BSc Project Topics proposed by Simon Winberg

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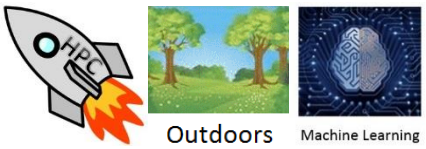
ID:	**SW-1**	
SUPERVISOR:	**Simon Winberg**	
TITLE:	**Investigation and performance analysis of Machine Learning plant recognition methods for automatic classification of fynbos using stem textures**	
DESCRIPTION:	This project relates to the Fynbos Leaf-based Optical Recognition Application (FLORA), which is a system that aims to automatically recognize a variety of fynbos plans based on photographs. Currently, FLORA works on leaves that have some breadth to them – as opposed to being stick- or needle-like leaf structures. FLORA uses a combination of convex hull shape and area as parameters used in recognition, with K-means used for selecting best matches. We want to add additional techniques for recognition of plants with smaller leaf structures close to the stem, or leaf-textured stems (i.e. leaves with very small or missing petioles). Many species of fynbos have these types of leaves, some examples are provided below – the recognition would be based more on what the stems look like than the actual leaves. Code needs to be provided for both training the system and recognising plants. The proposed approach will extract textures from plant photos in training mode, and during recognise mode with perform comparisons between the extracted texture of the input photo and stored texture descriptors in a database. Most of the FLORA code is in C with some (swappable) modules that are in CUDA for speed enhancement. If time is available the speed of the processing methods could be enhanced using OpenCL or CUDA kernels.	
DELIVERABLES:	Code modules to add to the existing FLORA code project. Documentation concerning the new modules and how their integration with FLORA.	
SKILLS/REQUIREMENTS:	Programming. Some understanding of image processing is desirable but not essential as this can be learned during the project.	
ELO3: Engineering Design Perform creative, procedural and non-procedural design and synthesis of components, systems, engineering works, products or processes.	*Provision of well-documented algorithm description, provision of comprehensive design documents and well documented code. Report of performance testing and error tolerance of the produced code.*	

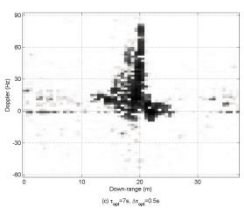
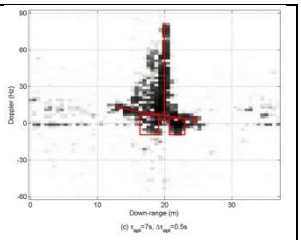
Lachnae aurea vulnerable

Caputia pyramidata (*Groot-tontelbos*, Afr.)

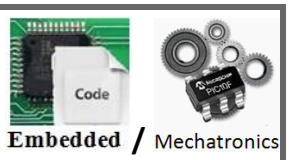
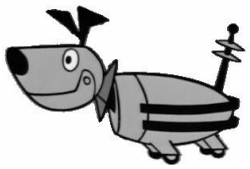
Agathosma apiculate (*buchu*, Eng.)

EXTRA INFORMATION:	
AREA:	Computer Engineering / Programming / Image Processing

ID:	**SW-2**	
SUPERVISOR:	**Simon Winberg & Yunus Gaffar**	
TITLE:	**Classification of ISAR images of sea vessels – extended Machine Learning techniques**	
DESCRIPTION:	This project involves classification of a limited selection of sea vessels from Inverse Synthetic Aperture Radar (ISAR) images. This is a follow-on project from an initial version of the project started last semester. The is tremendous scope for additions and experimenting with new techniques (the current solution is an initial and framework that can be built upon). The plan is to build upon and further refine the initial implementation, adding GUIs if time permits, and if desired the design can be drastically reworked and improved. ISAR is a radar signal processing technique used to generate radar images of moving targets, such as vessels and aircraft. When imaging sea vessels with 3-D rotational motion, it is the effective 2-D rotation that produces the resulting ISAR image. This project involves two components: The student will first develop and build upon the existing ISAR radar simulator, in order to gain an understanding of ISAR radar imaging. After this the student will then work on the target classification subsystem in order to refine the existing implementation and to add additional functionality and test new machine learning algorithms for the automatic classification of sea vessels. Classification of sea vessels involves deciding the class of the vessel (e.g. single hull, catamaran, one mast or two, etc.). The application is expected to locate the vessel within the ISAR image and predict its class. The simulator is currently very limited. If time permits (and the project can be refocused on this aspect if the student want to) the simulator needs to be extended provide simultaneous movement in multiple directions. The recognition program can also be extended to distinguish multiple vessels within a single ISAR image (similarly the simulator can be extended to generate simulations for multiple targets in the scene).	

		
Photo of test vessel (catamaran)	ISAR image of test vessle	Feature extraction and comparison

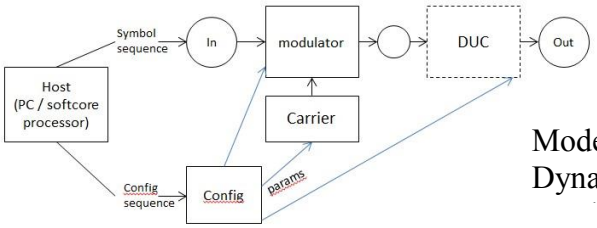
DELIVERABLES:	ISAR radar simulator with well documented code together with a set of simulation models (or configuration files) to describe a variety of different classes of vessel and various conditions (such as small and large sea swells). Classification program for classifying vessels using either input generated from the simulator and using real ISAR images from radar trials that have already been completed.
SKILLS/REQUIREMENTS:	Understanding of signal processing (e.g. having used digital filters and FFTs) is beneficial but the specific techniques used for generating ISAR images will be learned during the project. Good programming is important, although much of the work can be done in OCTAVE (or MATLAB).
ELO3: Engineering Design Perform creative, procedural and non-procedural design and synthesis of components, systems, engineering works, products or processes.	*Good documentation of simulator and classification application. Thorough evaluation and performance analysis of the classification techniques used (including any pre-processing steps applied to the input ISAR images). Provision of comprehensive design documents.*
EXTRA INFORMATION:	https://en.wikipedia.org/wiki/Inverse_synthetic_aperture_radar http://ieeexplore.ieee.org/abstract/document/6875528/
AREA:	Signal processing. Programming.
RESERVE REQUEST:	George De Kock DKCGEO002@myuct.ac.za

ID:	**SW-3**	
SUPERVISOR:	**Simon Winberg**	
TITLE:	**Findit Rover! (robot)**	
DESCRIPTION:	This project concerns a rover (wheeled) robot. The aim of the project is to instruct the rover to 'sniff out' (in order words detect) an item in the environment. While this system is planned around a small wheeled robot (see figure on bottom right) it may contribute useful techniques that could be scaled to larger robots for outdoor use. There are various potential real-world application, even for this small version; for example a key finding robot: if someone drops their keys in a soccer field the rover could be set loose in the field to find the keys – maybe it would take hours to cover the whole field but it may be better to sit back and let rover search rather than worry about replacement keys etc. Similarly the rover could be used to simulate a mine detector along roads or flat areas.	  

	The project comprises two parts: the rover robot which is controlled by a Raspberry Pi and the implementing of code for this, as well as PC-based path generator. The rover needs a detector of some sort, such as a metal detector that could be sensed by the Raspberry Pi via an ADC. The rover will operation using pre-programmed search paths that the PC needs to provided, these can be generated by specifying the dimensions of the room/area to search and then an algorithm runs to calculate an optimal search path (spiral search as illustrated above is one possibility that would work in a square space). This path (which could be commands such as "STEAR_LEFT 25% FORWARD 20 cm/s") is uploaded to the rover. The rover then executes the search path to find items of interest (e.g. coins placed in the floor). The rover should have a setting where it finds either 1) the first item and returns (i.e. doesn't complete the search path) or 2) completes the search path and then returns reporting where all the found items are. When the rover finds an item it needs to 'remember' where it is located (this may be e.g. which portion of a loop in the search spiral the item was found) and then report back to the human master where the item is located. As a more advanced feature (an optional enhancement if time permits) the rover should be able to lead the human master, via an optimal route – i.e. not retracing the spiral loops but just going straight) back to where the item was located. More advanced optional extras would be the ability to navigate around obstacles (and remember where they are in the search spiral). Alternate search patterns could also be attempted (e.g. random walk).
DELIVERABLES:	Rover system: working wheeled robot controlled by Raspberry Pi to execute search path; PC-based search path generator. Documentation for the design and use of the system.
SKILLS/REQUIREMENTS:	Programming. Some electronics (fairly easy level of building circuits and wiring up components). An understanding of control theory would be advantageous. This project is well suited to mechatronics or electrical & computer engineering students.
ELO3: Engineering Design Perform creative, procedural and non-procedural design and synthesis of components, systems, engineering works, products or processes.	*Good documentation of robot system and relevant software developed. Thorough evaluation and performance analysis of the system (including initial test of min & max speed that the robot can move at, accuracy of the steering,). Provision of comprehensive design documents.*
EXTRA INFORMATION:	The following kit from Sunfounder is provided and recommended for use (plan is to use a 4-wheel robot with front steerable wheels to follow curves) https://www.sunfounder.com/rpi-car.html Example metal detector circuit that can be adapted for sensor to robot: https://circuitdigest.com/electronic-circuits/simple-metal-detector-circuit
AREA:	Robotics / Embedded Systems.
RESERVE REQUEST:	Reservation request by Zwivhuya Mashau MSHZWI001

ID:	**SW-4**	 **Embedded**
SUPERVISOR:	**Simon Winberg & Prof. Michael Inggs**	
TITLE:	**Adjustable precision processor and computation cost analysis**	
DESCRIPTION:	The objective of this project is to construct a VHDL or Verilog framework by which to experiment with performing common signal processing operations at variable levels of precision. This project is based on research that has been started by John Collins on the topic of investigating the numerical precisions required to execute real world programs. The aim of this project is to compare the use of logic, electrical power usage and processing speed for a selection of processing operations using different levels of precision. Standard 32 bit floating point or fixed point numbers potentially provide more precision than what is needed, meaning more data is being stored and handled than necessary; and the extraneous bit switching that results can cause the system to utilize more power than necessary, as well as possibly taking longer to complete calculations (e.g. managing bit carries and transferring data etc.). This project sets out to measure costs of computation for a selection of processing operations. The plan is to first implement trial algorithms, running at full (32 or 64 bit) precision on a PC to check the calculations are correct and to establish a golden measure. Then implement the operations in VHDL/Verilog to run on an FPGA. Provide calculations (such as +, -, *, / to work for varying levels of precision and size, e.g. 8 bit, 12 bit, 16 bit, 24 bit and 32 bit floats). Compile the designs to see changes in compile (trace & route) times, logic elements used, maximum clock speed, etc. and report on these differences. The calculations can then be run on a simulator to investigate the results, how well they match to the golden measure. Further tests can be done to see at what point the computations break down due to too little precision. Then (if time permits) adjust the HDL code to run on an FPGA platform (e.g. a Rhino Platform what has power meters on board that can provide precise power usage measurement) – if it is not sufficient time to run on physical FPGA board then accurate estimates for the power usage can be calculated based on datasheet information and aspects such as number of bit inversions during processing (which can be calculated by saving simulation results to a file and writing a script to count the bit flips for each register/port logged. This project has much research potential and real-world application, which can make a useful contribution to the field of computing.	
DELIVERABLES:	HDL-based designs of selected signal processing operations (can have some simple operations such as peak detector, averaging filter, LPF, and if time permits more complex filters such as FIR filter but this is not a requirement for this BSc level project)	
SKILLS/ REQUIREMENTS:	Verilog / VHDL coding and C/C++. (Fortran programming beneficial).	
ELO3: Engineering Design	The project will involve designs, implementation/ simulation, analysis and evaluation of the system as per the requirements.	

AREA:	Computer Engineering

ID:	**SW-5**	 **Embedded**
TITLE:	**Dynamic HDL Synth and Mod/Demod device (Music)** (Music/signal generation e.g. for radio tx)	
DESCRIPTION:	The objective of this project is to construct a framework that can be configured to be either an audio device or a modulation system. This project involves using an FPGA platform (evaluation kit), connecting to a minimal set of external hardware (such as a 12-bit DAC and amplifier) in order to produce sound or modulated carrier frequencies. The audio device is to be integrated with a softcore processor that can accept a command sequence to configure parameters to the device (such as setting volume or a carrier frequency that is modulated). The processor can be used as a means to decode and buffer an (e.g. MIDI) audio stream from the host (e.g., via a serial/network link from a PC). The system should be design around allowing for low (audible) to high (inaudible) frequencies that can be fed either into an amp and speaker or IF stage of a radio transmitter. The project includes analysing the results of the device to determine the performance characteristics.  Model of Dynamic HDL	
DELIVERABLES:	Audio device design (VHDL / Verilog and schematic describing connections to hardware components external to the FPGA), device driver, audio codec (if needed).	
SKILLS/ REQUIREMENTS:	Verilog / VHDL coding. C programming ability.	
ELO3: Engineering Design	The project will involve design, implementation/simulation, usability analysis and evaluation of the system as per the requirements.	
AREA:	Computer Engineering	

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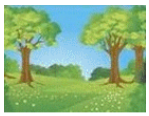
<tr><td>ID:</td><td>SW-6</td><td> 
Outdoors
Signal Processing</td></tr>
<tr><td>SUPERVISOR:</td><td colspan="2">Simon Winberg</td></tr>
<tr><td>TITLE:</td><td colspan="2">Isolating a moving object of interest from video frames that may exhibit background motion.</td></tr>
<tr><td>DESCRIPTION:</td><td colspan="2">Motion draws the attention of an observer. For example when someone is waiving a flag at the roadside your attention is likely drawn to that motion, which could be indicative of a potential change to the environment, which could possibly influence you. Moving objects may exhibit different types of motion: they may be simply vibrating or moving-back-and-forth quickly or slowly, which might have little influence on the observer. For example tree branches and leaves may be moving in the wind, or waves in the sea may be moving in a scene. This project involves isolating moving objects of interest from the rest of a scene that may comprise stationary and moving objects that are not significant. Experimental techniques will be trialled to extract moving objects of interest from a series of frames. Ultimately the goal for this processing would be to have the methods incorporated into a system that can process large amounts of video sequences and propose which moving objects may have caused an event in the environment monitored at a certain time – however the scope of this project is focused on extracting moving objects of interest from a series of images, the two figures below shows an example of what the application would do. Image processing techniques such as blurring (to eliminate small changes) together with Otsu's thresholding and Connected Component Labelling (CCL) to find a single, connected region (i.e. to separate a potential object of interest from the background). The application can be expanded further to utilize machine learning techniques to identify or classify the extracted object(s) in motion based on a database of learned shapes.
<table>
<tr><td>  </td><td>  </td></tr>
<tr><td>Object in motion (seagull) upon vibrating background (sea waves)</td><td>Object of interest (seagull) in motion isolated from scene</td></tr>
</table>
</td></tr>
<tr><td>DELIVERABLES:</td><td colspan="2">Prototyped program and well documented code. Experimental results, showing both accuracy (how well the object was extracted and if the extracted parts were all from the object of interest), quality (does the system perform consistency well) and performance (particularly speed) of the application.</td></tr>
<tr><td>SKILLS/REQUIREMENTS:</td><td colspan="2">Programming skills. Some experience in image processing is beneficial but is not a requirement as this project provides an opportunity for the student to develop these skills during the project.</td></tr>
<tr><td>ELO3: Engineering Design
Perform creative, procedural and non-procedural design and synthesis of</td><td colspan="2">Documentation and flowchart describing the moving object extraction techniques and resultant algorithms applied. Software design and well documented code for the prototyped program for extracting moving objects of interest from video frames.</td></tr>
</table>

components, systems, engineering works, products or processes.	
EXTRA INFORMATION:	
AREA:	Programming. Image processing.

ID:	**SW-7**  Machine Learning  Computer Graphics
SUPERVISOR:	**Simon Winberg**
TITLE:	**Visualizing the operation of hidden layer neurons using a vision wall.**
DESCRIPTION:	The Scientific Computing Research Unit (SCRU) at UCT makes use of artificial neural network (ANNs) and self-organizing maps (SOMs) to develop applications for simulating and predicting the behaviour of complex molecular processes related to disease, in particular different types of cancer. The behaviour of nodes in the hidden levels of large complex neural networks are typically difficult, for a human, to get a sense of what they are doing and whether they are operating efficiently – for example if there are neurons that are potentially disrupting accurate prediction rather than aiding it. This project proposes to develop 3D visualization techniques whereby the programmer can delve into the neural network (some of these contain hundreds of neurons in one hidden layer) and inspect how these neurons are working. The proposed technique will visualize neurons in different colours (based on their sensitivity to certain inputs) and polyhedral shapes (depending on their influence on other neurons) to give a sense of their operation for particular input sequences, i.e. for inspecting which neurons are more sensitive than others to inputs and their impact on subsequent layers and resultant prediction results. The general idea is that a program will be developed that will allow the user to 'travel through' the ANN or SOM (both have similar structures) and get a sense of how different parts are responding to different input stimuli, possibly allowing programmers a way to diagnose and tweak the automatically generated prediction models.
DELIVERABLES:	Prototyped program and well documented code. Survey from users reporting on the usefulness of the application. Experimental results showing both accuracy and performance of representative tests of neural networks. The SCRU has a 'vision wall' (i.e. a large screen) that is a few meters on either side and high resolution, a special software API is used to render images on the vision wall. It is proposed that once initial visualizations have been developed the code will be ported so that it works on the vision wall to allow programmers a way to provide high resolution visualizations on the wall allowing potentially fine details to be spotted by eye quickly that may otherwise only be found – if at all – by sifting through small segments at a time on a standard size monitor.

SKILLS/REQUIREMENTS:	Programming skills. Some experience with 3D graphics, such as OpenGL would be beneficial.
ELO3: Engineering Design Perform creative, procedural and non-procedural design and synthesis of components, systems, engineering works, products or processes.	Documentation and flowchart describing the application. Software design. Well design experiments to perform performance and usability tests.
EXTRA INFORMATION:	Done in partnership with SCRU: http://www.scientificomputing.uct.ac.za/ (workspace will be provided in computing lab close to vision wall)
AREA:	Programming. Computer graphics.

ID:	**SW-8**	 **Embedded**
SUPERVISOR:	**Dr Simon Winberg & Dr Tom Dietel (Physics)**	
TITLE:	**BPM-packetized Optical Trigger Interface Board to link to TTCrx**	
DESCRIPTION:	This project involves the development of an interface board to forward trigger events using the Timing, Trigger and Control (TTC) protocol, to a receiver module (TTCrx). These modules are used at the CERN's Large Hadron Collider (LHC) for timing and triggering tasks; the UCT physics department uses one of them on a detector (a spare for the ALICE Experiment at the LHC) that is used to train physicist locally on using the system, and to develop and test new features for the actual ALICE Experiment in Switzerland. This project gives the student an opportunity to learn more about CERN, the LHC and ALICE, and how particle physics experiments work in general. But you don't need to worry about all this complicated stuff. All that is needed for this project is a small converter system, but the convertor is not trivial making it BSc level. The converter is to replace a TTCvi and a TTCvx module, which are fancier and more complex than necessary for this setup, come at a significantly higher cost and would require a separate VME crate for their operation. The TTCvi generates two data streams (A,B), but we only need stream A that encodes the trigger decision, and synchronizes them with a clock signal. The TTCvx BPM-encodes and multiplexes the two streams and sends out the multiplexed optical stream. The converter will be a small PCB with a microcontroller (e.g. PIC) or PLD. It will receive the trigger signal through LVDS signals on an RJ45 connecter and send transmit the data stream via a LED module. It would need to operate at fairly high speed (around 40MHz). This project will be jointly supervised by Dr. Thomas Dietel (Physics) and Dr. Simon Winberg (Electrical Engineering).	

DELIVERABLES:	The project is expected to deliver a working and well tested interface module. Full documentation, including a brief user manual, needs to be provided which is planned around supporting potential further customization and refinement of the interface and signals provided.
SKILLS/ REQUIREMENTS:	PCB design and embedded systems, microprocessor or PLD programming
ELO3: Engineering Design	The project will involves design, implementation, usability analysis and evaluation as per the requirements.
EXTRA INFORMATION:	
AREA:	Embedded Systems / Computer Engineering