DEPARTMENT OF ELECTRICAL, ELECTRONIC AND COMPUTER ENGINEERING

UNIVERSITY OF PRETORIA
FACULTY OF ENGINEERING, BUILT ENVIRONMENT
AND INFORMATION TECHNOLOGY

ANNUAL NEWSLETTER 2021/22

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

Make today matter

Message from the Dean
Faculty of Engineering, Built Environment and Information Technology

Prof Wynand JvdM Steyn

The Faculty of Engineering, Built Environment and Information Technology (EBIT) strives to put innovation at the centre of everything it does. EBIT's Department of Electrical, Electronic and Computer Engineering dedicated its teaching, learning and research efforts to this goal during the period under review.

The Faculty is home to a generation of leaders and innovators who are dedicated to improving their lives, the lives of their families, their country and the world. As such, each academic department strives to deliver qualified, future-ready professionals with the ability to become an asset for our future.

The Department of Electrical, Electronic and Computer Engineering is the largest of its kind in the country, and offers qualifications in the broadest spectrum of specialisation fields. Through its exceptionally specialised academic programmes, the Department produces highly sought-after graduates who are ready for the Future of Work.

In this regard, technology has launched a digital transformation process that extends beyond tools and processes. Our Faculty has responded to novel challenges posed by the Fourth Industrial Revolution (4IR) by ensuring that we remain relevant and lead by example. Innovative, transdisciplinary research is imperative to make sense of this new digitised world.

The Department of Electrical, Electronic and Computer Engineering actively participates in the Faculty's research agenda through projects within EBIT's research focus areas of Energy, the 4IR, Smart Cities and Transportation, as well as Big Data Science, ICT, and Technology and Innovation Management. This is key to establishing the Faculty's thought leadership and frontline position on the global stage.

We are particularly proud of the Department's contribution to the University of Pretoria's ranking as the top university for electrical and electronic engineering in South Africa. The Department is ranked in the top 301–350 category in the QS World University Rankings by Subject. This is, indeed, a remarkable achievement.

Prof Wynand JvdM Steyn

Message from the Head of Department
Department of Electrical, Electronic and Computer Engineering

Prof Raj Naidoo

Global technological advancement happens on an exponential scale every day. In answer to this, the Department of Electrical, Electronic and Computer Engineering (EECE) is developing sustainable technologies for inclusive societies. We are rising to the challenge by aligning our research to the Sustainable Development Goals (SDGs) of the United Nations.

The Fourth Industrial Revolution (4IR) is a new epoch in social and economic life. It is driven by technological advancements that will broaden and deepen the connections between the biological, physical and digital worlds in unprecedented and unpredictable ways. This is a result of the confluence of multiple technologies, which have previously existed in isolation. The speed, breadth and depth of this evolution is forcing us to rethink how countries develop, how organisations create value and even what it means to be human. These advances not only bring about exciting new opportunities, but also potential challenges. The mission of the Department of Electrical, Electronic and Computer Engineering is to solve these challenges and help build a smart, sustainable Africa and world.

SNAPSHOT OF THE FACULTY AND DEPARTMENT

TOP 1%

OF ENGINEERING SCHOOLS IN THE WORLD

- **4** RESEARCH CHAIRS
- **4** RESEARCH CENTRES AND INSTITUTES
- **16** NRF-RATED RESEARCHERS
- **83%** OF ACADEMIC STAFF WITH A PhD

RANKED TOP 301–350

FOR ELECTRICAL AND ELECTRONIC ENGINEERING WORLDWIDE

#1 RANKED UNIVERSITY FOR ELECTRICAL AND ELECTRONIC ENGINEERING IN SOUTH AFRICA

3 SPECIALISED FIELDS: ELECTRICAL ENGINEERING, ELECTRONIC ENGINEERING, COMPUTER ENGINEERING

Prof Raj Naidoo

DEPARTMENT OVERVIEW

Welcome to the first edition of the annual newsletter of the Department of Electrical, Electronic and Computer Engineering, which covers the activities of the Department for 2021/22.

The Department is proud of the contribution it could make to the University of Pretoria's ranking as the top university for electrical and electronic engineering in South Africa. It participates actively in the research agenda of the Faculty of Engineering, Built Environment and Information Technology by focusing its research on the challenges related to the United Nations' Sustainable Development Goals (SDGs). This is aligned to the Department's mission, which is to help build a smart, sustainable Africa and world.

Many of the Department's graduates are world-class engineers and leaders in their field. They are also top inventors and entrepreneurs.

The Department maintains close contact with industry, government and other institutions through contract research and consultation activities in all three its disciplines: electrical engineering, electronic engineering and computer engineering.

Its academic staff component comprises a diverse blend of experience, race, culture and gender. These individuals are continuously contributing to industry through consultation work with both the government and the private sector, while ensuring a constant flow of new patents and venture capital companies with the support of the University.

Sixteen of the researchers in the Department have ratings from the National Research Foundation (NRF). The Department was proud to include another two in this number during the period under review: Prof Ian Craig, who obtained his B2 rating, and Dr Allan de Freitas, who obtained a Y2 rating. Three of its academics were promoted during the year under review: Prof Raj Naidoo, Prof Pieter de Villiers and Prof Derik le Roux. Prof Johan Joubert served as the Faculty's Deputy Dean: Research and Postgraduate Education during the latter part of 2022. The Department was, however, saddened to lose one of its esteemed colleagues, Dr Gerhard Hancke, a former Head of Department, who had served as an extraordinary professor.

On the international front, four student exchanges took place. Halleluyah Kupolati completed research for his master's degree at the University of Valladolid in Spain; Nishkar Naraindath spent some time at the University of South Florida; and Archie Rohde and Judas Masela performed microsystems research at the Karlsruhe Institute of Technology in Germany. The Department signed a Memorandum of Understanding with the University of Sharjah in the United Arab Emirates to establish joint collaboration on research related to the Just Energy Transition. This institution's engineering programme has attained international accreditation.

Funding from industry and the private sector contributes to the Department's ability to perform world-class research, and supports students with bursaries, which serve to further enhance the Department's research profile. The most prominent of these allocations of funding are the Exxaro Chair in Energy Efficiency, the Multichoice Chair in Machine Learning, the Rand Water Chair in Electrical Engineering and the Sentech Chair in Broadband Wireless Multimedia Communications.

Other sources of funding received during the course of the year included funding from the Department of Science and Innovation (DSI) and the South African Radio Astronomy Observatory (SARAO) for research conducted by the Carl and Emily Fuchs Institute for Microelectronics (CEFIM), from the South African National Energy Development Institute (SANEDI) for the Department's Smart Grid Programme, and under the BRICS (Brazil, Russia, India, China, South Africa) collaboration.

DEPARTMENT OVERVIEW CONTINUED

An emerging field of interest in which the Department is becoming increasingly involved relates to hydrogen fuel cells as an alternative source of energy. The Head of Department, Prof Raj Naidoo, has been appointed to lead the skills workstream of the South African Hydrogen Society Roadmap, an initiative of the Department of Science and Innovation (DSI). He also participated in the South Africa (SA)-United Kingdom (UK) Hydrogen Mission at Teesside University, which is at the forefront of the UK's transition to a green economy, as well as the accreditation of training in hydrogen fuel cells by the Quality Council for Trades and Occupations (QCTO).

On 9 November 2022, Prof Naidoo chaired a webinar on the creation of a South African Hydrogen Economy for Energy Security and Sustainability. It featured Dr Cosmas Chiteme of the Department of Science and Innovation, Zanele Mavuso Mbatha of Bambili Energy, Ompi Aphane from HC Vision Africa, and Fahmida Smith from Anglo American. It served to position the University, specifically the Department of Electrical, Electronic and Computer Engineering, as a leader in the field.

A highlight for the Department in terms of its teaching and learning activities was the full accreditation it obtained from the Engineering Council of South Africa (ECSA) for a further five-year term. This accreditation ensures that the Department's undergraduate programmes meet the academic requirements for the qualification of a professional engineer in South Africa. The accreditation visit took place from 9 to 13 September 2022.

The Department also received a visit from the audit panel of the Council on Higher Education on 6 September 2022.

The period under review marked the second year in which teaching had to be presented in an online or hybrid format due to the measures put in place by the government to curb the spread of the COVID-19 pandemic. An innovative solution was developed across the Department's three domains of electrical, electronic and computer engineering.

It entailed developing an integrated curriculum, making use of microcontroller-based autonomous robotic vehicles that could be used to teach elements across different modules, including digital systems, analogue electronics, control systems, and the design and construction of a robotic vehicle (see article on page 38). It made use of an initiative that was developed in 2013, the Faculty's annual Robot Race. It was named the joint winner in the Faculty's annual Teaching and Learning Awards and went through to the University's corporate teaching and learning competition.

The annual Robot Car Race Day was initiated by Prof Tania Hanekom in the Department of Electrical, Electronic and Computer Engineering. Its presentation over the past 10 years has proved so successful that it has been elevated to the status of a Faculty event. It involves microcontroller-based autonomous robotic vehicles (called MARVs), built by teams of third-year students who compete against each other to finish the track in the shortest possible time. We appreciate the generous support of our industry partners, who sponsor students who would otherwise not have been able to participate in this event. It forms part of the requirements to pass the third-year Microcontrollers module in the electronic engineering programme.

The Robot Race was also the inspiration behind a community engagement project launched in 2021 called the Robot School, which is presented free of charge to learners between Grade 8 and Grade 11. An outcome of the Robot School was the establishment of the spin-off Sensor School, which creates an awareness of careers in technology among high-school learners. The Department acknowledges the support of its industry sponsors who make the components used in the construction of the robot chassis available for use by the learners.

The Department was grateful to once again be able to present its annual project competition in a live format. This took place on 11 November 2022 and was attended by the Department's industry collaborators, as well as UP staff and students. Industry experts were invited to judge the projects, and prizes were sponsored by Etion, Rapid Mobile, Eskom and Exxaro.

The activities that are presented in the following pages present a glimpse of some of the Department's highlights in terms of its research, teaching and learning, and community engagement activities. As we resume contact tuition in 2023, we are confident that the Department can only improve upon the success it has achieved so far.

DEPARTMENT PROFILE

NO. 1 IN SA

ACADEMIC OFFERING

Undergraduate students can pursue either the BEng Electrical Engineering, BEng Electronic Engineering or BEng Computer Engineering degree programmes.

Postgraduate students can follow a range of academic career paths in accordance with their field of specialisation. The Department offers the following honours, master's and doctoral programmes:

HONOURS

- BEngHons Electrical Engineering
- BEngHons Electronic Engineering
- BEngHons Computer Engineering
- BEngHons Bioengineering
- BEngHons Microelectronic Engineering

MASTER'S

- MEng Electrical Engineering
- MEng Electronic Engineering
- MEng Computer Engineering
- MEng Bioengineering
- MEng Microelectronic Engineering

PhD

- PhD Electrical Engineering
- PhD Electronic Engineering
- PhD Computer Engineering
- PhD Electrical
- PhD Electronics
- PhD Biosystems

ECSA

All of the Department's degree programmes are accredited by the Engineering Council of South Africa.

STAFF PROFILE

197
REGISTERED POSTGRADUATE STUDENTS IN 2022

83%
ACADEMIC STAFF MEMBERS WITH A PHD

16
NRF-RATED RESEARCHERS ON STAFF

26 LECTURERS
15 SUPPORT STAFF
7 EXTRAORDINARY APPOINTMENTS
7 CONTRACT APPOINTMENTS

2022 STAFF MEMBERS

The Department's success over many years has proven to be the result of its high-quality lecturers and support staff. Most of the Department's lecturers have PhD degrees – while some even have two – or are currently pursuing PhD degrees. Many staff members are also NRF-rated researchers and registered professional engineers. Our academic staff component comprises a diverse blend of experience, race, culture and gender. These researchers are continuously contributing to industry through consultation work with both government and the private sector, while ensuring a constant flow of new patents and venture capital companies with the support of the University.

HEAD OF DEPARTMENT: PROF RAJ NAIDOO

- BSc Eng
- MSc Eng
- PhD
- Pr Eng

Director:
Smart Grid Laboratory

NRF-rating: C2

Find on Google Scholar

PROF IAN CRAIG

- BEng (*cum laude*)
- SM MIT
- PhD
- MBA
- Pr Eng

Group Head:
Control Systems

NRF-rating: B2

Find on Google Scholar

PROF PIETER DE VILLIERS

- BEng
- MEng (*cum laude*)
- PhD
- Pr Eng

Group Head:
Signal Processing and Telecommunications
Co-Chair:
Multichoice Chair in Machine Learning

NRF-rating: C1

Find on Google Scholar

PROF WARREN DU PLESSIS

- BEng
- MEng
- PhD
- Pr Eng

NRF-rating: C2

Find on Google Scholar

PROF MICHAEL GITAU

- BSc (Hons)
- PhD
- Pr Eng

Group Head:
Power Systems

NRF-rating: C2

Find on Google Scholar

PROF TANIA HANEKOM

- BEng
- MEng (*cum laude*)
- PhD
- Pr Eng

NRF-rating: C2

Find on Google Scholar

PROF JOHAN HANEKOM

- BEng (*cum laude*)
- MEng (*cum laude*)
- PhD
- Pr Eng

Group Head:
Bioengineering

NRF-rating: C1

Find on Google Scholar

PROF PIETER JACOBS

- BEng
- MEng
- PhD
- BMus
- BMus (Hons)
- MMus
- MMA
- DMA

NRF-rating: C2

Find on Google Scholar

PROF JOHAN JOUBERT

- BEng
- MEng
- PhD
- Pr Eng

NRF-rating: B3

Find on Google Scholar

PROF TRUDI-HELEEN JOUBERT

- BEng (*cum laude*)
- MEng (*cum laude*)
- PhD
- Pr Eng

Group Head:
Electronics and Microelectronics
Director:
Carl and Emily Fuchs Institute for Microelectronics

NRF-rating: C2

Find on Google Scholar

PROF DERIK LE ROUX

- BEng
- BEng (Hons)
- MEng
- PhD
- Pr Eng

NRF-rating: Y1

Find on Google Scholar

PROF HERMAN MYBURGH

- BEng (*cum laude*)
- BEng (Hons) (*cum laude*)
- MEng (*cum laude*)
- PhD
- Pr Eng

Group Head:
Advanced Sensor Networks
Director:
Centre for Connected Intelligence

NRF-rating: C2

Find on Google Scholar

PROF WIMPIE ODENDAAL

- BEng (*cum laude*)
- MEng (*cum laude*)
- PhD
- Pr Eng

Group Head:
Electromagnetism
Head:
Centre for Electromagnetism
NRF-rating: B3
Find on Google Scholar

PROF XIAOHUA XIA

- BEng
- MEng
- PhD
- Pr Eng

Group Head:
Energy Systems
Director:
Centre for New Energy Systems

Director:
National Hub for Postgraduate Programme in Energy Efficiency and Demand-side Management

NRF-rating: A2
Find on Google Scholar

PROF TINUS STANDER

- BEng (*cum laude*)
- PhD
- Pr Eng

NRF-rating: C3
Find on Google Scholar

PROF LIJUN ZHANG

- BEng
- MEng
- PhD
- Pr Eng

Find on Google Scholar

DR ALLAN DE FREITAS

- BEng
- MEng
- PhD

NRF-rating: Y2
Find on Google Scholar

DR FLIP PALUNČIĆ

- BEng
- BSc (IT)
- MEng
- DEng

Find on Google Scholar

PROF XIANMING YE

- BEng
- MEng
- PhD
- CMVP®

NRF-rating: Y2
Find on Google Scholar

DR WERNER BADENHORST

- BEng (*cum laude*)
- MEng (*cum laude*)
- PhD
- Pr Eng

Find on Google Scholar

DR MWANA WA KALAGA (KARL) MBUKANI

- MEng
- PhD

Find on Google Scholar

DR JOHAN SCHOEMAN

- BEng
- BEng (Hons) (*cum laude*)
- MEng (*cum laude*)
- PhD
- Pr Eng

Find on Google Scholar

DR JACQUES VAN WYK

- BEng
- MEng
- PhD
- Pr Eng

Find on Google Scholar

HANS GROBLER

- BSc (Hons) (*cum laude*)
- MSc (*cum laude*)
- MSc Eng (*cum laude*)
- BEng

Group Head:
Intelligent Systems

Find on Google Scholar

LEBOGANG MASIKE

- BEng
- MEng

Find on Google Scholar

KEALEBOGA MOKISE

- BEng
- MEng

PART-TIME LECTURERS

- **DR HEINRICH LAUE** – PhD
- **DR TRESOR MBUNGU** – PhD
- **DR AR SINGH** – PhD
- **NICHOLAS BLOMERUS** – MEng
- **HERMAN BOTHA** – MEng
- **ZODOK OLINGA** – MEng
- **TONY VAN DER LINDEN** – MEng
- **LISA MASIPA** – BEng (Hons)

EXTRAORDINARY APPOINTMENTS

PROF ATTAHIRU ALFA

- PhD, University of New South Wales, Australia

PROF REZA MALEKIAN

- PhD, Universiti Teknologi, Malaysia

Find on Google Scholar

PROF MARGRET BAUER

- PhD, University College London, UK

Find on Google Scholar

DR ADNAN ABU-MAHFOUZ

- PhD, University of Pretoria, South Africa

Find on Google Scholar

PROF GERHARD HANCKE

- PhD, University of Pretoria, South Africa

Find on Google Scholar

DR GERHARD HANCKE

- PhD, University of Cambridge, UK

Find on Google Scholar

PROF KEVIN LAND

- Dr Ing, University of Freiburg, Germany

Find on Google Scholar

DR WALDO KLEYNHANS

- PhD, University of Pretoria, South Africa

Find on Google Scholar

INAUGURAL ADDRESSES

TRANSFORMING THE ELECTRICITY GRID THROUGH DIGITAL INTERVENTIONS

PROF RAJ NAIDOO

Prof Raj Naidoo, Head of the Department of Electrical, Electronic and Computer Engineering in the Faculty of Engineering, Built Environment and Information Technology, delivered his inaugural address on 13 October 2022. The topic of his address was: **"Digital transformation for an adaptable and sustainable power grid"**.

In addition to being Head of Department, he also heads the University's Smart Grid Laboratory research. His passion lies in smart grids and a just energy transition, which includes smart distribution systems, and establishing a smart grid workforce for distribution utilities and optimal energy management.

According to Prof Naidoo, the Fourth Industrial Revolution (4IR) is a new epoch in social and economic life. It is driven by technological advancements that will broaden and deepen the connections between the biological, physical and digital worlds in unprecedented and unpredictable ways. Digitalisation has transformed many industries, and is continuing to transform the world. Driven by operational and business needs, it can accelerate electric grid transformation, while delivering security, reliability, operational excellence and cost objectives.

There are currently five geographic power clusters that service Africa's electricity demand. The continent's economic growth is not just affected by electrical connectivity, but also by internet connectivity. The conventional electrical grid can therefore benefit from 4IR connectivity, as well as sensors, smart devices and information sharing across the many components of the electricity grid.

In his presentation, Prof Naidoo illustrated several concerns that are being addressed through some thought-provoking research activities. "The Department's key research contributions relate to smart asset management and a just energy transition," he explained. This includes research focused on energy management and optimisation solutions within microgrids, and using advanced algorithms for model predictive control, machine learning and blockchain.

With digital transformation, multiple technologies, which have previously existed in isolation, are converging. The speed, breadth and depth of this revolution is forcing us to rethink how countries develop, how organisations create value, and even what it means to be human. These technologies typically include artificial intelligence (AI), cloud computing and the Internet of Things (IOT). "Data from smart IOT sensors is applied to machine learning and advanced algorithms that connect the physical and digital worlds." Findings from this research indicate that utilities can change from being reactive to being predictive by utilising IOT intelligence. This can improve planning, operations and maintenance, and ensure a reliable, flexible and cost-efficient grid operation.

According to Prof Naidoo, a smart grid is a digitally enabled electrical grid that collects, distributes and works on the information it receives about the behaviour of suppliers and consumers to improve the efficiency, reliability and sustainability of electricity. Enhanced operations are achieved through data collection and data processing. "By focusing research on the digitalisation of power system operations and protection, we are looking at mitigating the risks of renewable energy integration, as well as enhancing the quality of the power generated, while protecting the power system."

Virtual power plants are a dynamic and rapidly developing technology that is set to make a significant impact on the future of electricity generation, distribution and consumption. It enables distributed energy resources, including solar and battery storage devices, to connect to the electricity grid through smart inverters. Research in this regard relates to the development of smart algorithms for improved power system operation and control, as well as making use of digital twinning.

A problem that is often encountered is the fact that motors account for more than two-thirds of the electrical power consumption in some countries. This provides an opportunity to reduce energy consumption, which can be accomplished by replacing inefficient motors with high-efficiency motors; estimating the efficiency of an in-service induction motor, without withdrawing it from service. This led to the development of a method to make motor-driven processes more efficient.

Climate change and the increased need for decarbonisation have led to the mass penetration of renewable energy and new energy trading markets for solar, green hydrogen, wind and hydro energy. This has led to the need for localised energy markets to sell excess renewable energy. A key concern of these new markets is the risk of them being inequitable in terms of market regulation. Research in this regard is addressing these concerns by developing a novel blockchain-based market mechanism that can transparently facilitate and regulate decentralised energy market transactions, and enable peer-to-peer energy trading.

Prof Naidoo concluded his presentation by explaining how digitalisation can accelerate the transition from fossil fuel-based energy generation to renewable energy-based operations. “By creating new business models, we are able to create win-win tariffs.” The work done in this area entails an analysis of the composition of municipal tariffs, which incorporates aspects such as municipal inefficiencies (including faulty metering and ghost vending), the increased penetration of renewable energy, increased purchase tariffs, load shedding and maximum demand charges.

An important point of departure in this regard relates to system performance efficiency. Hydrogen fuel cell management systems is an emerging field that will contribute vastly to the just energy transition.

“The Department’s key research contributions relate to smart asset management and a just energy transition.”

INAUGURAL ADDRESSES

SEEING A DYNAMIC WORLD THROUGH THE EYES OF SENSORS

PROF PIETER DE VILLIERS

Pieter de Villiers, a professor in the Department of Electrical, Electronic and Computer Engineering in the Faculty of Engineering, Built Environment and Information Technology, delivered his inaugural address on 4 October 2022. The theme of his address was **"Seeing a dynamic world through the eyes of sensors"**. Prof De Villiers heads the Department's Signal Processing and Telecommunications Research Group, and is Co-Chair of the MultiChoice Chair in Machine Learning. The focus of his research includes statistical signal processing, machine learning (with a focus on signal processing), sensor and data fusion, and Bayesian inference.

The application areas of his current research include audio and video processing, radar, financial risk and machine condition monitoring. It has an impact across several of the Faculty's research focus areas, as well as two of the United Nations' Sustainable Development Goals (SDGs): SDG 9: Industry, innovation and infrastructure, and SDG 15: Life on land.

According to Prof De Villiers, the fusion and interpretation of data from multiple sources and sensors are important for automating complex tasks, such as tracking pedestrians or aircraft, or coordinating robots or autonomous vehicles in complex and dynamic environments. During his public lecture, he introduced a philosophical view of the sensing problem, how it is formalised in Bayesian probability, how the Bayesian models are used to make inferences and predictions, and how these inferences are then used to take action.

Prof De Villiers explained that two things are needed to make inferences: models and data. "Current research in the field focuses on the parallelisation of information fusion algorithms, and uncertainty representation and reasoning in information fusion," he said. "Other efforts focus on the intersection of machine learning and information fusion, as well as concepts of explainability and trust in these methods."

Due to the transdisciplinary nature of the problems that need to be solved by adopting Bayesian and other probability methods, the solutions developed through signal processing and machine learning have many application areas.

Prof De Villiers discussed a few of the applications and use cases addressed in his research. Safety and security use cases include the classification of humans and animals using Doppler radar for counter-rhino poaching operations and behavioural modelling for the classification of maritime vessels for anti-abalone poaching and anti-piracy. Recently, he has been considering using Bayesian neural networks to quantify uncertainty in synthetic aperture radar images for target detection, as well as to improve training in scarce data applications.

He detailed further use cases of his research efforts in broader application domains, such as video broadcasting and video streaming, financial risk modelling, machine diagnosis and prognosis, and the modelling of gene expression lineages.

Although this field is gaining increasing traction, researchers are experiencing some challenges. These include the computational efficiency brought about by parallelisation, where algorithms are split between processors, and the use of machine learning for modelling, where the target behaviour needs to be learnt. Furthermore, when human lives are at stake, well-placed trust in the answers provided by machines is essential, and needs to be in accordance with reliability and performance.

Prof De Villiers concluded his presentation with a future vision for sensor and data fusion research, where intelligent sensing in machine automation is becoming increasingly prevalent.

INAUGURAL ADDRESSES

CHANGING THE ENERGY MIX FOR SUSTAINABILITY

PROF MICHAEL GITAU

Michael Gitau, a professor in the Department of Electrical, Electronic and Computer Engineering in the Faculty of Engineering, Built Environment and Information Technology, delivered his inaugural address on 21 October 2021. The theme of his address was **"Effects of changes in the energy mix and types of loads on future power grids"**.

He explained that fossil fuels dominate the present-day energy mix. "The benefits of a higher share of renewable energy in the energy mix include lower harmful emissions and water demand, and higher operational efficiency."

Renewable power generation utilises power electronic converters and DC power transmission and distribution. "With dispersed renewable energy sources, bidirectional power flow becomes inevitable in distribution grids that previously handled only unidirectional power flow," he says. The widespread adoption of electrified transportation will therefore see a marked increase in the number of DC loads.

Furthermore, renewables provide additional electricity to compensate for a lower share of fossil fuels in the energy mix. "Changes in the energy mix and loads lead to an increase in DC grids, a need to develop bidirectional solid-state/DC protection systems, and a need to develop control strategies for dispersed energy storage to ensure that dispersed renewable energy sources operate efficiently."

There is also a need to expand the electrical grid to cater for energy previously transported by other means. These changes create an opportunity to structure future grids differently for better performance, particularly grids divided into different levels of subsystems and with modular design at all levels, and introducing DC transmission and distribution in areas where they offer more benefits than AC. Consequently, suitable power electronic converters that provide energy management services, bidirectional DC protection, and reduced interaction between the various subsystems will be needed. Converters to interface subsystems will also have to be developed.

RESEARCH PROFILE

#1
IN SA FOR ELECTRICAL AND ELECTRONIC ENGINEERING

4
RESEARCH CHAIRS

4
RESEARCH CENTRES AND INSTITUTES

The Department produces world-class engineers. Many of its graduates are leaders in engineering, and also top inventors and entrepreneurs in the world, and many of its lecturers are world-class researchers. The Department also maintains close contact with industry, government and other institutions through contract research and consultation activities in its three disciplines.

Electrical engineering focuses on the generation, distribution, conversion and efficient utilisation of electrical energy. Traditional generation stations include coal-fired, hydro and nuclear power stations. There is increased penetration of renewable energy generation, such as wind or photovoltaic power, into traditional grids. Communication and data collection technologies are integrated to provide more information on the state of the grid and improve its efficiency. These elements apply to electrical grids at various levels of scale, including industrial, commercial, residential and micro-grid scale.

Electronic engineering encompasses all kinds of electronic systems. Subfields include microelectronics, signal processing, power systems, bioengineering, control systems, optics and electromagnetism. Electronic engineering manifests itself in telecommunications (television, radio, cellular communications and optical communication), manufacturing plants (control systems and power systems), military systems, transport systems and biomedical applications.

Computer engineering has its focus in both hardware and software; combining these to produce optimal solutions to real-world problems. Disciplines include software engineering, the internet, biometric security systems, wireless communication, telecommunication, computer networks, data security, data storage, electronic banking, electronic commerce, signal processing, image processing, embedded systems, and designing artificial intelligence algorithms for various applications.

RESEARCH FOCUS AREAS

- Advanced sensor networks
- Bioengineering
- Control systems
- Electromagnetism
- Electronics and microelectronics
- Energy systems
- Intelligent systems
- Power systems
- Signal processing and telecommunications

RANKED TOP 301–350

FOR ELECTRICAL AND ELECTRONIC ENGINEERING WORLDWIDE

ADVANCED SENSOR NETWORKS

Sensors are the building blocks of advanced sensor networks. These are compact, highly accurate, power-efficient and reliable electrical devices that detect and respond to inputs from the physical environment. Devices in the network, incorporated with embedded software and electronics, collect or "sense" data using sensing modules. Data is then transferred via communication modules to a central processing unit to be processed and analysed, which either results in an action being executed or information being disseminated.

Sensors convert these inputs (temperature, blood pressure, humidity, speed, etc.) into signals, which can be measured electrically. The signals can either be displayed at the sensor location itself or transmitted to a central location for further processing. Sensors communicating with each other via wireless links form a wireless sensor network (WSN). A WSN can consist of hundreds to thousands of sensor nodes. Such a sensor node includes a sensor, a radio transceiver, an interfacing electronic circuit and an energy source, such as a rechargeable battery. These nodes are multifunctional with computing and processing capabilities. Incorporating radio frequency identification (RFID) with the sensor nodes can further optimise these networks for object tracking and identification-based applications. RFID technology uses radio waves to transmit a unique object identifier from an RFID tag to an RFID reader.

The integration of these WSNs with people, data and applications, and incorporating technologies such as wireless networks, mobile networks and internet technologies, result in an intelligent, interactive environment that is able to monitor itself and take proactive steps without human intervention.

Such an integration is better known as the Internet of Things (IoT). The IoT envisages an advanced inter-connectivity of devices, systems and services via the internet, covering various protocols, domains and applications. It is based on the premise that all devices (people, machines, etc.) are connected, always, anywhere.

The Advanced Sensor Networks Research Group is headed by **Prof Herman Myburgh**, who has a C2 rating with the National Research Foundation (NRF). The multi-disciplinary application areas of advanced sensor networks include the following:

- Transportation (vehicle and asset tracking, traffic monitoring, flow and congestion control, smart parking)
- Healthcare (e-health, long-term surveillance of critically ill patients or elderly persons, early detection warning of medical conditions, management of chronic medical conditions)
- Environmental services (forest fire detection and prevention, air pollution monitoring, earthquake detection and early warning systems)
- Agriculture (crop and fruit monitoring, precision agriculture: distributing fertilizers, pesticides, irrigation as needed, weed detection)
- Water management (wastewater treatment, water quality monitoring, water leakage detection)
- Mining (monitoring of vibration on mining equipment, mine safety monitoring)
- Animal sciences (tracking of wildlife, monitoring of migration patterns, detecting behavioural patterns, animal health)
- Smart homes and cities (energy-saving smart grids, heating, ventilation and air conditioning, light and temperature control)
- Industrial uses (preventative maintenance and machine surveillance)

Advanced sensor networks have a vast and diverse application potential, which can enhance safety and security, generate new knowledge, improve productivity and improve the quality of food and water. The challenge lies in realising the full potential of advanced sensor networks due to their resource-constrained characteristics, challenging operating environments, the scale of the networks and the interdependent multidisciplinary nature of the solutions required for the practical and widespread adoption common to complex systems.

Other members of this research group are:

- Dr Allan de Freitas (allan.defreitas@up.ac.za)
- Kealeboga Mokise (kealeboga.mokise@up.ac.za)
- Prof Gerhard Hancke Jr (ghancke@ieee.org)
- Prof Adnan M Abu-Mafouz (A.Abumahfouz@ieee.org)
- Prof Gerhard Hancke Sr (g.hancke@ieee.org)

CENTRE FOR CONNECTED INTELLIGENCE

The Centre for Connected Intelligence was established in 2004 as the Centre of Excellence in Teletraffic Engineering (CeTEIS). Its initial purpose was postgraduate training in engineering and related fields to obtain the expertise required in the telecommunications field through the execution of Centre of Excellence projects. It is funded by two industry partners: Telkom and Redshift Cyber Security. Its Director is **Prof Herman Myburgh**.

Initially focused on research in the field of telecommunications, its emphasis has gradually expanded to include a number of related fields such as the Internet of Things (IoT) or machine-to-machine communication, data science, data security and the use of machine learning for various relevant estimation and optimisation problems.

This led to the centre being reimagined in 2018 and its name changing to the Centre for Connected Intelligence. Its main aim is the production of impactful research in all the fields that form part of the IoT, which is considered the next step in the evolution of the internet. This includes applications such as smart phones, wearable sensors, smart home systems and intelligent vehicles through the management and presentation of data to end-users.

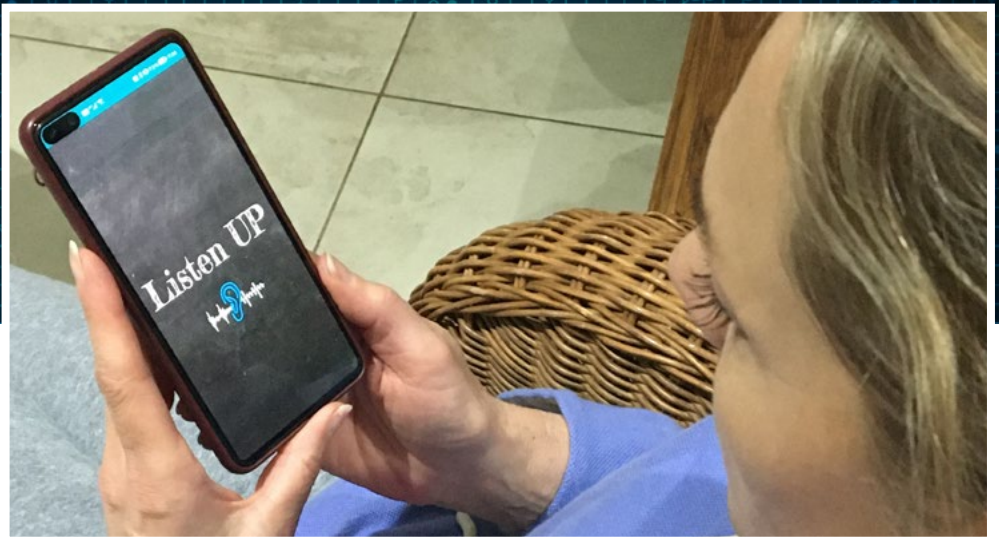
Among the applications the Centre has been working on over the past few years include underground communication and sensing systems for use in mines, intelligent water resource monitoring and management, intelligent transportation systems, low-cost mobile audiological screening, diagnosis and patient management, robotic vision and scene understanding for autonomous operation, medical data analysis, disease onset prediction and patient management, and intelligent farming in the dairy industry.

BIO-ENGINEERING

The Department's Bioengineering Research Group performs research in the wide subject area of medical and biological engineering. Its core work is in the field of sensory prostheses, with a primary focus in auditory neuroscience and cochlear implants for the deaf. As a specialist field, bioengineering includes medical or biomedical engineering and biological engineering, built on a foundation of electronic engineering.

The Bioengineering Research Group is headed by **Prof Johan Hanekom**. Research focuses on understanding human sensory processing and solving problems related to neural prostheses. Research topics include the following:

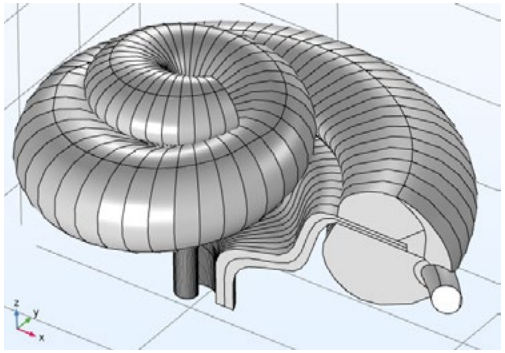
- Cochlear stimulation electrodes, electrical fields and nerve activation
- Computer modelling of the normal and electrically stimulated auditory system



- Psychoacoustic research involving normal-hearing people and cochlear-implant users
- Acoustic models of cochlear implants
- Medical imaging and visualisation
- Speech processing
- Computational auditory neuroscience

Other members of this research group are:

- Prof Tania Hanekom (tania.hanekom@up.ac.za)
- Dr Werner Badenhorst (werner.badenhorst@up.ac.za).



What is a cochlear implant?

A cochlear implant is probably the most successful bioengineering product ever conceived. It is a device that electrically stimulates the auditory system of profoundly deaf individuals to elicit a sensation of sound. Tens of thousands of profoundly deaf people worldwide have regained some hearing by using cochlear implants. These are people who could not benefit from hearing aids, but have now regained the ability to use the telephone.

The implanted part of the device is an array of electrodes that is inserted in the cochlea during surgery. The outer part consists of a microphone and a speech processor that transforms and encodes the sound signal. The encoded sound is transmitted to the implanted electrodes by a radio signal. The electrodes then electrically stimulate nerve fibres in the cochlea to elicit a sensation of sound.

From a clinical viewpoint, cochlear implants are safe, reliable and provide adequate sound information to deaf people. Despite being so successful, cochlear implant systems do not sound like normal hearing. Some users describe the sound as being similar to a radio that is tuned off the station. Not all users perform equally well, and some users derive very little benefit due to the poor quality of the sound. Even the best implant listeners have difficulty following speech in noisy conditions, and most implant users do not like the sound of music.

Ideally, cochlear implants should emulate normal hearing. Most of the current research on cochlear implants worldwide revolves around the problem of how to achieve improved sound quality. The Department's researchers are aiming to provide an improved understanding of the relationship between the design of the cochlear implant and the perceived sound.

Despite the success of cochlear implants from a clinical viewpoint, this relationship is not well understood. Research in the Department includes the computer modelling of cochlear implants and psychoacoustic experimental work. One of the valuable contributions is a very flexible model of the implanted cochlea. This model is used to explore the influence of different designs and the placement of cochlear implant electrodes in targeting the stimulation of specific regions of nerve fibres. This, in turn, aids understanding how changes to different aspects of the cochlear implant design may result in improved sound quality.

Researchers have been developing three areas of work targeted at research questions in cochlear implants. The first involves the electrode: the design, the electrical fields around it, and the nerve fibres targeted by the electrodes. This is investigated using finite element models. The second aims to understand the relationship between stimulus and perception. This is investigated by creating computer models (that exist primarily in Matlab) of the signal processing in the normal auditory system and the electrically stimulated auditory system. The modelling work is supported by psychoacoustic experimental work involving individuals with normal hearing, as well as cochlear implant users. The third area of research aims to enable people with normal hearing to listen to the sounds that cochlear implantees hear. To this end, acoustic models of cochlear implants are created. The hope is that appropriate acoustic models may assist researchers to develop improved speech processing algorithms.

CONTROL SYSTEMS

The Control Systems Research Group strives to address industrial needs through the application of the most recent advances in control theory. The Control Systems Research Group is headed by Prof Ian Craig, who has a B2 rating with the NRF. Its aim is not only to promote, but also to apply automation and control for the benefit of humankind. Research areas of specific interest include model-based control and optimisation in the process industries, and the model-based control of disease networks.

In the case of model-based control and optimisation in the process industries, the aim is to assist industries to "live" lighter on the planet by optimising energy usage in both main and peripheral processes. Better use of energy does not only result in a reduced carbon footprint, but can increase the profitability of a process.

Process optimisation can also be used to increase efficiency in terms of quality and quantity to offset declining profit margins.

To control and optimise a process, it is necessary to have an adequate model of the process. Although significant advances have been made in process modelling, many of the models are not suitable for dynamic process control. The challenge remains to construct low-cost control-relevant process models for use in optimisation and model-based control strategies.

Performance metrics for processes can be incorporated into economic objective functions that form part of a network of advanced process controllers. Additional criteria such as overall equipment effectiveness, energy efficiency, water management, and medium and reagent usage can be included in these objective functions. Information and communication technology, smart mining and industrial internet solutions can be used to optimally integrate the mineral processing supply chain in the form of a distributed network of advanced process controllers. Smart mining concepts such as material tracking and supply chain integration will play a significant role in assisting process controllers to reduce disturbances and extract more benefit from the mineral processing value chain.

Control systems theory also has the potential to provide significant benefits to the medical industry. In the case of the model-based control of disease networks, pinning control of contact networks can potentially reduce the impact of diseases such as HIV/Aids and tuberculosis. The aim is to model the spread of these diseases and develop strategies to guide how and where to administer medicine for the most significant impact.

Other members of this research group are:

- Prof Derik le Roux (derik.leroux@up.ac.za)
- Prof Margret Bauer
- Dr Laurentz Olivier
- Dr Dries Wiid

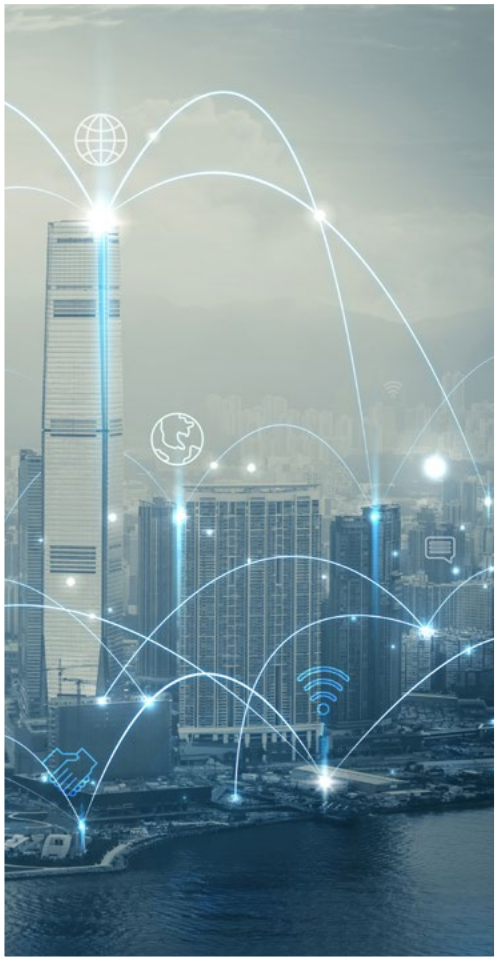
ELECTRO-MAGNETISM

The Department's Electromagnetism Research Group has long been recognised for providing specialised research on a wide variety of microwave components and antennas, as well as computational methods and antenna measurement techniques. The research group is headed by Prof Wimpie Odendaal, who has a B3 rating with the NRF. It was established in 1986 when the University of Pretoria was awarded the first Centre of Excellence in Electromagnetism by the former Foundation for Research Development (now the NRF).

It received a major stimulation in 1990 with the opening of the Compact Antenna Test Range for antenna and radar cross-section measurements. The facility was significantly upgraded in 2010. It is the only university-owned Compact Antenna Test Range in the southern hemisphere to enable the characterisation of antennas in the frequency range of 0.75 to 40 GHz.

Current research activities of the Electromagnetism Research Group include the following:

- The design and analysis of slot and planar antenna elements and arraying such elements for a wide variety of applications
- The use of metamaterials in single antenna elements and antenna arrays with the aim of enhancing the radiation properties of such antennas
- The development of waveguide horn antennas and transverse electromagnetic (TEM) horns of extreme bandwidth, suitable for impulse radar applications, as well as wideband signal detection
- The development of improved wideband double- and quad-ridged horn antennas
- The design and analysis of passive microwave components such as filters, impedance-matching networks and coax-to-waveguide transitions
- The improvement of antenna measurement techniques, such as improved gain accuracy and the calibration of ultra-wideband antennas using complex transfer functions.



Other members of this research group are:

- Prof Johan Joubert (jjoubert@up.ac.za)
- Prof Warren du Plessis (wduplessis@up.ac.za)
- Prof Pieter Jacobs (jpjacobs@up.ac.za)

CENTRE FOR ELECTRO-MAGNETISM

Established in 1996 and headed by **Prof Wimpie Odendaal**, the Centre for Electromagnetism (CEM) conducts research on electromagnetism in its comprehensive measurement facilities. Over the years, the Electromagnetism Group has developed very strong computational abilities in various aspects of electromagnetism. Research is focused on achieving a high level of excellence in electromagnetic technology, particularly the design, development and evaluation of microwave antennas, radar backscatter and antenna measurements.

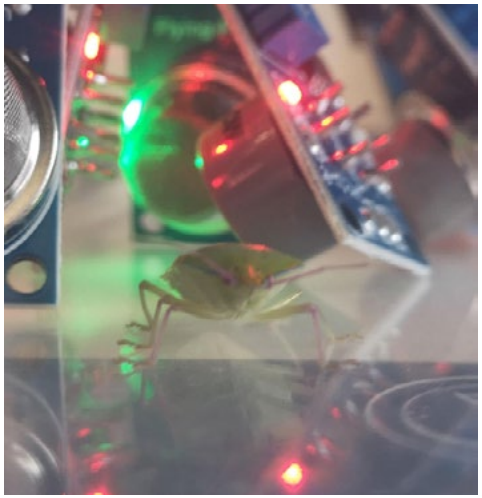
The Centre's objective is to improve interaction on electromagnetism (theoretical analysis and verification measurements on radiation and scattering) with industry through the development of human resources, research and development, and service delivery. It is funded through contract research and compensation for measurement services rendered.

Its endeavour to develop human resources for the country entails the development of undergraduate, postgraduate and research programmes to encourage engineering students and young engineers to pursue research and entrepreneurship in support of the country's economic and social prosperity. It also aims to develop and maintain a centre of expertise in electromagnetism, and to encourage students to get involved. In the process, it promotes electromagnetism through formal and informal continuing engineering education.

Its research and development initiatives focus on electromagnetic analysis, synthesis, verification measurements and measurement metrology.

Research highlights include the development of improved calibration techniques for cellphone base station antenna gain measurements, and an active calibration target for full polarimetric monostatic and bi-static radar cross-section (RCS) measurements.

The Centre identifies the requirements and develops solutions of national interest in cooperation with national calibration standards, the national Department of Health, civil aviation and other interested parties. It also provides other services related to electromagnetic applications. It actively publishes new results at the meetings of local professional societies and by means of technical and other appropriate media.



ELECTRONICS AND MICRO-ELECTRONICS

The Electronics and Microelectronics Research Group is part of the Carl and Emily Fuchs Institute for Microelectronics (CEFIM). Headed by Prof Trudi-Heleen Joubert, who has a C2 NRF rating, it specialises in integrated sensor systems and mm-wave systems.

Research challenges span component development, discrete circuits and systems, embedded systems, and mixed-mode integrated circuit chip design. It also investigates modern additive manufacturing processing technologies for implementing next-generation electronic systems. The research in integrated circuits, discrete analogue and digital signal processors, and radio frequency circuits are applied to solutions in the multidisciplinary domains of health, water, wireless communications, radio astronomy and climate sciences.

Its prominent research focus areas include the following:

Embedded signal processing systems

This research focus area has two main driving applications:

Opto-electronics and imaging
There has been tremendous interest within the research community to expand electro-optical systems by reducing cost and optical complexity through the introduction of lenseless holographic imaging, as well as developing single-pixel camera systems for very expensive sensing devices.

Both methods require advanced image reconstruction algorithms, from which further parameters can be extracted through computer vision methods. The group's focus is on the development of such a system with application in atmospheric pollutant characterisation and concentration detection, as well as in water quality monitoring systems for rural areas. These application areas offer exciting research opportunities, while contributing to the quality of life of all South Africans. A prototype digital inline microscope that is capable of breaking the resolution limit set by the physical dimensions of a sensor's pixels has recently been demonstrated.

High-speed digital signal processing for radio astronomy
Radio astronomy receivers generate an unimaginable amount of digital data that is well beyond the processing capabilities of general computing platforms. The goal is to enable radio astronomers to make both continuum and spectral line observations over a very wide radio frequency band. This research area's focus is on the implementation and optimisation of high speed digital radio astronomy algorithms on parallel computing platforms like field

programmable gate arrays (FPGAs) and graphics processing units (GPUs).

Integrated microelectronic sensor systems

Smart ubiquitous sensing requires sensitive and robust signal readout at low power and low cost, often with wireless connectivity to the Internet of Things (IoT). The integration of microelectronics, energy harvesting and sensor networks provide potentially powerful solutions to challenges in this field. Microsystems research emphasises applications in the environmental monitoring of water and air quality, precision agriculture, as well as human and veterinary biosensing and diagnostics.

This research focus area has three main driving applications:

Mixed-signal integrated circuit design
CMOS technology is well suited to robust signal processing at low power and low cost at economies of scale. Many custom mixed-mode analogue building blocks are considered, but emphasis is on electro-optical and electro-chemical sensor readout circuits and systems.

Printed electronics
Printing methods are investigated as digital processing technologies that have the potential for affordable, bendable, disposable and recyclable electronic systems. Structures and circuits' printed paper and plastic via screen printing and inkjet printing are studied for fine-feature printing. In addition, aerosol jetting holds promise for high-resolution conformal printing.

Heterogeneous integration
Additive manufacturing technologies provide flexible, small-scale, lower cost, automated fabrication in decentralised production facilities. The system packaging can be 3D co-fabricated with smart functional elements. Although extrusion printing is used, design and modelling are performed for stereolithographic printing.

Microwave and millimetre-wave research

This focus area has three main driving applications:

Millimetre-wave microelectronics for terrestrial communications
System-in-package (SiP), system-on-chip (SoC), and hybrid packaged devices are preferred at millimetre-wave frequencies due to the reduced interface complexity. Research gaps in the hybrid packaging of semiconductors in this frequency range, as well as the performance of on-chip passive components, limit the commercial viability of these technologies. Current research includes novel on-chip and hybrid millimetre-wave silicon germanium (SiGe) bipolar CMOS devices and advanced techniques for passives modelling on-chip.

Characterisation and detection of degradation and damage in microelectronic devices
With the ever-increasing deployment of mm-wave transceivers in a variety of applications (5G and 6G communications, automotive RADAR, etc.), there is a need to test these devices for performance degradation during production and *in situ*. Pioneering research uses oscillation-based built-in self-testing (OBIST) to detect faults and estimate the high frequency performance of circuits, without the need to apply test equipment.

Radio-frequency electronics and microelectronics for radio astronomy
Research investigates a wide range of radio-frequency electronic and microelectronic solutions for radio astronomy. These include the development of ultra-wideband receivers with the CMOS system-on chip integration of mid-frequency aperture array low-noise amplifiers and analogue-to-digital converters, and low-cost mm-wave integrated precipitable water vapour radiometry systems.

Other members of this research group are:

- Prof Tinus Stander (tinus.stander@up.ac.za)
- Dr Johan Schoeman (j.schoeman@up.ac.za)

CARL AND EMILY FUCHS INSTITUTE FOR MICRO-ELECTRONICS (CEFIM)

CEFIM is a centre of expertise in microelectronics, providing research and specialist training since 1981. CEFIM establishes facilities for new fields of research, creating a knowledge hub in integrated sensor microsystems and millimetre-wave systems – on-chip, off-chip and in hybrid implementations using modern additive manufacturing technologies, such as printed electronics. These will find applications in point-of-need sensing scenarios, and in future 6G backhaul networks with point-to-point connectivity.

CEFIM researchers regularly produce journal papers and conference proceedings, and are active in organising international scientific conferences. The institute has a history of founding spin-off companies to commercially exploit its research outputs. Over the decades, CEFIM has made valuable contributions to the microelectronics industry, and many expert CEFIM alumni have established themselves as leaders in the field, both in South Africa and internationally.

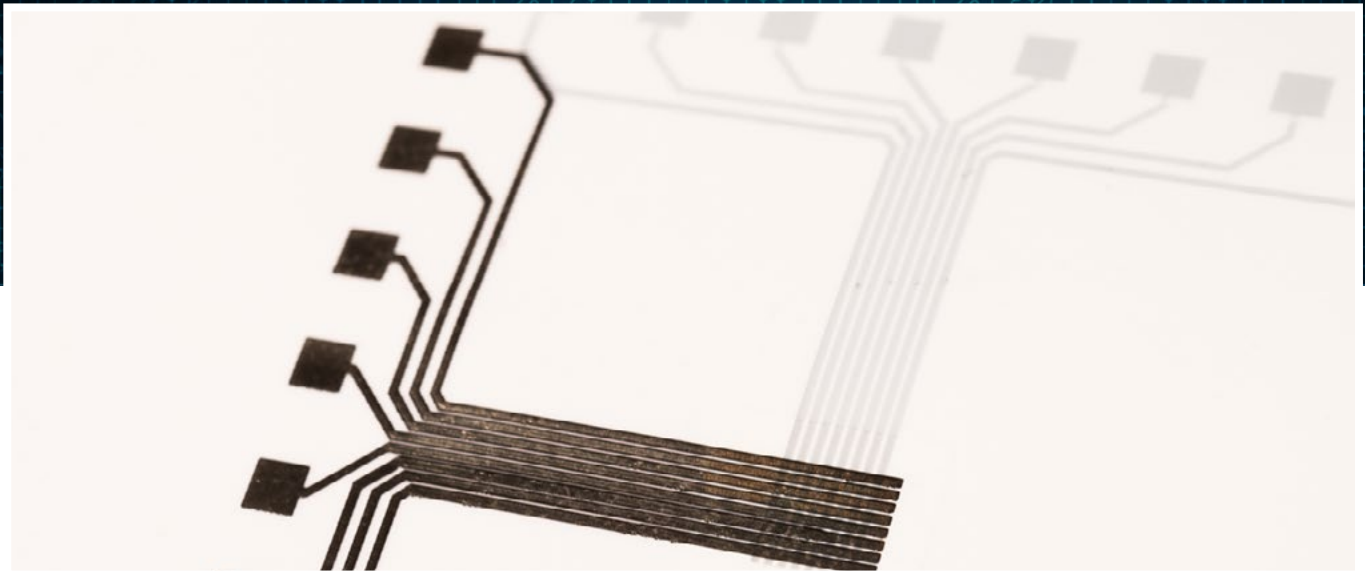
The additive manufacturing of electronic systems

In its flagship project on additive manufacturing for electronic systems (AMES), CEFIM is on a quest to establish integration strategies that best exploit modern additive manufacturing technologies for electronic systems at the micron scale. CEFIM aims to develop low-cost, simple and efficient additive manufacturing processes, and to research the design techniques, modelling methods and tools that can collectively support the reliable integration of systems. AMES enables the realisation of novel solutions in optical, electrochemical, millimetre-wave and microfluidic sensor systems that can impact on society, while contributing to and competing in the global knowledge ecosystem.

A growing demand for inexpensive, rapid, flexible and easy-to-use point-of-care diagnostics has resulted in the rapid growth of the field of printed electronics globally. While research continues to develop the processes and components for printing complete electronic systems, the hybrid integration of off-the-shelf components on low-cost substrates, such as paper and plastic, is important in this domain.

As an example, a low-cost microcontroller-based electronic nose (e-nose) was developed using an array of gas sensors and machine learning algorithms. The instrument had to be portable and, therefore, battery powered. Equipping the device with IoT capabilities enabled valuable distance monitoring. An application investigated for the e-nose is in the field of smart agriculture: the semi-quantitative monitoring of an Amitraz insecticide concentration in a cattle dip solution. On the one hand, an inadequate concentration was found to be ineffective as an insecticide, but on the other, careful concentration control was necessary because tick resistivity against the acaricide is becoming a problem. This device is not only useful at the dipping troughs of affluent farms, but can positively impact on rural African agriculture by making the monitoring of plunge dipping tanks accessible to rural farmers. In future, CEFIM will use functional printed electronics to explore the component development of metal-oxide gas sensors for tighter integration and size, weight and cost efficiency.

Integrated circuit design is an established strength of CEFIM's research, and additive fabrication processes are explored to heterogeneously integrate CEFIM's custom mixed-signal integrated circuit chips into microsystems. For example, CEFIM researchers



are working on integrating CMOS sensor readout chips into a 3D-printed microfluidics lab-on-chip microsystem implementation. An example CMOS design is a capacitive sensing array as part of a non-flow biosensing microsystem for whole-cell counting applications. The microfluidic channel can be printed into the device's housing by stereolithographic (SLA) resin-printing technology. The integrated microsystem will be employed to detect water contamination by bacteria such as *Escherichia coli*, which is the standard indicator organism of faecal pollution.

Another application of additive manufacturing addressed at CEFIM is the creation of low-cost, lightweight, high-frequency antenna components for satellite systems. Here, CEFIM researchers have been exploring different methods of creating antenna assemblies using readily accessible SLA resin-printing technology, and plating the finished parts with non-toxic silver and copper processes. This process reduces the production lead time and environmental impact of these critical components, while making them light enough to be launched from low-cost CubeSat platforms. Initial results are extremely promising, with waveguide components and antenna arrays in the 18–26 GHz frequency range, achieving electrical performance comparable to their copper-extruded counterparts.

The additive technologies CEFIM is currently using include planar and 2½-D processes, but it is looking forward to the flexible, true 3D conformal printing of fine features with a wide range of materials, potentially for fully printed integrated electronic systems.

Expanding the use of materials and processes that facilitate sustainable and responsible production approaches will contribute considerably to the achievement of sustainable development. Its consideration of low-cost, low-volume production technologies is envisaged to enhance scientific research and support domestic manufacturing infrastructure, extending it to small-scale industrial enterprises.

Through the additive manufacturing of electronic systems, CEFIM's transdisciplinary research will help innovate our tomorrow in the domains of health, water, wireless communications, radio astronomy and climate sciences.

ENERGY SYSTEMS

The Energy Systems Research Group draws its research expertise from the Centre for New Energy Systems (CNES), the Exxaro Chair in Energy Efficiency, and the National Hub for Postgraduate Programme in Energy Efficiency and Demand-side Management (EEDSM). The Exxaro Chair in Energy Efficiency leads research in the broad field of energy security for energy-efficiency improvement, while the EEDSM Hub meets the human resource development needs of an expanding and sustainable energy industry in South Africa. The research group is headed by Prof Xiaohua Xia, who has an A-rating with the NRF. He is supported by Prof Xianming Ye.

CENTRE FOR NEW ENERGY SYSTEMS

The Centre for New Energy Systems has gained a reputation as a premier research institute in energy management both nationally and internationally. Its mission is to be a world-class centre of excellence that addresses the research, education, development and industrial applications of energy optimisation and management. The thematic focus on energy management includes both supply-side and demand-side management. The cost-effective supply and end-use of energy are promoted through collaborative research within the Department's Energy Systems Research Group. The Centre's research forms the interface with energy systems, econometrics, control theory and financial mathematics.

It collaborates with research centres on energy management within and outside the country. It prepares courses and seminars to improve opportunities for students, researchers and engineers, organises national and international meetings, workshops and conferences on topics related to energy optimisation and management, and promotes theoretical research and technology transfer. Current research themes include a control system approach to energy management, pricing issues of electricity, demand-side management, unit commitment and a deregulated electricity market, and renewable energy.

The Centre's research focus areas include the following:

Industrial energy optimisation

Existing studies include the development of energy modelling, optimisation and control system approaches, and their application to industrial systems and processes. Examples range from research on model predictive control methods and their application to energy optimisation problems related to colliery, conveyor belts, winders, ventilation systems, water pumping systems, coal beneficiation processes and cogeneration systems to new ideas such as optimal control and load management. The group is actively collaborating with industrial partners, such as Exxaro, to identify and solve problems that are of essential importance to society. One of the group's goals is to seek real-world applications of its research outputs through collaboration with industry.

Energy efficiency and management in buildings

Research in this area covers building energy consumption analysis, building retrofitting, maintenance planning and green building concepts. The key research methodologies are energy management and optimisation, and control system approaches. Existing studies cover research on home appliance scheduling, the hot water stratification phenomenon in electric geysers, heat pumps, and heating, ventilation and air conditioning (HVAC) system control and optimisation.

Transport efficiency

The modelling and optimal control of heavy-haul trains have been studied extensively. Moving forward, an integrated approach to improving the energy efficiency of railway systems in terms of a multi-layer energy system has been proposed and discussed with Transnet, and is under investigation. Future research on this topic will cover an integrated energy approach for railway systems and other types of transport systems, such as mining trucks and conveyor belts.

New methodologies in energy optimisation

A model predictive control (MPC) approach for a class of resource allocation problems has been introduced as one of the priority tools in energy optimisation. The convergence, robustness and integer solutions are obtained. This work brings to light new classes of problems, which will have a far-reaching impact on the research of control theory and energy optimisation. Besides the MPC methodology, observer design techniques and geometric steady states are investigated, and their application in motor efficiency is under investigation.

The general classification of energy efficiency in terms of its performance, operation, equipment and technology are also being studied, in which applications in building energy management and general energy audit are found. This approach has also been taken by Exxaro in developing energy-efficiency specifications for its conveyor belts and other facilities. Further study of this topic for possible improvement and applications are currently being sought.

Energy system performance evaluation

This is a relatively new topic driven by the need for energy conservation and environmental pollution mitigation. The main contents of this topic include the mathematical modelling of energy system measurement and verification, an optimal measurement and verification plan,

collective behaviour in the mass roll-out of energy efficiency programmes, the clean development mechanism (CDM) related to modelling and optimisation, optimal sampling, the socio-economic evaluation of energy systems, demand response modelling, and standard offer and standard product programmes. Case studies include the lighting system renovation and heat pump roll-out programme. More than 300 industrial and commercial energy efficiency projects are run, which provide ample opportunities for postgraduate researchers to practise energy-efficiency principles, build industrial connections and gain extra financial support.

Classical and renewable power systems and electricity policy

Facing the current energy crisis and environmental issues, a better solution for power supply and usage has never been more important. This topic covers a broad area, ranging from classical power flow management and dispatching, generating unit maintenance and reserve margin optimisation, to modern solutions to power supply such as the electricity market, smart grids, renewable energy systems and micro-grids. The generation, distribution and consumption of power all play vital roles in the road to energy-efficiency improvement and better resource utilisation. Generation dispatching and maintenance scheduling are actively investigated. Power distribution control, rural area electrification and intentional islanding are also studied. Research into hybrid renewable power generation systems, as well as electricity market-related research, is ongoing. Future research focus areas are the system efficiency and integration of renewables into the main grid.

EXXARO CHAIR IN ENERGY EFFICIENCY

The Centre for New Energy Systems hosts the Exxaro Chair in Energy Efficiency. The Chair leads research in the broad field of energy security for energy-efficiency improvement. Its primary focus is demand-side energy-efficiency studies in the mining, manufacturing, commercial and residential sectors. With cooperation from Exxaro, the research is put to immediate use. The training of PhD and master's students in applying advanced tools in the study of energy efficiency and demand-side management improves the University's international reputation through research results published in leading international journals. It also speeds up research in the field of energy security in our country.

NATIONAL HUB FOR ENERGY EFFICIENCY AND DEMAND-SIDE MANAGEMENT

The South African National Energy Development Institute (SANEDI), a joint initiative of the Department of Science and Innovation and the Department of Mineral Resources and Energy, selected the University of Pretoria to house the EEDSM Hub. It has identified energy efficiency and demand-side management as key research and development themes for South Africa. The EEDSM postgraduate programme was initiated as one of the targeted, government-funded programmes to generate high-quality master's and doctoral graduates who are specifically trained to meet the needs of an expanding and sustainable energy industry in South Africa.

INTELLIGENT SYSTEMS

Developing systems that can operate in dynamic and unpredictable environments requires advances beyond those typically possible in isolated knowledge fields. Systems found in nature appear to seamlessly integrate concepts from a wide range of knowledge fields. This has proven challenging to mimic and has been the source of inspiration for many innovations. In addition, animals and humans incorporate various levels of reasoning and can interact with their environment.

The Department's Intelligent Systems Group (ISG), led by **Hans Grobler**, specialises in the theory and application of systems that perceive, reason, learn and act intelligently. The aim of the group is to create real-world, intelligent systems that are applicable in the South African context. It endeavours to develop complex systems that not only incorporate different knowledge fields, but exhibit the ability to reason about, and interact with, the environments in which they must operate.

In addition to developing truly intelligent systems, the ISG works on incrementally applying advances in the theory of intelligent systems to existing systems. This often entails incorporating algorithms from the fields of artificial intelligence and machine learning to classical systems approaches.

Its research focus therefore lies in the theory and methods whereby various degrees of intelligence can be simulated in systems. Although intelligence can be applied in various real-world applications, and the ISG's activities include such applications, the focus of the ISG is the development of new approaches to simulated intelligence. The assumption is that such new approaches will be tested in various applications, ranging from the obvious, such as robots, to the less obvious, such as music and planning systems. The various applications and specific systems being developed therefore represent particular test cases of more general theory and methods being developed.

Some of the group's focus areas include the following:

Data fusion

The formal definition of data fusion includes sensor resource management, which results in active changes to the sensing process. It involves combining information and the extraction of patterns – in the broadest sense – to estimate or predict the state of some aspect of the universe, so that the resulting combined information is richer and more informative for the objective at hand. This includes investigating theoretical aspects and applications, specifically those aspects that are important in a South African context. It not only encompasses the combination of lower-level information, such as multiple sensor data, but also high-level (processed) information. The theoretical basis for such methods is the Bayesian statistical approach, which involves the combination of prior knowledge with sensed data. Research in this area aims to address a lack of expertise in the field of data fusion in South Africa. It furthermore focuses on developing methods to correctly integrate the various data streams available, and to detect and extract patterns.

Digital image processing and computer vision

Digital image processing entails the manipulation of images in the form of two-dimensional matrices of pixel values. The most common operations are those of image enhancement and noise reduction. The images under consideration are not limited to the visual spectrum, but may consist of multiple spectral bands. Whereas digital image processing focuses on low-level operations on images, computer vision focuses on the extraction and interpretation of information from images. The most common operations entail the extraction of 3D information from one or more 2D images, and the recognition and

interpretation of the objects contained in the images. As vision is one of humans' most powerful senses, the combination of image processing and computer vision represents one of the most powerful sensing approaches available to artificial systems. However, there is currently only a limited understanding of the human vision system, so there is still significant scope for the advancement of the theory and methods of image processing and computer vision. The primary area currently being investigated is real-time 3D ridged and non-ridged object recognition and pose estimation as part of robotic systems.

Music and artificial intelligence

There is currently a strong interest in developing systems that can recognise, interpret, transcribe, analyse, perform and create music. Recognition of music has become especially relevant in view of the large quantities of music that is currently available in digital format, for example for download from the internet. Pertinent topics range from low-level feature extraction, such as real-time pitch tracking from the raw audio signal, to the use of machine learning and pattern recognition techniques to recognise the genre, mood and performer.

A practical application is intelligent playlist compilation or recommendation systems. Intelligent systems that involve music making at some level have included interactive accompanying systems, as well as automated composition algorithms that accommodate various styles. This typically incorporates approaches based on stochastic process models, grammars, genetic algorithms and neural networks. The current main research focus is on music recognition or interpretation systems in the recognition case, focusing on genre and performer. This allows for specific research topics that might be defined in accordance with students' musical interests and theoretical backgrounds. Other knowledge fields that form the theoretical basis of the group's activities include communication systems, control systems, embedded systems, parallel processing, robotics and autonomous mobile vehicles, and real-time systems.

Other members of this research group are:

- Prof Pieter de Villiers (pieter.devilliers@up.ac.za)
- Prof Pieter Jacobs (jpjacobs@up.ac.za)

Large-scale point cloud data enables the automated creation of realistic VR imaging

The Department's Virtual Reality (VR) Project is developing techniques that will allow the visualisation of real-world mining environments using VR technology. Advances in sensor technology enable real-world environments to be digitalised in the form of a collection of 3D points called point clouds. At the same time, VR technology has advanced to the point where affordable platforms for the visualisation of 3D environments are available. Although colour information may also be captured by sensors, point clouds can typically only be visually interpreted at a distance and lose meaning when viewed at close proximity.

This effect is particularly problematic when point clouds are visualised directly in a VR environment. In order to produce realistic VR visualisations, a number of transformations must be applied to the point cloud. Among other things, surfaces must be generated, and these surfaces must be colourised and ideally texturised. Another factor to consider is the constraints of the commercially available VR platforms, which limit the size of the point clouds that can be visualised.

These aspects were addressed in the initial phase of the VR Project, and a system was developed to allow the VR visualisation of static real-world environments. However, the surfaces produced by the approach described above do not have a geometric and/or semantic meaning attached to them. The generated VR visualisations are therefore static in nature and do not generally allow manipulation.

In the current phase of the research, methods are being researched to extract domain-specific geometric and semantic meaning from point clouds using techniques from the field of artificial intelligence. Researchers involved in the research are also investigating the automated extraction of 3D models, as well as motion analysis performed for sequences of point clouds and other data sources such as image sequences. They are also planning to investigate techniques to utilise both the 3D models and the extracted motion information to produce dynamic 3D visualisations of real-world environments.

As the current industry approach to the generation of VR simulations typically entails the laborious hand crafting of models and their motions, the primary objective of this research is to significantly enhance the viability of using VR for the realistic visualisation and analysis of real-world dynamic environments.

POWER SYSTEMS

The Power Systems Research Group is headed by Prof Michael Gitau, who has a C2 rating from the NRF. It focuses on integrating renewable energy generation, such as wind or photovoltaic power, into traditional grids, as well as reducing inefficiency and emissions at all levels, from small energy sources like a home photovoltaic (PV) cell to large sources like a wind energy farm. Its two main research areas are renewable energy and smart grids.

Renewable energy

The Department's work on renewable energy includes the following focus areas:

- Diagnostics for renewable energy systems
- Assessing and optimising energy storage solutions
- Utility-scale energy storage and optimisation

- Distributed energy storage and value chains
- Developing and delivering energy storage projects

Smart grids

The Department's Smart Grid Laboratory has established itself as a leader in smart grid research. It delivers high-quality research, products, services and capabilities that fill the widening gap between end users and electricity suppliers across the African markets. Some of the practical applications and opportunities for research include renewable energy integration, smart prepaid metering (with time of use), advanced metering infrastructure (AMI) security and active network management.

The University has a close relationship with the South African National Energy Development Institute (SANEDI), Rand Water and the Department of Mineral Resources and Energy.

Being within the City of Tshwane, it has also established strong ties with the local municipality. Together, they are paving the way for new approaches to solving Africa's energy crisis.

The Department's work on smart grids includes the following focus areas:

- Smart distribution systems
- Smart metering and system diagnostics
- Renewable energy integration

Ultimately, smart grid technology is focused on collecting more information on how electricity and power are being used to make better management decisions.

Other members of this research group are:

- Prof Raj Naidoo (raj.naidoo@up.ac.za)
- Dr Karl Mbukani (mwanawakalaga.mbukani@up.ac.za)
- Lebogang Masike (lebogang.masike@up.ac.za)

Smart grids spark the modernisation of South Africa's energy grid

One of the biggest threats to South Africa's economy at present is its reliance on coal-fired energy and the instability of the country's electricity-generating capacity, giving rise to intermittent loadshedding events. Researchers are making use of Fourth Industrial Revolution (4IR) technology to enable the integration of renewable energy into the county's energy grid.

The application of communication and data collection techniques to provide more information on the state of the country's energy grid is a particular focus area of the Smart Grid Laboratory. This is where the power grid meets the Internet of Things (IoT).

Among other things, projects aim to determine how best to integrate renewable energy sources into conventional power systems using smart grids. This entails the application of smart distribution systems, smart metering and system diagnostics, and renewable energy integration.

Making use of smart technology such as sensors and smart devices to share information not only affects the national electricity system, but can improve efficiency in residential, commercial and industrial sectors through connectivity as well.

This is done by collecting important information from sensors in electrical

systems that can reduce wastage and help investigate alternative sources of energy for specific tasks and times. By deploying sensor technology, engineers working on an electrical grid can obtain additional information about the status of the grid, which will ultimately improve the efficiency of the system. This can help reduce wear and tear, extend the lifetime of the grid, and improve future grid design.

The Smart Grid Laboratory offers a fresh approach to smart grid research that empowers end users, delivers savings and benefits utilities and municipalities. These benefits will be realised across the residential, commercial and industrial sectors.

For the household, the smart grid provides information on energy use in the house, which can advise homeowners on cost-saving activities.

This incorporates systems such as solar water heaters and double glazing on windows. Municipal managers can also use this data to properly shape pricing for electricity and forecast future power demands to better service the community.

For the commercial sector, smart grids can maintain productivity for a company by integrating secondary power sources and prioritising them accordingly.

For industry, this technology can vastly improve the efficiency of various electronic components.

Capacity building and training forms an important element of the Smart Grid Laboratory's strategic planning. It currently has 15 master's degree and 13 PhD students, who are engaged in research related to the power grid.

Research topics range from the protection of distribution systems and cost-effective ways of incorporating the distributed energy resources into the current grid to optimise renewable energy.

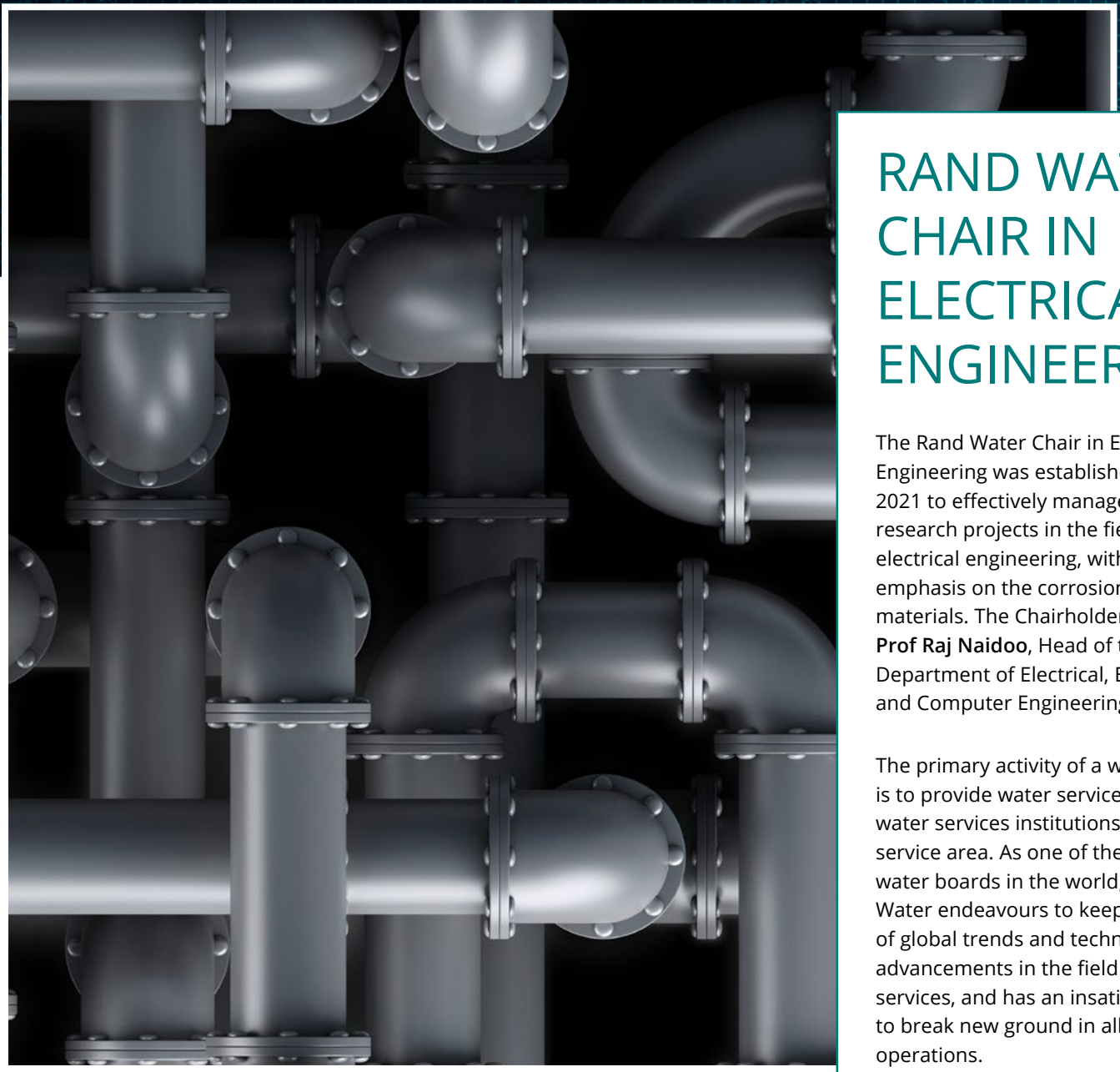
Staff members of the Smart Grid Laboratory also present short courses in partnership with the Department of Mineral Resources and Energy (DMRE) and SANEDI on smart metering for beginners, practical smart metering, with a focus on audits and installation practices, a systems approach to smart metering implementation at municipalities, cybersecurity essentials with a focus on AMI security in smart grids, and smart grid power distribution.

Towards the end of 2020, the Department trained graduates from technical and vocational education and training (TVET) colleges on hydrogen fuel cell systems in partnership with Bambili Energy, the Ministry of Higher Education, Science and Innovation, and the Energy and Water Sector Education and Training Authority (EWSeta). The purpose of this training was to develop competent, capable and work-ready technicians for the deployment, installation and maintenance of hydrogen fuel cell systems in South Africa and beyond.

This is of particular significance for the future of renewable energy, as fuel cells are expected to play a significant role in providing energy to buildings and in off-grid electrification, particularly in areas where grid extension is not economically viable.

In addition, the Department's smart grid researchers offer consultation services to industry. In this capacity, they provide advice on aspects such as smart cities and smart grids, the green economy, product design and development, remote diagnostics, and the design and optimisation of renewable energy systems, including microgrids.

They are also working with entities such as SANEDI, Rand Water and the DMRE to understand and prevent the potential data security threats that might compromise smart grids.



RAND WATER CHAIR IN ELECTRICAL ENGINEERING

The Rand Water Chair in Electrical Engineering was established in 2021 to effectively manage diverse research projects in the field of electrical engineering, with particular emphasis on the corrosion of pipe materials. The Chairholder is **Prof Raj Naidoo**, Head of the Department of Electrical, Electronic and Computer Engineering.

The primary activity of a water board is to provide water services to other water services institutions within its service area. As one of the largest water boards in the world, Rand Water endeavours to keep abreast of global trends and technological advancements in the field of water services, and has an insatiable thirst to break new ground in all sectors of operations.

The Rand Water Chair in Electrical Engineering was established to develop a research niche that is relevant to the South African water supply sector. This will position the University of Pretoria and Rand Water at the forefront of local and international developments.

A particular emphasis of the research conducted in the Chair is the corrosion of pipe materials. Of more importance is the possibility of Rand Water generating power using its own water to supply the current used in the presently impressed system. Activities include teaching at the advanced undergraduate level, being a study leader for undergraduate and postgraduate research projects, liaison with Rand Water, performing investigations and research for Rand Water, and the supervision of support staff.

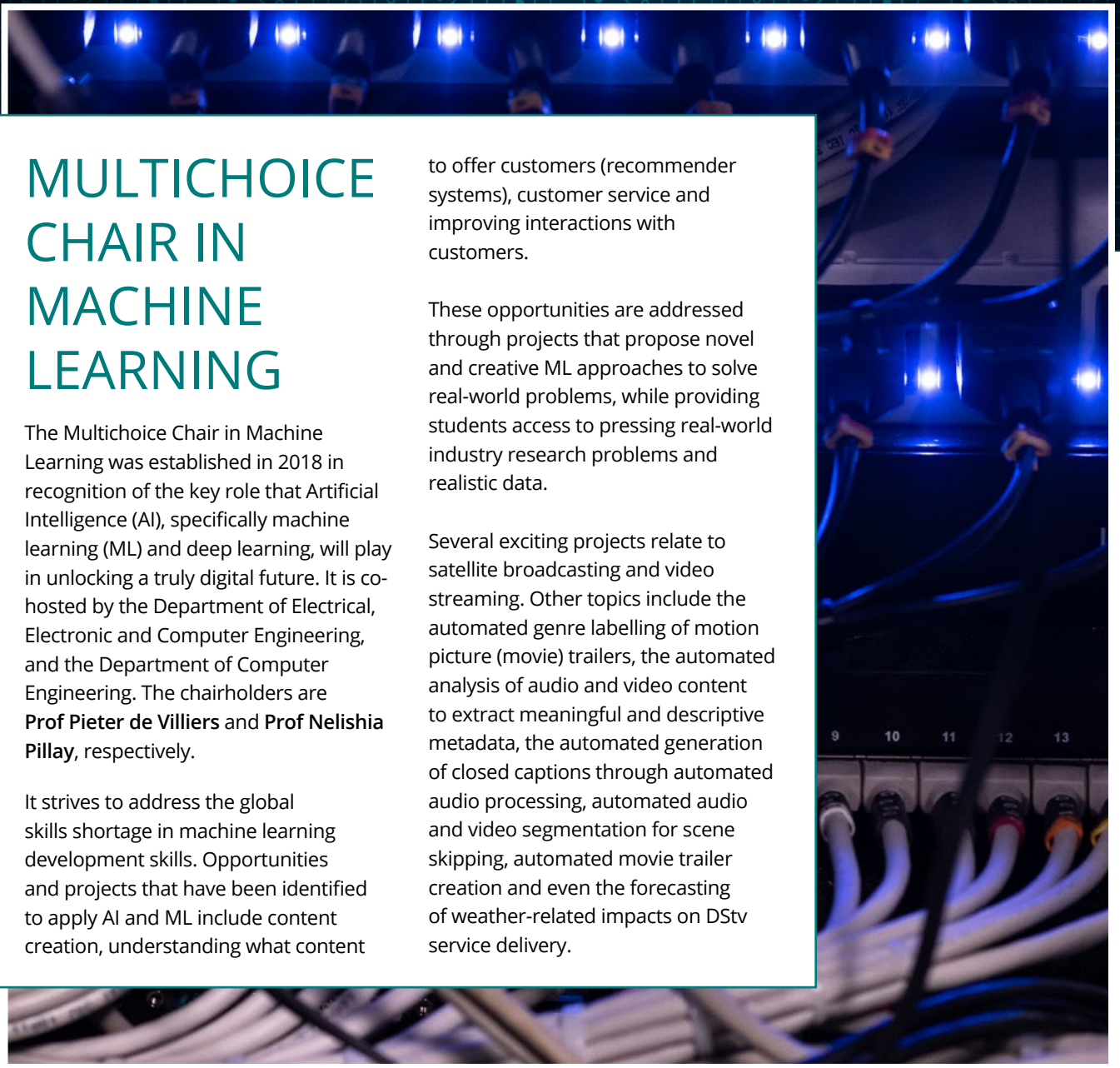
The primary role of the Chair will be the development and execution of projects with clear measurable objectives in response to research questions raised by Rand Water. Other objectives include the development of human capital, achieving operational integrity and using best-fit technology, and helping Rand Water maintain financial health and sustainability.

SIGNAL PROCESSING AND TELE-COMMUNICATIONS

The Signal Processing and Telecommunications Research Group performs research into the manipulation of electrical and electromagnetic signals for the purposes of electronic sensing, communications and inference. The group has particular interests in modulation and coding, which make communications more efficient and reliable, data fusion, which involves the combination of signals from different sensors and sources, and Bayesian inference, a rigorous statistical formulation for the inference of sensed quantities in the world. Machine learning is also used on signals to perform automated tasks such as interpreting signals (for example extracting text from recorded voice signals, or recognising objects within digital images or video). The Signal Processing and Telecommunications Research Group is headed by Prof Pieter de Villiers, who has a C1 rating from the NRF.

Other members of this research group are:

- Prof Sunil Maharaj (sunil.maharaj@up.ac.za)
- Dr Jacques van Wyk (jhvanwyk@up.ac.za)
- Dr Filip Paluncic (filip.paluncic@up.ac.za)



MULTICHOICE CHAIR IN MACHINE LEARNING

The Multichoice Chair in Machine Learning was established in 2018 in recognition of the key role that Artificial Intelligence (AI), specifically machine learning (ML) and deep learning, will play in unlocking a truly digital future. It is co-hosted by the Department of Electrical, Electronic and Computer Engineering, and the Department of Computer Engineering. The chairholders are **Prof Pieter de Villiers** and **Prof Nelishia Pillay**, respectively.

It strives to address the global skills shortage in machine learning development skills. Opportunities and projects that have been identified to apply AI and ML include content creation, understanding what content to offer customers (recommender systems), customer service and improving interactions with customers.

These opportunities are addressed through projects that propose novel and creative ML approaches to solve real-world problems, while providing students access to pressing real-world industry research problems and realistic data.

Several exciting projects relate to satellite broadcasting and video streaming. Other topics include the automated genre labelling of motion picture (movie) trailers, the automated analysis of audio and video content to extract meaningful and descriptive metadata, the automated generation of closed captions through automated audio processing, automated audio and video segmentation for scene skipping, automated movie trailer creation and even the forecasting of weather-related impacts on DStv service delivery.

Read more
www.up.ac.za/ebit: About us – Publications

Developing a movie recommendation system using deep learning features

Following the popularisation of media streaming, a number of video-streaming services are continuously buying new video content to generate a potential profit. As such, the newly added content has to be handled well to be recommended to suitable users. Video-sharing websites rely heavily on video recommendation systems to assist users to discover videos they may enjoy.

With the enormous increase in the number of new videos constantly being uploaded, some video-streaming services have to deal with unrated, unaudited and completely new content, which they know nothing about. Recent studies on video content analysis and video-retrieval tasks use various types of deep learning features extracted using pre-trained models due to their outstanding performance in different domains, compared to hand-crafted features.

A video recommendation system is a user-level video-filtering service that helps users explore the videos that are available to watch. It offers a more personalised experience for users by recommending the most relevant and appropriate videos for them to watch. In order to do this, algorithms are used to analyse the information about the videos and the users, as well as the past interactions between them.

Existing recommendation systems use one of three approaches: the collaborative filtering recommendation method, the content-based recommendation method and the hybrid recommendation method, which is a combination of the first two.

Most video-streaming services that use a video recommendation system to compute the video's relevance based on user feedback use the collaborative filtering method because of its state-of-the-art accuracy. This feedback is used to model the user-video preference, and compute video-to-video relevance scores to provide personalised recommendations. However, this approach suffers from the new item cold-start problem.

A master's research project by one of the Multichoice bursary holders, Adolfo Almeida, addressed the new item cold-start problem by exploring the potential of various deep learning features to provide video recommendations.

Various deep learning features extracted from multi-modal, extremely high-dimensional information in videos are used to enhance the quality of recommendations. These features include those that capture the visual appearance, audio and motion information from video content.

In the process, the deep learning features were compared to genre features and hand-crafted features. Different fusion methods were explored to evaluate how well these feature modalities can be combined to fully exploit the complementary information captured by them. This was done to improve the recommendation quality in terms of accuracy and beyond accuracy metrics.

Experiments on a real-world video dataset for movie recommendations show that deep learning features outperform hand-crafted features.

Finally, an ablation study was performed to empirically assess the importance of using a diverse range of video content features on the overall recommendation quality, while taking full advantage of the available data.

The results suggested that the fusion of visual, audio and action features provides more accurate video recommendations to users when compared to the fusion of only visual and audio features. In addition, the combination of various deep learning features with hand-crafted features and textual metadata yields significant improvement in recommendations compared to combining only deep learning features.

SENTECH CHAIR IN BROADBAND WIRELESS MULTIMEDIA COMMUNICATIONS

The Sentech Chair in Broadband Wireless Multimedia Communications (BWMC) offers a world-class research environment with state-of-the-art research facilities. Collaboration takes place with industry and internationally renowned researchers in the field of wireless broadband multimedia communications for the benefit of Sentech, the University and South Africa in general. The Chairholder is **Prof Sunil Maharaj**, former Dean of the Faculty of Engineering, Built Environment and Information Technology, and current Vice-Principal: Research, Innovation and Postgraduate Education of the University of Pretoria.

The Research Chair promotes postgraduate study and research in the field of mobile broadband multimedia communications networks, products and services, and encourages the further interaction between academic institutions and industry in general, and specifically between the University of Pretoria and Sentech. It emphasises research and product development in the fields of radio-frequency communications, digital transmission technology, digital network technology, telecommunications and speech processing. Furthermore, it strives to develop high-quality technical skills and expertise for industry and the research fraternity, and to contribute to the global competitiveness of Africa and South Africa, in particular.

Research activities include the following:

- MIMO channel modelling issues
- MIMO channel modelling: information theoretic approach
- Measurement campaigns for different channel configurations
- Super-orthogonal complementary complex spreading sequences: realisation of novel extended families
- Multidimensional code position modulation in DSSS with coding
- MIMO fading channels – theoretic, simulation and real-time realisation of channel simulator
- Non-binary sparse graph codes and STC: LDPC, RAC, DFC, etc.
- Channel estimation and performance analysis of MIMO-OFDM schemes
- Characterisation and development of a WiMAX and MIMO-WiMAX simulation platform
- Beam-forming techniques and models for MIMO-OFDM
- Cognitive radio technology

DEPARTMENTAL FACILITIES

World-class laboratories support quality research outputs

The world-class laboratories of the Department of Electrical, Electronic and Computer Engineering provide a platform to conduct cutting-edge research. They also equip students with the practical skills they need to excel in their future careers as electrical, electronic and computer engineers.

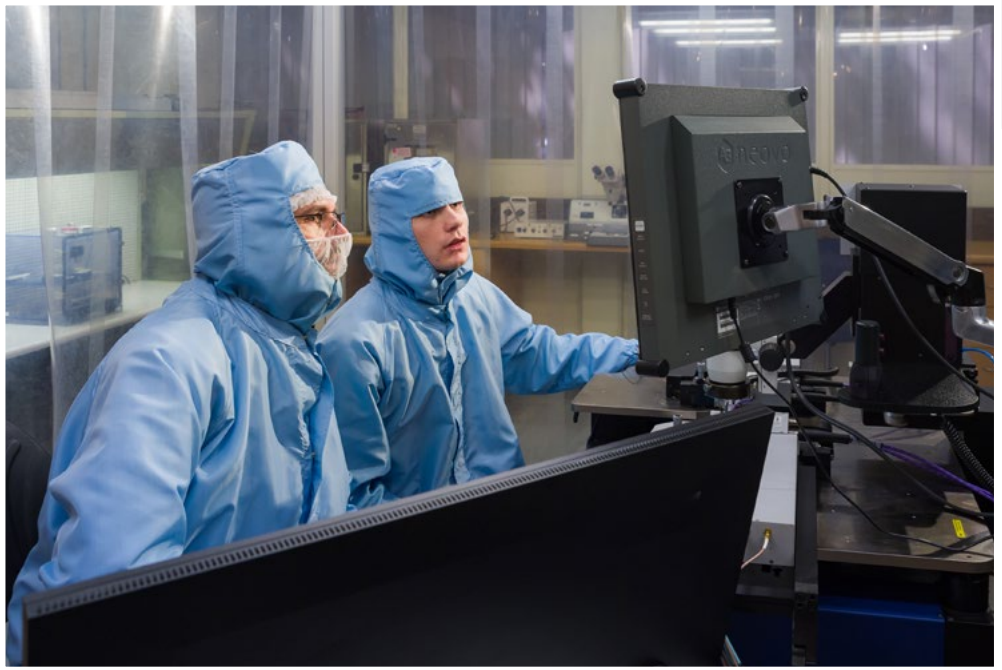
FLAGSHIP LABORATORIES

The Agilent Computer-aided Education Centre (CAEC)

This facility was established in 2012 with the support of Agilent Technologies, an internationally renowned life sciences company that provides instruments, software services and consumables for the entire laboratory workflow. It is the largest undergraduate electrical engineering training laboratory in South Africa, with 144 workstations and state-of-the-art equipment, including a digital oscilloscope with a built-in function generator, a dual-display multi-meter and a triple output DC power supply. First- and second-year engineering students from all engineering disciplines do their practicals here as part of their training in electronic circuit theory.

The Compact Antenna Measurement Range

This is a state-of-the-art system in the Centre for Electromagnetism that can measure the radar scattering characteristics of objects as large as 1.8 m or as small as a golf ball. It can also perform the task of measuring the radiation characteristics of antennas. It is a unique facility in southern Africa, and only a few universities in the world have such a facility.



The compact range and anechoic chamber are used to gain a deeper understanding of electromagnetic scattering and radiation mechanisms, including the relationship of signal frequency and polarisation to an object's size and shape.

Other laboratories in the Department

- Sentech Laboratory
- Huawei Laboratory
- Intelligent Systems Group Laboratory
- Bioengineering Laboratory
- Microwave and Antenna Laboratory
- Signal Processing and Telecommunications Laboratory
- CISCO Laboratory
- Smart Grids Laboratories
- Nano-micro Manufacturing Facility
- Printed Electronics Laboratory
- Light and Vision Laboratory
- Power Electronics Laboratory
- Millimetre-wave Laboratory
- Electrical Heavy Machines Laboratory

RESEARCH FEATURE

ENERGY SECURITY DEPENDS ON THE DEVELOPMENT OF SOUTH AFRICA'S HYDROGEN ECONOMY

Given the country's current energy crisis and the increasing problems related to the supply of coal-fired sources of electricity, the time has come to consider expanding South Africa's current alternative energy sources. As an institution committed to pursuing research that addresses complex societal challenges, the University of Pretoria has identified energy as one of its core institutional research themes.

Research in the Department of Electrical, Electronic and Computer Engineering, under its Power Systems research focus area, is looking at optimising and developing new approaches to the country's energy and power systems. A particular focus is building capacity to support the development of South Africa's hydrogen potential and the creation of a South African hydrogen economy for energy security and sustainability.

While fossil fuels such as coal, oil and natural gas have long proven their effectiveness in producing heat and providing power for domestic and industrial use, they are becoming harder to extract in a cost-effective manner. Their effect on the environment and human health in terms of their carbon emissions is becoming an increasing source of concern globally.

The drive to find alternative sources of energy finds its origin in the Paris Agreement, signed by 196 parties at the United Nations Climate Change Conference in 2015. This agreement seeks to limit the global increase in temperature to less than 2 °C by the end of the century. Achieving this target depends on reducing our dependence on fossil fuels and realising carbon neutrality.

Although South Africa has made huge strides in entering the renewable energy sector through the introduction of solar, wind and hydro power over recent years, there are many arguments in favour of adding hydrogen to the list of alternatives. At the same time, this will contribute to establishing South Africa's hydrogen economy. Most of the challenges facing the large-scale adoption of renewable energy relate to the efficient storage and transportation of clean energy.

Hydrogen – particularly green hydrogen – is exceptionally energy dense per unit of weight compared to other fuels. This facilitates its storage and transportation. Through its direct combustion, coupled with its use in fuel cells and as an industrial feedstock, it can be produced cost effectively to support decarbonisation, and presents enormous opportunities for South Africa in the global carbon economy. Green hydrogen, as an alternative fuel source, is produced in a sustainable manner with the zero emission of carbon. It is mainly produced through the electrolysis of water.

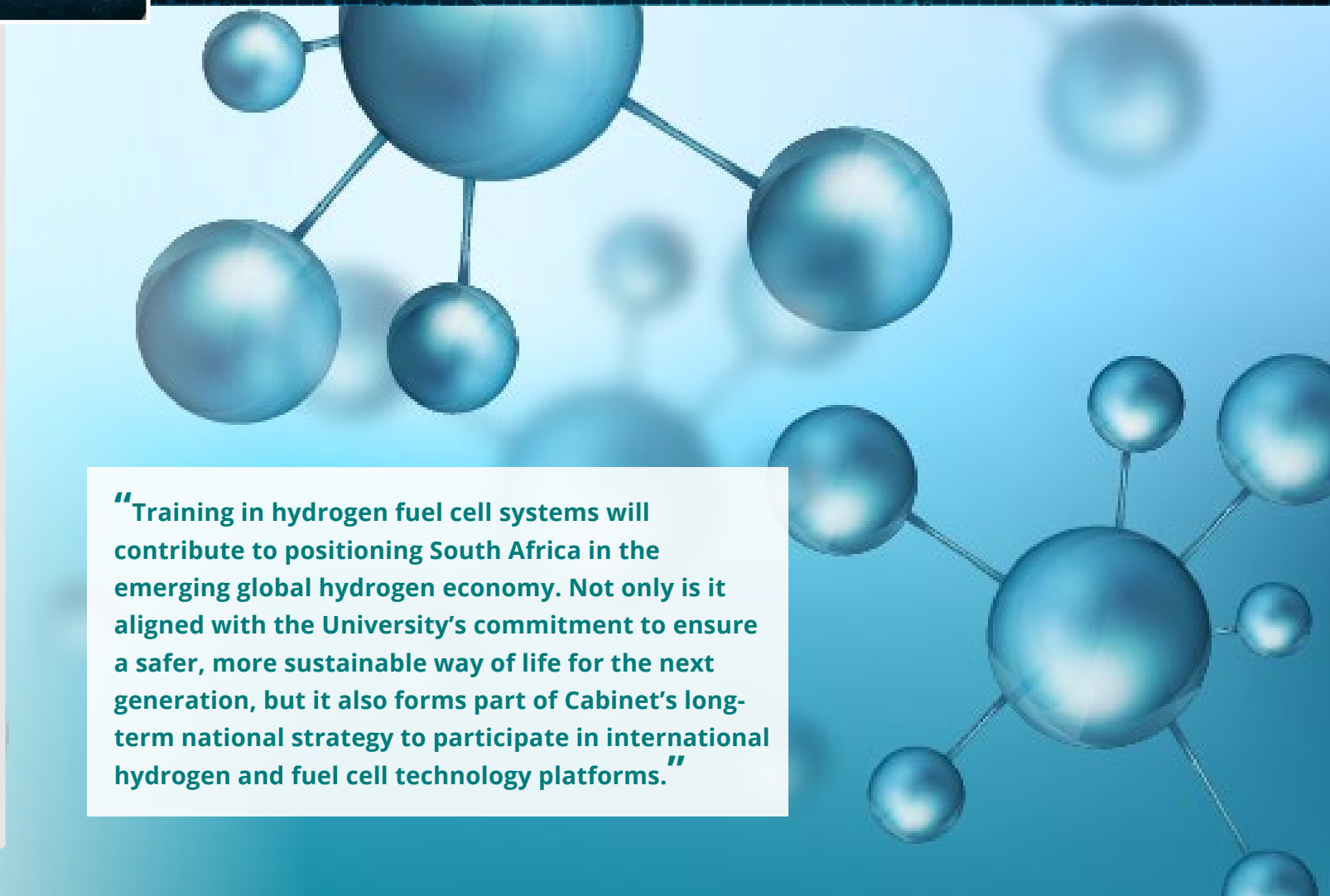
Since South Africa is a water-scarce country, use is increasingly being made of desalinated water for this purpose. An additional contribution to the economy is the beneficiation of the country's platinum group metals (PGMs) that are used in the manufacture of the hydrogen fuel cells.

The South African National Energy Development Institute (SANEDI), an agency established by Parliament to direct, monitor and conduct energy research and development, and to promote technology innovation to establish the efficient use of energy, has identified the University of Pretoria as a leader in research into energy efficiency and the integration of renewable energy into the national energy grid.

In partnership with Bambili Energy, one of the country's leading manufacturers of hydrogen fuel cells and their subcomponents, the Department is

building capacity to safely install, operate, maintain and refuel the hydrogen fuel cell systems on which the creation of a hydrogen economy depends. This training, launched at the end of 2020, is aimed at developing competent, capable and work-ready technicians for the deployment, installation and maintenance of hydrogen fuel cell systems. Some of the graduates of this training have gone on to complete internships at Bambili Energy, and are currently employed in the organisation's maintenance team.

According to Head of Department, Prof Raj Naidoo, training such as this will contribute to positioning South Africa in the emerging global hydrogen economy. Not only is it aligned with the University's commitment to ensure a safer, more sustainable way of life for the next generation, but it also forms part of Cabinet's long-term national strategy to participate in international hydrogen and fuel cell technology platforms.



"Training in hydrogen fuel cell systems will contribute to positioning South Africa in the emerging global hydrogen economy. Not only is it aligned with the University's commitment to ensure a safer, more sustainable way of life for the next generation, but it also forms part of Cabinet's long-term national strategy to participate in international hydrogen and fuel cell technology platforms."

TEACHING AND LEARNING IN THE DEPARTMENT

THE SPONTANEOUS AND ORGANIC GROWTH OF AN INTEGRATED CURRICULUM

A team comprising lecturers across the three domains of electrical, electronic and computer engineering have succeeded in combining their talents to develop a unique intervention for students to apply what they have learnt in an engaging and a stimulating way across several modules.

This team, which was the joint winner of the Faculty's Teaching and Learning Award for 2022, taught several modules in the Department's curricula. it comprises Prof Tania Hanekom (third-year Microcontrollers), Prof Trudi-Heleen Joubert (second-year Digital Systems and third-year Analogue Electronics), Prof Tinus Stander and Dr Werner Badenhorst (third-year design modules), Prof Ian Craig and Prof Derik le Roux (third-year Control Systems), Pieter Roodt (the Robot School) and Willem van Jaarsveld (EBIT Robot Race).

This initiative had two objectives: to provide world-class engineering education so that students can make a meaningful contribution to addressing local and global challenges through technology; and to spark an interest in electrical, electronic and computer engineering among learners.

The initiative had its origin in 2013 when Prof Tania Hanekom developed a project-based learning initiative known as the EBIT Robot Race. Students had to work together to design and build a microcontroller-based autonomous robotic vehicle.

In 2015, Prof Trudi-Heleen Joubert identified a potential alignment opportunity between the design of an analogue sensor system and the embedded system facets of the robotic vehicle, particularly as the third-year Analogue Electronics module runs concurrently with the third-year Microcontrollers module, in which the Robot Race was being presented at the time. At the same time, second-year Digital Systems students were introduced to a practical assignment in which they had to design a rudimentary navigation strategy for a robotic vehicle, and implement this strategy on the programmable component platform. This was in anticipation of the design and implementation of the robotic vehicle to be built in their third year.

The impetus for the current intervention occurred in 2020 with the advent of the COVID-19 pandemic. As students could not come to campus, they received component kits with which to build their robotic vehicles. A staffing shortage also led to the combination of individual design modules for electrical, electronic and computer engineering.

Prof Tinus Stander then approached Prof Hanekom about using the contextual framework of the microcontroller-based autonomous robotic vehicles to teach engineering system design in the Department's third-year design modules. This provided the perfect opportunity to implement a new level of integration.

“A further outcome of this initiative has been its utilisation as a community engagement project in the Faculty.”

In the Department’s third-year design modules, the design of the robotic vehicle was split into three separate subsystems, and a software hub was written to allow the remote integration and testing of the individual subsystems. Each of the subsystems targeted a specific discipline, although the three programmes (electrical, electronic and computer engineering) had sufficient background to master the design challenges associated with all the subsystems.

Another module that had to find an emergency hands-on home-based alternative to laboratory-based work during the pandemic was the third-year Control Systems module presented by Prof Ian Craig and Prof Derik le Roux. This module runs concurrently with the design modules.

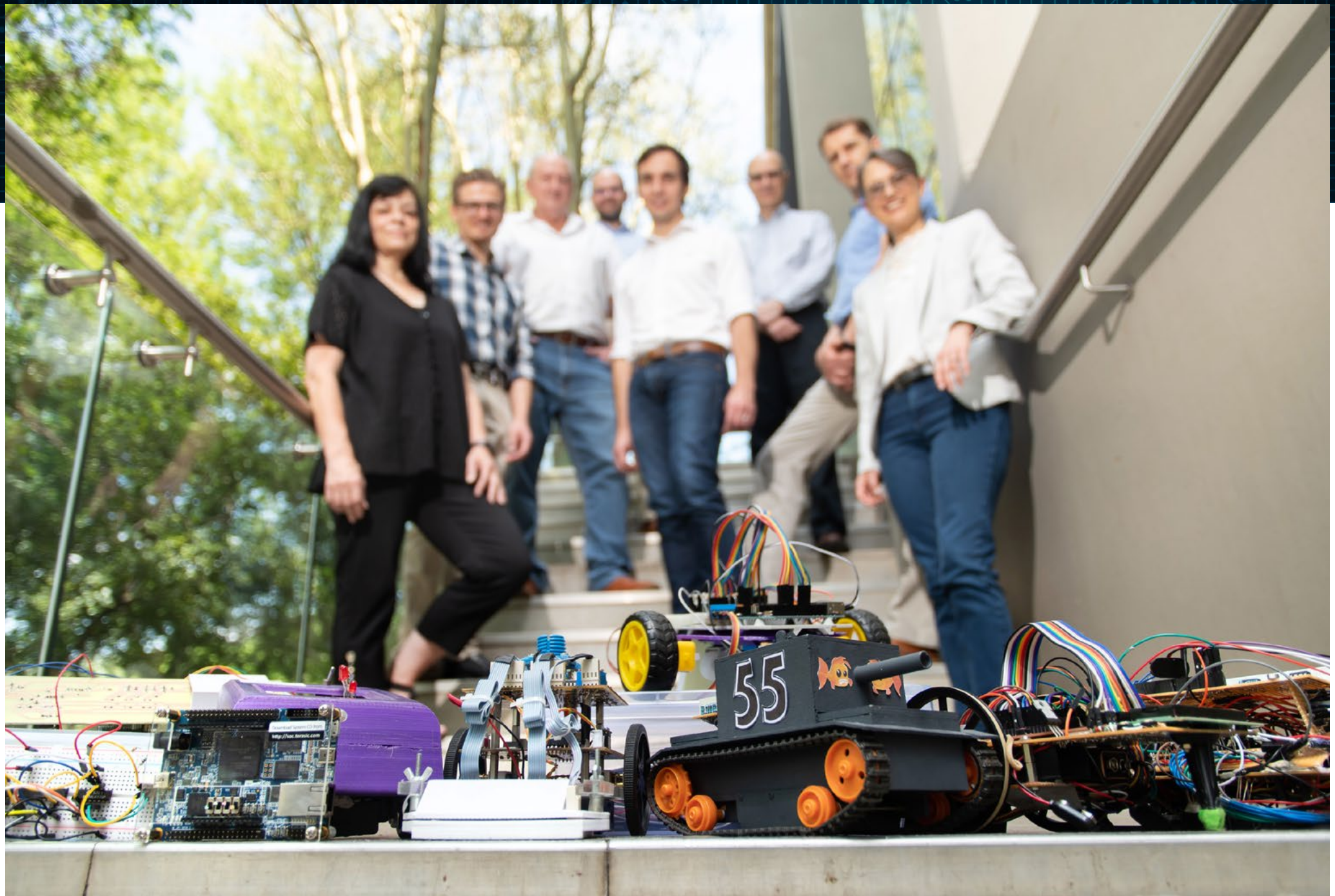
According to Prof Hanekom, the logical approach was to piggyback on the design module hardware by using the microcontroller-based autonomous robotic vehicles as the plant to be controlled. Students were therefore asked to implement a rudimentary control system, similar to the one required in the Microcontrollers and Design modules, while they had to analyse the robotic vehicles to design and implement a sophisticated proportional integral derivative control system for the Control Systems module. This allowed cross-module comparison between different control system strategies to develop a deeper understanding of the behaviour of control systems implemented at different levels of complexity.

In 2021, while pandemic conditions were still prevailing, the EBIT Robot Race was taken online in the Microprocessor and Analogue Electronics modules.
Dr Werner Badenhorst joined the design modules with the responsibility to build on the foundation that had been laid in 2020. His mandate was to review and amend the practical challenge so that students could reiterate the design of their robotic vehicles from a systems engineering perspective, instead of simply repeating the experience from the previous semester.

A new dimension was introduced to the traditional EBIT Robot Race challenge when students had to connect two types of sensors to the same hardware platform. This was done to satisfy the requirements of the Control Systems module. “The project in its present shape is being refined,” said Prof Hanekom. “It is now in its third iteration, and is reaching maturity.”

A further outcome of this initiative has been its utilisation as a community engagement project in the Faculty to encourage school learners to follow a career in science, technology, engineering and mathematics. A project such as the EBIT Robot Race provides the ideal platform to drive social change, and alter the perception that engineering is predominantly a male career. This led to the founding of the Department’s Robot School.

Second-year students can use this platform to teach robotics to school learners as part of the community work they are required to perform as part of their curriculum. Pieter Roodt is managing and driving the development and implementation of this programme, which has the added advantage of exposing students beyond the Department of Electrical, Electronic and Computer Engineering to the principles of robotics.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THE FACULTY'S ROBOT RACE DAY

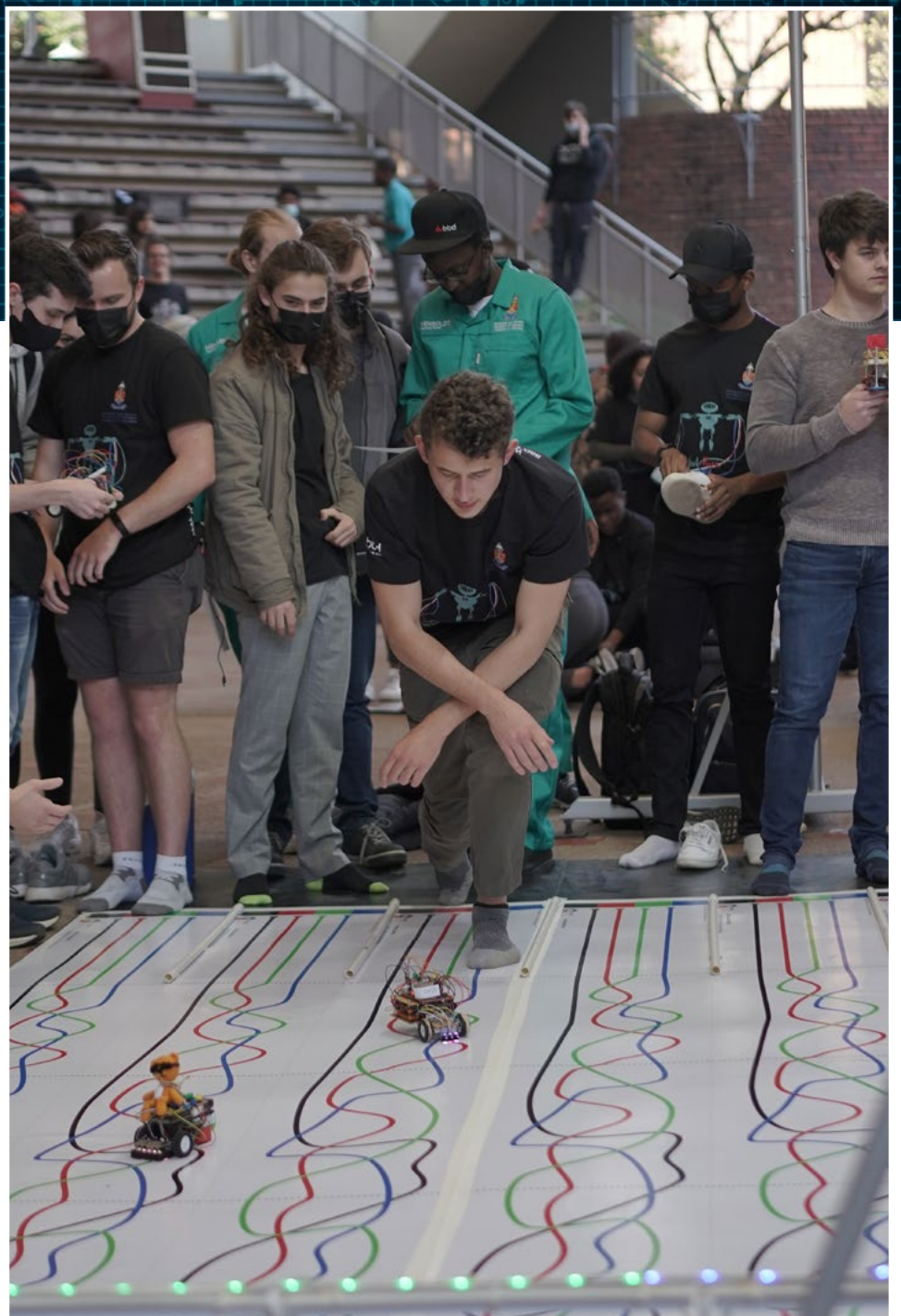
The annual Robot Race of the Faculty of Engineering, Built Environment and Information Technology (EBIT) was initiated by Prof Tania Hanekom in 2013 in an attempt to create an engaging, enjoyable practical project for the third-year Microcontrollers module as students were really struggling with the module.

The intent was to generat excitement in the students about the learning material by creating a formal opportunity to play and explore. Inviting spectators to attend the Robot Race, which was initially no more than the final practical assessment in the Microcontrollers module, provided the opportunity for other students and members of the public to see what the students were doing in class.

Students had to work together in small groups to design and build a microcontroller-based autonomous robotic vehicle. The outcome of the project was for the autonomous vehicle to navigate a coloured line laid out to purposefully cross over other coloured lines and not veer off course, in the shortest time possible.

The project has been extended to other modules within the Department, enabling the horizontal and vertical integration of learning content in the respective programmes.

The Robot Race is also the inspiration behind a Robot School community engagement project, launched in 2021. This involves second-year and final-year students in the Department, who need to complete a period of work-integrated learning. The Robot School curriculum is targeted at Grade 8 to Grade 11 learners, and is presented free of charge between April and October each year.



COMMUNITY ENGAGEMENT: ROBOT SCHOOL AND SENSOR SCHOOL

Second-year and final-year students in the Department of Electrical, Electronic and Computer Engineering who need to complete a period of work-integrated learning are enabled to teach learners how to build robots and how sensors work in the Department's Robot School and its Sensor School.

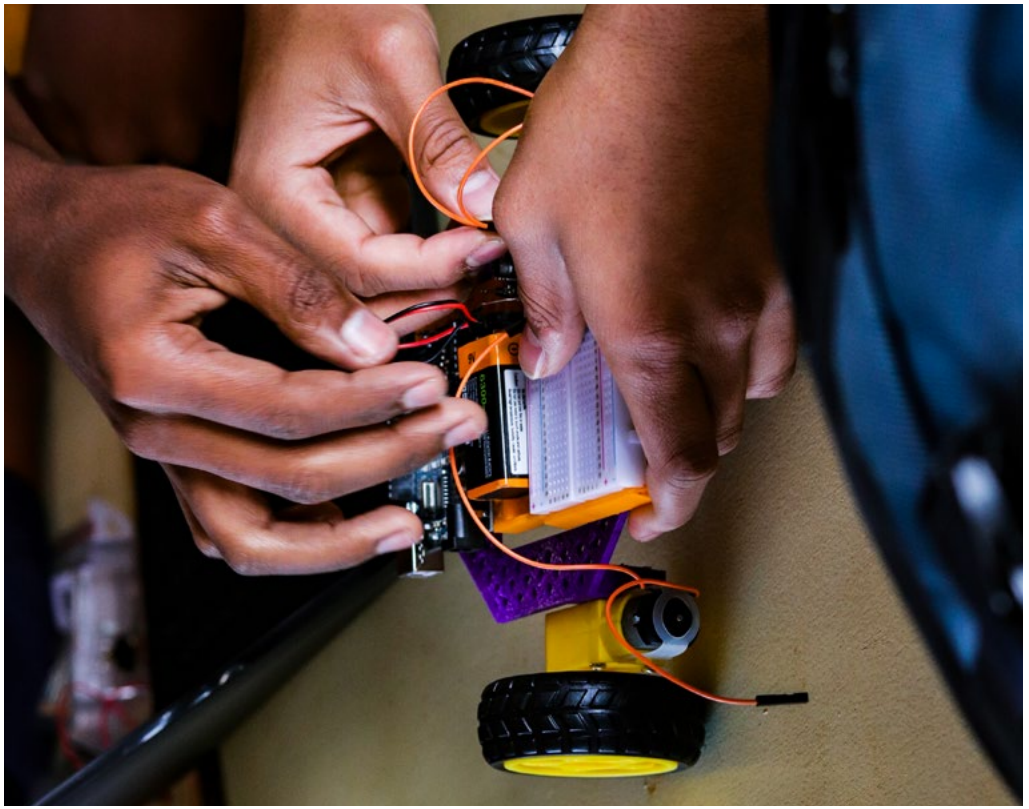
Two mini courses comprising eight lessons each are presented free of charge to learners from Grade 8 to Grade 11. The Robot School takes learners through all the basic steps of building a simple, self-navigating robot, while the Sensor School enables learners to explore the wonderful world of sensors.

The Robot School classes cover the 3D design and printing of the robot chassis, constructing the electronics of the robot, assembling it, programming it on an Arduino microcontroller development board to make the robot follow a track, and testing the robot.

The Sensor School classes cover the basics of how sensors are able to detect natural quantities.

This project provides a platform through which students can serve the community by presenting fun activities related to science, technology, engineering and mathematics to learners. The curricula were designed by the Department's staff members in collaboration with postgraduate students. They centre around low-cost hardware platforms that take accessibility into account.

The classes are presented at the University's Moja Gabedi community garden in Festival Street, Hatfield.



2022 PROJECT DAY

The Department's final-year project competition took place on 11 November 2022. It was attended by industry collaborators, as well as staff and students. Industry experts were invited to judge the projects, and prize sponsorships were received from Etion, Rapid Mobile, Eskom and Exxaro.

Electrical Engineering

STUDENT	PROJECT TITLE	SUPERVISOR
Jordan Pym	Induction cooker plate with pot size detection	Dr Werner Badenhorst
Rainer Spruyt	Design and construction of DC motor-driven go-kart with cruise control	Prof Xiaohua Xia
Marco Visser	Dual-axis tracking PV system	Dr Thabo Hlalele

Electronic Engineering

STUDENT	PROJECT TITLE	SUPERVISOR
Joe Stegmann	Automatic Helmholtz resonator	Prof Ian Craig
Dylan Brown	Guitar-playing robot	Prof Ian Craig
Hein Ungerer	A planar millimetre-wave diplexer for communications	Prof Tinus Stander

Computer Engineering

STUDENT	PROJECT TITLE	SUPERVISOR
Jean-Pierre de la Rey	A cheap digital microscope with a microfluidic input channel	Dr Johan Schoeman
Reynhardt Rademan	Voice-controlled writing robot	Prof Ian Craig
Kian Strydom	Digital CMOS neural network processing element	Dr Johan Schoeman

TRIBUTE TO PROF WILHELM LEUSCHNER

It was with a heavy heart that staff and alumni of the University of Pretoria bade farewell to a former Head of Department in the Department of Electrical, Electronic and Computer Engineering, Prof Wilhelm Leuschner, who passed away on 31 December 2021.

Prof Leuschner was born in Heidelberg, Gauteng, on 10 August 1949. After matriculating with three distinctions from the Afrikaans Hoër Seunskool in Pretoria, he went on to obtain his BSc (Eng) Electrical degree in 1971, his BSc (Eng) (Hons) Electrical degree in 1976, his MEng (Electrical) degree in 1983 and his DEng (Electrical) degree in 1986.

His career at UP started as a temporary lecturer and consulting engineer in the Department of Architecture from March to May 1976. He was appointed as a lecturer in the Department of Electrical Engineering in June 1976, and was promoted to senior lecturer in 1984, associate professor in January 1987 and full professor in January 1990.

In April 1993, he was appointed as acting Head of the Department of Electrical and Electronic Engineering. He took up the position of Head of Department in October 1994, and served in this capacity until April 2011, followed by an appointment as an Emeritus Professor in the Department until January 2015.

Prof Leuschner was instrumental in introducing new degrees in Computer Engineering at postgraduate level at the beginning of 1998, and at undergraduate level in the form of the BEng (Computer Engineering) degree at the beginning of 1999. He established the Department's Light and Vision Laboratory in May 2011.

His research interests included radiometry, photometry, LED lighting and ultraviolet germicidal irradiation. During his career, he supervised 12 master's degree students and two doctoral candidates. He also co-authored 20 peer-reviewed articles and four conference papers. He presented 20 conference papers and published seven expert reports.

As an ECSA-registered professional engineer since 1975, he served on the Engineering Council of South Africa's Professional Advisory Committee for many years. He was also a member of the Illuminating Engineering Society of North America, as well as the Illuminating Engineering Society of South Africa.