# IEEE Instrumentation and Measurement Society New Zealand Chapter

## Workshop on Sensing, Measurement and Instrumentation for Healthcare, Food, Agriculture, Environment and Security

2 – 3 November 2023
Auckland University of Technology

City Campus

WZ416

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**Workshop webpage**
wise.aut.ac.nz/ims

# Welcome

On behalf of Auckland University of Technology, the School of Engineering, Computer & Mathematical Sciences (ECMS), and the IEEE Instrumentation and Measurement Society NZ Chapter, it is our pleasure to extend a heartfelt welcome to all delegates, presenters, and attendees of the Annual Workshop on Sensing, Measurement, and Instrumentation for Healthcare, Food, Agriculture, Environment, and Security.

We encourage you to engage in vibrant discussions and present your latest research findings, innovative ideas, developments, and applications in sensors and Measurement Technologies. This workshop serves as a shared platform for networking and exchanging insights with fellow researchers. With a diverse array of topics, a substantial number of attendees, and over 40 oral presentations, including four esteemed invited speakers, this year's event promises enriching discussions and valuable collaborations.

We are especially grateful for the support and interest shown by all attendees, speakers, and volunteers, without whom this event would not be possible. Our sincere appreciation goes to our sponsors for their generous financial contributions, enabling the realization of this workshop for the third time at AUT.

Lastly, we invite you to join us at the Thursday Networking Buffet, providing a relaxed setting to foster further connections and discussions.

Dr Akbar Ghobakhlou
AUT University
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Prof Andrew Taberner
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# Workshop Venue

## WZ Building, Lecture Theatre WZ416
## 34 St Paul Street, Auckland

AUT


## SCHOOLS

**Art & Design** – Level 3, WE building
**Business** – Level 1, WF building
**Communication Studies** – Level 12, WG building
**Engineering, Computer & Mathematical Sciences** – Level 3, WZ building
**Future Environments** – Level 11, WG building & level 3, WZ building
**Hospitality & Tourism Reception** – Level 3, WH building & level 3, WB building
**Language & Culture Reception** – Level 4, WB building
**Law** – Level 6, WY building
**Science** – Level 1, WS building
**Social Sciences & Public Policy** – Level 5, WQ building
**Te Ara Poutama Reception**– Level 3, WB building

## STUDENT HUB

Level 2, WA building

## SERVICES AND FACILITIES

**AUT International** – Level 16, WO building
**AUT Security** – Corner St Paul & Wakefield St, WO building
**AUT Shop** – WH102, WH building
**AUT Student Association** (AUTSA) – Level 2, WC building
**Learning Lab** – Level 3, WA building
**Library** – Level 4, WA building
**PinkLime** (print services) – Level 3, WA building
**Student Accommodation** – WR building
**Student Accommodation & Recreation Centre** – WQ building
**Student Counselling & Mental Health** – WB204, WB building
**Student Medical Centre** – WB219, WB building
**Tech Central** – Level 4, WA building

- Student Hub
- Student lounge & study space
- Café
- Library
- Gym
- Conference facility
- City Campus-South Campus shuttle bus stop
- Baby feeding rooms
- Mobility parks
- Defibrillator

**WA4** Hikuwai Plaza, outside library
**WB222** Health & Counselling Centre
**WF01** Lift lobby
**WG1** Help desk in the atrium
**WH209** Piko restaurant
**WO2** Security reception
**WS01** Lift lobby
**WY1** Mayoral Drive – lift lobby
**WQ3** Reception area

For more details, use MazeMaps

## Invited Speakers

Andrew Lowe is a Professor in Mechanical Engineering, and Director of the Institute of Biomedical Technologies at Auckland University of Technology. His current research activities are directed towards measurement and modelling of the cardiovascular system in order to improve cardiovascular risk management in primary and community care and advancing measurement of electrical signals generated by the human body.

David Wilson is an Associate Professor in Electrical Engineering at Auckland University of Technology. Prior to joining AUT he was on the faculty at Karlstad University in Sweden following a position at the Swiss Federal Institute of Technology (ETH) in Zürich, Switzerland. David's main research interests are modelling, simulation and control of industrial processes. Currently he is a director of the research-based Industrial Information and Control Centre (I2C2) where he manages multi-faceted research projects for international clients such as PETRONAS in Malaysia, and large New Zealand companies such as Transpower and Fonterra.

Michael Hayes is an Associate Professor in the department of Electrical and Computer Engineering. He is the director of the Mechatronics Programme and has research interests in Instrumentation, Signal Processing, Embedded Systems, Robot Localisation, Elastic Wave Propagation in Wood, Inverting Electromagnetics, Insect Acoustics, and Synthetic Aperture Sonar Systems.

Paul Harris is a Distinguished Scientist at the Callaghan Innovation. He was awarded the Royal Society R.J. Scott Medal for outstanding contribution to engineering, science and technology and their applications (2009) and the New Zealand Electronic Product Excellence Award (1999). His research includes custom transducers design and development for many applications of ultrasonic technology including: 3D ultrasonic imaging using miniature broadband array technology, single element and array transducers and systems for NDT and medical imaging, annular array transducers for microscope applications, and transducers used for ultrasonic targeted drug delivery in treatment of neural disorders, treatment of hearing loss.

**Workshop on Sensing, Measurement and Instrumentation for Healthcare, Food, Agriculture, Environment, and Security**

| Thursday 2nd November 2023 (Day 1) | Start | End | Activity | Description | Speaker |
|---|---|---|---|---|---|
| | 8:30 AM | 9:00 AM | Break | Registration And Welcome Coffee | |
| | 9:00 AM | 9:15 AM | | Opening Ceremony and Welcome and Housekeeping | Akbar Ghobakhlou |
| | 9:15 AM | 9:45 AM | | Invited Talk: Measuring Biopotentials from Wearable Devices | Andrew Lowe |
| | 9:45 AM | 10:30 AM | Session 1 | Session 1: (45 Minutes) | |
| | 9:45 AM | 10:00 AM | | Data Annotation of Wearable Sensors | Hayden Randles |
| | 10:00 AM | 10:15 AM | | Towards A Consumer-Grade IMU Sensor For Real-Time Data Streaming: A Pilot Study | Chengwei Feng |
| | 10:15 AM | 10:30 AM | | An Eye Tracking Puck for Inexpensive and Accessible Measurement of Eye Motion | Mohammad Norouzifard |
| | 10:30 AM | 11:00 AM | Break | Morning Tea Break | |
| | 11:00 AM | 12:30 PM | Session 2 | Session 2: (90minutes) | |
| | 11:00 AM | 11:15 AM | | Real-Time Measurement and Control of Force and Length of Cardiac Tissue | Emily Lam Po Tang |
| | 11:15 AM | 11:30 AM | | Multi-Jet Injection | James McKeage |
| | 11:30 AM | 11:45 AM | | pyCamSet: Fast and Friendly Multi-Camera Calibration | Robin Laven |
| | 11:45 AM | 12:00 PM | | Development Of a System to Control Skin Tension During Needle-Free Drug Delivery | Julia Nadler |
| | 12:00 PM | 12:15 PM | | Calibrating Spatial Sensitivity of a Flow-Through Calorimeter | Maryam Rahmani |
| | 12:15 PM | 12:30 PM | | Energy Optimal Control of Mobilerobots in Offshore Aquaculture | Loulin Huang |
| | 12:30 PM | 1:30 PM | Break | Lunch Break | |

| Workshop on Sensing, Measurement and Instrumentation for Healthcare, Food, Agriculture, Environment, and Security | | | | | |
|---|---|---|---|---|---|
| Thursday 2nd November 2023 (Day 1) | Start | End | Activity | Description | Speaker |
| | 1:30 PM | 2:00 PM | | Invited Talk: Exploiting Cheap Imaging Technologies for Quality Control in The Food Processing Industries | David Wilson |
| | 2:00 PM | 3:00 PM | | Session 3: (60 Minutes) | |
| | 2:00 PM | 2:15 PM | Session 3 | Enhancing Healthcare Efficiency with RFID Technology: Tracking ICU Resources in Real Time | Biswash Paudel |
| | 2:15 PM | 2:30 PM | | UAV-Enabled Software Defined Data Collection from An Adaptive WSN | Pejman Karegar |
| | 2:30 PM | 2:45 PM | | Early-Stage Human Tumour Detection with SWB Antenna Array Imaging | Wasan Althubitat Alamro |
| | 2:45 PM | 3:00 PM | | Robust In-Vehicle Vital Sign Monitoring with Mmwave Radar | Anuradha Singh |
| | 3:00 PM | 3:30 PM | Break | Afternoon Break | |
| | 3:30 PM | 5:00 PM | Session 4 | Session 4 :(90 Minutes) | |
| | 3:30 PM | 3:45 PM | | Instrumentation And Measurements of a Large Aperture Antenna in New Zealand for Deep Space Tracking | Asif Rayhan Rasha |
| | 3:45 PM | 4:00 PM | | Sensor Fusion-Based Crash Detection Model for Autonomous Vehicles Accident Reconstruction | Mohammad Mahfuzul Haque |
| | 4:00 PM | 4:15 PM | | Aerial Visual Inspection of Electrical Conductors: Leveraging Domain Knowledge for Automation | Zhicheng Pan (Steven) |
| | 4:15 PM | 4:30 PM | | Visual Marker Design Optimization for Webcam Eye Tracking Systems Calibration | Xiang Ma |
| | 4:30 PM | 4:45 PM | | Dynamic Emotional Landscapes in Video Content: An Innovative Approach for Real-Time Emotion Visualization | Thu Giang Mai |
| | 4:45 PM | 5:00 PM | | Modelling A Camera Spectral Sensitivity Function | Sanush Khyle Abeysekera |
| | 5:00 PM | 5:45 PM | | IMS Committee Meeting | |
| | 6:00 PM | 7:30 PM | Break | Networking Buffet | |

| Workshop on Sensing, Measurement and Instrumentation for Healthcare, Food, Agriculture, Environment, and Security | | | | | |
|---|---|---|---|---|---|
| Friday 3rd November 2023 (Day 2) | Start | End | Activity | Description | Speaker |
| | 9:00 AM | 9:30 AM | | Invited Talk: Transcranial Ultrasound for Drug Delivery | Paul Harris |
| | 9:30 AM | 10:30 AM | Session 1 | Session 1: (60 Minutes) | |
| | 9:30 AM | 9:45 AM | | Multi-Measurement Investigation of Feed Supplements in A Rumen Bioreactor | Chernet Woju |
| | 9:45 AM | 10:00 AM | | Assessment Of Swallowing and Phonation with High-Density Electromyogram Recordings | Leo K Cheng |
| | 10:00 AM | 10:15 AM | | Simultaneous Extracellular and Intracellular Recordings of Rat Gastric Slow Waves | Omkar N. Athavale |
| | 10:15 AM | 10:30 AM | | A Smart Electrode for Determining Timber Properties of Logs | Bill Heffernan |
| | 10:30 AM | 11:00 AM | Break | Morning Tea Break | |
| | 11:00 AM | 12:30 PM | Session 2 | Session 2: (90 Minutes) | |
| | 11:00 AM | 11:15 AM | | Investigating Toroidal CT For High Impedance Faults Detection in LV Distribution Network | Minyu Zhang |
| | 11:15 AM | 11:30 AM | | Data Acquisition System for An Electromagnetic Field Sensor Array | Jarrod Zhu |
| | 11:30 AM | 11:45 AM | | An Intelligent Approach for Non-Destructive Asphalt Pavement Density Measurement | Muyang Li |
| | 11:45 AM | 12:00 PM | | Impact Solenoid Modelling for Current-Estimated Piston Position | Sam Anthony Spekreijse |
| | 12:00 PM | 12:15 PM | | Electromagnetic Field Detector and Amplifier Design for An Electromagnetic Field Sensor Array | Stanley Perry |
| | 12:15 PM | 12:30 PM | | Harnessing Industrial Sensor Data for Anomaly Detection With LSTM-VAE: A Cybersecurity Perspective | Yuri Andrea Pinto Rojas |
| | 12:30 PM | 1:30 PM | Break | Lunch Break | |

**Workshop on Sensing, Measurement and Instrumentation for Healthcare, Food, Agriculture, Environment, and Security**

| | Start | End | Activity | Description | Speaker |
|---|---|---|---|---|---|
| Friday 3rd November 2023 (Day 2) | 1:30 PM | 2:00 PM | | Invited Talk: An Efficient Electromagnet Driver for Groundwater Sensing | Michael Hayes |
| | 2:00 PM | 3:00 PM | | Session 3: (90 Minutes) | |
| | 2:00 PM | 2:15 PM | Session 3 | A Wearable Open-Source Electrical Impedance Tomography Device | Andrew Creegan |
| | 2:15 PM | 2:30 PM | | Ionic Hydrogel Used for Underwater Impedance Measurement | Cheng Huan Lu |
| | 2:30 PM | 2:45 PM | | An Advanced Smart Traffic Light System for Real-Time Emotional Well-Being Monitoring in High-Stress Environments | Minh Nguyen |
| | 2:45 PM | 3:00 PM | | Electric Impedance Muscle Analysis for Wearable Robotic Devices | Alberto Gonzalez Vazquez |
| | 3:00 PM | 3:30 PM | Break | Afternoon Break | |
| | 3:30 PM | 5:00 PM | Session 4 | Session 4: (90 Minutes) | |
| | 3:30 PM | 3:45 PM | | A Gen AI Approach of Emotion Sensing for Autism Therapies | Boyuan Qian |
| | 3:45 PM | 4:00 PM | | Deep Learning for Understanding Overlapping Shoeprints in Noisy Images | Chengran Li |
| | 4:00 PM | 4:15 PM | | Utilizing Semi-Supervised Deep Learning to Estimate Fur Seal Population Counts | Rujia Chen |
| | 4:15 PM | 4:30 PM | | Application Of Machine Learning for Asthma Risk Prediction | Widana Kankanamge Darsha Jayamini |
| | 4:30 PM | 4:45 PM | | Role Of Augmented Reality Model Integrated with AI In Improving First-Aid Delivery in The Healthcare Sector | Rawinder Singh |
| | 4:45 PM | 5:00 PM | | Indoor Localisation & Human Sensing: Challenges and Opportunities | Fakhrul Alam |
| | 5:00 PM | 5:15 PM | | Students Awards and Closing Ceremony | |

# Contents

# Measuring Biopotentials from Wearable Devices

Andrew Lowe
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Measuring high-quality electrical signals (biopotentials) from heart (ECG), brain (EEG), muscles (EMG) and other body systems are crucial in healthcare, and valuable in fitness and increasingly, consumer entertainment. Traditional wet/gel electrodes are difficult and time-consuming to apply, irritate skin and fail over time, or are highly affected by movement. Consequently, there is increasing interest in using dry and even capacitive electrodes in wearable devices.

In this MBIE-funded research we investigate a number of the more critical factors that degrade biopotential signal quality as recorded by wearable, biopotential sensors. These factors include electromagnetic interference, electrode-tissue impedance, skin-endogenous biopotentials, electrical double-layers, and tribo-electric effects. We review the theory and practice of mitigation strategies related to electrode geometry, material choice, circuit design, system design and model-based signal processing.

We find that best-practice instrumentation design for wet/gel systems is insufficient to adequately address the issues arising in dry electrodes. Further, the various sources of noise are highly inter-related in both causes and effects, resulting in limited effectiveness of noise reduction methods targeting any individual source.

# Data Annotation of Wearable Sensors

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The annotation of data is an important part of making measurements. Without proper context of when/where/how/why the measurement was made, and who/what it was made by, valuable data can become unusable to third parties, and insights can go unnoticed. Work is being undertaken to implement the IEEE 11073 family of standards which is a standardised way of annotating data in a healthcare context. These standards ensure consistency and accuracy in the annotation process, making it easier for multiple users to interpret the same data. These standards allow for the annotation of data objects that represent devices and the observations that those devices generate. This family of standards also provides protocols for the communication of medical devices, allowing easy connection and communication of devices within a computer network. Unlike some other data annotation standards, IEEE 11073 can describe generic sensors and measurements without the need for them to be predefined by the standard itself. Devices can be categorised by type, such as its operating principle, power source, and observations it can generate. Observations are then classified by the data-structure of the measurement – such as Arrays, String, Compound, Discrete, Numeric, Boolean. This annotated data format will be useful for the 12 Labours project being undertaken at the Auckland Bioengineering Institute to allow researchers and clinicians to make better decisions in both research and clinical spaces.

# Towards a Consumer-Grade IMU Sensor for Real-Time Data Streaming: A Pilot Study

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Contemporary research in kinesiology, healthcare, sport equipment, ergonomics and workspace safety suggest a growing trend and interest in applications of Inertial Measurement Units (IMUs).

In the pursuit of an open-source solution for a low-cost consumer-grade Inertial Measurement Units (IMU) sensor that could provide real-time data streaming, in October 2023 there are 149 public repositories (https://github.com/topics/imu-sensor) suggesting even broader application contexts, highlighting various challenges associated with sensor integration and data interpretation. To address the need for a generic low-cost real-time inertial sensor data streaming system, this research presents: (1) a low-cost consumer-grade battery-powered IMU sensor development coupled with (2) Java-based demo software. By employing the ESP8266 microcontroller paired with the JY61 sensor module it is possible to achieve data streaming required for common human activity detection. Although the initial validations did not include quantification of known-phenomena such as acceleration noise resulting in erroneous position calculation drift or data rates variation over time, the tests conducted on 50 and 100 Hz data sampling rates suggest application potential for common human activities applicable to kinesiology and biomechanics research. We aim to extend the application of the presented ESP8266-JY61-based system from athletic training to healthcare, hence promoting its adoption within the broader research community interested in rehabilitation, work safety, elderly care and activity monitoring in real time. Future directions include extending this research to diverse motion patterns and future sensor design refinements including domain specific sensor design alternatives emphasising open-source collaboration and adoption within a broad research community.

# An Eye Tracking Puck for Inexpensive and Accessible Measurement of Eye Motion

Mohammad Norouzifard[1], Jason Turuwhenua[1], Simon Fraser[2], Hamid GholamHosseini[3], Joanna Black[1], Misty Edmonds[4], Benjamin Thompson[1,5] and Rebecca Findlay[1]

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Optokinetic nystagmus is a distinctive involuntary eye beating that naturally occurs when a patient perceives a constant drifting motion. In clinical practice, an optometrist will use OKN to determine visual acuity (the measure of detail as determined by an eye chart) in non-verbal patients such as young children or non-verbal adults. A spinning drum apparatus with vertical stripes of known spatial frequency is spun in front of the patient. If motion is perceived, then OKN will be induced in the eye if it is not then it will not be. The spatial frequency of the drum is varied until the threshold frequency is found (the visual acuity). However, this is a highly subjective process. We have been working on an eye tracking solution to the objective measurement of OKN. We report here a very inexpensive eye tracker designed specifically for the measurement of optokinetic nystagmus (OKN) in response to a drifting stimulus synched to a stimulus display and analysis system. Our device makes specific use of the fact that OKN is yoked across eyes, and that vision testing is generally performed monocularly (per eye). Our solution is an eye tracker contained in a simple "puck" that slips into standard trial frames used in optometric testing to both occlude and at the same time measure the untested eye. Our device is integrated with a system that presents stimulus and then automatically measures the presence or absence of OKN. Results suggest that this device could present a promising solution for inexpensive and accurate measurement of OKN, and moreover the detection of visual acuity deficits in non-verbal adults and young children. Detecting amblyopia in its early stages empowers healthcare providers to initiate timely interventions, potentially preserving and improving the visual health of young children. This innovation has the potential to revolutionize the way amblyopia is diagnosed and treated, offering hope for a brighter future for those at risk of visual impairment.

# Real-time Measurement and Control of Force and Length of Cardiac Tissue

Emily J. Lam Po Tang, Toan Pham, Jordyn Chan, Kenneth Tran, June-Chiew Han, Khoon Lim, Poul M. F. Nielsen and Andrew J. Taberner

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Cardiac trabeculae are small samples of heart muscle tissue that can be dissected and studied in vitro to better understand the underlying physiology of cardiac muscle. However, instruments for such experimentation often involve mounting the delicate muscle to a force sensor at one end and a motor at the other often using hooks, the position of which are often measured using expensive equipment such as laser interferometers. While this approach allows precise force and length measurement and control, the length of the muscle is determined by the position of the sensor and actuator, where in reality, the muscle tissue may move with respect to these, and does not always contract uniformly.

Here, we present a novel device that allows trabeculae to be secured by a visible-light photo-initiated hydrogel, manipulated via a cantilever force sensor, and stimulated while being imaged. We use our robust, accurate image registration techniques in real-time (164 Hz) to measure trabecula, cantilever and gel deformation using the intrinsic features of the object of interest during trabecula contraction. This provides a measure of trabecula displacement and force production during twitches. These estimates are used to inform feedback control of muscle length and force by controlling a motor to which the force sensor is attached. This approach removes the need to use expensive equipment to track the movements of the hooks to which the muscle is attached, and allows feedback control of any point in the muscle itself, instead of only ends of the tissue.

# Multi-jet Injection

James McKeage, Andrew Tan and Andrew Taberner
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Intravenous (IV) drug delivery is currently the best method of delivering large drug volumes through the skin. Unfortunately, this approach is time consuming, requires a hospital or infusion centre, and is responsible for approximately 50% of the total treatment cost. In contrast, drug delivery to the subcutaneous fat can lower consumer costs, reduce the burden on the healthcare system, and offers the potential for self-administration (eg. Insulin). Many highly effective medicines are currently delivered intravenously simply because the delivery volume is greater than the typical ~2 mL limit for subcutaneous delivery. While some recent technologies have been developed for large volume subcutaneous delivery these are slow, inconvenient, and based on needles. We are developing a novel approach based on needle-free jet injection to deliver very large volumes as many smaller, simultaneous injections. By breaking-down the injection in this way we can avoid the volume limits of subcutaneous injection and the need for a large needle to perform the delivery.

In this talk I will present our initial multi-jet injection prototype, and discuss the measurements involved in assessing the consistency of jet development, and drug delivery, when forming a liquid into multiple simultaneous jets.

# pyCamSet: Fast and Friendly Multi-Camera Calibration

Robin Laven[1], Thiranja Prasad Babarenda Gamage[1] Gonzalo Maso-Talou[1], Martyn Nash[1,2], and Poul Nielsen[1,2]
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Cameras are powerful measuring devices, with a range of impressive temporal and spatial resolutions. However, the calibration model of a camera can be complicated - especially if multiple cameras are used. While multi-camera models are common in the literature, there is no simple solution for robustly calibrating a multi-camera system. The standard computer vision toolkit, OpenCV, can only calibrate up to a stereo pair. Other tools, such as CERES by Google, require specialist knowledge to interface with and extend. To address these challenges, we present pyCamSet, an easy-to-use open source python library for modelling and calibrating camera systems. It builds upon the existing OpenCV python library to provide: 1. Easy, single function, calibration. 2. Calibration of "n" camera systems. 3. An object oriented approach to camera systems. 4. Clear communication about calibration results. pyCamSet is designed with extension in mind, and provides methods for defining new types of calibration targets, and new calibration methodologies. As an example, we use pyCamSet to calibrate a camera system for localised tracking of skin surface deformation for applications in breast cancer biomechanics. In summary, pyCamSet provides a solution for instrumentation systems that require multiple cameras, making calibration and system use quicker across many measurement tasks.

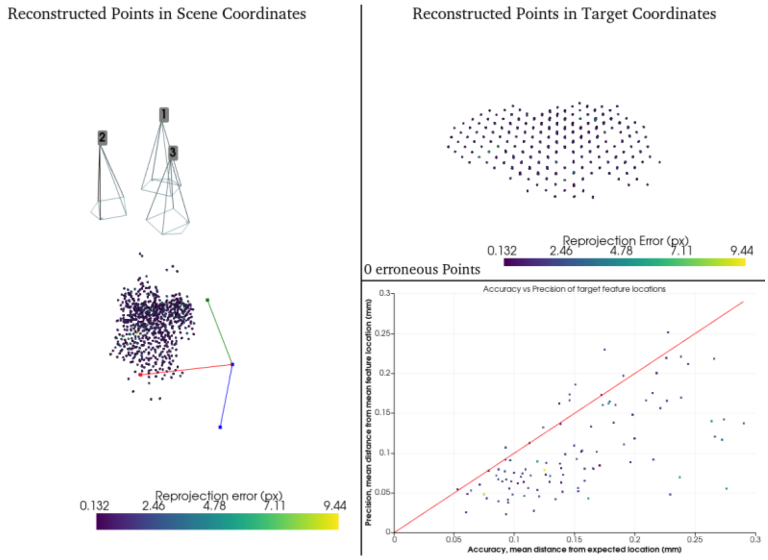


Figure: 1. An example of a selection of output results for the calibration of a prototype camera system consisting of 31 megapixel cameras that can be applied to tracking deformation of the skin surface. The results show the reconstruction of detected features of the calibration target in world and object coordinates, a visualisation that highlights numerically suitable but physically inconsistent calibrations. The calibration was performed using a ChArUco based calibration target.

# Development of a System to Control Skin Tension During Needle-free Drug Delivery

Julia Nadler
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The average person receives 165 needle sticks throughout their lifetime. Despite this being common practice, further research is needed to improve the experience of the patient and the health professional, while receiving and administering drugs. Needle free drug delivery via liquid jets is an appealing option for those with needle phobia, yet the ideal conditions for conducting these injections are still being explored. Many drugs are delivered by attempting to pierce the skin barrier, which is an anisotropic, non-linear, highly variable biological material. Previous studies have failed to explore the effect of in-plane stress applied to the skin before and during drug delivery injections.

We are developing a uniaxial stretching device to explore the impact of tensioning skin in-plane and with known in-vivo orientations, prior to and during injections. This system has three force sensors to measure 1) the in-plane skin stretching force 2) normal force, and 3) needle- or jet-penetration force; a linear motor to stretch the skin; and a voice coil motor to pierce the skin with needles or liquid jets. By controlling the in-plane skin stress, and its direction with respect to the known tissue stiffness anisotropy we hope to find the ideal skin tension to apply prior to injection. We hope that this knowledge can then be used to improve existing and new drug delivery techniques.

# Calibrating Spatial Sensitivity of a Flow-Through Calorimeter

Maryam Rahmani, Kenneth Tran, June-Chiew Han, Andrew Taberner
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We have designed and constructed a flow-through calorimeter that can measure heat production of respiring muscle. The calorimeter consists of a measurement chamber that hosts the muscle. Two thermopiles are positioned below and external to the measurement chamber – upstream and downstream of the muscle. Experimental solution flows along the muscle and, hence, the sensitivity of the thermopiles depends on the position of the muscle relative to the two thermopiles. To calibrate the thermopiles, a thin-film resistor (1 KΩ) soldered to a flexible circuit film was used. Calibration was performed by liberating a square wave of electrical power using the resistor. The resistor was translocated along the measurement chamber. The flow rate of the solution was controlled at 0.6 µL/s – a rate of flow that maximises the viability of muscle. The calibration of the calorimeter revealed its maximum sensitivity to be 3198 V/W when the resistor was positioned at the proximal edge of the downstream thermopile. Sensitivity was zero when the resistor was at the middle of the upstream thermopile. From these calibrations, future experiments would have the centre of the muscle positioned at the location where the maximum sensitivity is obtained.

# Energy Optimal Control of Unmanned Underwater Vehicles (UUVS) in Offshore Aquaculture

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In offshore aquaculture remote from the traditional power grid, optimal energy utilization is essential for the operations of mobile robots such as unmanned underwater vehicles (UUVs) which are typically equipped with power supply units of limited capacity. It is also critical for enhancing both productivity and the sustainability of production processes in offshore aquaculture in which the application of UUVs and other unmanned robotic systems is becoming popular due to factors like harsh working environments and labour shortages.

This talk introduces the background and motivation for the research on energy-optimal control of UUVs in offshore aquaculture undertaken at Auckland University of Technology. It covers key issues related to controller development including the modelling of UUVs and their working environments in a fish farm in New Zealand, control methodologies, high-fidelity simulation for controller tuning and validation, challenges in controller's real-time implementation and approaches to address these challenges.

# Exploiting Cheap Imaging Technologies for Quality Control in the Food Processing Industries

David Wilson
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The Industrial Information & Control Center has for some years undertaken projects exploiting the fact that cheap imaging hardware can be used to quantify what would otherwise be hard to measure quality control variables in the food processing industries. While cameras and videos have long been used in manufacturing, they have often only been used for error detection, or perhaps sorting. This talk will cover two applications of using imaging in the food processing industries, namely assessing the appearance of milk powder, and the extent of drying in dried fruit. The first application is to quantify the "lumpiness" of milk powder. This project, in collaboration with Fonterra, was initiated because customers were concerned that different batches of supposedly similar milk powder looked, and behaved, noticeably differently. Such a nuanced measurement is clearly problematic, but with current 3D scanning software using something as simple as a cell phone, we were able to quantify using a variety of methods, the lumpiness of powder. Such a metric can then be used to correlate and subsequently improve the production operations to make a consistent product. A second imaging application is where we are interested in drying fruit. In this application, the idea is to remove the moisture to improve the shelf life of the food, but without overly changing the look and taste of the fruit pieces. For this we used a clever colour analysis, combined with some machine learning to improve the robustness of the technique.

# Enhancing Healthcare Efficiency with RFID Technology: Tracking ICU Resources in Real Time

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In the realm of critical healthcare, accuracy, and timeliness of data are indispensable for saving lives and delivering high-quality care. New Zealand faces a challenge with a low ICU bed per capita ratio, adversely affecting patient care. The availability of ICU beds hinges more on adequate staffing than equipment, with nurse-to-patient ratios varying based on patient severity. A low ICU bed capacity is associated with increased mortality rates, particularly during infectious outbreaks. Accurate knowledge of national ICu bed capacity is vital for effective healthcare planning. The exchange of timely health data is especially critical during pandemics. Minimum datasets (MDS) facilitate data organization, yet the COVID-19 crisis exposed flaws in reporting ICU bed availability. The Critical Healthcare Resources Information System (CHRIS) relies on manual data entry, necessitating innovation. This study devolves into the potential use of Radio Frequency Identification (RFID) technology, specifically UHF RFID, to enhance the accuracy and timeliness of ICU data, with a particular focus on pandemics. The project explores how RFID technology can track ICU bed availability, as well as other vital resources like nurses, ventilators, filters, and personal protective equipment (PPE). A dashboard is designed to receive and display data collected by RFID antennas, providing information on the types, quantities, and locations of available ICU resources. An experiment employing an Impinj R700 RFID Reader and various RFID tags in a paramedic room at Auckland University of Technology proves successful in showing the items in the dashboard. This technology offers real-time tracking and updates the ICU resources, greatly enhancing healthcare efficiency and the quality of patient care.

# UAV-Enabled Software Defined Data Collection from an Adaptive WSN

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Unmanned aerial vehicle (UAV)-based data gathering from wireless sensor networks (WSNs) is one of the recent research topics that has currently attracted research interest. One of the challenges for the UAV-aided WSN data collection efforts is to design an energy-efficient UAV/drone communication with arbitrarily dispersed ground sensors by improving the ground network structure. This research project aims to develop a technique titled 'UAV Fuzzy Travel Path' that supports UAV smooth path design and enables ground network topology shifting. A comprehensive UAV-based data collection model is proposed to enable dynamic orchestration/re-orchestration of wireless ground sensors to jointly improve network performance and UAV path fluidity. This provides a more flexible ground network framework that can be restructured based on network demands and UAV optimal paths, effectively allowing for a software-defined network concept. According to simulation testing findings, the proposed software-defined ground network system demonstrates encouraging results in terms of network performance metrics including energy consumption of UAV in comparison to ground sensor nodes energy usage, packet delivery rate, and the communication time of the ground orchestrated or/and re-orchestrated network.

# Early-Stage Human Tumour Detection with SWB Antenna Array Imaging

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Lung and skin tumours are one of the most prevalent and lethal types of human diseases. This research presents a custom-designed super wideband (SWB) antenna for medical imaging, with a focus on early-stage lung and skin tumour detection based on dielectric contrast between the healthy and unhealthy tissues. The proposed antenna is arranged in a circular array of eight elements around the tissues to assess its capability in detecting different tumour types, depths and sizes, as well as the potential of the antenna's super wide bandwidth in enhancing the spatial resolution of the reconstructed images.

Two life-size torso phantoms are constructed using various human tissue-equivalent materials. Their dielectric properties are characterised over the covered frequency range of 3.1–40 GHz using the SWB antenna. Each phantom has five concentric layers (skin, fat, muscle, rib bone and lung) to mimic the torso structure. Seedless red grapes are used to represent the tumour, and embedded in different locations inside the phantom. The backscattered signals from all array elements are recorded and analysed in terms of the magnitude of their reflection coefficients. The recorded data is further processed with beamforming algorithms to reconstruct the image. A successful detection of the tumours with high spatial resolution is achieved.

# Robust In-Vehicle Vital Sign Monitoring with mmwave Radar

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Efficient health management, particularly in the context of driver health monitoring, has become increasingly important. However, in-vehicle vital sign monitoring faces several formidable challenges that impede its practical implementation. Conventional systems often falter in accurately estimating vital signs when multiple passengers occupy a vehicle, interfering with other passengers' respirations and body movements. Additionally, the in-vehicle environment is inherently noisy due to engine vibrations and road conditions, further compromising the precision of vital sign monitoring systems. To address these issues, we present a robust approach that leverages mm-wave radar technology, incorporating the resonance sparse spectrum decomposition (RSSD) and harmonic utilized algorithm (HUA) to enhance heart rate extraction. RSSD adeptly counters clutter and random body movement effects, while HUA harnesses harmonics to refine heart rate estimation. Further, we introduce an adaptive vibration feedback cancellation technique to eliminate dashboard-induced vibrations, a common source of noise. The mm-wave radar's wide bandwidth ensures our algorithms process signals reflected from distinct individuals within the complex multipath conditions prevalent in vehicle interiors. This segregation ensures accurate driver-specific vital sign estimation while filtering out noisy signals from other passengers. The method's efficacy is validated in a controlled lab environment, where radar platform vibrations are simulated using motors to replicate real-world dashboard conditions. The proposed method enhances the driver's safety and well-being by overcoming the intricate challenges associated with in-vehicle driver vital sign monitoring.

# Instrumentation and Measurements of a Large Aperture Antenna in New Zealand for Deep Space Tracking

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The surge in space explorations and study of the Earth's environment from space in recent years has escalated the demand for satellite ground stations equipped for deep space tracking. Space agencies such as NASA, ESA and others have their dedicated Deep Space Network spanned across different continents. However, they also rely on other observatories for communications with their spacecraft and satellites.

To cater to this growing demand, Space Operations New Zealand recently acquired the Warkworth Radio Observatory to provide deep space tracking while supporting Radio Astronomy. To equip the observatory with deep space tracking capabilities, it is essential to install new receiver and transmitter systems. As a prerequisite, it is necessary to check the surface quality and optical alignment to assess the suitability for the upgrade. Conventional measurement methods such as holography and photogrammetry are time-consuming, require specialized setup, and are impractical in this case.

In response to these challenges, this presentation explores the application of terrestrial laser scanning, a relatively novel method, for the comprehensive measurement of the 30 m Cassegrain Antenna. The exhibition will discuss the scanning process, data processing techniques, and the outcomes of these measurements. The preliminary results of measurements are published in the Journal of Astronomical Instrumentation.

# Sensor Fusion-based Crash Detection Model for Autonomous Vehicles Accident Reconstruction


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Research continues to contribute increasingly to the discipline of autonomous vehicles to improve advanced driver assistance efficiency and driving safety. Although developments in this field are significant, conducting vehicle crash analysis is still challenging when accidents occur. Challenges for vehicle crash investigators include data acquisition from a damaged recording module due to post-crash fire, possible removal of the module by a guilty party, and data collection technical challenges. The major problem for autonomous vehicle crash analysis is reconstructing an accurate description of what took place, taking into account that no driver error is involved in fully autonomous vehicles. This research proposes a Vehicle Crash Detection Model (VCDM) for reconstructing accurate descriptions of autonomous vehicle accidents from available sensor data. This study uses MATLAB-Simulink and its tools to reconstruct vehicle trajectories and implement a vehicle crash reconstruction model. A surround vehicle sensor fusionbased remote sensing technique is used for object detection and tracking, followed by trajectory-based events detection. The model facilitates crash reconstruction by detecting trajectory-based events such as normal driving, cut-in, conflict, potential crash, and crash events, which can be used by crash analysts to analyze the sequence of events leading to the accident. The evaluation result reflects that the proposed model performs better than two other recently proposed approaches and may be of use in future autonomous vehicle forensics.

# Aerial Visual Inspection of Electrical Conductors: Leveraging Domain Knowledge for Automation

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Monitoring the condition of assets such as electrical conductor lines is one of the contributing factors in the condition-based risk management (CBRM) model, particularly in predicting the probability of failure and remaining life expectancy (RLE). Manual condition assessment of such a vastly distributed network of powerlines is costly and time consuming. This research seeks to develop an automated machine vision strategy that inspects bare, stranded copper conductors of an electricity distribution network from images taken by drones flying above the lines. The outcome of the visual inspection, referred to as the "visual score" is a key component in calculating the overall health index in the CBRM model. Visual inspection of electrical assets is widely adopted by the electricity distribution industry due to its non-intrusive nature, which eliminates the need for de-energization and therefore minimizes operational disruptions. The inspection pipeline consists of two major tasks: the identification of conductors from input drone images, and the subsequent visual condition assessment from the identified region-of-interest. The first step is necessary because the conductors typically occupy less than 1% of the input image area. We exploited and took advantage of domain-specific knowledge to help implementing the automated pipeline. For example, the unique helical winding pattern of the strands, the linearity of a span within an input image, and the colours of the copper patina. The proposed automated pipeline can reliably locate the conductor spans from the input images with high accuracy. The generated region-of-interest images are saved locally for further analysis of visual condition. Various methods have been explored to classify a conductor section into predefined condition categories, which is encoded by the ordinal visual score. These methods include training a deep convolutional neural network; or considering shape factors from the image processing perspective to classify those severely degraded conductor sections with one or multiple branching broken strands.

# Visual Marker Design Optimization for Webcam Eye Tracking Systems Calibration

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Eye tracking is expected to be a major human-computer interaction technology in the future.[1] The first step of using webcam eye tracking system is calibration. Its accuracy not only depends on hardware parameters, but also on human visual cognition. In this study, we investigate the impact of various common marker designs [2] on the measurement accuracy of webcam eye tracking systems [3] through experimental comparison. We explore the influence of visual perception factors, such as visual attention, contrast/movement sensitivity, internal generative mechanism, in the design of the eye tracking calibration systems [4]. These results provide valuable insights into the importance of considering visual perception characteristics in the design of eye tracking systems and highlights the need for further research to ensure the development of accurate and effective human-computer interaction technologies.


**Fig.2** – Five types of marker design.

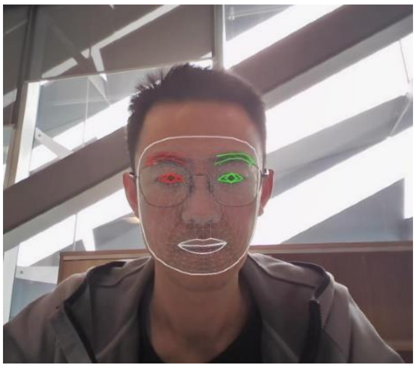

**Fig.1** – Feature mesh of the webcam eye tracking system.

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# Dynamic Emotional Landscapes in Video Content: An Innovative Approach for Real-Time Emotion Visualization

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Our research presents a novel method for real-time emotional visualization within video content, emphasizing viewer interaction and emotional comprehension. Harnessing the power of sophisticated emotion detection algorithms, video analysis techniques, and graphical visualization, we unveil the dynamic emotional fluctuations throughout a video's timeline. The system generates two distinctive graphical representations, capturing temporal changes in seven recognized emotions and the average occurrences of happiness and sadness. This innovative tool brings remarkable value for parents selecting appropriate content for their children, young viewers making conscious viewing decisions, and industry professionals seeking to optimize emotional engagement in their filmography. Our findings underscore the potential of this approach in enriching emotional engagement, augmenting viewer understanding, and steering emotional responses. The presented methodology opens novel avenues for content creation, pioneering new strategies for emotional resonance in video consumption.

# Modelling a Camera Spectral Sensitivity Function

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Cameras play a pivotal role in diverse computer vision applications, spanning colour rendering, image classification, multispectral imaging, and robotics. However, they often remain the least well-understood element of a computer vision system. In our research, we introduce an approach for recovering the spectral sensitivity function of cameras with linear or non-linear responses, using Singular Value Decomposition (SVD). While traditional methods rely on controlled laboratory setups featuring monochromators, integrating spheres, and spectrometers to measure camera sensitivities, our approach utilizes a colour checker under a programmable LED-based illuminant with a known spectral power distribution. We commence by presenting a generalized camera model that establishes a direct link between scene irradiance and pixel intensity, creating a foundation applicable to any camera system. Subsequently, we propose a data filtration method to selectively retain pixel intensity data that remains unaffected by the camera's non-linear transformations. Finally, the camera sensitivity is calculated using a set of basis functions from SVD. The basis functions are generated using a comprehensive database encompassing 124 camera sensitivity functions collected from publicly available datasets. Moreover, we evaluate the accuracy between our SVD-based method and direct inversion to acquire camera spectral sensitivity. This research advances our understanding of camera behaviour and holds the potential to enhance image processing, sensor design, and the broader scope of computer vision applications.

# Transcranial Ultrasound for Drug Delivery

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In developing treatments for human translation, a small-animal rat model is not ideal with its thin skull and small diploe pores having little impact on propagation (~>70%) at common ultrasound frequencies (~1MHz). For behavioural studies an animal of scale commensurate to that of humans is required to observe the effectiveness of drug release, with primates being ethically (and economically) beyond reach. Here we describe the use of a large-animal sheep model. Sheep undergo surgical procedures to impart Parkinson's disease-like signs and following a four-week observation period a transducer is implanted, bonded to the skull outer-table bone (under the scalp). Liposome containing drugs are intravenously injected and animal behaviours tracked prior to, during and post ultrasound administration; these experiments repeated for up to six months. From CT scans a mating section is made assuring the hemispherical [35mm dia, ROC 30mm] transducer is positioned for the desired focus for individual sheep, a nanocomposite used for rigid [~6MRayl] coupling to the skull. An electronics backpack provides remote [BLE-Zigbee] controlled [duty, PRF, repeat count] transducer excitation and monitoring [GPS location, motion]; video recording also used. Motor parameters, including drug-induced rotation and distance travelled, were measured to examine the effectiveness of release of the drug.

Transmission is greatly affected by wave scattering [~10% @1MHz, ~33% @500KHz]. However, ultrasound targeting the deep brain induced rotations indicating that drug release had occurred and targeted the receptors of interest.

# Multi-Measurement Investigation of Feed Supplements in A Rumen Bioreactor

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We have previously developed a bioreactor with pressure and methane/carbon dioxide sensing capabilities as an *in vitro* platform to study the biochemistry and microbial ecology of sheep and cow rumens. Here, we report on the use of the bioreactor in conjunction with a variety of measurement modalities to study the effect of feed supplements on *in vitro* anaerobic rumen fermentation. The study was designed to investigate the effect of low-moisture, molasses-based feed licks on the physical and chemical properties of the fermentation. Rumen contents from fistulated dairy cows were used as inocula for the fermentation. Gas composition and pressure in the presence and absence of the feed licks were recorded continuously over 24 hours. The amount of volatile fatty acids (physiologically the most significant energy source for the animal) and $NH_3$-N (essential source to synthesize microbial protein for the host animal) produced by the fermentation was measured using gas chromatography (GC) and phenol-nitroprusside-colorimetric methods, respectively. Separate experiments indicated that the use of feed licks reduced forth stability (which could be beneficial to prevent bloat in animals) by reducing the surface tension of the digesta. A mechanistic basis for this observation was established by using colorimetric measurements to detect the presence of sugar-fatty acid esters that act as biocompatible surfactants in the feed licks. The results establish the utility of multi-modal measurements to investigate rumen physiology in the laboratory.

**Keywords**— *In vitro*-rumen bioreactor, rumen gas production, gas composition, and sugar-fatty acid esters.

# Assessment of Swallowing and Phonation with High-Density Electromyogram Recordings

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Assessment of swallowing and phonation with high-density electromyogram recordings Leo K. Cheng, Auckland Bioengineering Institute, University of Auckland Swallowing and speech are usually taken for granted. However, some people are unable to execute these basic tasks, leading to poor quality of life, social isolation and even death. Dysphagia (difficulty in swallowing) and muscle tension dysphonia (difficulty with speech) are two such disorders. Current diagnostic methods are invasive and do not utilise the electrical signals that coordinate muscle contractions. Flexible high-density electrode arrays (256 electrodes, electrode diameter 5 mm, inter-electrode spacing 15 mm) were designed to conform to the neck and floor of the mouth. A thin layer of conductive gel was placed on top of each electrode and arrays were adhered to the skin surface with medical tape. Subjects performed a variety of swallowing and phonation tasks, with electromyographic (EMG) signals acquired using a commercial bio-amplifier and synchronised with audio recordings to determine the onset of tasks. In a subset of participants, manometry and endoscopy was also obtained to provide biomechanical references for validation. Electrodes were positioned in less than 5 minutes and did not restrict the subject during the prescribed tasks. Unique EMG signal morphologies and spatial activation profiles were obtained. The electrode array provided novel information that can be used to augment existing clinical workflows to provide an improved understanding of the relative contribution of muscles during swallowing and speech.

# Simultaneous Extracellular and Intracellular Recordings of Rat Gastric Slow Waves

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Coordinated electrical waves conduct through a network of excitable cells in the stomach wall to regulate gastric contractions. Measurement of these electrical waves, termed slow waves, is of interest to clinicians and scientists as they are biomarkers of gastric motility function. Rats are an important animal model for studying pathological conditions. However, to date rat gastric slow waves have not been recorded and mapped spatiotemporally.

Extracellular and intracellular signals were simultaneously recorded from an *in vitro* rat stomach tissue preparation. Extracellular electrodes were fabricated on flexible PCBs in rectangular arrays (8 x 4 grid; spacing 0.95 mm) and arrays were tessellated to cover approximately 60 $mm^2$ of the stomach surface. A glass microelectrode needle was used to impale a single cell and simultaneously record intracellular potential. The extracellular and intracellular datasets were acquired using separate hardware and synchronized using a trigger pulse.

The interval between simultaneously recorded slow waves in the intracellular and extracellular recordings exhibited some variability over 32 waves ($\mu$: -0.97 s; $\sigma$: 2.73 s). This variability was explained by changes in slow wave propagation direction observed in the spatiotemporally mapped extracellular recording. Subsequent *in vivo* rat studies with extracellular recordings showed that the slow wave signal morphology and frequency was consistent with *in vitro* experiments. These experiments are a foundation for further research using rats as an animal model for investigating gastric motility in health and disease.

# A Smart Electrode for Determining Timber Properties of Logs

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Recently, work has been carried out in New Zealand to develop Joule heating as a treatment for logs of Pinus radiata and other forestry species. Such heating has been shown to be of value in three applications, namely: phytosanitary treatment of export logs; pre-peel conditioning of veneer logs; and pre-sawing conditioning of collapse-prone Eucalyptus globoidea logs. To develop and control a reliable Joule heating method, an electro-thermal model of a log was built, for which the thermal and low-frequency electrical properties of unseasoned timber properties were measured, as functions of temperature between ambient and around 90o Celsius. From the inside out, logs from mature trees consist of a pith, a heartwood region, a sapwood region, and the bark. Some species also exhibit a marked transition region between heartwood and sapwood. In all cases, the sapwood is more electrically conductive than the heartwood (and the pith and bark), and its conductivity increases with temperature. Applying a current sensing electrode to one or both face/s of a log, and imposing a voltage between this and a return electrode, a current flows, with greater intensity in the sapwood than the other regions. By splitting the current sensing electrode into a sufficient number of segments, with some simple image enhancement techniques, the resulting current density map can be used to accurately determine the shape and dimensions of the various timber regions. The design of a proof-of-concept system employing 121 segments is described, with practical results.

# Investigating Toroidal Current Transformers for High Impedance Faults Detection in Low Voltage Distribution Network

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High Impedance Faults (HIFs) are a critical concern in power systems, as they can lead to severe damage and disruption. To prevent these harmful events, it is essential to develop reliable and accurate detection methods.

This presentation aims to investigate various methodologies employed in the detection of HIFs, with particular emphasis on the utilization of Toroidal Current Transformers (CTs). Subsequently, it will provide an in-depth exploration of HIF comprehension and expound upon the specialized testing facility established for the systematic investigation of HIFs, thereby ensuring their predictability and manageability.

The presentation will delve into the essential criteria governing sensor selection within the ambit of this research initiative and delineate strategies for attaining the highest precision in measurements employing these sensors. This involves elucidating the optimal approach to calibrate Toroidal CTs to guarantee their accuracy and dependability.

Furthermore, the presentation will elucidate a couple of encountered challenges during this research, specifically, the interplay of cross-checking reference stands and configuring Data Acquisition, as well as the calculation of sensors' phase angles.

Despite grappling with these challenges, it is worth noting that the research team has made substantial headway in the development of robust and precise methodologies for the detection of HIFs through the application of Toroidal CTs. This research endeavour carries the potential to enhance the safety and dependability of power distribution systems.

# Data Acquisition System for An Electromagnetic Field Sensor Array

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A data acquisition system has been developed for an electromagnetic field sensor array. This system measures disturbances in the current flow through a conductive medium, resulting from an applied alternating current voltage excitation. The system comprises 128 magnetic and 128 electric field sensors arranged in an 8 × 16 array. The system is arranged as 64 custom sensing boards and 8 custom data controller boards. Each sensing board amplifies four sensor signals and is designed to fit close to the sensors. All sensors are simultaneously sampled using 16-bit analogue to digital converters serially interfaced to an ARM Cortex M4 microcontroller. The microcontroller reads the analogue to digital converters using direct memory access and uses quadrature demodulation to provide a maximum likelihood estimate of the amplitude and phase for each channel. The estimated amplitudes are serially transmitted using RS485 to an array of data controller boards, with one data controller per eight sensing boards. Each data controller uses an ARM Cortex M4 microcontroller and interfaces to a PC using either USB or Ethernet. One of the data controllers generates the excitation voltage and differential synchronisation signals. This ensures that all the array signals are synchronously sampled. To date, eight of the sensing boards and one of the data controller boards has been constructed and tested. Each analogue to digital converter is sampled at 160 kHz for an excitation frequency of 10 kHz. With some tuning of the software, there is potential to double the sampling rate.

# An Intelligent Approach for Non-Destructive Asphalt Pavement Density Measurement

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Asphalt pavement density measurement plays an important role in the quality control of asphalt road construction. It is usually achieved by applying the coring method (CM), nuclear density gauge (NDG), and electrical density gauge (EDG). CM is the most accurate method, but it is a destructive method since the core samples should be taken from the asphalt pavement. NDG and EDG are non-destructive methods with high efficiency, but their measurement accuracy is poorer than that of CM. An NDG is more accurate than an EDG, nevertheless the nuclear radiation of NDG raises safety concerns. An EDG commonly used in density measurement is named pavement quality indicator (PQI). Unlike NDG, PQI is based on the electromagnetic induction. Its measurement accuracy is poor since it is sensitive to the temperature and moisture of the asphalt pavement and the internal algorithm does not work well on this. This paper presents an intelligent approach to improve the accuracy of the non-destructive methods (NDG and PQI). It is based on the artificial neural network (ANN), which processes the raw data got from NDG and PQI and produces the predicted asphalt density as the output. The density measured in CM method is used as the target density and the error between ANN-predicted density and target density is computed. To minimize this error, various ANN architectures and learning algorithms are tried in the ANN training process. Each established ANN model makes a substantial improvement in the performance of NDG or PQI in the asphalt pavement density measurement.

# Impact Solenoid Modelling for Current-Estimated Piston Position

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Impact solenoids create wide-band acoustic signals in the materials they hit, which can be used to characterise physical properties and geometry, or measure distances via time-of-flight. These acoustic signals are commonly approximated as Dirac deltas. However, at smaller timescales, or when multiple impacts occur due to bounces off of the target, more detail is needed. We seek a way to determining the impact profile from the current passing through the solenoid. Involved models for solenoid piston position exist, but are concerned with position control applications. These therefore assume both low piston velocity and a PWM excitation waveform switching much faster than the movement of the piston itself. We describe a family of physically-derived solenoid models which include the effects of piston velocity, and so are suitable for impact applications with a step excitation. These differential equations are solved to determine the location of the piston. This gives a family of more accurate impact functions relating the piston position to a measured solenoid current via dead reckoning. These models are assessed by firing an impact solenoid with a variety of stroke lengths, and recording the drawn current. The position estimations each model produces from this current data are validated against ground truth readings taken from a laser vibrometer for each individual firing. The models have RMS position error on the order of 10 um over durations of at least 7 ms, for multiple solenoid travel distances.

# Electromagnetic Field Detector and Amplifier Design for an Electromagnetic Field Sensor Array

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A new sensing and imaging technology requires an array of sensors to monitor small changes in a 10 kHz sinusoidal magnetic field. An air-cored search coil can be used to detect the magnetic field which induces a voltage proportional to the rate of change of the magnetic flux density according to Faraday's law.

The magnetic field sensor is required to be able to produce a 1 V output for a 500 nT flux density, and to be able to resolve field changes smaller than 1 nT. The EP10 coil former provides the best balance between being small (useful for spatial selectivity) and sensitivity. The size of this coil allows it to fit within a 20x20 mm circuit board. For every second column in the sensor array, the search coils are rotated by 90 degrees, allowing detection of both horizontal and vertical magnetic fields.

A non-inverting amplifier was designed with a gain of 1215 V/V to produce the desired output. The LT6230-10 opamp was chosen for its low noise and high gain-bandwidth product. The latter allows the entire gain at 10 kHz to be achieved using a single amplifier stage. The noise referred to the input of this sensor is about 2.4 pT/√Hz at 10 kHz. Each board also houses an electric field sensor, incorporating a transimpedance amplifier. It is not found possible to achieve the desired performance with a single opamp stage, so a second, voltage gain stage is added.

# Harnessing Industrial Sensor Data for Anomaly Detection with LSTM-VAE: A Cybersecurity Perspective

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Cyber-Physical Systems (CPS) are the core of critical infrastructures that support people's quality of life. Now, with the surge of Fourth Industrial Revolution technologies, CPS have been connected to the internet for management, monitoring, and process efficiency. However, broader connections also result in a larger attack surface. The number of cyberattacks targeting industrial sensors has been exponentially growing in recent years. Most of the research has focused on network security, but attacks targeting industrial sensors cannot be detected using traffic network analysis; therefore, cybersecurity in CPS is still an emerging research field. There is a need to establish more robust industrial detection systems that understand the characteristics of heterogeneous sensor data. We propose using feature engineering to create new series features that represent normal industrial sensor behaviour. The new features must be based on cybersecurity requirements for CPS. Our proposal improves the capacity of machine learning models to identify time-based anomalies connected to cyber-attacks. The proposed technique has several steps: 1) Data Collection and Integration; 2) Data Cleansing and Quality Assurance; 3) Feature Engineering, to create time-based specific features; 4) Normalisation and Scaling; 5) Feature Selection, and 6) Model Training and Evaluation. We model an unsupervised Long Short-Term Memory Variational Autoencoder (LSTM-VAE) to reconstruct the feature representation and capture complex temporal patterns that were not present in the original dataset. We successfully detected over 95% of the attacks present in the Secure Water Treatment (SWAT) benchmark dataset using information from a 120-second sequence length (window) to prioritize accurate detection in short time.

**Keywords**— Data Analysis, Anomaly Detection, Cybersecurity, Industrial Systems, Machine Learning.

# An Efficient Electromagnet Driver for Groundwater Sensing

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This paper presents an efficient circuit for driving a coil with a bipolar trapezoidal current waveform. This has application for measuring the flow of groundwater where large switched magnetic fields are employed to induce an electric potential by ions moving with the water. Switching is required to minimise zero drift due the highly correlated 1/f noise from the sensing electrode/electrolyte interface. However, since the voltage sensing geometry has a large unavoidable loop area, it is important that the steady portions are constant to reduce the effects of interference coupled into the sensing circuits. The proposed circuit uses a high voltage source to produce a fast magnetization and a low voltage source to set the steady state current. The duration of the magnetization stage is dynamically adjusted to ensure the steady state is quickly obtained after the transient induced by eddy currents in the coil. Magnetization energy is recovered using a capacitor when reversing the current direction through the coil. A prototype driver is described based on an FPGA for precise timing of the waveform stages with a configuration of eight MOSFETs. Results are presented from both simulation and measurements showing the driver achieves an efficiency greater than 70% with a nominal coil current of 50 A. Modelling of the transient response due to eddy currents in the coil is shown and compared with measured values.

# A Wearable Open-Source Electrical Impedance Tomography Device

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Electrical impedance tomography (EIT) is medical imaging technique in which small electrical signals are used to map the electrical impedance distribution within the body. It is safe and non-invasive, which make it attractive for use in continuous monitoring or outpatient applications, but the high cost of commercial devices is an impediment to its adoption. Over the last 10 years, many research groups have developed their own EIT devices, but few designs for open-source EIT hardware are available. In this work, we present a complete open-source EIT system that is designed to be suitable for monitoring the lungs of free breathing subjects. The device is low-cost, wearable, and is designed to comply with the industry accepted safety standard for EIT. The device has been tested in two regimes: Firstly in terms of measurement uncertainty as a voltage measurement system, and secondly against a set of measures that have been proposed specifically for EIT hardware. The voltage measurement uncertainty of the device was measured to be −0.7 % ± 0.36 mV. The EIT specific performance was measured in a phantom test designed to be as physiologically representative as practicable, and the device performed similarly to other published devices. This work will contribute to increased accessibility of EIT for study and will contribute to consensus on testing methodology for EIT devices.

# Ionic Hydrogel Used for Underwater Impedance Measurement

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SCUBA diving can incur substantial risk. This is associated with fatigue and pressure related injuries. A way to reduce the risk of diving injuries is to develop monitoring systems that track the diver's vital signals, both physical and physiological, and provide real-time warnings to the diver. How to detect heartrate and surface electric potential signals (e.g. ECG and EMG) in the underwater environment has presented a materials challenge; specifically: how to interface the divers skin for impedance measurements. During my research I have created an ionic-based hydrogel for surface electro-potential monitoring. This hydrogel has a strong underwater adhesion to skin, as well as high conductivity and stretchability, thus ideal for underwater electro-potential measurement. In order to test the material and demonstrate its ability to monitoring heartrate and etc., I have introduced it to our three-type heartrate system, which includes an electrocardiogram (ECG) sensor, seismocardiogram (SCG) sensor, and a photoplethysmography (PPG) sensor, and used it as the ECG electrode to test the heartrate in the open water environment during swimming. This study included five individuals who collected real-time signals in four different scenarios, both static and dynamic, in the water and on the ground. In this talk, I will describe the test results as well as the future studies and applications of this hydrogel.

# An Advanced Smart Traffic Light System for Real-Time Emotional Well-being Monitoring in High-Stress Environments

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This paper introduces a state-of-the-art Smart Traffic Light System with significant applications for emotional well-being in high-stress environments like healthcare facilities and educational institutions. The system fuses artificial intelligence, super-resolution algorithms, and facial recognition technology to offer both instantaneous and longitudinal insights into the collective emotional atmosphere. A unique feature of this system is its three-tier light indicator, employing a color-coded scheme to visualize emotional states across short-term, medium-term, and long-term contexts. This aids in situational awareness and plays a pivotal role in mental health intervention strategies. By leveraging closed-circuit television (CCTV) footage, the system employs a novel temporal expression recognition mechanism, capturing a wide array of human emotions. Additionally, it incorporates facial super-resolution techniques to enhance low-resolution data, thus augmenting the system's accuracy while adhering to stringent ethical standards on data collection and privacy. Beyond emotional recognition, this research offers a foundational step towards the creation of emotionally intelligent ecosystems in healthcare and education. By furnishing both real-time and historical data, the system enables informed decision-making and optimized resource allocation, aiming for an overall improvement in emotional well-being and mental health. This work contributes to the growing discourse on emotionally resilient and intelligent infrastructures, particularly in high-stakes environments where emotional well-being is a critical concern.

# Electric Impedance Muscle Analysis for Wearable Robotic Devices

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In the following years, the elderly population, and the prevalence of noncommunicable diseases will grow, increasing the number of people with disabilities. These demographic shifts will lead to a rise in the number of individuals with disabilities, thereby increasing the demand for rehabilitation services. A potential solution to address this challenge lies in the application of rehabilitation robots, designed to restore functionality and mobility for people with physical disabilities. To make these robots more user-friendly and intuitive, a Human-Computer Interface (HCI) is essential. This HCI can harness physiological signals as inputs. Myography techniques have become widespread in modern healthcare as wearable devices have opened opportunities for recording muscle signals on a long-term basis without limiting individual physical activities. Electrical impedance myography (EIM) is a non-invasive method used to measure muscle bioimpedance. It is sensitive to muscle shape changes caused by body movements, making it a promising candidate for HCI applications. This research proposes a novel approach based on bioimpedance analysis of the human lower leg to correlate changes in muscle bioimpedance with ankle movements. EIM measurements were obtained using a four-terminal scheme, involving electrode pairs for injecting AC current and reading voltage. The readings were taken for different current frequencies ranging from 10 kHz – 250 kHz while performing calf raises. Initial findings indicate that the system demonstrated movement identification capabilities, especially at lower frequencies, paving the way for further exploration in this innovative field.

# A Gen AI Approach of Emotion Sensing for Autism Therapies

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This research explores the innovative Gen-AI approach for autism therapies using advanced sensing algorithms to help individuals with autism. The project aims to address the inherent challenges faced by autistic children in expressing and understanding emotions. By harnessing the power of generative AI, the proposed system employs cutting edge technology for emotion detection and recognition, to sense and interpret facial expressions, body gestures, vocal cues, and language and behavioral patterns. It integrates advanced sensing algorithms into a mobile interface, fostering interactive engagements tailored to the unique emotional profiles of users. By utilizing state-of-the-art machine learning models, the system dynamically adapts therapeutic activities based on the user's emotional cues, creating a responsive and personalized environment for effective interventions. The research extends beyond the technological aspects to encompass ethical considerations, addressing privacy, consent, and inclusivity in the development of AI-driven therapies. By collaborating with healthcare professionals, educators, and the autism community, it ensures that the proposed system aligns with real-world needs and practices.

The outcomes of this research contribute to the broader field of sensing, measurement, and instrumentation for healthcare, offering a novel application of AI in the realm of emotional support for individuals with autism. This abstract encapsulates the potential of technology to positively impact the lives of those with autism, showcasing a Gen AI approach that goes beyond conventional methodologies.

**Keywords:** Gen AI, Autism Therapies, Emotion Sensing, Mobile Interactive Interfaces, Artificial Intelligence, Healthcare, Sensing and Measurement

# Deep Learning for Understanding Overlapping Shoeprints in Noisy Images

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While much research has been carried out on recognizing multiple objects in an image and classifying them, the problem of how to recognize and distinguish overlapping objects in noisy image remains problematic. This research investigates the capability of deep learning for separating overlapping shoeprint images with complex noise conditions prior to recognition. A dataset containing bounding boxes of shoeprints was utilized to train a YOLO model. The model achieved an accuracy surpassing 85% in identifying distinct shoeprint locations, with this confidence slightly decreasing for highly overlapped images but remaining above 70%. The network's performance, when confronted with different degrees of overlap, varied due to the intrinsic complexity of the images. Challenges emerged in labelling extensively overlapped samples, leading to detection inaccuracies. It was observed that the neural network predominantly relied on non-overlapped regions for prediction, as indicated by heatmaps of distinct neuron activation patterns. While the YOLO model seemed resilient to this noise in our dataset, real-world application necessitates more refined labelling techniques. Rotatable bounding boxes or more precise segmentation methods using polygons could offer improvements. This study underscores the promising potential of deep learning models in forensic applications, such as separating and recognizing overlapping fingerprints and shoeprints at crime scenes, while also highlighting areas for further research in understanding noisy images containing multiple overlapping objects of interest.

# Utilizing Semi-Supervised Deep Learning to Estimate Fur Seal Population Counts

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Estimating animal species' populations is of growing significance within the realms of conservation and ecology, particularly in light of the increasing apprehension surrounding climate change's impact on global fauna. Yet, counting animal numbers in the wild remains a challenging and sometimes perilous task. The utilization of drone imagery for animal detection and counting holds promise as an essential component of conservation strategies aimed at acquiring real-time population estimates.

This paper introduces a novel approach, employing the Faster-RCNN algorithm within the domain of deep learning, to accurately count fur seals on Alejandro Selkirk Island using drone-acquired images. By adopting a semi-supervised methodology, the conducted experiments yield promising results, with an overall precision rate of 0.86. This preliminary research underscores the potential of machine learning techniques applied to remote sensing through drone imagery as a valuable tool for estimating fur seal populations, and it paves the way for potential extensions to other contexts where swift and accurate animal population assessments are crucial for ecological and conservation objectives.

**Keywords** — Object detection, Deep learning, Remote monitoring, Faster R-CNN.

# Application of Machine Learning for Asthma Risk Prediction

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Asthma, a chronic respiratory ailment characterised by airway inflammation, poses a significant global health concern. In 2019, it affected 262 million individuals, leading to an annual average of 461,000 fatalities, underscoring the urgency of effective asthma management. This study endeavours to anticipate the asthma attack risk using a machine-learning approach. Data encompassing hospital, pharmaceutical, and mortality records from January 1, 2008, to December 31, 2017, were sourced from the New Zealand Ministry of Health's National Datasets, amassing 1,566,349 asthma patient records featuring 71 attributes. Before developing models, a sequence of data preprocessing steps, feature selection, derivation, encoding, and standardisation, were conducted. Subsequently, two machine-learning prediction models, Random Forest and XGBoost, were built. The dataset was partitioned into training (75%) and test (25%) sets for model validation. Model performance was evaluated using the Area Under the Receiver Operating Curve (AUROC). In addressing data imbalance, Synthetic Minority Over-sampling Technique and Random Under-sampling were employed. Optimising model performance, hyperparameter tuning was executed via Grid Search. The models were constructed using Python with Spyder IDE on a computer with a 3.50 GHz processor and 128 GB of RAM. Overall, the Random Forest model with Random Under-sampling exhibited superior performance, achieving an AUROC of 0.77. Notably, the frequency of previous asthma attacks emerged as an important predictor of imminent attacks. In future endeavours, we aspire to refine model performance further. These predictive models hold the potential to be integrated into smart medical devices, facilitating enhanced disease management, potentially saving lives and reducing government healthcare costs.

# Role of Augmented Reality Model Integrated with AI in Improving First-Aid Delivery in the Healthcare Sector

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ABSTRACT Cardiac arrest remains a leading cause of death in New Zealand, claiming numerous lives annually with only an 11% survival rate amongst the approximately 2,000 affected. Immediate intervention via CPR and AED application is vital, seeing as every minute of delay reduces the chance of survival by 10-15%. However, in New Zealand, only 4.4% of the population and 8.7% in workplaces are trained in First aid. This is further complicated by existing training materials, which are generally regarded as complex and hard to memorize. To address this pressing issue, our research introduces an innovative First-aid delivery system that leverages Augmented Reality (AR) and Artificial Intelligence (AI). This system is designed to overlay essential First-aid information as interactive holograms, enabling users to engage using their voice, thus allowing even untrained individuals to act effectively in emergency situations. A high-fidelity prototype of this system has been developed and tested using medical manikins to refine its functionalities, confirming its responsiveness, user friendliness, and operation in hypothetical, critical situations. The system utilizes advanced generative AI models to synthesize animated visual guides, combining illustrative imagery and voice, to deliver clear and concise real-time instructions. Our next steps include the enhancement of hologram manipulability for user-tailored interactions, integration of more straightforward instructional animations, and the incorporation of Computer Vision for accurate hand positioning via 3D pose estimation. These refinements are aimed at making First-aid procedures more intuitive and adaptable, ensuring universal accessibility to immediate and accurate medical response, thereby increasing the likelihood of saving lives in emergencies.

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