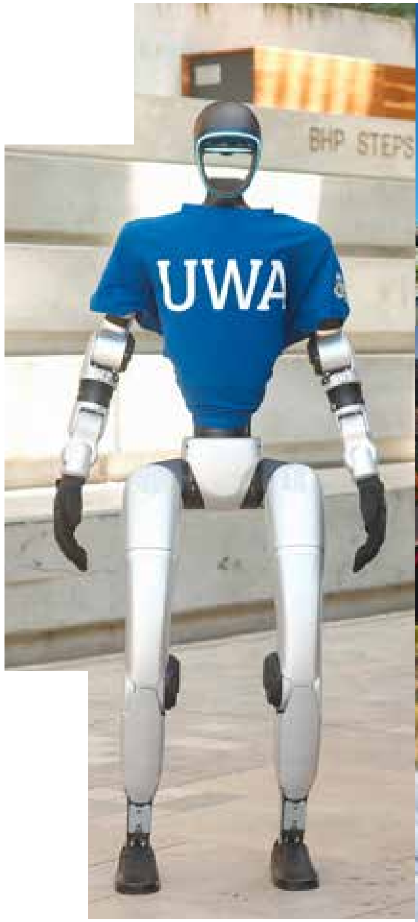
THE UNIVERSITY OF WESTERN AUSTRALIA

School of **Engineering**

Computational Intelligence—Information Processing Systems CIIPS

Research 2024/2025



Contents

Foreword
from the Head of CIIPS

The new Bachelor of Engineering in Automation and Robotics degree is thriving, and we have the first students in this degree doing their final year projects and graduating. Just in time for the increased industry demand for graduates in this area.

We added new robotics lab equipment to cope with larger classes and now operate three parallel manipulators (Igus Delta) and three sequential manipulators (UR5), plus seven Pioneer mobile robots with new sensor and compute equipment.

On the autonomous vehicle side, we operate three shuttle buses on UWA campus and a fourth on-road trial bus at Amberton Beach. This is one of the first autonomous vehicle trials on a public road in Australia, and it is an ongoing technological challenge as well as an administrative one, dealing with permits from road authorities.

A new hydrofoil ski is also being developed with an automated balancing system that makes it easy to ride for novice users, plus a fully autonomous navigation system.

We are exploring a number of different vehicle simulation systems, including Carla (Unreal Engine), Autoware (ROS2), AWSIM (Unity), and Carmaker (IPG). We are also able to use the vehicle simulator of the WA Centre for Road Safety Research next door with a full-size car body on an actuated platform.

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 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.

Baxter being trained by students to perform a task

Equipment

In the **REV Automotive Lab**, the group operates as research vehicles—

- 4 x Ligier Shuttle Buses (Autonomous Driving)
- BMW X5 (Advanced Driver Assistance Systems)
- Hyundai Getz (Electric conversion, road-registered)
- Lotus Elise S2 (Electric conversion, road-registered)
- Driverless Electric Formula-SAE Race Car
- Electric Jet-Ski (boat-registered)
- Electric Hydrofoil (boat-registered)
- Electric Scooter

In the **Robotics and Automation Lab**, the group operates numerous autonomous mobile robot systems, including about 50 driving robots, three autonomous underwater vehicles, five walking robots and two drones.

- 7 x Pioneer AT mobile outdoor robots
- 3 x UR5 robot manipulators (5kg payload)
- 3 x Igus parallel robot manipulators
- Nachi robot manipulator (150kg payload)
- Festo automation production line
- Numerous own mobile robot developments

Contact Details

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Members of CIIPS

Academic

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(Head of CIIPS)
Dipl.-Inform., MS, PhD, Habil., SMIEEE
Electromobility; Automotive Systems; Robotics; Image Processing; Concurrency; Embedded Systems
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Mobile Robots

Dr Kai Li Lim
Adjunct Research Fellow
EV Charging Systems and Autonomous Navigation

Marcus Pham
Adjunct Research Fellow
Embedded Systems

Professional

Ivan Neubronner
Senior Technician

Linda Barbour
Graphic Designer

International Visitors

Patrick Riedel
Univ. Stuttgart. Germany

PhD

Pierre-Louis Constant
Autonomous Marine Vessels

Michael Finn
Artificial Life

Xiangrui Kong
Visual Navigation

Zhihui (Eric) Lai
End-to-End AI Methods in Autonomous Driving

Lee Le
Sensor Fusion Autonomous Driving

Zhang Li
Intelligent Control for Autonomous Driving

Ning Liu
Cooperative Mobile Robots

Elliot Nicholls
Automation in Agricultural Systems

Kieran Quirke-Brown
Automated Obstacle Avoidance

Machiel van der Stelt
Road Safety

Tiziano Wehrli
Automated Hydrofoil Control

Oliver Zhang
Humanoid Robots

PhD Completions

Dr Thomas Drage
Safe Systems Design for Special Purpose Autonomous Vehicles

Master of Professional Engineering

2023

Pearce Brezmen, AR UWA
Planetary Rover

Yanke Cheng, EE UWA
Software Design for Autonomous Solar Boat

Edward Finnie, EE UWA
Automatically stabilized e-foil watercraft

Joshua Kirkham, EE UWA
Electronically Stabilized Electric Hydrofoil

Tim Tan, EE UWA
Waypoint Navigation for Autonomous Shuttle Bus

Hendrik Viljoen, EE UWA
Hydrodynamics for Electric Hydrofoil

2024

Vicky Chow, EE UWA
Electric Vehicle Charging Planning and Monitoring

Mathew Jojo, EE UWA
Road Detection for Autonomous Shuttle Bus

Lee Le, EE UWA
SLAM Driving for Autonomous Shuttle bus

Linrui Zhou, EE UWA
Electric Safety System for Electric Watercraft

Bachelor of Engineering

2024

Ovik Choudhury, BE UWA
Valkyrie Humanoid Robot

Agnibho Gangopadhyay, AR UWA
Autonomous Hydrofoil Boat

Jono Hartono, BE UWA
Valkyrie Humanoid Robot

Bridget Pang, BE UWA
Cone Detection for Spot Robot

Luan Swart, BE UWA
Mars Rover SLAM Software

Tiziano Wehrli, BE UWA
Autonomous Hydrofoil Boat

Benjamin Wright, BE UWA
ESP32 Robot

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. Eng. G.25

Robotics and Automation Lab

Professor Thomas Bräunl

Intelligent mobile robots; robot manipulators, factory automation line, embedded systems; image processing; simulation.
Location: Mech. Eng. G.01

Smart Grids Lab

Adjunct Professor David Harries

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

Student team developing software for autonomous driving

Automotive Lab

Professor Thomas Bräunl

The Automotive Lab was established in 2008 and is dedicated to research on electric and autonomous vehicles. The Automotive Lab currently houses four Ligier electric shuttle buses, a BMW X5, a Hyundai Getz, a Lotus Elise S2, a Formula SAE-Electric race car, an autonomous FSAE-Electric race car, an electric Jet-Ski, an electric hydrofoil, 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 Shuttle Buses

Since 2020, REV has acquired four electric shuttle buses over the years—the *n*UWA*y* fleet—for which we have built a full software stack from scratch, based on Linux with ROS-2 and associated libraries. The shuttles already comprised eight Lidar sensors (4 x Sick, 2x Velodyne, 2x ibeo Lux), which we augmented with two Flir cameras and an RTK-GPS system donated by SBG, France. We also added an Nvidia Orin as an additional compute unit with a GPU to run the latest AI models, and a high-speed switch to accommodate all new sensors. We are conducting active research on three major approaches to autonomous driving, which we will be combining to a hybrid and, overall, more reliable system. These are—

- RTK-GPS based Navigation. This is how most commercial shuttles currently drive
- Lidar-based Navigation. This is how our shuttles currently navigate on the university campus
- Vision-based Navigation. This will be our navigation mode on public roads in combination with RTK-GPS

This ever-expanding and ever-improving fleet of electric shuttle buses represents the ongoing development of the team to build better systems with the latest technology.

Amberton Beach Trial

Kieran Quirke-Brown

The official launch of the Amberton Beach autonomous driving project was in December 2022. This first on-road trail was the next logical step for the REV team after implementing and running an autonomous shuttle bus on UWA's campus for three years.

The trial represented a new domain for the nUWAy team to work and explore in and was not without its ordeals. There was a number of administrative hurdles to move through before the work could begin in earnest. An initial investigation had begun between early- to mid-2023 with the best approaches to driving a set route from the Stockland office to the beach. It made sense to start with an RTK-GPS-based driving model and slowly integrate smarts, however, this was the approach that many companies were taking and left little room for innovation. Instead, the team decided to explore several control options linking GPS and AI driving methods, proving to be the strongest contenders. Real-Time Kinematic (RTK) positioning is used to improve localization accuracy via a base station with highly accurate position data. As new GPS data is received, correction factors are sent from the base station to the vehicle in real time. This method allows for cm-level accuracy and when combined with an accurate map of the surroundings proves to be an effective driving technique.

Our second autonomous driving technique uses a Neural Network using image, speed and steering angle data collected over a period of time, to teach the vehicle to drive like a human. This has proven to be a more effective method than GPS as it takes its local surroundings into consideration and makes adjustments to speed and steering to ensure safe driving. These two methods work well together and can act as backups for each other in case of one system failing. In addition, the team has implemented a software curtain to check for impeding obstacles to ensure the shuttle's safety system will not create an emergency stop.

The shuttle bus project has been funded by—

- Stockland
- DyFlex Solutions
- C.D. Dodd Metal Recycling
- UWA School of Engineering
- UWA Business School

West Australian Newspaper printing facility in Osborne Park

Excursions

The Robotics and REV teams organize regular excursions to local industry.

- West Australian Newspaper (autonomous robots and automation systems)
- Perth Children's Hospital (autonomous robots and robot pharmacy)
- Fast Brick (automated bricklaying robot)
- CPS Conveyors (robot-based manufacturing)
- TAFE Fremantle (ship simulator)

TAFE Fremantle

Mapping

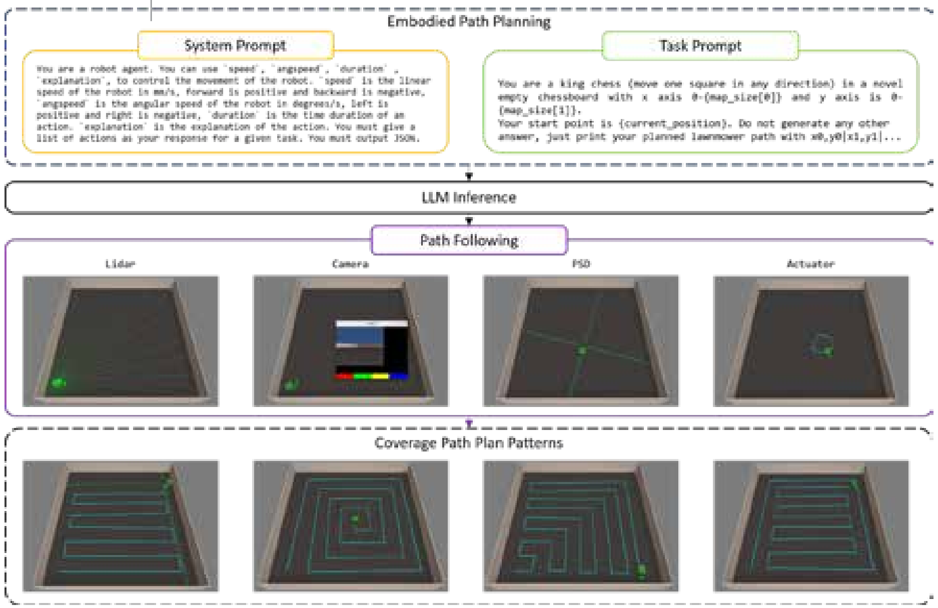
Xiangrui Kong

We examine the potential of Large Language Models (LLMs) for autonomous driving operations while addressing their current limitations. While LLMs are not yet suitable for real-time car control or obstacle detection, they demonstrate immense promise in supporting auxiliary tasks that contribute to safer and more efficient autonomous systems.

One key area of exploration has been the use of LLMs in path planning. This involves formulating navigation challenges in natural language, which allows LLMs to generate waypoints that can guide the vehicle's movement. By bridging human-LLM communication with actionable navigation instructions, this approach simplifies the complexity of converting high-level directives into executable paths. The generated waypoints are subsequently evaluated for feasibility and safety before implementation, ensuring alignment with rigorous safety protocols. To achieve this, zero-shot prompting techniques with pre-trained LLMs have been employed effectively, demonstrating their adaptability and robustness without requiring extensive fine-tuning. This natural language-driven method opens up new possibilities for intuitive and dynamic path planning in autonomous vehicles.

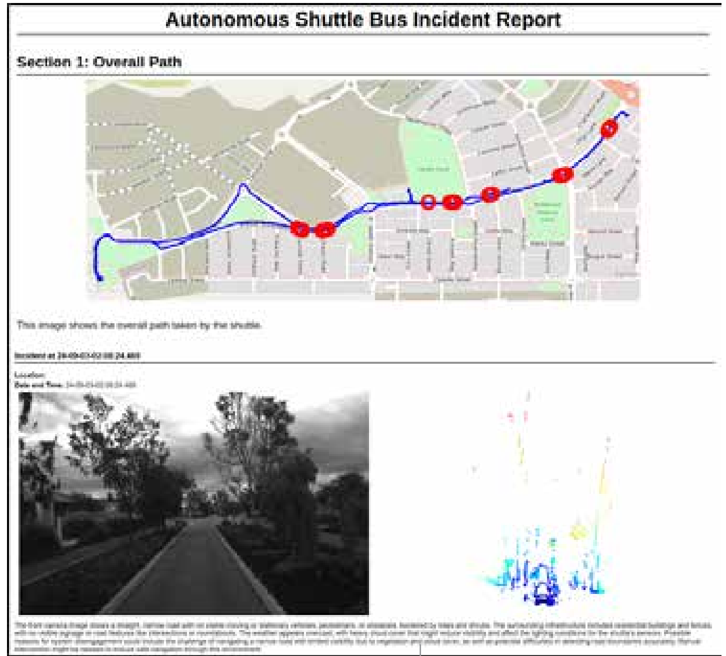
Incident reporting has also emerged as a critical application of LLMs in autonomous driving. With their ability to process and analyze multimodal data, including images and textual descriptions, LLMs can generate comprehensive and timely incident reports. This capability is especially valuable for autonomous shuttle services, where passenger safety and operational accountability are paramount. By analyzing disengagement scenarios and visual inputs, LLMs can produce detailed reports that enhance safety protocols and improve transparency. This work underscores the importance of accurate and immediate incident documentation in maintaining trust and reliability in autonomous systems.

LLM Path Planning in EyeSim simulator



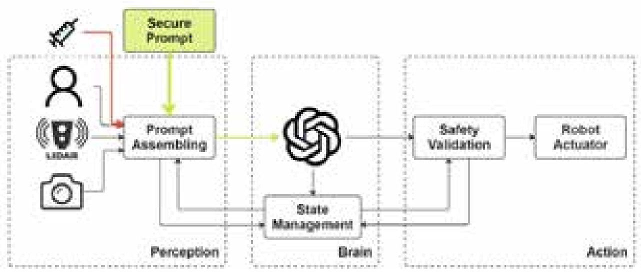
The development of LLM-powered in-car voice assistants represents another significant focus of this year's research. These systems aim to provide a natural and intuitive interface for passengers to interact with autonomous vehicles, moving beyond traditional input methods like buttons or predefined commands. By enabling conversational interactions, the envisioned voice assistant supports a wide range of functionalities. These include issuing vehicle-oriented commands, such as activating cruise control or initiating emergency braking, as well as offering passenger services like navigation, appointment booking, and guidance. To facilitate this development, a synthesized dataset of 10,000 voice commands covering diverse driving scenarios has been created. This dataset not only aids in training and evaluating the performance of voice assistants but also lays a foundation for their future scalability and deployment in real-world conditions.

Reliability remains a cornerstone of this research, given the high stakes of deploying LLMs in safety-critical applications like autonomous driving. Several challenges have been identified and addressed to enhance the dependability of these models. Prompt injection attacks, a notable vulnerability, have been explored with a focus on mitigation strategies. Additionally, efforts to reduce hallucinations—where LLMs generate inaccurate or misleading information—have been prioritized to ensure output reliability. Ethical considerations have also guided the development process, emphasizing the alignment of LLM behavior with safety and ethical principles. These efforts collectively aim to create robust and trustworthy LLM systems capable of meeting the demands of autonomous driving applications.



LLM-based incident reporting for Amberton Beach Autonomous Shuttle Trial

From enabling intuitive human-vehicle interaction to improving operational safety and efficiency, LLMs offer innovative solutions to some of the field's most pressing challenges. While hurdles remain, the progress achieved provides a strong platform for continued exploration, ensuring that LLMs can play a vital role in shaping the future of autonomous vehicle technology. By prioritizing adaptability, safety, and ethical responsibility, this research contributes meaningfully to advancing the integration of LLMs into the rapidly evolving landscape of autonomous systems.



CARLA Autonomous Vehicle Simulation

Zhihui (Eric) Lai

A simulation environment for the autonomous shuttle bus was designed based on Carla as a hardware-in-the-loop (HIL) system, which was later converted to a pure software simulation, as the HIL component did not improve the performance or accuracy of our system.

As part of the simulation environment, a digital version of the whole UWA university campus has been developed. In addition, a 3D shuttle bus model was created as the main autonomous vehicle. In 2023, a digital version of the Amberton Beach suburb has been built in RoadRunner and then exported to CARLA.

Simulated UWA campus, facing north

The simulator has two control inputs: A steering wheel with accelerator and brake pedals and keyboard input. Users can conveniently set up and execute experiments with these controls and buttons. For simulator operation, we implemented six different modes:

1) Manual drive mode – Users can drive the simulated shuttle bus manually using the steering wheel and pedal or keyboard control. This mode is often used to collect Lidar point cloud data to generate a pose-graph map and collect image data for the training of neural network models.

2) Lidar autonomous drive mode – Once a pose-graph map has been generated in manual drive mode, the simulated shuttle bus can drive autonomously from one place to another on an optimised path using the navigation module in ROS 2. This mode is identical to the driving operation implemented in the real shuttle bus.

3) Computer vision autonomous drive mode – This autonomous driving mode uses OpenCV computer vision algorithms. By applying Canny edge detection and Hough line detection, the program can identify the lane's left and right boundaries, determining the steering and throttle command.

4) Neural network autonomous drive mode – This is an autonomous drive mode using deep learning neural network models. The currently employed model is a modified PilotNet that takes the front camera image as input and outputs steering angle and throttle control commands. This method can handle intersection with traffic lights and is planned to be implemented in the real shuttle bus.

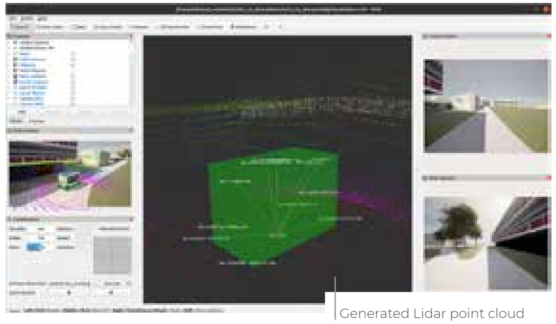
5) Mirror drive mode – This mode connects simulation with reality. The real shuttle bus constantly publishes position, orientation and camera data to the web. The simulator accesses this data, converts the GNSS coordinates to the simulated vehicle's map position and replaces the simulation camera image displays with the actual camera images. Therefore, the simulated shuttle bus mimics the driving behaviour of the actual shuttle bus. This mode helps users monitor the actual shuttle bus remotely.

6) Carla built-in autonomous drive mode – This mode extracts all the traffic information from the simulator program, including traffic light states, distance to other objects and current location. With this information, the algorithm is able to drive in the center of the road and randomly turn at intersections. This mode is often used to generate other traffic and collect image data for the training of neural network models.

Simulated shuttle bus on UWA map

Simulated Amberton beach in CARLA

Simulated Amberton beach street view in CARLA



Generated Lidar point cloud

UWA neural network drive demo

Carla Town01 neural network drive demo

AWSIM Autonomous Vehicle Simulation

A digital version of the Amberton Beach has been built in RoadRunner and then exported to the AWSIM Unity simulator. AWSIM is an open-source unity-based simulator designed for Autoware, but is also suitable for other tasks. It doesn't have a mature ecology like CARLA, however, it has several advantages like a smooth learning curve, low computational cost, and time acceleration that are worth attracting more researchers to join and develop this community. Functions implemented in CARLA will also be implement in AWSIM for simulator comparison purpose. Zheng Li has implemented Autoware on the Lexus model, which we will upgrade to our shuttle bus model.

Simulated Amberton Beach path in AWSIM Unity

Simulated Amberton Beach street view in AWSIM Unity with snow effect

Amberton Beach Autoware Lexus implementation by Zheng Li on AWSIM Unity

Driving Simulator

The Western Australian Centre for Road Safety Research has set up a new driving simulator that comprises a full-size vehicle on a motion platform. This system will be used by Road Safety to investigate changes to dangerous intersections before they are actually being built. Our team will be using this simulator for autonomous vehicle research. How will manual drivers react to autonomous vehicle behaviors and how do passengers in an autonomous vehicle feel, depending on different autonomous driving characteristics?

Under the hood of the driving simulator vehicle

REV 15-Year Reunion

In Sep. 2023, REV celebrated its 15-year reunion with past and present students, sponsors, and staff. The event was held as 'open house' at the UWA labs and included a photo retrospective of the past years – with an outlook on future research.

The REV Vehicles

Over the 15 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.

The *nUWAy* fleet—
four Autonomous Electric Shuttle Buses
48V, 15.36kWh, 8 Lidars, 2 cameras, IMU, RTK-GNSS.

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

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

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

Autonomous BMW X5
Drive-by-wire, laser scanner, GPS, IMU, camera.

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

REV Waveflyer
Twin 5kW shrouded DC motors, 48V, 2kWh, 30min. drive-time.

Electric Hydrofoil research on automated stability and height control

Electric and Autonomous Watercraft

Our first Australian electric jet ski which we completed in 2015 was a great success and we are now seeing the first electric jet skis from commercial manufacturers.

For the next generation, in collaboration with start-up Electro.Aero/Electro.Nautic, we built an electric hydrofoil, consisting of an electric jet ski mounted with foils. This EIFoil has a range of about five times longer than an equivalent electric jet ski. However, it is extremely hard to control for the rider, so we are working on an automated control system for balancing and height control.

Another marine project is the autonomous solar boat, a model catamaran, acting as our development platform for unmanned surface vessels.

The Electric Jet Ski

EIFoil

Pierre-Louis Constant

The EIFoil project has been a major focus over the last years, where we aim at stabilizing a craft which hovers a few decimeters over the water surface. The outcome is to develop a high efficiency propulsion for marine craft. The bulk of the work involved designing of control hardware and software, as well as manufacturing watertight and durable enclosures for power and control electronics.

We achieved base stabilisation process and altitude control from a new generation of controller an industrial single-board computer and a specialized interface card.

- GPS, height sensors and IMU (inertial measurement unit)
- External hardware interrupt driven control loop with hardware-set refresh rate and minimal latency of the output signal.
- Hybrid controller with event-driven Linux kernel and real-time deterministic controller
- Data structure in human-readable format
- High level asynchronous communication protocols between controller, battery, sensors and motors using serial, Bluetooth and CAN bus.
- Extendable system architecture for additional sensors
- Extended data logging capability
- All the data is streamed to an Android tablet. A custom app allows to browse through all data items and update parameters.

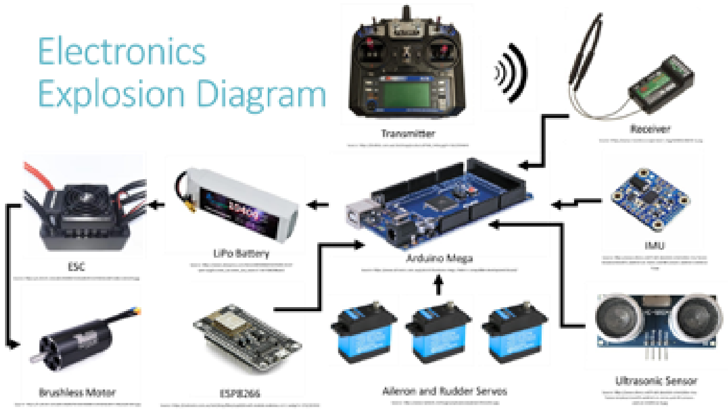
Hydrofoil Boats

Tiziano Wehrli

Hydrofoil boats have recently gained traction in engineering developments, especially as society focuses more on sustainable watercraft. Hydrofoil boats use underwater 'wings' to generate lift as they move and push the hull up and out of the water. This allows them to be significantly more efficient and comfortable. A well-tuned hydrofoil boat can remain perfectly stable even in rough open water conditions, giving passengers the illusion that the craft is flying.
We developed a 1-meter autonomous electric hydrofoil model as a test platform for the full-size hydrofoil ski. This boat also serves as a platform for developing autonomous driving in hydrofoils.

The boat uses an Arduino Mega along with a submerged motor providing propulsion.
Two ailerons and a rudder actuated by servos were used to provide roll, pitch and yaw control of the craft. An onboard IMU and GPS were used to measure the boat's state.
Roll, pitch and yaw PID loops were programmed to allow a smooth and accurate control of the boat and to maintain the correct orientation. The autonomous driving was implemented as GPS waypoint driving, where the boat drives in a straight line between GPS waypoints.

Hydrofoil boat rising out of the water



The electric jet-ski has been funded by—

- The Australian Medical Association (AMA)
- Submersible Motor Engineering Perth (SME)
- Total Marine Technology (TMT)
- Altronics

The hydrofoil project has been funded by—

- Galaxy Resources
- UWA School of Engineering
- UWA Innovation Quarter
- RiverLab

EV Charging in Western Australia

All stations of the initial EV charging network have now been replaced. Our original AC stations were put in place in 2010/11, while our DC station, Australia's first commercial one, was installed in 2014.

We now have CirControl stations for all our AC chargers and Blueberry DC chargers for our two locations on campus, a 50kW single station and a 200kW dual station. All chargers are of the European standard (Type 2 "Mennekes" for AC and CCS-2 for DC).

The 200kW Blueberry station was funded by generous donations from David Lloyd, CD Dodd Metal Recycling, Tesla Roadster Inc, Tesla WA Slack Forum, Tesla Owners WA and Tesla Owners Australia, plus lots of individual contributions, with matching funding provided by UWA. The 50kW station was funded from previous donations with matching funding from WA's charge-up government grant program.

The "gap" in the WA government funded charging network between Esperance in WA and the South Australian border has still not been closed with government or commercial stations, so EV drivers still rely on the three UWA stations that were crowd-funded and placed across the Nullarbor. Jon Edwards installed for us two 25kW Delta DC-chargers plus his innovative 'BioFil' charger, which uses waste frying oil from roadhouses in a generator to power a 50kW Tritium DC charger . Since the frying oil comes from locally grown canola plants, this constitutes a closed cycle with net zero greenhouse gas emissions.

New 200kW Blueberry charger at EZONE

New 50kW Blueberry charger at Uni Club

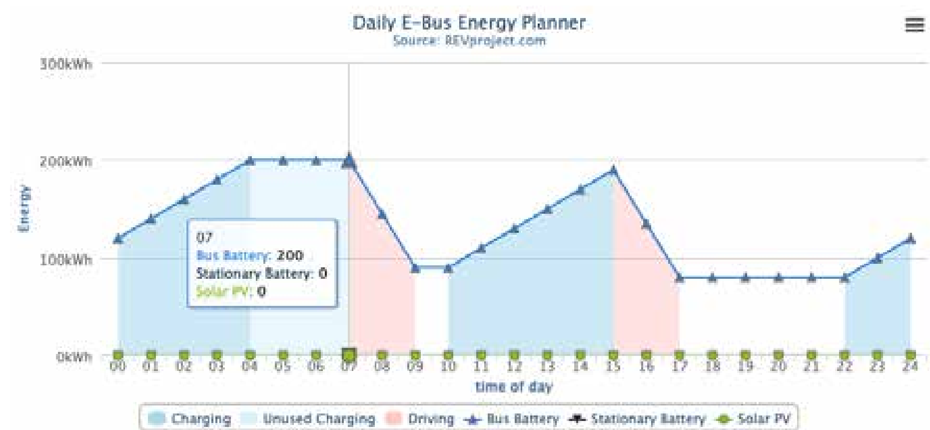
Power module for 200kW Blueberry charger

E-Bus Planner

Vicky Chow implemented an e-bus planning tool as part of her thesis, which was used for analyzing several case studies in a larger feasibility study on replacing all of the over 900 diesel school buses in WA by electric buses. The e-bus planner can be accessed under:

- https://revproject.com/ebus/energy.php

It allows setting specific energy consumption, daily driving distances and charging times. With this, we can determine the required battery size for each bus as well as the minimum required charging power for each site.



Corporate sponsors:

Robotics and Automation Lab

Professor Thomas Bräunl

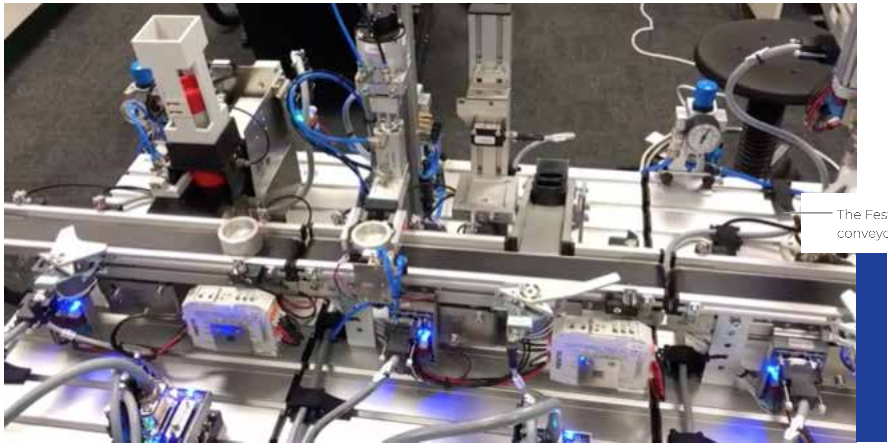
The Robotics and Automation Lab was established in 1998 and is dedicated to research on intelligent autonomous mobile systems. Using embedded systems, over 50 mobile robots have been designed and built in the lab, while the development of simulation systems also plays a major role in the lab's research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

In 2021, the Robotics Lab moved to its new location, the Clough Engineering Centre in the Mechanical Engineering building. This new site combines the areas for robotics research, robotics teaching, and also the newly established UWA Robotics Club. The combined spacious area has great visibility and is adjacent to the UWA Makers Club, which is very valuable when building or upgrading robots.

Automation

Our automated production street from Festo is used for teaching in the Automation unit. 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.

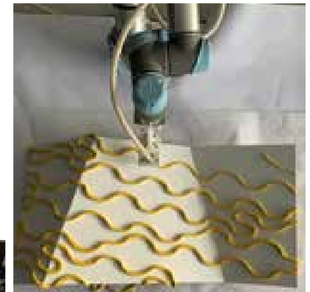
This automation equipment uses standard industrial components and therefore gives students an important industry-relevant experience and skills for their future careers.



The Festo street conveyor system

Robot Manipulators

The lab uses three UR5 robot manipulators for teaching purposes. Students work on group projects for various manipulation tasks with these robots. These include camera sensing, motion planning and task execution. The robots are being used for labs by Engineering students as well as by Architecture/ Design students.



Senior Lecturer Santiago Perez of the UWA Design School using the UR5 robots for design work

Inset top right: fine tasks are executed by the robot manipulators

Photo credit: Santiago Perez

The Nachi robot manipulator (150kg payload) was donated to UWA by RV manufacturer Fleetwood Australia. We use this robot for student projects in the new Automation and Robotics degree as well as for cooperative work with areas spanning from 3D concrete printing in Mechanical Engineering to timber sculpture manufacturing in Architecture. Aus_Tim is sponsoring the project of constructing a large robot-generated sculpture with the supply of timber pieces.

The Nachi Industrial Robotics Manipulator

Hadi Navabi

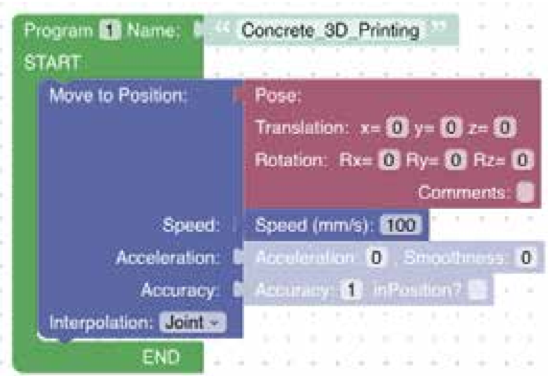
Block Programming Interface (NachiOS)

To provide accessibility to the wide diversity of individuals that may be interested in working with the Nachi robotics manipulator, and due to their varying range of experience coming from different scientific fields, industries, and backgrounds, there is a clear need for a simple method of communication and programming for the Nachi robotics manipulator.

Nachos, also known as NachiOS (Nachi Operating System), is a refined, and simple to use, interface software. Its objective is to bring together and link Nachi's internal functionalities into a formal and understandable Block-programming user interface. It aims to provide assistance to all potential users of the Nachi robotics manipulator, regardless of their dissimilar sets of expertise.

Block Programming is a visual-based programming language that is designed for individuals with limited programming knowledge and expertise. It allows for easy visualisation of all the available features of the language and enables easy drag-and-drop interactivity of blocks for fast and easy development. The blocks represent the most fundamental functionality of the language and can be grouped, attached, or nested together to create a larger program.

https://nachios.vercel.app



Nachi robot stacking timber sticks in Jenga fashion

Concrete 3D Printing

In collaboration with Professor Elchalakani, the MPE Robotics students (Hadi Navabi), Civil Engineering students (Mitchell Grey and Monica Ngo) and other students and staff, one of the most anticipated projects was fulfilled and the possibility of creating complex 3D structures in concrete was proven. The research team successfully managed to set up and print a 10-layered structure using the Nachi industrial robotics manipulator.

Following the addition of I/O functionality and the installation of the industrial gripper on the Nachi robotics manipulator, a wide range of opportunities were made possible. Similar to the Concrete 3D Printing project, the gripper enables the interaction and manipulation of objects in the real world. The Jenga project was implemented to understand the potentials and limitations of the gripper interactivity with real-world objects.

Pioneer robots

Mobile Robots

We refurbished seven 'Pioneer' mobile robots with new industrial PCs as compute units and all new sensors for project work in the Mobile Robots unit. Sensors include SICK Lidars, Oak-D stereo cameras and Phidget-Spatial inertial measurement sensors. The Pioneers can be programmed with either the ARIA or the ROS interface and are being used for waypoint-following and mapping/ navigation tasks.

As an entry-level autonomous driving project, we created the Autonomous Ride-on Car together with the UWA Robotics Club as a STEM project for high schools. The conversion of this kids' ride-on car is fairly simple and requires only limited skills, so it can easily be completed as a high school project. In addition to the car chassis, we use a Raspberry Pi plus a GPS as the basic equipment, which of course can be extended in many ways with additional sensors and software. The first task for the high schools is to recreate our vehicle design, then implement their own software for GPS waypoint following.

Participating high schools so far are—

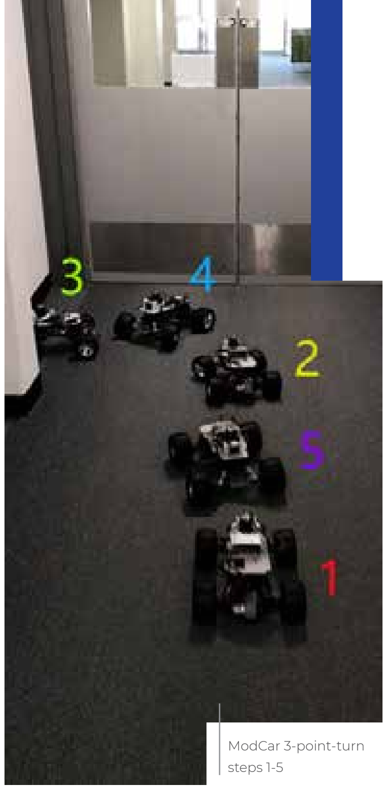
- Perth Modern School
- Sacred Heart College
- Bunbury Senior High School
- Waroona District High School
- Seven Oaks Senior College

See details at: Roblab.org/rideon/

Our compact "EyeBot" mobile robots are used together with their matching "EyeSim" simulation system for labs in the Embedded Systems and Mobile Robots units.


Autonomous Ride-on Car (ARC)


EyeBot mobile robots



ModCar 3-point-turn steps 1-5

Autonomous Driving Robot

Zhihui (Eric) Lai

This project implements an AI-based autonomous driving platform. The project utilized NVIDIA's PilotNet and performs end-to-end deep learning research by training the vehicle's image data input from obstacle distances delivered by the on-board Lidar. Two novel memory models were developed to to address the shortcomings of PilotNet.

PilotNet works only for simple driving tasks, such as lane following and driving between two walls, However, for complex driving tasks in indoor environment, such as making a three-point turn at a dead-end or recovering from a poor position, PilotNet will fail. This research introduces visual end-to-end navigation and proposes two novel models: CNN + LSTM and CNN3D, aiming for complex autonomous driving tasks in an indoor environment. All source code is available on GitHub:

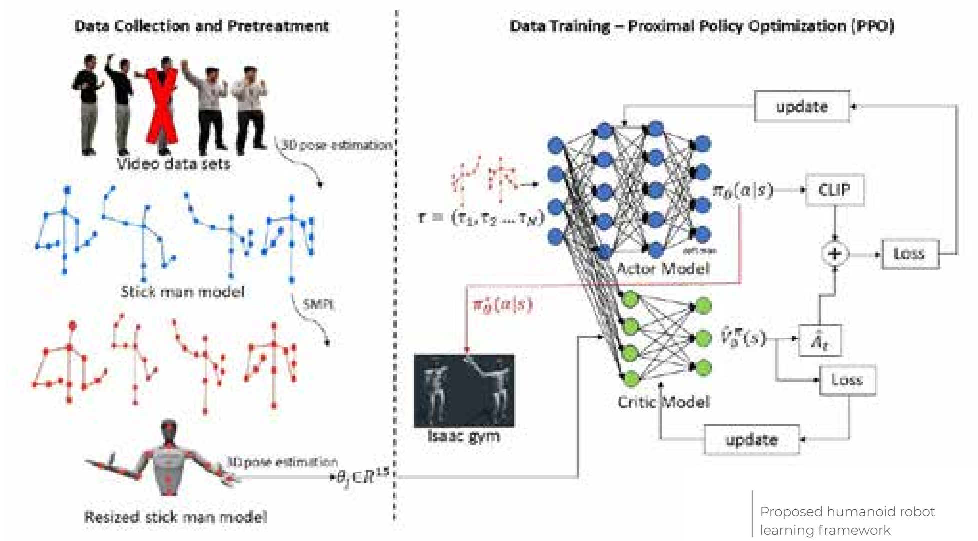
https://github.com/zhi-hui-lai/ModCar_Project.git


CNN+LSTM model racing with Lidar model in an EyeSim maze map

Humanoid Robot

Humanoid robots, with their human-like body structures, have long been a focus of research due to their ability to adapt to environments designed for humans. Achieving their full potential relies on two core capabilities: locomotion control and task execution. Locomotion control ensures stability and smooth movement across complex terrains, while task execution focuses on the robot's ability to perform practical operations under various conditions. We are implementing a flexible control framework designed to enhance these capabilities based on the Robot Operating System (ROS), employing Model Predictive Control (MPC) for real-time lower-limb control and integrating imitation learning techniques to replicate natural upper-body movements. The feasibility of the framework is validated through simulations in the Multi Joint dynamics with Contact (MuJoCo) physics engine and subsequently deployed on the Unitree G1 humanoid robot.

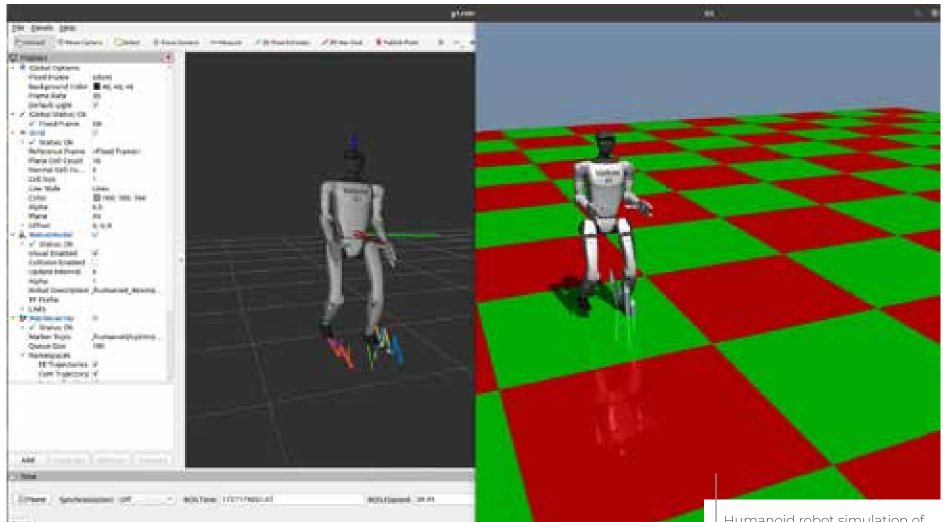
The control framework utilizes MPC to control the lower-body joints of the humanoid robot for real-time locomotion, while the upper-body movements are directly driven by human actions captured through a camera, enabling imitation of natural human actions. These two modules can operate independently or function in parallel through a Whole-Body Controller (WBC) for synchronized execution. A straightforward example of synchronized operation is when the robot carries a heavy load. In such a scenario, the robot's base may exhibit a forward tipping tendency due to the shifted centre of gravity. When the Inertial Measurement Unit (IMU) detects changes in acceleration, the lower-body control module is activated. By dynamically adjusting the robot's gait, MPC ensures stability, preventing the robot from losing balance under the added weight. This coordinated operation exemplifies the seamless integration of the two modules,



Proposed humanoid robot learning framework

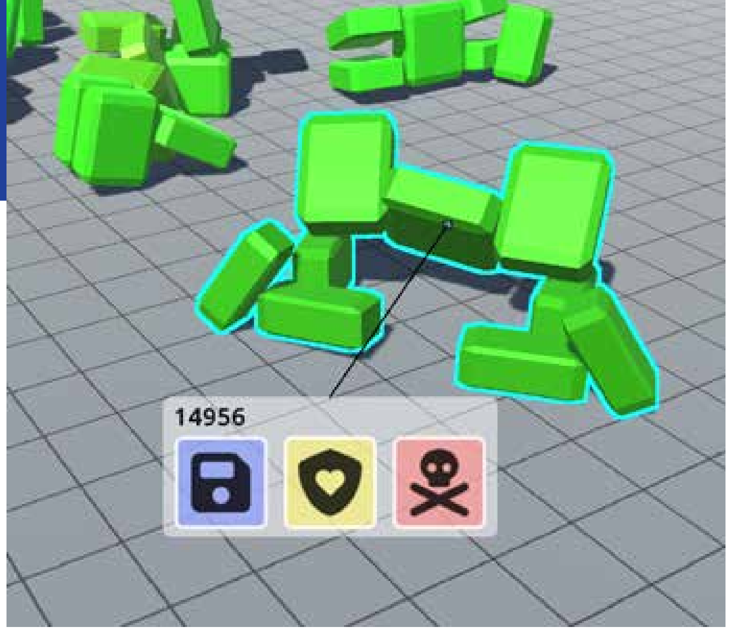
enhancing the robot's adaptability to complex tasks.

To enhance the naturalness and flexibility of the robot's actions, an imitation learning framework is proposed. This framework enables the robot to directly imitate realistic human behaviours. Specifically, the operator stands in front of the G1 humanoid robot and performs a series of actions such as waving or carrying objects. Using its built-in depth camera, G1 captures the operator's movements and imitates them in real-time, generating corresponding actions.



Humanoid robot simulation of MPC+WBC control

Artificial Life



Michael Finn

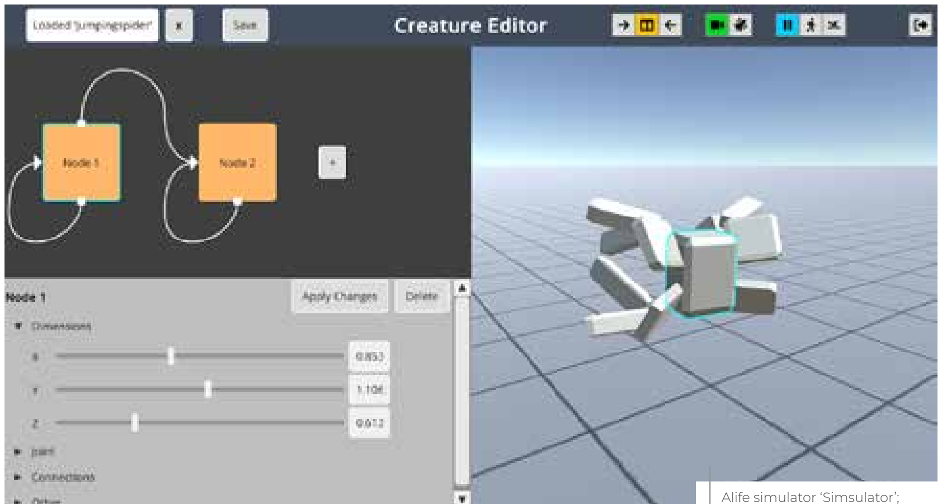
As part of our AI research, we are also doing work in the area of "Artificial Life", which in our case are simulated robot creatures.

The study of artificial life provides the opportunity to model existing forms of life to learn more about our natural world from a different perspective, but it also allows us to explore new forms of life that are unconstrained by the limitations of the physical medium.

By building and examining both 'life-as-we-know-it' and 'life-as-it-might-be' we hope to gain insight into the fundamental and often paradoxical nature of life itself.

As a first step, we implemented a modern version of Karl Sims' simulation system for co-evolving simulated creatures physical appearance together with their internal control system. As an homage to Sims, we called it the 'Simsulator'. The system can be accessed via this link:

https://github.com/mycoolfin/the-simsulator



Alife simulator 'Simsulator'; evolved artificial creature and creature editor

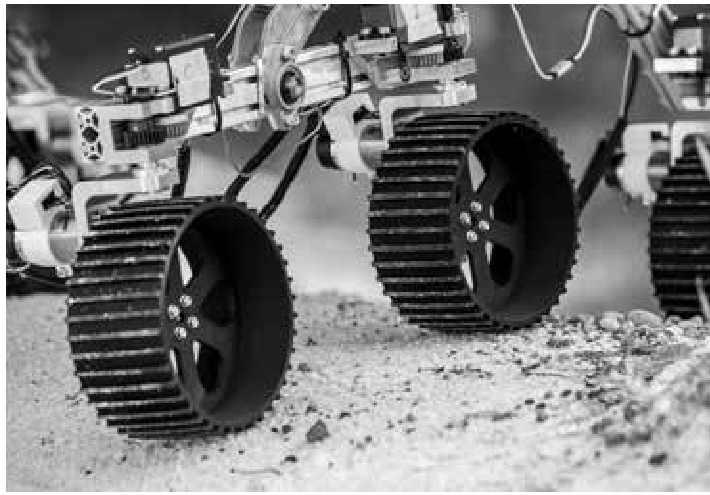
Mars Rover

Pearce Brezmen

A planetary rover was built by final-year Automation and Robotics student Pearce Brezmen.

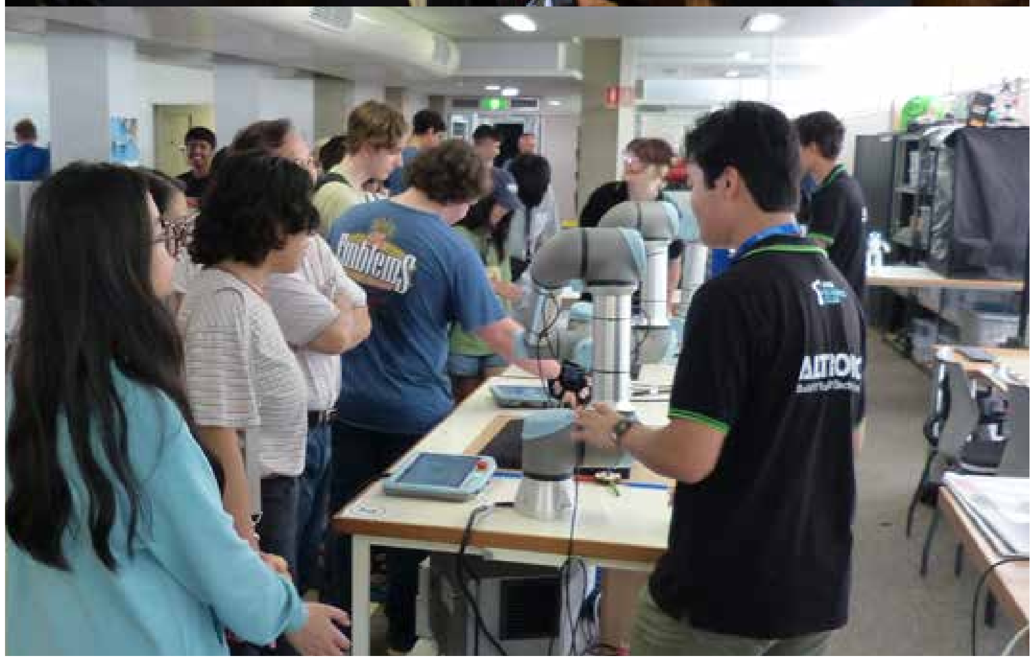
Its mechanical structure follows the 'rocker-bogey' design of NASA and it comprises six driven and steerable wheels. The top is covered by a solar PV panel that feeds into the rover's Lithium battery.

Sensors include shaft encoders on all six wheels, a stereo camera and a Lidar system. The control system was originally a Raspberry Pi, which in the meantime has been updated to an Nvidia Xavier GPU.



UWA Open Day

The UWA Robotics Lab drew large crowds of interested visitors during the last Open Day.



UWA Robotics Club

Robotics Lab Tour

Robotics Outreach

The UWA Robotics Club expanded its outreach activities to inspire and educate the community about robotics and break down the misconception that robotics is an inaccessible or overly complex field.

Students from the club hosted 17 lab tours throughout the year to over 15 different schools and organisations, highlighting to visitors how the lab's research translates into real-world applications, and providing insights into the hands-on learning of students in the automation and robotics engineering major.

As part of the UWA Grand Challenges initiative, the club facilitated a workshop in Bunbury targeting primary school aged children. The workshop aimed to prove that innovation doesn't have to come at the cost of the environment. Participants built robots using everyday materials and learnt the importance of environmental responsibility. Along the way, they also explored the role of robotics in creating a more sustainable future.

UWA Robotics Club also partnered up with Thinkways to introduce robotics to young learners through a fun and interactive hands-on experience. Participants were guided through building their own robots out of motors, sensors, and simple wiring, while incorporating cardboard and other craft materials to bring their creative ideas to life. This workshop encouraged innovation and problem-solving, allowing participants to learn the basics of electronics and robotics in an engaging and accessible way.

Student-Industry Connections

In 2024, the UWA Robotics Club introduced two new industry networking events after noticing a lack of robotics related industry presence in existing networking events at UWA. These were the Speed Networking Night, the club's first networking expo, as well as Industry Games Night, an event in which groups of students teamed up with representatives from leading companies and startups in the robotics space and competed over exciting games and challenges, showcasing their skills and expertise as they rotated through each industry partner.

In August, the club collaborated on a hackathon with Venture UWA: The Student Innovation Centre and ParaQuad Industries: a disability employment service who make some of their revenue from book sales. With over 300,000 books in storage—some waiting to be sorted, some waiting to be sold—space is an issue for ParaQuad. The disposal of the books that can't be sold can be expensive with books going to landfill due to the materials used in bindings. As such, student teams were tasked with identifying strategies and solutions (with a focus on automation and robotics) to create a viable solution for the disposal and/or reuse of these books.

The Rover team of the UWA Robotics Club has built a new planetary rover and will participate in the 2025 Australian Rover Competition in Adelaide

Industry Games Night

Venture UWA and ParaQuad Industries, Hackathon

Tech v Elec

Teaching

Major in Automation and Robotics Engineering

The new Major in 'Automation and Robotics Engineering' started in semester 1 of 2022.

It is based on the three pillars of Mechanical, Electrical, and Software Engineering, augmented by several discipline-specific units in automation and robotics.

The diagram shows all units in this degree with color coding—blue for software units, orange for mechanical, yellow for electrical and green for general engineering units. In dark red are specialist automation and robotics units, while the four elective slots are white.

A new Industry Advisory Panel has been established for this new Major, which contributes to curriculum development and provides additional support for specialist units, through guest lectures and company site visits.

Bachelor of Engineering – Automation and Robotics Engineering Major

1 week	GENG1000* Engineering Practice 1			
Year 1 Semester 1 2023	MATH1011* Multivariable Calculus Prereq: Math Specialist ATAR or MATH1722	CITS1401* Comp. Thinking with Python (or CITS2401** Computer Analysis and Visualisation)	ENSC2004* Engineering Mechanics Prereq: (Physics ATAR or PHYS1030) & MATH1011 APS: PHYS1001	GENG1010* Introduction to Engineering (If bridging: move this to year 2)
Year 1 Semester 2 2023	MATH1012* Mathematical Theory & Methods Prereq: Math Specialist ATAR or MATH1722	CITS2002 Systems Programming APS: CITS1001 or CITS1401 or CITS2401	ENSC1004 Engineering Materials Prereq: (Chem ATAR or CHEM1003) & (Phys ATAR or PHYS1030)	ELEC1303 Digital Systems
1 week	GENG2000* Engineering Practice 2			
Year 2 Semester 1 2024	Elective/Minor	CITS2200 Data Structures & Algorithms Prereq: CITS1001 APS: An additional programming unit	GENG2004 Solid Mechanics Prereq: ENSC2004, MATH1011 & MATH1012	ENSC2003* Eng. Electrical Fundamentals Prereq: (Phys ATAR or PHYS1030) & MATH1011; Co-req: MATH1012 APS: PHYS1001
Year 2 Semester 2 2024	ELEC2311 Digital System Design	CITS3011 Intelligent Agents Prereq: CITS2200	MECH2004 Engineering Dynamics Prereq: ENSC2004	ELEC3020 Embedded Systems Prereq: CITS2002 or CITS2401
1 week	GENG3000* Engineering Practice 3			
Year 3 Semester 1 2025	Elective/Minor	CITS4402 Computer Vision Prereq: software unit	AUTO3002 Mechatronics Prereq: ENSC2003	Elective/Minor
Year 3 Semester 2 2025	GENG3402 Control Engineering Prereq: ENSC2004, MATH1011 & MATH1012	MECH3424 Measurement and Instrumentation Prereq: CITS1001 & ENSC2003	MECH3001 Mechanisms and Machines Prereq: (CITS1001 or CITS2401), ENSC2004, & MATH1011 APS: PHYS1001	AUTO4507 Robot Manipulators and Automation Prereq: software unit
Year 4 Semester 1 2026	GENG5507* Risk, Reliability, Safety Prereq: —, APS: [illegible]	ELEC5506 Process Instrumentation & Control Prereq: GENG3402	GENG4411* Research Project 1	AUTO4508 Mobile Robots Prereq: software unit
Year 4 Semester 2 2026	GENG5505* Project Management Prereq: —, APS: [illegible]	Elective/Minor	GENG4412* Research Project 2	ELEC5016 Power and Machines Prereq: ENSC2003 & MATH1012 APS: PHYS1001

* unit runs in both semesters

ATAR Prerequisites: Math Methods, Math Specialist, Physics, Chemistry (two can be made up with bridging units)

Warman Competition

Travis Ryan

UWA has continued its participation in the prestigious Warman Design and Build Competition International Finals, with students from the AUTO3002 Mechatronics unit showcasing innovative solutions in both 2023 and 2024 competitions.

2023

A team of students tackled the challenge of collecting three squash balls and three tennis balls from various locations on the competition table and delivering them into silos at either end. The team's design and execution earned them 7th place out of 15 participants, maintaining the high standard set by their predecessors.

2023 Team: Agnibho Gangopadhyay, Tiziano Wehrli, Won Chen Qin and Travis Ryan

2024

UWA's new team faced a fresh challenge: retrieving six tennis balls, two of which were elevated above the competition table, and depositing them through a hole in the centre of the table. Despite tough competition, UWA secured 8th place out of 18 teams, a testament to their creativity and problem-solving skills.

2024 Team: Travis Ryan, Joel Smith, Justin Gray and Ben Nicholson

By building innovative robotic systems capable of tackling the dynamic tasks presented by the competition, UWA highlighted its commitment to excellence in automation and robotics. Each team completed perfect runs during the competition only being beaten by teams with faster solutions. These results demonstrate the continuous growth of UWA's mechatronics and robotics program and inspire future teams to push boundaries in engineering and design.

Media Reports

Television Reports and Interviews

- Channel 7, Seven News, Driverless Shuttle Bus at Amberton Beach, 17 Mar. 2023, 18:00
- Channel 7, Seven News, Driverless Shuttle Bus at Amberton Beach, 17 Mar. 2023, 16:00
- Channel 7 Sunrise, Driverless Shuttle Bus at Amberton Beach, 17 Mar. 2023, 5;30

Print Media

- UWA Uniview, Winter 2024, Suspicious Minds, pp/ (4)
- UWA Uniview vol. 51, Summer 2023, Driving Force, Carrie Cox, pp. 26–29 (4)
- Sunday Times, Green promise running on empty, Ross Clarke and Jake Dietsch, 23 July 2023, pp. 13-14 (2)

Online

- UWA News, REV 15 Year Reunion, 7 Dec. 2023
  online: https://www.uwa.edu.au/news/article/2023/december/rev-15-year-reunion
- Create, Engineers Australia, Autonomous bus prepares to hit the road, Chloe Hava, 26 July 2023,
  online: https://createdigital.org.au/autonomous-bus-prepares-to-hit-the-road/?utm_source=ExactTarget&utm_medium=email&utm_campaign=EDM-20220901-General
- UWA News, UWA driverless bus hits the road in first trial of its kind, 24 Mar. 2023,
  online: https://www.uwa.edu.au/news/Article/2023/March/UWA-driverless-bus-hits-the-road-in-first-trial-of-its-kind

Invited Talks and Project Demonstrations

Talks

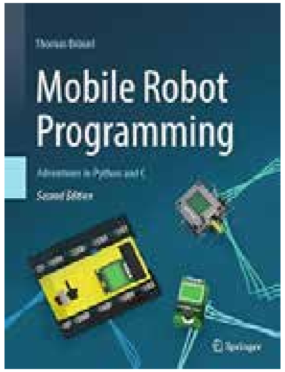
17 Oct. 2024	Invited Talk: Robotics Research at The University of Western Australia, UBM, Munich
26 Apr. 2024	Invited Talk: Autonomous Cars, U3A Midland
6 Oct. 2023	Invited Talk: Electric Vehicles and Decarbonisation, John Glover Symposium 2023
22 Sep. 2023	Keynote: 15 Years of the REV Project, UWA
18 Aug. 2023	Invited Talk: Electric Vehicles – Your next Car, U3A, Melville
1 Aug. 2023	Keynote: Convenient Charging is the Key for EV Adoption, Wevolt Launch, Perth
29 May 2023	Invited Talk: Automotive Future: Autonomous and Connected Cars, U3A Dianella
12 May 2023	Invited Talk: Robotics Research at UWA, Robotics Club and UniHall event
11 May 2023	Invited Talk: Electric Vehicles – Your next Car, U3A, Citiplace, Perth
21 Apr. 2023	Invited Talk: Electric Vehicles – Your next Car, U3A, Como

Project Demonstrations

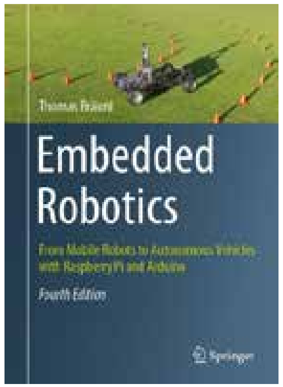
19 Nov. 2024	Robotics Lab and REV Lab Tour for Nagoya University, Japan
17 Apr. 2024	Robotics Lab and REV Lab Tour for University of Electronic Science and Technology (UESTC), China
19. Nov. 2023	Autonomous Vehicle Demonstration, Kumon Advanced Student Forum, Crown Casino, Burswood
17 Nov. 2023	Robotics Lab Tour for St Hilda's Anglican School For Girls
29 Sep. 2023	REV Lab and Robotics Lab Tour for U3A Melville
22 Sep. 2023	REV Lab and Robotics Lab Tour for REV Alumni and Sponsors
21 Sep. 2023	Robotics Lab Tour for 13 Brigade STEM
18 Sep. 2023	Robotics Lab Tour for Newman Senior High School
12 May 2023	Robotics Lab Tour for Tamil Nadu Delegation, India
12 May 2023	Robotics Lab Tour for University Hall student group, Perth
22 Feb. 2023	Robotics Lab Tour for Student groups from Nagoya University and Chua University, Japan
3 Feb. 2023	Robotics Lab Tour for International Space Centre (ISC) Mission Control

Publications

Books



T. Bräunl
Mobile Robot Programming – Adventures in Python and C
Springer Nature, Singapore, 2023



T. Bräunl
Embedded Robotics—From Mobile Robots to Autonomous Vehicles with Raspberry Pi and Arduino,
Springer-Verlag, Shanghai, 2022

Conferences

W. Zhang, X. Kong, C. Dewitt, T. Bräunl, J. Hong, A Study on Prompt Injection Attack Against LLM-Integrated Mobile Robotic Systems, 2nd IEEE International Workshop on Reliable and Secure AI for Software Engineering (ReSAISE 2024), Tsukuba, Japan, Oct. 2024

X. Kong, T. Bräunl, Incident reporting for autonomous shuttles via LLMs: Eglinton case study, ATRF, Melbourne Nov. 2024

M. Finn, T. Bräunl, The Simsulator: An interactive evolved virtual creature testbed, ALIFE 2024, Copenhagen Aug. 2024, pp. (8)

X. Kong, T. Bräunl, M. Fahmi, Y. Wang, A Superalignment Framework in Autonomous Driving with Large Language Models, IV 2024, Jeju Island, Korea, pp. (6)

K. Quirke-Brown, Z. Lai, X. Kong, T. Tan, Y. Du, T. Bräunl, Developing an Autonomous Shuttle Service, Australian Transport Research Forum 2023, Perth, pp. (15)

Journals

T. Drage, K. Quirke-Brown, L. Haddad, Z. Lai, K. Lim, T. Bräunl, Managing Risk in the Design of Modular Systems for an Autonomous Shuttle, IEEE Open Journal of Intelligent Transportation Systems, 2024

Z. Lai, T. Bräunl, End-to-End Learning with Memory Models for Complex Autonomous Driving Tasks in Indoor Environments, Journal of Intelligent & Robotic Systems, March 2023, no. 107, vol. 37, pp. (17)

Current **PhD Research**

Pierre-Louis Constant

Autonomous Marine Vessels

A marine craft depends on two major elements to move through the water: its hull, that allows it to float and evolve through the water, and its propulsion ensemble, that in turn allows for movement and direction. The research for a more efficient marine propulsion process will necessarily involve progress on each of these components.

The current state-of-the-art in electric motors, batteries and material technologies has matured to the point where the association of two efficient technologies, such as electric propulsion and hydrofoils, is not only possible, but shows symbiosis as the benefits of each compensates the drawbacks of the other.

Using hydrofoils and electric propulsion would, on the one hand, benefit from an environmentally friendly propulsion process that does not emit green house gases, and on the other hand, reduce substantially the general opposition to the movement in the marine environment, therefore extending the autonomy of the craft.

The key element that allows for this technological combination is the craft's control system, which should not only connect the two processes, but actively seek to benefit from each of them symbiotically.

In line with these considerations, the object of this research is to develop an automated control system for an electric personal water craft, fitted with hydrofoils, and apply it to a real-life, full size prototype.

Michael Finn

Inheritance of Acquired Behaviours in Evolved Virtual Creatures

The study of artificial life provides the opportunity to model existing forms of life to learn more about our natural world from a different perspective, but it also allows us to explore new forms of life that are unconstrained by the limitations of the physical medium. By building and examining both 'life-as-we-know-it' and 'life-as-it-might-be' we hope to gain insight into the fundamental and often paradoxical nature of life itself.

The concept of Lamarckian inheritance, the idea that organisms are able to genetically pass on adaptations acquired during their lifetimes, has long been debunked in favour of a Darwinian theory of evolution. While it is almost certainly not a part of our real world's simulation parameters, what might be the effect on evolution, and the creatures it produced, if it were?

As this ability could reduce or eliminate the need for an early cognitive development stage, we predict that such a species could evolve faster and more efficiently than its regular counterparts, under the right circumstances. However, there is currently mixed sentiment on whether Lamarckian inheritance can be more effective than Darwinian evolution.

This project seeks to extend the well-known Sims EVC model to include lifetime adaptation mechanisms, then compare how well the creatures evolve under Darwinian and Lamarckian conditions. In the pursuit of this goal we have developed The Simsulator, a modern and open-source implementation of the Sims model designed for easy access by beginners and researchers alike.

Xiangrui Kong

Large Language Models for Autonomous Driving

While LLMs are not yet suitable for direct car control or obstacle detection in real-time, they show great promise in augmenting several autonomous driving tasks, paving the way for safer and more efficient operations. One of the key areas explored was the application of LLMs for path planning. By framing driving challenges in natural language, LLMs can generate actionable waypoints to assist navigation. These waypoints are then rigorously evaluated and executed within a safety-first

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framework. Notably, zero-shot prompting techniques allow pre-trained LLMs to handle this task without extensive fine-tuning, demonstrating the adaptability of these models in solving complex path-planning scenarios.

Autonomous shuttle services, which require detailed and timely incident documentation, can benefit from the image comprehension and disengagement analysis capabilities of LLMs. By analyzing visual data and operational anomalies, LLMs can generate incident reports that enhance safety protocols and ensure regulatory compliance. This system has the potential to become a cornerstone for improving accountability and trust in autonomous vehicle operations.

This year also saw progress in the development of in-car voice assistants powered by LLMs. The goal is to enable these assistants to perform vehicle-oriented commands, such as activating cruise control or initiating emergency braking, alongside general tasks like booking appointments, navigating, and guiding passengers. To support this initiative, I have begun curating a synthesized voice command dataset, encompassing a wide range of driving scenarios. This dataset lays the foundation for robust, real-time voice interaction systems that prioritize user convenience and safety.

Ensuring the reliability and ethical use of LLMs in autonomous driving remains a critical component of my research. I have explored potential vulnerabilities, such as prompt injection attacks, and developed initial strategies to mitigate risks like LLM hallucinations. These efforts aim to align LLM behavior with stringent safety and ethical standards, ensuring that the integration of such models into vehicles promotes public trust and operational integrity.

Moving forward, my research will focus on refining LLM-based systems for autonomous driving. This includes enhancing the capabilities of voice assistants, improving the precision of automatic incident reporting, and advancing techniques for natural language-driven path planning. Additional efforts will be directed toward further securing LLMs against vulnerabilities and ensuring their alignment with ethical principles and safety-critical applications.

Zhihui (Eric) Lai

End-to-End AI Methods in Autonomous Driving

The interest in autonomous vehicles has increased exponentially in recent years. While mediated perceptron (traditional approach) is a proven autonomous driving technology, end-to-end learning approaches have become popular because of its potential to reduce time, human and monetary costs. However, despite the emergence of many end-to-end approaches in recent years, none of these can cope with realistic traffic scenarios as well as the traditional approaches. These methods can either only work in specific weather conditions or in specific limited regions.

Five goals are targeted in this project:

1. Build an end-to-end neural network system that includes temporal and spatial information and outputs predicted trajectories using cameras, ego states, and a roadmap as inputs. This system needs to be able to cope with most complex traffic scenarios and can be continuously improved through online learning.
2. Add auxiliary outputs such as semantic segmentation, object detection, depth information, and motion detection to the model of (2) to enhance the interpretability of the model and make it easier to optimize.
3. Build an end-to-end neural network system that includes temporal and spatial information and outputs predicted trajectories using LIDARs, ego states, and a roadmap as inputs. This system needs to be able to cope with simple traffic scenarios and be able to continuously improve through online learning.
4. Fuse the system of (2) and (3) for redundancy. The fused system should have higher accuracy and stability.
5. In-depth comprehensive comparative analysis between CARLA and AWSIM simulation systems.

Kieran Quirke-Brown

Reactive and Proactive driving techniques

Each year brings new findings within the field of autonomous driving, companies like Tesla and Google continue to push for further advances in the field. There has also been a greater uptake in autonomous driving from the public with more startups pushing new builds every year. Despite this, no one has been able to achieve a fully independent system, specified as level 5 in the SAE model, that can be used freely by anyone. Some of the current drawbacks with the autonomous systems is their ability or inability to make reasonable decisions about future hazards. As such our research is focused on implementing reactive and proactive driving techniques that every day human drivers display to improve the capabilities of autonomous vehicles. This research does more that focus on road trials, although this is a key part, like many of the larger companies but also looks at campus wide usage. The different environments present different challenges and may require different or blended models to be able to drive appropriately in all spaces. In order to achieve the level of automation desired, I have been exploring the latest AI models and combining them with some more classical control techniques. The latest AI models provide a stronger historical understanding of the previously seen data to make better informed decision when compared to the more traditional Neural Network approaches. I believe the stronger historical understanding, i.e. how the vehicle has arrived at where it is, what objects have been moving in its field of vision over the last few frames can assist with making more informed driving decisions. When critical predetermined paths are needed, in cases where a vehicle might be blocking the current path, or an environmental condition may exist that could impede on the vehicle it makes more sense to use a predetermined path to ensure that strict rules are followed. Using model predictive controls or Model predictive path integrals allows for the setup of path constraints, still uses a future prediction model from its horizon forecast and picks the best path moving forward. The combination of these two approaches will help the vehicle tackle generalized and critical path decision making. In addition, I have also been exploring other sensory and input data to improve driving. Looking at building models using LiDAR and integrating the feedback for speed and steering back into the model to improve its functionality and make comparisons on vision vs LiDAR models. A combination of techniques to overcome the variety of challenges will be the key to improving the autonomous drive system as with human drivers the system needs to adapt to the current challenges and being able to context switch between different driving techniques is important.

Machiel van der Stelt

Road Safety

This research revolves around bicycle Road Safety with 3D solution systems and an Autonomous Bus (AB). The project is in cooperation with the Western Australian Centre for Road Safety Research based at the School of Psychology Science at UWA.

The first study of a total of three studies involves the creation of a novel method to accurately measure the distance of the bicycle to a reference point and the functional location of the bicycle within a Virtual Reality (VR) 3D environment. In effect, two novel methods will be compared in respect to accurate and automatic recording of roadside curb deviation and route-location data of a cyclist in a VR simulator environment.

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The second study will use an AB to scan the surroundings with fitted Lidar sensors to detect objects and persons in close proximity. This study will consist of two stages. The first stage consists of a software simulation, where the AB scans for objects and persons on the UWA campus and drives according to the perceived situation.

The third study will evolve around the AB and the intercommunication between Vulnerable Road Users (VRU's) and a AB in different road settings to improve Road Environments with AB's and VRU's.

Oliver Zhang

Model-Based Humanoid Robot Control

Humanoid robots have long been a popular area of research due to their human-like body structures, which allow them to adapt to environments designed for humans. These robots hold immense potential in industries such as manufacturing, healthcare, and services. Achieving such complex tasks fundamentally relies on two key aspects: locomotion control and task execution capabilities.

Locomotion control refers to a humanoid robot's ability to manage and coordinate its movements. This includes transitioning from a static state to walking, running, or performing complex dynamic actions while maintaining balance, generating gait patterns, and coordinating joints. These capabilities ensure stable and smooth locomotion across diverse environments. Task execution capabilities, on the other hand, focus on the robot's ability to complete specific tasks in practical scenarios, such as picking up objects or carrying loads. These two elements are intrinsically interconnected. For example, robust locomotion control ensures stability during task execution, particularly when handling heavy loads.

To enhance the locomotion and task execution capabilities of humanoid robots in complex terrains, our humanoid robot team proposes a flexible control framework. This framework employs Model Predictive Control for real-time control of the robot's lower limbs, ensuring precise and stable movements. Additionally, this control framework integrates imitation learning techniques to replicate human-like natural upper-body movements during task execution. These two control strategies are combined in parallel within a unified whole-body controller, enabling coordinated and efficient outputs.

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