Sydney, National, *Hydrofoil Jetski*, Kirsten Aiken, 2 Aug. 2019, 17:49

ABC News Afternoon Briefing, Sydney, National, *Hydrofoil Jetski*, Kirsten Aiken, 2 Aug. 2019, 16:29

Channel 10 News First, *Jetski Junkies*, Narelda Jacobs, 2 Aug. 2019, 17:26

Channel 9 News, *Electric Hydofoil Jetski*, 2 Aug. 2019

Channel 7 News, *Electric Hydofoil Jetski*, 2 Aug. 2019

Radio Interviews

ABC Radio National, *Electric Vehicle Charging Networks*, Program Rear Vision, Interview with Zoe Ferguson, 17 Mar. 2020, 11:00

2GB Sydney, 4BC Melbourne, 2CC Canberra, *Hydrogen Vehicles versus Electric Vehicles*, interview with John Stanley, 29 Jan. 2020, 15:00

ABC Radio Program Drive with Geoff Hutchison, *The Future of Automobiles*, 18 Oct. 2019, 17:45

6PR Radio, Newsreader, *Electric Hydrofoil Jetski*, 2 Aug. 2019, 16:03

6PR Radio, Newsreader, *Electric Hydrofoil Jetski*, 2 Aug. 2019, 14:04

6PR Radio, Newsreader, *Electric Hydrofoil Jetski*, 2 Aug. 2019, 12:02

ABC Radio with Andrew Collins, *Electric Vehicle Targets in Australia*, 1 April 2019, 16:00

2ser Radio Sydney, Radio interview with Tyler Dias, *Electric Vehicle Uptake in Australia*, 19 Feb. 2019, 7:45

Print Media

Subiaco Post, *Funding fillip for autonomous vehicle project*, 23 May 2020, p. 68 (1)

West Australian Newspaper, *Getz conversion proves UWA's electric potential*, West Wheels Cover Story, Olga de Moeller, 11 Mar. 2020, full-page article p. 6 (1)

Cambridge Post, *Hands-free driving, Road safety minister Michelle Roberts opening new research centre with REV autonomous car*, 14 Dec. 2019, p. 3 (1)

Albany Extra, *Cars keeping an eye on you*, 6 Dec. 2019, p. 14 (1)

West Australian Newspaper, *Cars keeping an eye on you*, West Wheels Cover Story, Olga de Moeller, 4 Dec. 2019, p. 4 (1)

Cambridge Post, *Flying over the water*, Hugo Timms, vol. 46, no. 32, 9 Aug. 2019, cover page, p. 1 (1)

Online

UWA News, *Renewable Energy Project's autonomous vehicle wins federal funding*, 13 May 2020, http://www.news.uwa.edu.au/2020051312076/awards-and-prizes/renewable-energy-project-s-autonomous-vehicle-wins-federal-funding

Proactive Investors, *Strategic Elements gains Federal support for Electric Drive Systems and Driverless Vehicles project*, 29 Apr. 2020, https://www.proactiveinvestors.com.au/companies/news/918354/strategic-elements-gains-federal-support-for-electric-drive-systems-and-driverless-vehicles-project-918354.html

The Driven, *WA buries report on low cost charging network, frustrating EV industry*, 12 Feb. 2020, https://thedriven.io/2020/02/12/west-australia-plan-delay-for-cheap-electric-car-charging-network/

Scitech Particle Video Podcast and Interview: *Robotics and Automation with Professor Thomas Bräunl*, Kyle Brown, 8 Aug. 2019, https://particle.scitech.org.au/podcast/particle-podcast-robotics-and-automation/

ECU Broadcasting, Video Interview, *Electric hydrofoil jet ski*, Andrew Murdoch, 6 Aug. 2019

The National Tribune, *World's first electric hydrofoil jet ski*, 2 Aug. 2019, https://www.nationaltribune.com.au/world-s-first-electric-hydrofoil-jet-ski/

UWA News, *World's first electric hydrofoil jet ski*, Jess Reid, 2 Aug. 2019, http://www.news.uwa.edu.au/2019080211532/research/worlds-first-electric-hydrofoil-jet-ski

New Atlas, *WaveFlyer electric hydrofoil jetski rises above the water*, Paul Ridden, 2 Aug. 2019, https://newatlas.com/waveflyer-electric-hydrofoil-jetski/60881/

ABC News, *Prime Minister Scott Morrison says an electric vehicle can't tow a boat or trailer. Is he correct?* RMIT ABC Fact Check, 10 May 2019, pp (7), https://www.abc.net.au/news/2019-05-10/federal-election-fact-check-electric-vehicle-tow-boat/11078464?nw=0

Aus SMC, *EXPERT REACTION: Labor's 2019 climate policy*, 1 Apr. 2019, https://mailchi.mp/smc/expert-reaction-labor-climate-policy?e=ede5d3cf4e

Projects and Sponsorships

Project Funding

Automotive Engineering Graduate Program (2019–2021)

Joint Projects/Sponsorship

Synergy, Galaxy, MainRoads, Altronics, Phoenix Contact

Publications

Conferences

N. Burleigh, J. King, T. Bräunl
Deep Learning for Autonomous Driving
Intl. Conference on Digital Image Computing: Techniques and Applications (DICTA), Dec. 2019, Perth, pp. (8)

S. Sun, J. Zheng, Z. Qiao, S. Liu, Z. Lin, T. Bräunl
Architecture of a driverless robot car based on EyeBot system
3rd International Conference on Robotics: Design and Applications (RDA 2019), Xi'an, China, April 2019

Journals

T. Bräunl, D Harries, M. McHenry, G. Wäger
Determining the Optimal Electric Vehicle DC-Charging Infrastructure for Western Australia
Transportation Research Part D: Transport and Environment, 2020

S. Sun, J. Zheng, Z. Qiao, S. Liu, Z. Lin, T. Bräunl
The Architecture of a Driverless Robot Car Based on EyeBot System
Journal of Physics: Conference Series. AIACT 2019, vol. 1267, no. 012099, 2019, pp. (7)

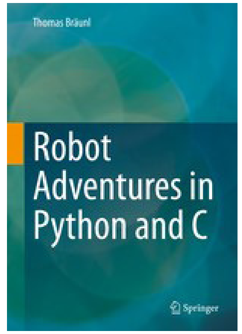
K. Lim, T. Drage, C. Zheng, C, Brogle, W, Lai, T. Kelliher, M. Adina-Zada, T. Bräunl
Evolution of a Reliable and Extensible High-Level Control System for an Autonomous Car
IEEE Transactions on Intelligent Vehicles *(Q1)*, vol. 4, no. 3, 2019, pp. 396–405 (10)

C, Brogle, C. Zheng, K. Lim, T. Bräunl,
Hardware-in-the-Loop Autonomous Driving Simulation without Real-Time Constraints
IEEE Transactions on Intelligent Vehicles *(Q1)*, vol. 4, no. 3, 2019, pp. 375–384 (10)

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, Feb. 2019, pp. 283–298 (16)

Books

T. Bräunl
Robot Adventures in Python and C
Springer-Verlag, Heidelberg, 2020



Book Chapters

K. Lim, S. Speidel, T. Bräunl
Chapter 8: REView: A Unified Telemetry Platform for Electric Vehicles and Charging Infrastructure
in Zaigham Mahmood (Ed.), Connected Vehicles in the Internet of Things, Springer International Publishing, 2020, pp. (52)

R. Reid, K. Lim, T. Bräunl
Cooperative Multi-Robot Navigation—SLAM, Visual Odometry and Semantic Segmentation
in Chao Gao (Ed.), Cooperative Localization and Navigation, Taylor & Francis, 2019, pp. 181-198 (18)

PhD Dissertations

Franco Hidalgo Herencia

Supervisors: Prof. . T. Bräunl, Dr. A. Boeing

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 scientist 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 Robot Operating System (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 in 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 Oriented FAST and Rotated BRIEF (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.

Kai Li Lim

Supervisor: Prof. T. Bräunl

Connected Autonomous Electromobility Visual Navigation and Charging Analytic Frameworks

The growing ubiquity of electric vehicles (EVs) is often characterised through their increasing auton-omy and connectivity. This has led to catalyse the foundations of smart cities and intelligent transportation systems, where the applications of electromobility are often given a pivotal role towards their realisation.

As the title suggests, this thesis presents its investigations into electromobility applications across two key fronts: (1) computer vision-based autonomous driving; and (2) data management and analyses of EV charging stations.

The study into vision-based navigation aims to address the problem of developing an autonomous driving system that predominantly utilises the camera as the vehicle's primary environmental perception sensor. This research gap is attributed to the greater algorithmic complexity in computer vision, as compared to LiDARs or radars. Additionally, the general attainability of cameras, and the diminishing cost of parallel computation has further contributed towards the motivation for this study. To this end, the requirements for visual navigation are centred upon localisation and scene understanding. More specifically, this thesis describes applications pertaining to visual odometry and semantic segmentation following an extensive literature survey. These methods are first tested for its feasibility on datasets and mobile robots, and then verified on an autonomous Formula SAE electric car as the test bed, enabling the vehicle to perform object detection, lane keeping and dead reckoning in real time. Experiments were conducted for road scenes and traffic cone drives, yielding fast and accurate results for detections, classifications and odometry.

The EV charging station network managed by The REV Project comprises 23 AC stations at 7 kW and one DC station at 50 kW. Each station is connected to a centralised server over the mobile network, perpetually transmitting telemetric data to the server's daemons. The data generated from these stations effectuates the investigation into the charging behaviours across AC and DC stations, leading to the study of EV trends around Perth. Results from this study comprise of a combination of time series analyses that compares the cycles and energy consumption between AC and DC charges among local stations. A web-based telemetry monitoring platform, REView, is further described in this thesis. In addition to the charging stations, REView consolidates data from the project's EV fleet and solar power generation into a unified framework that features on-demand monitoring for connected infrastructures. These are further detailed according to its back-end processes, encompassing its communication architectures, data management, data visualisation and presentation.

The cumulation of works that are presented here conforms to The REV Project's goal that describe contributions towards the fields of intelligent vehicles and the Internet of Vehicles. These contributions are exemplified in this thesis through the successful application of visual autonomous driving, and the analyses towards the EV trends in Perth, which should subsequently encourage further developments in this area.

Stuart Speidel

Supervisor: Prof. T. Bräunl

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. EVs 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 enough 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 consider 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 EV technology, driving/usage/charging patterns of EVs, as well as renewable energy and EV charging infrastructure.

Current PhD Research

Craig Brogle

Supervisors: Prof. T. Bräunl, Prof. F. Boussaid

Automotive Simulation

As advanced driver assistance systems (ADAS) become increasingly prevalent in modern vehicles, and autonomous vehicles move closer towards being used unsupervised in real-world environments, there is a growing need for accurate simulation systems, both for enabling increased development velocity through more rapid and lower risk testing, and for validating systems in a diverse set of conditions in an economical manner. This need is reflected in the extensive use of simulation systems by major automotive manufacturers, and the ongoing development of simulation systems by companies such as Waymo, Cognata, rFpro and Nvidia. A number of open source autonomous vehicle simulation softwares are also in development, including CARLA, LGSVL Simulator, and AirSim. Due to the current pandemic environment and associated restrictions, simulation has become critical in allowing companies to continue to progress, with companies including Embark Trucks, Aurora, Cruise and Waymo making heavy use of simulation systems while unable to operate their physical fleets.

These simulation systems must be capable of emulating the full range of sensors utilised by autonomous vehicle platforms, including photo-realistic cameras, LiDAR, RADAR, GPS, ultrasonic sensors, and odometry. In addition, they must be able to realistically model vehicle handling and dynamics while factoring in varying road surfaces and weather conditions in order to be used effectively, especially for use in system validation tasks. Hardware-in-the-loop capabilities are integral to the use of these systems for autonomous vehicle development and testing, as it allows for compute hardware and control software identical to that used in physical autonomous driving platforms to be used with a simulation system.

Above: Autonomous F–SAE

Thomas Drage

Supervisors: Prof. T. Bräunl, Dr A. Boeing

Control and Safety Systems for Autonomous Driving

The Renewable Energy Vehicle (REV) Project at the University of Western Australia conducts research into electric vehicles, vehicle automation and autonomous driving systems. Recent projects include the development of an Autonomous Formula-SAE Electric car (pictured above). This vehicle is an open-wheeled, electric drive race car, with electronic drive-by-wire and electromechanical brake/steering actuation. The vehicle serves as a compact, flexible test-bed for sensor testing and the development of autonomous driving algorithms. The group's current focus is the high-level automation of a passenger shuttle bus, using an electric drive-by-wire platform from French bus manufacturer Ligier, but with our own navigation system. The shuttle will operate as a self-driving people mover on campus shuttle and will be flexible enough to dynamically plan its route. All sensory and navigation processing is on-board; there will be no dependence on cellular networks or other high-bandwidth communication systems or remote servers.

Development of Level 3+ Autonomous Driving Systems (ADS) presents a significant risk to both people and infrastructure due to the requirement for complex, software driven electromechanical systems to now provide safe driving behaviour under normal conditions. Indeed, whilst Autonomous Vehicles have been heralded with promises of improved traffic safety and lower collision rates, current technology may not offer these advantages and significant progress is required in the realms of safety and reliability, with disengagement of autonomous systems, requiring resumption of manual control to achieve safety still relatively common. With technologies improving rapidly, the situation is expected to improve. However, like the critical systems used for aeronautical control, there is significant room for improvement of the processes used to assure safe performance.

This year, our work with the Formula-SAE car involves replacement of the braking system with a fail-safe pneumatic actuation system, controlled by a new automotive grade safety system. This work has been sponsored by SMC Pneumatics and will significantly improve the safety and performance of the vehicle. In the case of the nUWAy shuttle bus, current work involves assessment and augmentation of the bus's existing sensing, control and safety systems to allow us to achieve our target of intelligent autonomous driving.

Mohsen Shokri

Supervisor: Prof. T. Bräunl

Human–Robot Interaction

Every robot application has some form of interaction with the human, other robots and environment. A vast number of applications with a significant level of interaction between humans and robots have been introduced in industrial and domestic domains over the past decade. This has introduced a new challenge to how humans and robots can interact safely while not compromising any of the robot system's unique characteristics like payload capacity, speed, and accuracy.

Cooperative manipulators can be classified as an intermediate step towards a seamless Human-Robot Interaction (HRI) system. The problem of cooperative robotic tasks can be defined as a multi-robot coordination problem, which requires an effective control strategy to control the interaction between multiple dynamic systems (robotic arms, environment, and objects).

This research aims to evaluate HRI methodology, technology, and algorithm in academic and industrial researches. I seek to further assess intelligent manipulators' characteristics for a safe HRI in a less structured environment. This study intends to assess industrial robot manipulator design, control and operation for safety and dependability as key characteristics of a safe HRI.

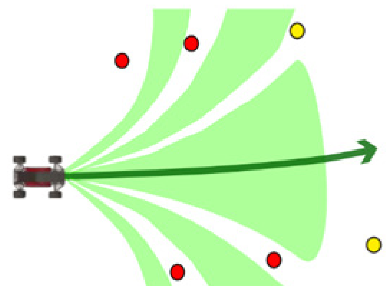
The results of this work will be expanded to a case study where two UR5e manipulators and human operator will cooperate to complete a cooperative tasks.

Chao Zhang

Supervisors: Prof. T. Bräunl, Prof. Farid Boussaid

Vision-based Safety System for an Autonomous Vehicle

For the UWA REV autonomous SAE project, safety is always the biggest concern especially when the vehicle must be deployed under a dynamic environment. Programmed algorithm is generally stable when handling static scenes. However, under a dynamic environment, the system may fail in an unpredictable manner. This was a problem when I was doing the experiment on the visual system developed in my final year thesis. The performance, in this case, the accuracy and processing time, of the visual system varies with different environments. Either a low accuracy output or a long processing time can be dangerous in a fully autonomous driving application. To solve this problem, I propose a solution by applying a lightweight artificial neural network on the visual data to evaluate the expected performance from a visual perception system. The research will be carried out using the autonomous shuttle bus nUWAy and the hardware-in-the-loop simulation system built by a student team in my final year engineering research project as a test bench and data source.



Above: LiDAR based path finder

Master of Professional Engineering Dissertations

Farhad Ahmed

Supervisor: Professor Thomas Bräunl

Semantic Segmentation of Merged Data from Multiple LiDARs on an Autonomous Vehicle for Obstacle and Driveable Area Detection

It is necessary to ensure the safe and efficient operation of an autonomous vehicle to be able to get it on the road and remove the requirement of human intervention altogether. It is possible to ensure such operation only when the perception system of the vehicle is always robust enough to represent the environment around it accurately. LiDAR plays a crucial role in perception in the sense that it provides an accurate point cloud data of the surrounding. However, the software algorithms and the processes used to process this data play a key role in determining the accuracy of the perception system.

The proposed project aims to leverage the use of Deep Learning on LiDAR data for Semantic Segmentation (SS) of the environment, projection to Bird-Eye-View, and determination of obstacles and driveable path. The objective would be to detect objects such as cars, cyclists and pedestrians and identify them as individual class instances. It is to be noted that there has been significant development in recent years on different algorithms for SS. However, most of them are focused on the urban road or highway environment.

In this research, the goal would be to develop a pipeline utilising the state-of-the-art method for SS and object instance labelling. The available methods, however, need to be tuned suitably for the purpose here, which is a shuttle bus operating in a University Campus. This environment is expected to have a different set of problems in comparison to a regular road due to the high number of pedestrians and cyclists, their highly dynamic nature and the absence of lane markings. Also, the shuttle bus has multiple LiDARs, so an attempt would be made to merge the data from all of them to generate a consolidated point cloud before using it for SS. Such merging would help to give a more holistic view of the surroundings. It is also necessary to ensure that the final output of the pipeline is in a meaningful format and that it is made available to the decision-making systems to carry out a more informed and safe motion decision.

The development would initially be carried out in a simulated environment before being implemented on the actual hardware. The neural network model for SS would initially be trained and validated on LiDAR point cloud data from the KITTI dataset and then tried out with real-world data. A qualitative analysis of the accuracy would be carried out to evaluate the performance of the proposed pipeline.

Nicholas Burleigh

Supervisor: Professor Thomas Bräunl

Autonomous Driving on a Model Vehicle Lane Detection and Control

Autonomous driving systems have increasingly become a topic of anticipation in recent years. In development of these systems, it is useful to test potential strategies in a controlled environment, and a common means of accomplishing this is using miniature model vehicles on a track, both in a physical environment and in simulations. These model vehicles typically include the expensive sensory and computational hardware that the full-size road vehicles use.

The aim of this research was to construct a functional autonomous driving system on the comparatively inexpensive Eyebot hardware and software developed at the University of Western Australia, with its limited computational power and sensory equipment. The primary focus was on creating a comprehensive and reliable model of road markings, aiming to develop a system wherein a vehicle could reliably navigate a track in both simulated and physical environments with no errors. Subsequent to this aim was to implement more complex driving behaviours.

Methods would first be developed and tested in a simulated environment, using the Eyesim software to run test drives in a virtual environment. After a method was identified as conceptually sound in this software, it would then be implemented in the practical environment. From there, the issues in transferring from simulation to reality would be identified and software was adjusted accordingly.

A functional system was created which was capable of navigating the simulated and practical tracks while remaining within the road boundaries. Due to spatial constraints the practical track contained extreme circumstances relative to the expected environment. The robot was able to successfully navigate this track, albeit with a lower rate of successfully detecting lanes.

Wesley Coleman

Supervisor: Professor Thomas Bräunl

Using a Solar Powered Autonomous Raft to Collect Oceanographic Data

Previous UWA MPE students have created a Solar Powered Autonomous Raft (SPAR) that can be controlled remotely over a 3G connection. The goal of this project was to explore one of the potential uses of such a platform: the collection of oceanographic data.

To achieve this, several sensors were integrated into the SPAR to record ocean temperature and salinity, and to capture still images. The possibility of collecting additional types of data (such as ocean depth and wave height) was considered during the early stages of the project, however upon investigation these plans were discarded due to a combination of cost, impracticality, and time constraints.

Additionally, the layout of the existing hardware on board the SPAR was improved to allow room for the new sensors, new motor mounts were designed and installed, and the software controlling the network interface was updated to correspond with an update of the SPAR's server architecture that was conducted as a simultaneous project.

Kyle Crescencio

Supervisor: Professor Thomas Bräunl

Waypoint Navigation, Object Avoidance and User Interface

This paper describes the methods used to design the navigation system of the University of Western Australia EasyMile Cyber Car also known as nUWAy. Waypoint path planning, obstacle avoidance and user interface systems all fall under the scope of this design paper. Using GPS and IMU data, nUWAy will be able to localise and navigate to any predetermined location within a given range on campus whilst actively avoiding obstacles and adjusting its path accordingly.

The User Interface described will take in information about a given location and display the current path of the bus to the rider. The path planning system will create a collection of waypoints using known a free space map to great a global path.

Each pair of waypoints will then be connected using a Hermite spline method to create a smooth path for the vehicle to travel on. When an obstacle is detected a Virtual Waypoint path will be created between the two current navigation waypoints to navigate around said obstacle.

When selecting the optimal avoidance path, multiple paths will be calculated and—using a costing method considering the distance from the base frame and smoothness—the most efficient one will be selected.

Yuchen Du

Supervisor: Professor Thomas Bräunl

Simultaneous Localization and Mapping based on LiDARs and IMU for nUWAy

Laser-based systems are the preferred choice amidst a number of solutions to the SLAM problem due to their capability to give a robust result in outdoor environments. However, when applying a lidar-based solution to the nUWAy project some difficulties arise.

Firstly, nUWAy is equipped with several lidars, including four SICK 2D lidars, two Velodyne 3D lidars and two Ibeo Lux lidars. It can be observed that SICK lidars only scan the environment at a lower height while Ibeo Lux lidars do it at a higher height. If lidars are used at only one altitude for SLAM, obstructions at other heights would not be recorded in the map. The path planner may thus treat a place with obstacles as a possible route. Therefore, under conditions where a total of eight lidars are loaded on nUWAy, the way these 2D and 3D lidars are combined to gain a better grid map result presents the first prob-lem.

In addition, in order to achieve accurate localization, simply relying on the front-end odometry is not sufficient. The lidar odometry, for example, roughly estimates the current pose based on one or a few past scans, so the error from the initial state would accumulate with each step. The presence of the drift would result in serious deviation in localization after a long time.

This paper investigates these two issues and tries to present a method to fuse the data from lidars, IMU and other sensors so that a better result from the SLAM process can be achieved.

Marius Fink

Supervisor: Professor Thomas Bräunl

Implementation of Formation Control with Optimal Path Planning and Collision Avoidance

This thesis investigates the implementation of formation control with a leader-follower approach for differentially driven robots. In this way, the positions of multiple robots are controlled such that they attain a specified formation. Furthermore, an optimal path planning algorithm is discussed and implemented.

In combination with the leader-follower controller, the generated path is used as a virtual leader to navigate multiple robots along the desired trajectory. In the planning algorithm, the system dynamics of the robots and the avoidance of known obstacles is considered. Additionally, the formation controller is extended to incorporate on-board position sensitive devices in order to detect and avoid any obstacles close to the robot.

All of these control schemes are first evaluated in simulation while measurement noise and subsequently in real experiments. The resulting combination of control schemes is able to navigate the robots to a goal position in an arbitrary world setup without any collisions.

David Gregory

Supervisor: Professor Thomas Bräunl

nUWAY Autonomous Bus

Avoiding collisions with pedestrians is a crucial building block for the mass deployment and widespread adoption of autonomous vehicles. Avoiding collisions with pedestrians comes in two stages, the detection of pedestrians and the prediction of their path. A core benefit of prediction is the increased time to react to a potential collision which provides a greater distance to stop which leads to less intense braking. Sudden braking can potentially cause injury to passengers on a bus as bus seats often lack seatbelts and passengers are often standing.

The nUWAy bus is no exception to this with a capacity of 10 students (six seated and four standing). Typically, pedestrians will also actively avoid collisions and will plan their path around moving vehicles. However, given the societal trend of pedestrians using mobile phones while they walk, they become passive agents that cannot be relied on to avoid colliding with vehicles.

This research project aims to equip the nUWAy autonomous bus with the ability to predict if a pedestrian is distracted and model the likely path of non-distracted and distracted pedestrians to predict potential collisions. The method proposed is to utilise a convolutional neural network and support vector machine to classify pedestrians into distracted states and whether or not they are moving. This information can be combined with university class times and the current location of the bus to determine a probability map for the pedestrians.

The final output of the model can be used by other systems in the bus to avoid pedestrians and plan the optimal path around them.

Eduardo Arteaga Guadarrama

Supervisor: Professor Thomas Bräunl

Advanced SLAM Integration and Optimisation for Multi-Modal Vehicles

The Localisation and Mapping problem is a crucial but difficult-to-address issue for advanced autonomous driving; identifying a vehicle's position usually requires a map and mapping its surroundings requires an accurate estimate of its location. A simultaneous approach to engaging this paradoxical problem, commonly referred to as 'SLAM', has previously been enabled by software frameworks alongside increasingly powerful and accessible sensors such as RADAR, GPS and LIDAR. However, despite the associated increase in computational complexity, Vision Cameras have emerged as a competitive tool for acting as the primary sensor for the sensor-suites required for tomorrow's autonomous vehicles. This is primarily attributed to the comparatively low cost, and the sensory richness available (akin to the human eye).

This paper presents a design and implemen-tation of a parallel Vision and LIDAR Stereo-SLAM system to demonstrate the capabilities of advanced vision-based sensor-suites. The designed system is geared towards use in performance vehicles, to accommodate a wide range of driving modes and scenarios. Using dual cameras and multiple lidars, the sensors are integrated into a software framework with rapid computational performance to accommodate for real-time autonomous driving. The final output of this system is a node that interacts with other modules in the vehicle's high-level control system, such as the navigation and path planning, to allow real-world autonomous driving. Results are shown as functional performance tests and visualisations created from field test-drives.

Jeremy Guo

Supervisor: Professor Thomas Bräunl

REV Jet Ski Design Improvement Project

Electrical hydrofoil is an innovative design built by UWA with help of external companies and fund supported by lithium producer Galaxy Resources. The project is still quite new, hence there are areas that still can be improved on. The aim of this study is to improve the functions in both mechanically and electrically.

Mechanically, this study will investigate into how to improve the efficiency and stability of the hydrofoil such as looking into different configurations and designing mechanisms to aid the jet ski's functions. Utilising mod-ern simulations such as CAD and CFD, this study will present different configurations and its efficiency for drag and lift ratio and power for comparison in order to improve on the design.

Electrically, this study will endeavour to expand the functionalities of the current jet ski design such as implementing new micro-controller and micro-computers, ad-apting live tracking functionality for crucial parameters of the jet ski, and many more.

Junwen Huang

Supervisor: Professor Thomas Bräunl

Redesign the Safety System of an Autonomous Formula SAE-Electric Vehicle

The safety system is a crucial part of an autonomous vehicle, which can protect the vehicle, driver, and people nearby. By implementing the safety system, the driver can instantly stop the vehicle by several methods or stop by vehicle itself when failures happen, especially when the autonomous driving mode is processing.

This dissertation describes the redesigned development of the safety system, which has implemented on an autonomous Formula SAE vehicle. A printed circuit board (PCB) was designed as independent hardware for the safety system. The PCB design process through Eagle CAD, which is consists of two major stages, schematic and board layout, is described. The selection of electronic components based on the expected function will be discussed in the schematic stage, and the optimisation in the board layout design process will be demonstrated.

A Launchpad (Hercules TMS570LC43x) from Texas Instruments, which specially designed for the vehicle field, will be introduced as the controller of the safety system. Software tools, a code generation tool (HALCoGen), and a Code Composer Studio (CCS) that based on C language are introduced to the controller to execute the safety functions.

The new vehicle dashboard will be applied for the introduction and deletion of the device to fix the new safety system. Future development is considered during the process, and it presents in this dissertation.

Jordan King

Supervisor: Professor Thomas Bräunl

SIFT-like Keypoint Cluster-Based Traffic Sign Recognition with Deep Learning

State-of-the-art convolutional neural network-based architectures similar to MobileNet were shown to have the capability to surpass human performance in the German Traffic Sign Recognition Benchmark (GTSRB) held for IJCNN 2011; however, traffic sign detection systems that operate in real-time for ARM-based devices with limited computational power (e.g., less than 200 MFLOPS) have remained elusive.

In this paper, a traffic sign detection pipeline is proposed for inexpensive autonomous driving robots and driver-assistance systems using a novel approach for ROI candidate generation with SIFT-like keypoint cluster-generated regions and TensorFlow. The pipeline has been implemented to detect a subset of the traffic signs present in the Carolo Cup, and has been deployed on mobile driving robots at UWA using the EyeBot 7 controller platform and a Raspberry Pi 3B with MobileNet for image classification.

The pipeline is highly configurable can operate at an average of 18.80 Hz for QVGA-sized true-colour video if detecting a subset of signs, achieve an accuracy of 89.10% in the GTSRB, and yield an IoU of 0.7273 for a modified KITTI semantic segmentation dataset. The novel detection architecture brings feasibility to inexpensive monocular driver-assistance systems or autonomous driving robots, but the skeleton may be repurposed.

The ROI proposal method lends itself to applications where computational power is limited, SIFT-like keypoints are already generated, or when the environment is sparse; for example, when using inexpensive ARM-based devices such as Raspberry Pi, if the robot is already using ORB-SLAM, or in underwater environments.

Joey Koh

Supervisor: Professor Thomas Bräunl

Temporal Context of Dynamic Free Road Space

Free space (FS) detection is a key issue for modern autonomous vehicles (AV), as it is used in navigation as well as improves other perception functions such as object detection.

Recently, the intended operational domain of AVs has expanded more towards the shared traffic environment—such as campuses and public spaces. Yet, most FS detection algorithms focus on detecting navigable areas without providing information about the dynamic travel conditions of the area.

One aspect not considered is how this unoccupied FS is likely to change with time due to other dynamically moving road agents. We propose a novel method to produce a probability map of FS region integrity—whether the region will remain unoccupied in the next time instance.

The methodology is three-fold. Firstly, we leveraged bird's eye LIDAR point cloud and monocular front-facing camera data in a joint 3D-2D based method to detect FS. Simultaneously, we used Frustum PointNets to detect 3D objects.

Secondly, we developed a common coordinate space for prior detected FS and objects, thereafter developing a velocity prediction method.

Thirdly, we reflected the future occupancy spaces of road agents from predicted velocity, to model a probability distribution over FS regions and reflect potential change in occupancy with time. Testing and validation of the method was done on the KITTI Moving Object Detection dataset.

As a benchmark for the motion detection task we used future frames to verify the motion prediction results. The extraction of a new layer of temporal information of FS contributes towards increasing the scene understanding capability of modern AV's perception systems. Thus, leading to an extra input of contextual information in path planning and navigation.

Layla Krishna

Supervisor: Professor Thomas Bräunl

WaveFlyer Hydrofoil Analysis and Rear Mechanism Design

From the 1990's, Personal Watercrafts became a must have toy providing endless fun for all ages. Since then Personal Watercrafts have come a long way with design however still produce high emissions and noise, therefore banning them in many places.

This led to the development of the "WaveFlyer" which is an electric powered Personal Watercraft which glides on hydrofoils through the water. The WaveFlyer is eco-friendlier producing very limited noise, zero emissions and brings a new form of riding to the Personal Watercraft world.

However, due to riding on foils, the current design possesses stability issues in which requires rider balancing to ride the watercraft.

The first half of this thesis focuses on improving and perfecting the hydrofoil's design, thus leading into further stability improvements. This is done using computer aided technology and programs, XFLR5 and ANSYS Fluent, to model the watercraft and analyse lift, drag, angles and flow fields.

Analysis of water testing is presented to compare to the computer models for verification. The end aim is to allow zero rider experience to operate the WaveFlyer like a normal conventional Personal Watercraft.

The second half of this thesis proposes new designs for the hydrofoil rear mechanism on the WaveFlyer. Addressing the problem of retraction of foils when trailering the watercraft and aesthetics when the WaveFlyer develops into production.

This thesis overall adds to the design of the WaveFlyer to improve rider experience.

Dylan Leong

Supervisor: Professor Thomas Bräunl

REVSki Data Transmission, Storage, and Visualisation

The Renewable Energy Vehicle Jet ski (REVSki), an experimental electric personal watercraft, has undergone many changes throughout several years and it is expected that the vehicle will continue being upgraded in the future.

In order to assist with ensuring the normal operation of the REVSki continues even throughout these changes, this thesis is concerned with the real-time tracking and logging of the vehicle when it is in use.

To be more specific, the project is concerned with the wireless transmission of certain parameters such as location, motor speed, voltage, and current of the REVSki via a modem to a database, as well as providing a webpage to view these parameters.

As the vehicle is also being augmented with a water sensor, information about the water will be made available on the webpage, visualised in the form of a satellite-view map.

Marti James Leven

Supervisor: Professor Thomas Bräunl

System Architecture and Instrumentation for Electric Jet Ski Project

The Renewable Energy Vehicle Project is a long-running project with the goal of revolutionising personal transport by building a zero-emission solution for the future. The REV project plans include exploring electric propulsion technology, powered through renewable energy sources, to replace the current fossil fuel dominated transport system. The REVski is an experimental project to convert a petrol Jet Ski to an electric propulsion system with a 50kW AC motor and 80Ah of battery capacity. The REVski project aims to develop a Jet Ski alternative that is environmentally friendly, produces less noise, and greatly reduces running costs compared to conventional combustion motors.

During the conversion the existing Electronic Control Unit (ECU) was removed along with the motor assembly, requiring the development of a new ECU that is specialised to run with electric vehicles. The Electronic Control Unit in development needs to facilitate running a CAN communication network, fault checking, running the user display, collecting data from outboard water sensor cluster, along with position tracking through GPS. Additionally, the ECU will log data to send status updates to the REV project database using 3G communication from the GPS.

This thesis documents the development of an ECU, the corresponding system architecture, and instrumentation for electric conversion vehicles with the goal of developing a flexible system for use within future REV projects.

Ze Lin

Supervisor: Professor Thomas Bräunl

Instrumentation and Water Quality Sensor

The aim of the Renewable Energy Jet ski project is that the function and performance of the oil-powered Jet ski can be realised as much as possible by replacing all the oil-powered parts with electric ones. Moreover, the purpose of this project is to reduce the pollution of seawater caused by the exhaust gases and the noise pollution caused by the operation of the oil-powered engine. At present, after the previous efforts of several other teams, the first version of the REVski has been completed. However, there are still many issues to be solved. This thesis is about the further optimisation and upgrading of the display instrumentation according to the current issues and the addition of water quality sensor system to detect the parameters of people's interest in seawater, such as temperature distribution, conductivity distribution, and so on.

First of all, the display instrumentation is an indispensable part of any modern vehicle, which enables the driver to have a more intuitive understanding of the vehicle itself and the warning of dangers. This part focuses on the improvement of the control module of the display instrumentation, and a PCB designed to integrate each interface such as the RS232 serial port, power supply, digital input, and analog input and provide a convenient and reliable connection. Also, it adds temperature and moisture sensors to detect temperature and moisture of the box of the control modules, and also adds a 4G communication module which is used for communication between the vehicle and the cloud server.

Then, the water quality Sensor system is based on Analog EC Meter SKU: DFR0300 Conductivity Sensor and DS18B20 Temperature Sensor. It connects with the MCU through analog IO and digital IO, and the collected data is transmitted to the cloud server for storage and analysis by the 4G module or GPS logger with a 3G module.

Timothy Masters

Supervisor: Professor Thomas Bräunl

Autonomously Landing UAVs on a Moving Platform (Stealth Tech.)

With recent booms in online retail industry there has been an unprecedented increase in demand for personal delivery services. The current method of using delivery vans for the last leg to the consumer may be both less cost-effective and less environmentally friendly than utilising a small electric UAV to deliver the product. However due to range limitations of UAVs and the infeasibility of making a distribution centre within the required distance of every single home, a hybrid truck-drone solution may be found to be optimal.

If this approach is to be utilised, then there needs to be a reliable and precise way to land the drones on the ground vehicle, ideally without it needing to stop every time a drone needs to take off or land.

This project aims to develop a robust system for the landing of a small quadcopter UAV on a moving platform, using onboard camera and image-processing to identify and follow the ground vehicle. It is proposed that an optical fiduciary tag system is used to locate the vehicle, and an Extended Kalmann Filter is used to provide accurate state estimation through sensor fusion of the onboard IMU, GPS, and camera feed.

Victor Oloworaran

Supervisor: Professor Thomas Braunl

Standalone Simulator for Articulate Robots

We currently live in an age where robot use and advancement is flourishing, may it be the physical technology of robots themselves or the extension of software capabilities. With this, the accurate simulation of robotic behaviour is paramount to efficiently designing and manipulating robots. The increase in robot usage has led to simulation software trending towards improved accessibility for non-specialists. Existing software include use established or self-developed robot programming frameworks and complex libraries to encapsulate robot control theory. Though still, this can prove complicated to use for those without knowledge of robotics or programming.

This thesis paper presents a standalone articulate robot simulation system with additional interface to a real small robot manipulator. This software package seeks to provide a free, small and self-contained simulation system available for multiple platforms which is more suitable for educational purposes or informal small robot testing. The system provides a convenient and easy to use experience, simulating robots which can easily be manipulated both with high-level programming and through the use of the graphical user interface. Furthermore, the simulation will also implement an interface to operate a real small robot manipulator to demonstrate the use of robot simulation for real robots.

The simulator is based on creating an updated version of the application RoboSim, made in 1996. Implemented in Unity3D, the presented system replicates the movements of any user modelled articulate robot, accounting for physical interactions, and allows for manipulation or high-level programming of this robot. To that extent, a physical robot is being constructed in reality and modelled in the simulator, which will be detailed in this paper. Denavit–Hartenberg parameters are used to fully define a robot pose and calculate transformations needed for each robot link in order to manipulate the robot. To test the quality of the system, the simulation of the physical arm will be completed and compared to results gained from the real-world robot through various tests and criteria.

Xiaoqing Ran

Supervisor: Professor Thomas Bräunl

REVski Safety System and Water Quality Detecting System

The REVski project is a branch of the University of Western Australia's renewable energy vehicle (REV) project. It commenced in the second semester of 2012. The original intention of REVski project was to build a safe, reliable and stable electrically powered Jet Ski that could meet all the functions of petrol-powered Jet Ski.

Because it was an electric motorboat, and it is used in water for a long time, to avoid potential safety incidents, the construction of the safety system was regarded as the core element of the whole project. From 2012, every year, a series of improvements have been made to the safety system of the entire motorboat to continually improve its safety. This paper will elaborate on the contributions to the safety system during

2018-2019 and the construction of the water quality sensor. Since the battery has been used for an extended period, the team checked the battery after each test. After many tests, the team replaced the problematic battery and used a new way to connect the battery. This new connection avoided battery damage and made better use of the cabin space. The previous safety system had sensors to detect leaks under shells, however the detection was unsuccessful. So, the author will reuse the sensors inside the cabin to detect leaks. Finally, to make the entire security system more accessible, the diagram was re-made to show the connection of the entire safety system.

To be able to detect salinity while the Jet Ski was running, a conductivity sensor and a water temperature sensor were added to the Jet Ski. Both sensors need to be in direct contact with the water. Due to being restricted from drilling holes in the Jet Ski, the team extended both sensors and built special facilities (covers) to mount them on Jet Ski and protect them from waves.

Anthony Ryan

Supervisor: Professor Thomas Bräunl

End-to-End Learning for Autonomous Driving Robots

This thesis presents the development of PilotDrive, a high-speed, low-cost, end-to-end deep learning based autonomous robot. This project builds on previous research undertaken at the University of Western Australia, where the robot was first developed with a single LIDAR scanner as its only sensory input as a baseline for future research into autonomous vehicle capabilities with lower cost sensors. PilotDrive is comprised of a Traxxas Stampede R/C Car, Wide-Angle Camera, Raspberry Pi 4 using UWA's RoBIOS software and a Hokuyo URG-04LX LIDAR scanner.

PilotDrive aims to demonstrate how the cost of producing autonomous robots can be reduced by replacing expensive sensors such as LIDAR with digital cameras combined with end-to-end deep learning methods and Convolutional Neural Networks to achieve the same level of autonomy.

PilotDrive is a small-scale application of PilotNet, developed by NVIDIA and used in the DAVE-2 system. PilotDrive uses TensorFlow and Keras to recreate the same neural network architecture as PilotNet which features 9 layers, 27,000,000 connections and 252,219 parameters. A Convolutional Neural Network was trained to map the raw pixels from images taken with a single inexpensive front-facing camera to predict steering angle commands to control the servo and drive the robot.

This end-to-end approach means that with minimal training data provided from manual driving, the network learns to steer the robot without any human input, lane markings or distance sensors. This eliminates the need for an expensive LIDAR scanner, as an inexpensive camera is the only sensor required as well as eliminating any lane marking detection or path planning algorithms and improve processing speeds.

Jiajian Shao

Supervisor: Professor Thomas Bräunl

Path Planning for Autonomous Driving Vehicles

This project is essentially a "design and build" project focusing on the modification and improvement of the existing path planning software for the UWA Electric SAE (Society of Automotive Engineers) Race Car.

The modified local path planner aims to enable the SAE car to achieve autonomous driving in unknown environments without predefined geographical information. The modified local path planner is based on a customised probabilistic roadmap algorithm to enable the SAE car to avoid obstacles. This algorithm relies on the information provided by the odometry and LiDAR (light detection and ranging) sensors on the SAE car to detect obstacles. The software is composed in C++ programming language, operated in Linux environment and coordinated by ROS (Robot Operating System) software framework.

With only a single strategy of path planning, the existing local path planner tends to fail to find a valid path in some complicated configuration space.

As a result, the most significant feature in the modification to the existing path planner is the prediction feature, which allows the vehicle to predict its following manoeuvres. With the modified local path planner, when the SAE car detects possible collision at a predicted manoeuvre, it will roll back to the prior predicted manoeuvres iteratively until it finds another valid path with a different steering angle. The modification makes use of more information provided by the sensors and certainly enhances the autonomous driving capacity and flexibility of the existing local planner.

Vihanga Akash Thathsara Silva

Supervisor: Professor Thomas Bräunl

Vision Based End to End Self-Driving using Convolutional Neural Networks

Biomimetics is solving human problems through observation and imitation of natural elements, models, and systems. One of these systems is the human visual cortex, which processes signals transmitted by the eyes and associates it with people, objects, and structures that are familiar to that specific individual. While the exact mechanism is unclear, it is theorised that the associations are made through extraction of features within a scene, which build up in complexity, layer by layer, from colours and shapes to objects. This natural system serves as an inspiration for Convolutional Neural Networks (CNN), which similarly produces outputs through feature extraction, layer by layer, in increasing complexity.

This study aims to develop a robust and efficient model that uses neural networks to achieve full autonomy in a self-driving car. The primary input into the model will be visual data from cameras. This data is to be processed using CNN and fused with secondary sensors to produce an output to the motor controllers and drive actuators. This model is optimised through supervised and reinforcement deep learning methods, which also imitate learning methods used by humans.

The primary outcome from this study is evidence that CNN-based End to End Self-Driving method for autonomous cars is a feasible option with current technology. A secondary finding is that CNN-based model can be implemented on compact processing units that are low cost. This is critical to the mass utilisation of the technique as it reduces the barrier for entry. Though the model is feasible in its current state there are still multiple improvements that can be made. Future research should focus on breaking the model into sub models focused on specific areas of autonomy problem, which could lead to higher model accuracy.

Samuel Tennent

Supervisor: Professor Thomas Bräunl

Development of Robotic methods for accessing marine piles (CEED)

Currently jetty piles can only be accessed through either rope access or divers or often both. These methods require significant safety apparatus and are slow, manpower intensive activities. As well as this, they make precise work difficult due to the low stability of the work environment. KAEFER Integrated Services in collaboration with UWA is intending to design a robotic platform to more efficiently access these areas and remotely conduct works. This will ensure the processes are conducted much more reliably and precisely whilst increasing speed and accuracy. This new approach will require new robotic technologies and methods to operate in these environments. Some examples of these new technologies included 3d Printing, AI Computer Vision, low cost micro-controllers and more. As well as these operating advantages, the ability to remotely access equipment and monitor it is becoming more in demand as companies seek to further digitally integrate processes on work sites. So one can easily see how robotic solution will significantly improve work process in this traditionally difficult and hazardous role

Morgan William Arthur Trench

Supervisor: Professor Thomas Bräunl

Developing a Single Page Web Application to Monitor and Control a Solar Powered Autonomous Boat

This document describes work completed for the Solar Powered Autonomous Boat/ Raft project. The existing web interface for controlling the boat over HTTP wasn't able to be easily modified to handle changes being made to the boat itself. To address this complication, development of a Single Page Application (SPA) was proposed. Developed using the Angular platform, the basic design of the application is outlined in this document.

The application program interface (API) that supports communication with the boat was modified to also communicate with instances of the SPA, as well as support extra sensor data originating from the boat. The intended usage of each of the endpoints of the API is also described. A functional control application was created, however real world testing was not achievable due to confounding factors.

Liyang Xu

Supervisor: Professor Thomas Bräunl

Low-cost IMU Based Pose Estimation System for Hydrofoil Jet Ski

The REV Hydrofoil project aims to develop the world's first fully functional electric hydrofoil watercraft, and as such, the project explores the possibility of higher speed and power efficiency by the implementation of hydrofoil components on an electric jetski. Although the project has yielded reliable hydrofoil implementation solution on an electric jetski, no means of pose detection exist on the current model of the hydrofoil jetski. Thus, an opportunity arises to implement a pose estimation system on the hydrofoil jetski to accurately obtain real time information of its orientation, heading and position.

This thesis project aims to design and implement an end-to-end pose estimation system that will output the real time pose information of the hydrofoil jetski. The proposed system will incorporate three major components: a low-cost Inertia Measurement Unit (IMU), the Extended Kalman Filter (EKF) and the Attitude Heading Reference System (ARHS). The IMU will measure and produce uncompensated output about the jetski's pose, which is then passed through the EKF to correct any noise and measurement bias in the output.

Lastly, the AHRS will interpret the corrected IMU outputs to obtain readable real time pose information of the jetski. The use of a low-cost depth sensor to monitor the depth of the hydrofoil component in the water will also be explored in this thesis project, and the depth sensor will be incorporated to work in conjunction with the proposed system during the later stages of the project.

The thesis project will also investigate the feasibility of a graphical user interface to relay the pose information from the proposed estimation system to the user or rider to be viewed and for data collection.

Yingjie Yao

Supervisor: Professor Thomas Bräunl

Integration of Cone detection and SLAM for Autonomous Driving

Object detection and Visual SLAM are key technologies in the field of autonomous driving. With the rapid development of embedded processors, it has become possible to apply object detection and visual SLAM to autonomous driving.

In this thesis, the author uses labelled cone images on different environments to pre-train YOLOv3-Tiny model and uses the generated weights to implement cone detection. Then, YOLOv3-Tiny model is integrated with Robot operating System (ROS) and deployed on the embedded development platform Jetson AGX Xavier.

The author evaluates the accuracy of cone detection and retrains data to improve results. Besides, the author uses ORB-SLAM2 algorithm to implement the localization of autonomous cars and mapping. When YOLOv3-Tiny model is used for cone detection, it achieves better than 15 FPS in Jetson AGX, which has satisfied the initial demand for autonomous driving. The experimental results prove the feasibility of the YOLOv3-Tiny model and ORB- SLAM2 algorithm used in the field of autonomous driving.

Jia Yu

Supervisor: Professor Thomas Bräunl

Sensor Fusion of Autonomous SAE car

Autonomous driving is a multifunctional technique based on utilizing a wide variety of sensors that can transfer different types of messages from the environment to processors. Sensors installed on Autonomous SAE car consists of wheel encoder, IMU, GPS, cameras, and Lidar. To achieve better outcomes, sensor fusion becomes an essential element in autonomous driving, it can combine several sensory-data to provide a reliable, accurate, and robust result. Sensor fusion has wide applications in many areas of robotics such as localization of mobile robot, object recognition, and environment mapping.

In exploring sensor fusion, this paper focuses on the localization of the SAE car; it demonstrates a fusion of odometry, IMU, and GPS by implementing an Extended Kalman Filter. As a result, the accuracy of localization by using sensor fusion is obtained. A comparison between this result and the individual sensor's accuracy is demonstrated. In order to fulfil the potential of the SAE car to achieve a higher quality of functions, Velodyne Lidar is installed. The author describes the process of installation, features, and potential utilization in the future of this powerful sensor.

Tuo Zhang

Supervisor: Professor Thomas Bräunl

Integration of Real-Time Semantic Segmentation for Autonomous Driving

The REV-SAE project is an ongoing project in the University of Western Australia, with the aim of achieving fully autonomous driving capability for the SAE electric car. Previously, the vision module of the SAE car only utilized traditional image processing techniques for tasks such as cone detection and lane detection. The reason for this was that traditional methods had better runtime performance while neural networks would introduce additional latency while the improvement in accuracy was not significant. With the continued improvement in processing power of the hardware as well as in machine learning algorithms, especially in semantic segmentation, the advantages of utilizing neural networks has far exceeded the cost.

The main objective of my research is to develop, test, deploy and integrate semantic segmentation algorithm to the SAE car. Apart from that, generating depth image with the existing stereo camera and fuse it with the point cloud generated by the lidar are also part of my project. If these objectives are achieved, the autonomous driving capability of the SAE car would be greatly improved.

Yi Zhang

Supervisor: Dr Thomas Bräunl

Safety System Redesign with New Microcontroller and Electrical Circuit

The problem of designing reliable electrical safety systems in autonomous driving is a critical one ensuring safe operation for driver and for the protection of the internal components within the vehicle. Autonomous driving is a complex engineering project. For a vehicle to attain the L4 level of safety, autonomous driving cannot be separated from the support of hardware technology. Therefore, this project is a system engineering one. In addition to excellent software systems, it is also necessary to pay attention to the requirements and challenges of hardware devices in the mechanical and electronic parts. Also, the electrical connections across the systems and installations in the vehicle must reach the ISO26262 standards of electronic, electrical and programmable devices.

In exploring the hardware of safety systems, this paper is a "design and build" project focusing on the development of the safety system of SAE car.

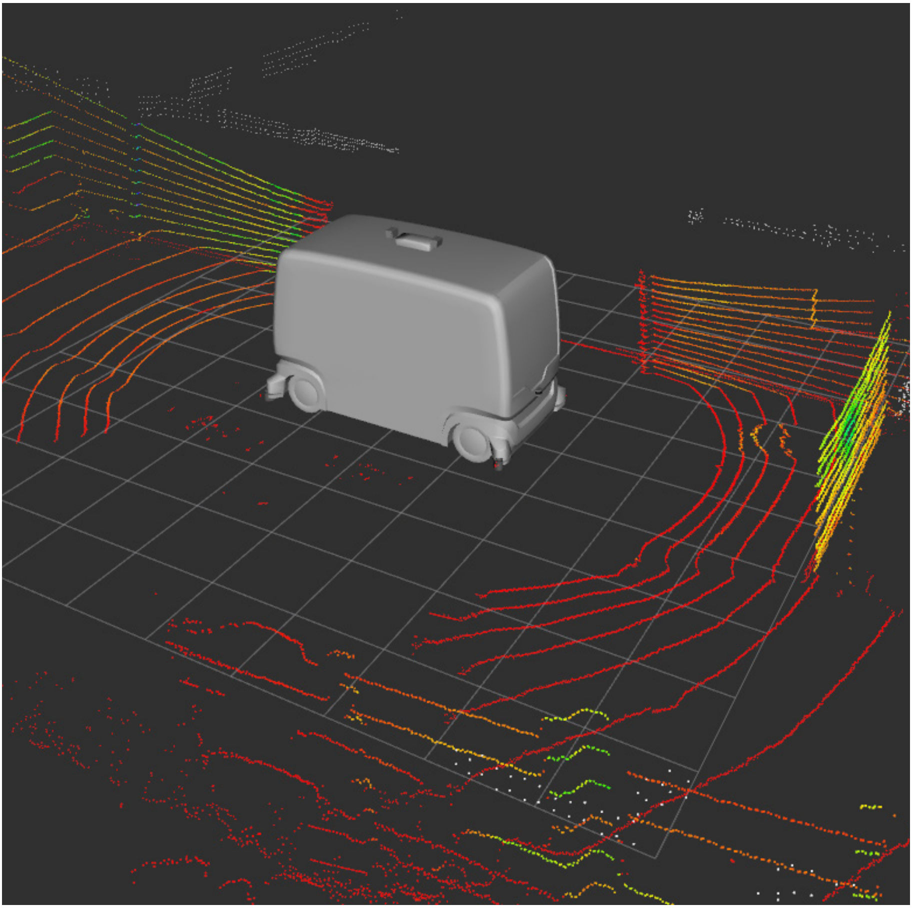


Image: Lidar scan from autonomous shuttle bus

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