School of Electrical and Information Engineering

University of the Witwatersrand, Johannesburg

ELEN 4000/4011 Design II Project (2022)

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Introduction

This document lists the available projects for Design II (ELEN4000/4011) for 2022. The following pages details each of the projects and the summarised list of projects is shown in Table 1. Students should take note of the appropriate streams and listed prerequisites before making selections on projects.

Table 1: Summarised list of projects.

Topic No.	Field	Supervisor	Project Title
1	Antenna Design	Dr. D. Nitch	Design and evaluation of a direction-finding array
2	Biomedical and Artificial Intelligence	Prof. V. Aharonson	Someone to talk to: The emotive Chat-Bot
3	Control Systems	Prof. A. van Wyk	Probabilistic methods for intelligent control of passenger elevators
4	High Voltage I	Dr. H. Geldenhuys	HVAC undersea cable supply link to “Robin Island” (and other islands.)
5	High Voltage II	Prof. C. Gomes	Designing of lightning protection system for a pole-mounted transformer in KZN on a landscape with high soil resistivity
6	Optical Communications	Dr. M. Cox	“Fibre” without the fibre: Wireless optical communications
7	Power and Energy I	Prof. D. Dorrell	Design of an electric vehicle drive system
8	Power and Energy II	Prof. W. Cronje	Dimensioning a renewable energy hybrid system with storage
9	Software I	Prof. T. Celik	Deepfake hunter: An AI-enabled software platform for detecting deepfakes on the Internet
10	Software II	Prof. K. Nixon	Data driven platform to understand the energy usage in transportation systems
11	Systems Engineering I	Prof. D. Limebeer	Target spotting in long-range shooting
12	Systems Engineering II	Dr. N. West	Design, remote control and monitoring of a micro aquaponics system
13	Telecommunications	Prof. F. Takawira	Machine learning based adaptive modulation and coding scheme

Field of interest:
Topic 1: Antenna Design (EM) and numerical modelling

Proposed title of project:
Design and evaluation of a direction-finding array

Supervisor:
Dr. D. Nitch

Stream:	**Pre-requisite courses (if any):**
EE	ELEN4001 (HF Techniques)

Brief description of content and scope of project:

The ability to detect the origin of electromagnetic radiation plays an important role in the military and in civil society. In the military, direction finding (DF) systems are used to determine the direction of a threat, the location and movement of enemy transmitters and the direction of enemy jammers. They are also used in civil society for the location of radio frequency (RF) search-and-rescue beacons and animal tracking. ICASA (Independent Communications Authority of South Africa) uses DF to hunt down rogue transmitters that are illegally transmitting in both the licensed and unlicensed bands.

This project involves the design and evaluation of a DF antenna array. Each student will be given a different antenna array configuration and will be required to optimise it for maximum direction-of-arrival resolution. The students will be given the design of an existing array and will be required to use the performance of this array as a benchmark for their design.

The report should include the performance of their DF array relative to the reference design, and the trade-offs of the parameters investigated.

Field of interest:
Topic 2: Biomedical and Artificial Intelligence

Proposed title of project:
Someone to talk to: The emotive Chat-Bot

Supervisor:
Prof. V. Aharonson

Stream:	**Pre-requisite courses (if any):**
EE or IE	None

Brief description of content and scope of project:

Chat-bot is the popular term used for digital agents which communicate with humans and assist them toward a goal. These bots are employed in a growing variety of applications and on different platforms. Chat-bots employ a wide range of artificial intelligence algorithms to provide the "rational thinking / rational acting" characteristics sought in this challenging field. The goal that human and bot interaction aim to reach have evolved from the practical "choose a product" into mental and emotional support as well. The need for this has significantly grown in the time of the pandemic, when people of all ages encountered loneliness, anxiety and depression. A Chat-bot can induce confidence and closeness and both detect ("think") and respond ("act") to these user's needs to alleviate considerable burden from the user.

This project entails a design of an intelligent Chat-bot that can effectively communicate with its users on their emotional needs. The Chat-bot design can employ text and/or speech user inputs and responses.

Field of interest:
Topic 3: Control Systems

Proposed title of project:
Probabilistic Methods for Intelligent Control of Passenger Elevators

Supervisor:
Prof A. van Wyk

Stream:	**Pre-requisite courses (if any):**
EE or IE	None

Brief description of content and scope of project:

With the fourth industrial revolution unfolding, smart buildings and smart cities are becoming ever closer to realisation. In smart buildings, intelligent elevator control systems are expected to significantly improve both the convenience of moving around inside multi-floor buildings and the sustainability of the elevator systems. Due to uncertainty caused by random flow of people inside buildings, traditional elevator control algorithms are not capable of operating efficiently. As opposed to conventional approaches to elevator control, an intelligent control algorithm is expected to utilize the information about passenger group sizes and their waiting time and then apply probabilistic decision-making models to conduct Bayesian inference and update the variable parameters of the control systems. Due to the huge numbers of variables in this context, variable elimination techniques and Expectation-Maximization are required to reduce the computational complexity associated with calculation of marginal and conditional probabilities and to ensure the completeness of the data sets. To adapt to changing environmental conditions, the control algorithm needs to adjust the probability distributions of the variables affecting the decision-making process. Machine-learning methods based on probabilistic graphical models are well-suited for these kinds of applications.

Such an intelligent control algorithm must be designed for controlling several elevators for use in a smart building setup. For several well-defined scenarios (to be identified as part of the work), the algorithm must be evaluated by comparing the target floor levels of the resulting decisions with expected floor levels. For these identified scenarios, sensitivity analyses must be performed to assess the robustness of parameter choices made by the algorithm. An important measure of the success of the design is an improvement of the average “user satisfaction” (to be defined by you) across these different scenarios.

Important: Mastery of the theory and methods ELEN3007 and ELEN3016 are essential for this project.

Field of interest:
Topic 4: High Voltage I

Proposed title of project:
HVAC undersea cable supply link to “Robin Island” (and other islands.)

Supervisor:
Dr H. Geldenhuys

Stream:	**Pre-requisite courses (if any):**
EE	ELEN4003 (HV Engineering)

Brief description of content and scope of project:

The project should establish the power requirement for an island. The demand profile for the area needs to be determined on a daily and monthly basis, to produce a 20-year growth forecast for the area. The electrical transfer capability of different voltage levels (for example 11, 22, 33, 66, 132 kV) should be explored and matched to the need for medium term and long-term power demand. The net-present value of viable options should be used to propose an optimum phased plan, considering advantages and disadvantages of different phased rollouts. A least cost 20-year plan should be proposed.

The electrical design of the required XLPE cable should be analysed and discussed. Considering the allowed maximum electrical stress in the cable. (Only the cable is to be considered, not any of the terminal equipment). The technical challenges related to laying the cable on the seabed and the environmental considerations for this should be investigated and recommendations for minimising and how to deal with it should be discussed. Consider the routine and breakdown maintenance of the cable and make recommendations that will ensure the sustainability of the project.

Field of interest:
Topic 5: High Voltage II

Proposed title of project:
Designing of lightning protection system for a pole-mounted transformer in KZN on a landscape with high soil resistivity

Supervisor:
Prof. C. Gomes

Stream:	**Pre-requisite courses (if any):**
EE	ELEN4003 (HV Engineering)

Brief description of content and scope of project:

KwaZulu-Natal (KZN) is a region with high lightning ground flash density. There are many landscapes in the area that has quite a high soil resistivity. This is quite favourable for lightning-related damage to pole-mounted transformers. The student could adopt a medium voltage (MV) power system, pole-mounted type transformer, pole configuration, earthing system, and a soil mass to simulate the system on a suitable software platform. He/she then should inject lightning current (may be developed in MATLAB) into the system at potentially vulnerable point/s and analyse the potential and current distribution in the components. Based on the results the lightning protection system (LPS) components such as air-termination, down conductor, earthing and surge protection should be designed. The LPS design should be cost effective. A rationale should be given to the choices of components. Once the protection system is developed, he/she should demonstrate in the software platform that the power system components and structure are protected from an above average lightning current.

Field of interest:
Topic 6: Optical Communications

Proposed title of project:
"Fibre" without the fibre: wireless optical communications

Supervisor:
Dr M. Cox

Stream:	**Pre-requisite courses (if any):**
IE or EE (with conditions)	Any IE 3rd year courses If EE, ELEN4001 (HF) is a pre-requisite

Brief description of content and scope of project:

By 2050, most of the world's population are expected to live in an urban environment [WHO2014]. Rapid urbanisation is occurring across many developing nations, where settlements are often informal with little or no infrastructure for electricity, water, or communications. The pandemic has emphasised the critical importance of communication technologies for remote education, work, and health care. South Africa is one such nation. While our government is constitutionally mandated to provide infrastructure in these rapidly evolving settlements, the inevitable timescales for conventional infrastructure roll-out leaves an unmet need in the interim.

Solving this problem at large scale will be an expensive exercise, but an impact could be made with relatively low cost. Can schools and community centres that have no local fibre infrastructure benefit from nearby infrastructure using wireless links? Due to the inevitable spectrum congestion and interference problems that would be encountered by a radio-based solution, this project is focussed on designing a license-free, wireless optical solution.

An unconnected school in Johannesburg will be specified at the beginning of the project. This school should be assumed to have no conventional Internet access (i.e. mobile data, fibre, etc. is not available on site). Electricity access and network access facilities on site (such as WiFi) are out of scope and can be assumed. The high-level objective of this project is to design a hypothetical system to provide high-speed (i.e. Mbps or more – the final decision should be justified in the design) Internet access via a wireless optical link to this school: in a sense this can be thought of as "fibre before the fibre".

This design project will begin with the site evaluation (for example where can high-speed internet be sourced from, given the school location), a subsequent justification for the design requirements and specifications and finally a detailed design for a long-range (on the order of a kilometre) wireless optical communication system to meet those requirements. Theoretical evaluation of the final link design is required using standard metrics such as link budget, outage probability, capacity, etc.

Since this project is offered to both IE students and EE students who have done the HF course, the emphasis of the individual designs may vary. Naturally, it is anticipated that IE students would go into more detail about the communications aspects of the design, while EE students may wish to go into more detail on the electronic aspects of the system. Regardless of specialisation, detail in terms of the key physical parameters (such as aperture size, for example) is obviously required, and so are key metrics with respect to the communications design and performance. This is nothing that an enthusiastic engineer cannot self-study if required.

There are numerous online resources and textbooks in the Wits library detailing such systems. A good tutorial / review paper to start with could be https://doi.org/10.1364/JOSAB.399168 which is downloadable from https://bit.ly/3tm1qZq. This paper is not comprehensive, and the designer is obviously expected to broaden their search for applicable techniques and other information.

Field of interest:
Topic 7: Power and Energy I

Proposed title of project:
Design of an electric vehicle drive system

Supervisor:
Prof D. Dorrell

Stream:	**Pre-requisite courses (if any):**
EE	ELEN4014 (Electromechanical Conversion) OR ELEN4023 (Renewable Energy)

Brief description of content and scope of project:

Electric vehicles are coming to the fore in modern transportation. Their use is growing rapidly in developed countries and are being introduced in developing countries. They are simpler than hybrid-electric vehicle and sizing and design can be carried out using calculations and engineering choices.

The project is to design the drive and energy storage solution for an electric vehicle. This includes the drive motor, speed range, torque range, gearing, energy storage solution, charging mechanism, range extending, etc.

These will be derived from a specification of a vehicle and require engineering solutions and calculations to be done. For a successful design, a simulation can even be developed. If key information is not available, the student should decide on what would be appropriate for that information with good engineering decision making.

The key components are:

- The motor/generator;
- The gearbox/mechanical drive system;
- The power electronic drive (inverter);
- The DC busbar system;
- The battery pack (or other energy storage); and
- The charger.

These will dictate the system and can be addressed individually, but their specification is interlinked with other system components.

The student should be able to apply electro-mechanical conversion principles. They should be able to apply basic mechanics and understand system losses. The use of a variable-speed drive is key, and the student should address this.

Electric vehicles come in a variety of forms. The vehicle could, for instance, be a basic car, a high performance sport car, an SUV, a taxi, a bus, or even a motorcycle. They all have different requirements.

Field of interest:
Topic 8: Power and Energy II

Proposed title of project:
Dimensioning a renewable energy hybrid system with storage

Supervisor:
Prof W.A. Cronje

Stream:	**Pre-requisite courses (if any):**
EE (IE only after consultation with supervisor)	Any 3rd year EE courses

Brief description of content and scope of project:

Based on real-life consumption pattern data for a particular application, the student is required to design a feasible renewable energy hybrid system including an energy storage facility, if a wind-turbine and/or a photo-voltaic array are available as sources of renewable energy. The fluctuations in the availability of the renewable energy sources as well as the load must be taken into account. A cost analysis has to be done for the system in order to arrive at a reasonable commercially acceptable system.

Field of interest:
Topic 9: Software I

Proposed title of project:
Deepfake Hunter: An AI-enabled Software Platform for Detecting Deepfakes on the Internet

Supervisor:
Prof. T. Celik

Stream:	**Pre-requisite courses (if any):**
EE or IE	None

Brief description of content and scope of project:

The last decade has witnessed a revolution in Artificial Intelligence (AI), mainly due to advances in computing technologies, the availability of open-source data, and several breakthroughs in deep learning. Deep learning has successfully solved complex problems across domains and has overpassed humans' performance on specific tasks such as image recognition. Deep learning methods, such as deep neural networks, can now generate synthetic data that follows the distribution of information we may more likely observe in our natural world. Deepfake algorithms based on deep learning methods can generate fake images and videos that humans cannot distinguish from real ones. Deepfakes can cause threats to society and national security.

In this project, students will design an AI-enabled software platform that ordinary citizens can use to verify the authenticity of an image or video on the Internet. Some of the essential design considerations include:

1. Hardware requirements;
2. Data acquisition, storage, and processing;
3. Use of open-source data and software;
4. AI-model governance;
5. Sensitive user information must have adequate protection;
6. How will users interface with the system? Special attention must be given to the user interface and user experience;
7. Use of crowdsourcing to verify and rectify incorrect predictions from deepfake detectors;
8. Security of the system against cyberattacks;
9. System architecture;
10. Scalability and fault tolerance;
11. Maintainability of the system;
12. Estimated cost to develop such a system;
13. The carbon footprint of the platform.

Field of interest:
Topic 10: Software II

Proposed title of project:
Data driven platform to understand the energy usage in transportation systems

Supervisor:
Prof. K.J. Nixon

Stream:	**Pre-requisite courses (if any):**
EE or IE	None

Brief description of content and scope of project:

The sustainable use of energy, especially with respect to transport systems, is particularly important both within the local and the global context. The objective of this design is to develop a data driven platform that can be used to quantify the energy usage in one or more transportation systems. The term platform implies everything from data collection, through to transmission, storage, processing, analytics and ultimately presentation. The publication by Abraham et al. on solar charging for urban electric minibuses is a good starting point for some ideas [1].

It is very important that the proposed design solution:

1. is cost effective in terms of the technologies used, and can scale (think morning rush hour for vehicles vs the traffic at 1am local time),
2. can record and present data such that informed decisions can be made in migrating to alternative energy sources or schemes,
3. can be used for full analytics and visualisation,
4. includes legal and regulatory considerations such as POPIA,
5. caters for multiple stakeholders.

The substantial size of the system involved means that each student may be required to focus on one or more specific sub-components of the design, but also be able to contextualise their solution in the broader design. Whilst not necessary it is highly recommended that a basic proof of concept prototype or Minimum Viable Product (MVP) is produced to establish confidence in the proposed design.

Note that a hardcopy engineering notebook is **not** a required deliverable. Prototype code or software design documentation to be shared on an appropriate system such as github.

[1] C.J. Abraham, A.J. Rix, I. Ndibatya, M.J. Booysen, “Ray of hope for sub-Saharan Africa's paratransit: Solar charging of urban electric minibus taxis in South Africa”, Energy for Sustainable Development, Volume 64, 2021, Pages 118-127, ISSN 0973-0826, https://doi.org/10.1016/j.esd.2021.08.003.

Field of interest:
Topic 11: Systems Engineering I

Proposed title of project:
Target spotting in long-range shooting

Supervisor:
Prof. D. Limebeer

Stream:	**Pre-requisite courses (if any):**
EE or IE	None

Brief description of content and scope of project:

When shooting at long ranges there is an observational problem related to informing the shooter as to his/her fall of shot that allows the shooter to make sight adjustments. The old-school approach to this problem is a spotting scope, but this is highly reliant on skill of the shooter. For a modern approach, one might consider the use of high-performance equipment or techniques such as camera-equipped drones, wifi-equipped local cameras or image enhancing devices fitted to a spotting scope.

The design problem is to produce a feasible solution using the modern approach.

Field of interest:
Topic 12: Systems Engineering II

Proposed title of project:
Design, remote control and monitoring of a micro aquaponics system

Supervisor:
Dr. N. J. West

Stream:	**Pre-requisite courses (if any):**
EE or IE	None

Brief description of content and scope of project:

You have been approached by a company that wants to set up a small-scale (micro) aquaponics plant for use especially in rural areas. The plant is set up to grow two types of green vegetables (spinach and cabbage). The fish to be used are tilapia. The aquaponics plant in question should be capable of producing around 25 of kg of vegetables and around 50-100 kg of fish per year. The aquaponics plant is being set up and you, as an electrical engineer, is asked to assist with the automation of the system. It has been suggested that the pond should be around 10 m^3. The request is that the system be fully automated and ultimately self-sufficient. As the system is to be likely used in rural areas, it should be reliant on renewable sources of energy. The plant performance should also be able to be monitored (and controlled) remotely. As such, a big part of the project will be careful management or energy usage. Special consideration should also be made regarding water management as this plant will be installed in different part of the country with very different weather conditions (ranging from very dry to very wet). At the same time, the costs of the project are to be kept at a minimum.

Field of interest:
Topic 13: Telecommunications

Proposed title of project:
Machine learning based adaptive modulation and coding scheme

Supervisor:
Prof. F Takawira

Stream:	**Pre-requisite courses (if any):**
IE	Any 3rd year IE courses

Brief description of content and scope of project:

Modern communication systems (such as LTE and 5G) have adopted the use of Adaptive Modulation and Coding (AMC) schemes in order to optimize the average spectral efficiency of a digital communication system as the channel Signal-to-Noise Ratio (SNR) varies. In an AMC scheme, the transmitter constantly changes the modulation type depending on the estimated channel conditions to achieve the desired Bit-Error Rate (BER). A crucial parameter required to enable adaptation is the Signal-to-Noise Ratio (SNR) at the receiver. SNR estimation techniques have been widely researched and successfully applied to 802.11, LTE, 5G etc type networks.

Machine learning (ML) is a new paradigm that is being successfully applied in many telecommunications domains. In wireless communication, ML has been applied in physical layers, modulation recognition, channel estimation, power allocation, and signal detection. Some recent publications have applied Deep Learning (DL) for SNR prediction in non-OFDM systems as well as in 5G systems.

Using machine learning techniques of your choice, design an AMC system for use in an LTE-type communication system. The machine learning approach should be used to estimate the SNR which will then be fed back to the transmitter to determine an appropriate AMC.
Your design should specify and justify your choice of the following:

- Modulation and channel encoding schemes and their corresponding demodulation and decoding.
- The architecture of the ML scheme and the corresponding adaptive algorithms.
- The performance of the final AMC scheme with ML based SNR estimation. The simulation results can be based on your choice of simulation platform.