

Research Topics for MEngSc Theses and PhD Dissertations

For students starting in 2022

5 December 2021

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1 Introduction

This document gives an indication of potential supervisors for prospective students in the master's and PhD programmes of the Institute for Biomedical Engineering (IBE). The supervisors' research areas and potential research topics are also given. The topics described here should be considered to be a broad indication of the type of topics, and not a precise prescription of topics. Prospective students should contact the supervisors and formulate more specific topics in discussion with the supervisors.

A topic's title is striked through when that topic is not available any more, because it was already allocated to a student.

Note that the research topics in the IBE are normally co-supervised by someone outside the faculty of the main supervisor, because the IBE programmes are aimed at interdisciplinary research. In some cases, the co-supervision will be determined when the student's topic has been defined more closely.

Also note that "TBD" indicates that the particular aspect is still "to be determined".

2 Prof Jacomine Grobler (Industrial Engineering)

Faculty: Engineering

Email address: jacominegrobler@sun.ac.za

Research areas: Optimisation algorithm development, data science, and machine learning applications for improved decision support.

2.1 Identification of intraventricular haemorrhage in neonates through an analysis of sonar images

Co-supervisor: Dr Lizelle van Wyk (Paediatrics and Child Health)

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? Yes (At least tuition fees)

Description of topic:

Intraventricular hemorrhage (IVH) is most commonly seen in premature infants and has a significant impact on infant mortality. This topic will investigate the use of data science for the identification of IVH in neonates. A detailed literature review will need to be conducted to identify best practices in IVH identification and image processing techniques already used in this context. Domain experts will also be consulted to obtain a better understanding of the indicators of IVH. A dataset consisting of sonar images will be obtained from Tygerberg Hospital. This dataset will be cleaned and analysed and used to train and test various image processing algorithms with the aim of identifying IVH in the sonar images. Finally, the results will be validated by domain experts.

2.2 Identification of tuberculosis in children through an analysis of x-ray images

Co-supervisor: Dr Lizelle van Wyk (Paediatrics and Child Health)

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? Yes (At least tuition fees)

Description of topic:

The clinical signs of tuberculosis in children differ from the clinical signs of tuberculosis in adults. A significant amount of research has been done in the identification of tuberculosis, but there is an opportunity for novel research in the detection of tuberculosis in children from x-ray images.

This topic will investigate the use of data science for the identification of tuberculosis in children using x-ray images. A detailed literature review will need to be conducted to identify best practices in tuberculosis identification and image processing techniques already used in this context. Domain experts will also be consulted to obtain a better understanding of the indicators of tuberculosis in children. A dataset consisting of x-ray images will be obtained from Tygerberg Hospital. This dataset will be cleaned and analysed and used to train and test various image processing algorithms with the aim of identifying tuberculosis in the x-ray images. Finally, the results will be validated by domain experts.

2.3 Predicting trans epidermal water loss in neonates

Co-supervisor: Dr Lizelle van Wyk (Paediatrics and Child Health)

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? Yes (At least tuition fees)

Description of topic

Prematurity of the skin has several consequences for the preterm infant. The skin is the dominant route of fluid and heat loss and inefficient functioning may lead to a high trans epidermal water loss (TEWL), dehydration and hypothermia. There are various factors thought to influence TEWL, including gestational age, ambient relative humidity and more. The aim of this topic is to investigate the use of data science for predicting TEWL and subsequently, the weight of the infant. A dataset with extensive TEWL readings and other variables, are available from Tygerberg Hospital. This dataset will be cleaned and a thorough exploratory data analysis will be conducted. Various prediction algorithms such as neural networks and support vector machines, will then be tested on the dataset to predict TEWL. Finally, the results will be validated by domain experts.

3 Dr Andie de Villiers (Applied Mathematics)

Faculty: Science

Email address: andiedevilliers@sun.ac.za

Research areas: Computational Biomechanics, Finite element method, Continuum mechanics, Peridynamics

3.1 Peridynamic modelling for engineered tissues

Co-supervisor: Prof Tobias Louw, Process Engineering

Is it suitable for a MEngSc (Structured) research assignment? Yes

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? No

Description of topic:

Tissue engineering entails the *in vitro* growth of human tissue with applications in tissue repair, with common targets including cartilage, bone, blood vessels, and skin. However, many of the engineered tissues are developed with inferior mechanical properties. A fundamental understanding of the mechanical properties of tissue, which consists of a complex matrix of cells, extracellular matrix, and scaffolds, will assist in the development of engineered tissues with suitable mechanical properties. Peridynamics provides a continuum mechanics framework that captures non-local effects and discontinuities naturally. It is similar to classical continuum mechanics in that it is a continuum formulation, but unlike classical continuum mechanics it is a non-local theory and each material point is governed by its interactions with other material point located within its neighbourhood. It is widely used to model damage and breakage and have also been used to model growth. To solve complex problems multifield formulations including peridynamics have been developed to solve amongst others, porous flow. Peridynamics therefor offers a suitable approach to investigate tissue mechanics.

3.2 Modelling hemolysis in rapid transfusion

Co-supervisors: Dr Willem de Villiers (Anaesthesiology and Critical Care), Prof Francois Smit (Applied Mathematics)

Is it suitable for a MEngSc (Structured) research assignment? Yes

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? No

Description of topic:

During resuscitation, medical personnel frequently need to expedite red blood cell concentrate (RBC) transfusions. One method to expedite transfusion is by using a syringe. In this method blood is aspirated into the syringe and then it is forcefully injected into the patient. Even though it has been shown that syringing can cause ten times more hemolysis

(damage to red blood cells) than using a pressure bag, it is a very effective method and might be the only option in limited resource settings.

This project will employ computational modelling to investigate the shear stresses RBC undergoes, as well as the flow patterns of blood when forcefully aspirated and injected. The effect that different geometries of the syringe as well as the applied aspiration and injection pressure has on the shear stress will be probed. The aim is to develop guidelines to ensure safe syringing in low resource settings.

~~3.3 Investigating the effects different cushioned shoes and footstrike patterns have on the stress distribution in runners' tendons and ligaments~~

Co-supervisors: Proff. Wayne Derman and Rob Lamberts

Allocated to: Cornel Stander (PhD)

~~Is it suitable for a MEngSc (Structured) research assignment? No~~

~~Is it suitable for a MEngSc (Research) thesis? Yes~~

~~Is it suitable for a PhD in Biomedical Engineering? Yes~~

~~Are bursaries offered for this topic? No~~

Description of topic:

Injuries amongst long distance runners are very common. Two types of foot injuries, namely plantar fasciitis and Achilles tendinopathy, are particularly common. Two factors that play a role in these injuries are running shoes and footstrike pattern. The aim of the project is to develop a finite element (FE) model to investigate the stress experienced by the tendons and ligaments in the foot while running with different foot strike patterns. This FE model will make use of motion capturing devices and force measurements to capture the relevant data, and will also employ OpenSim to supply necessary boundary conditions.

4 Prof Anna-Mart Engelbrecht (Physiological Sciences)

Faculty: Science Faculty

Email address: ame@sun.ac.za

Research areas: cancer, chemoresistance, tumour microenvironment

4.1 Whole Sample Toxicity Measurements: The Development of Cancer Mutation Assays and In-Field Biosensors for Agricultural Application

Co-supervisor: Dr Wendy Stone (Stellenbosch University Water Institute), Prof Willie Perold (Electrical & Electronic Engineering)

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? Waiting for outcome of funding application

Description of topic:

Currently, truckloads of waste sludges from local drinking water treatment works and wastewater treatment works are being transported to landfill sites. Valuable nutrients (N, P, K) are being concentrated (along with pollutants) in landfill, whereas there are acres of nutrient-poor sandy soil in the proximity of the plants producing the sludges, currently relying on fertilizer and compost to build the soil fertility.

This project explores the risks and benefits of diverting the sludges into local nutrient-poor sandy soils, particularly in the Philippi horticultural area. Cancer toxicity of sludges will be a focus area.

The primary pollutants of interest in sludges are heavy metals, micropollutants and pathogens, of which there are more than 70 000. The primary aim is the development of a sensor that measures whole-sample toxicity, rather than a sensor that measures individual micropollutants.

Project 1: Cancer toxicity studies of waste sludges and the identification of appropriate markers indicative of whole-sample toxicity.

Project 2: The development and implementation of a biosensor to determine the level of cancer risk from whole-sample analysis.

4.2 Study 1: In vitro evaluation of the possible mechanism in which green gold nanoparticles stimulates cell death in breast cancer lines or

Study 2: In vivo evaluation of the possible mechanisms of action of green gold nanoparticles in a tumour-bearing mouse model

Co-supervisor: Prof Willie Perold (Electrical & Electronic Engineering), Dr Sanjeev Rambharose (Physiological Sciences, Science Faculty)

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? No

Description of topic:

The most common forms of cancer therapy include surgery, chemotherapy, and radiotherapy. However, these therapies are associated with several side and often with the induction of treatment resistance (Meier et al., 2005). Multi-drug resistance (MDR) due to the repeated drug administration in the chemotherapy treatment course and the insensitivity of hypoxic cancer cells to ionizing radiation are the major causes of failure of chemotherapy and radiotherapy (Peer and Margalit, 2006); (Brown and Wilson, 2004). Therefore, the development of new approaches to improve screening, early diagnosis, and treatment for cancer has been an area of emphasis in research (Kennedy et al., 2011).

The use of nanoparticles in improving the delivery of anticancer agents to tumors is one of the most promising research areas in the field of nanotechnology (Beik et al., 2019). Gold nanoparticles (AuNPs) are defined as small particles having one structural dimension ranging

from 1-100 nm, which makes them comparable in size to subcellular level (Sun et al., 2019). Due to their physical and chemical properties such as small sizes, convenience in their preparation, bioconjugation, and biocompatibility, making them useful in several biotechnology applications and attractive candidates for cell imaging, targeted drug delivery, diagnostic and therapeutic techniques (Gu et al., 2009). The synthesis of AuNPs can be performed using various methods such as, physical, chemical and biological methods. However, the physical and chemical methods of gold nanoparticles are considered to be toxic, hazardous and expensive because of the reducing and stabilising agents, as well as the heavy equipment used during the process of synthesis (Singh et al., 2019).

Therefore, the green synthesis of gold nanoparticle is more advantageous than the other methods because it is fast, simple, tractable, cost-effective and produces large scale synthesis, in which the size, shape and composition can be managed (Singh et al., 2019). Plant-mediated synthesis of gold nanoparticles is a green chemistry approach that connects nanotechnology with the characteristics of plant extracts. Additionally, Since the generation of the concept of green nanoparticle preparation by Raveendran et al., there has been a growing need for eco-friendly metal nanoparticle synthesis that do not use toxic chemicals, neither standard acid/base compounds nor elevated temperatures in the synthesis protocols to avoid adverse effects in the medical application (Raveendran et al., 2003).

The aims of the proposed studies are to investigate the anti-cancer activities that is activated by using green gold nanoparticles.

Student 1: Will study the aforementioned effects in an in vitro setting (cancer cell lines)

Student 2: Will study the aforementioned effect in an in vivo setting (tumour-bearing mouse model)

5 Prof Kristiaan Schreve (Mechanical and Mechatronic Engineering)

Faculty: Engineering

Email address: kschreve@sun.ac.za

Research areas: Machine Vision; Robotics

5.1 Motion Capture for Mountain Bike Tracking

Co-supervisor: TBD

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? No

Description of topic:

An offline SLAM (Simultaneous Localisation and Mapping) algorithm must be implemented to track markers on a cyclist and mountain bike. The camera(s) used for tracking will be mounted on a drone. The drone will have stereo vision cameras to determine the 3D positions of the markers. The SLAM algorithm is needed to determine the position and orientation of the

drone over time. The SLAM algorithm will use camera images and possibly other sensors such as inertial sensors and GPS as input data. An existing algorithm may be used, if one can be found, in which case the focus of the project will be on the testing of the algorithm. If an existing algorithm cannot be found, the focus will be on developing the algorithm with a basic demonstration of its capabilities.

6 Dr J van der Merwe

Faculty: Engineering

Email address: jovdmerwe@sun.ac.za

Research areas: Implant design

~~6.1 Neural correlates of dual-task transitional movements in individuals with Parkinson's disease~~

Co-supervisor: Prof Jochen Baumeister (Universiteit Paderborn, Germany; Movement Neurosciences)

Allocated to: Dr Karen Welman (MEngSc, Research)

~~Is it suitable for a MEngSc (Structured) research assignment? No~~

~~Is it suitable for a MEngSc (Research) thesis? Yes~~

~~Is it suitable for a PhD in Biomedical Engineering? Yes~~

~~Are bursaries offered for this topic? No~~

Description of topic:

Investigating the effects of cognitive versus motor interference in individuals with mild to moderate Parkinson's disease by using EEG as a neurophysiological biomarker.

7 Prof Sara Grobbelaar (Industrial Engineering)

Faculty: Engineering

Email address: ssgrobbelaar@sun.ac.za

Research areas: Health Systems Engineering; Technology management; innovation management; sector development

7.1 System dynamics modelling of innovation systems / Sector development and value chain analysis

Co-supervisor: TBD

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? Yes – approx. R40,000 p.a.

Description of topic:

A range of projects available to consider the qualitative analysis and quantitative modelling of regional innovation systems / sectoral innovation systems (specific projects will focus on health technology)

Project 1: We utilize System Dynamics and agent-based modelling to develop decision support tools of policy making and sector development strategy development for health technology sector development.

Project 2: We develop new conceptual methods and ways to understand innovation on the sectoral level using the dynamic capabilities and innovation systems perspectives – here we consider the different hierarchies of capabilities to be developed in order to support health technology development on a regional and sectoral level.

7.2 Development and diffusion of rolling out 4IR technologies on the firm/sector level

Co-supervisor: TBD

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? Yes – approx. R40,000 p.a.

Description of topic:

The strategy to roll out 4IR technologies for health technology implementation needs to be approached systematically and through consideration of various factors. Careful analysis is needed to consider what has to be measured and under what conditions, building capabilities over time. We will develop a decision support framework to assist Small and Medium sized firms in the health technology sector to plan for the development and deployment of 4IR technologies (the project will be scoped to have a more specific focus based on student interest).

7.3 Technology platforms and dynamic capabilities

Co-supervisor: TBD

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? Yes – approx. R40,000 p.a.

Description of topic:

We have several options for projects to further develop the work we have completed previously on applying dynamic capabilities as a perspective to innovation platforms. This relates to technology platforms but also innovation platforms as environments / places and spaces for innovation (e.g. innovation accelerators).

7.4 Monitoring and evaluation of innovation

Co-supervisor: TBD

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? Approx R80k-100k per annum

Description of topic:

Project 1: We have a programme where we develop decision support framework to use logdata analysis from mhealth Apps. We will expand this programme to explore how to improve the mapping and evaluation of user satisfaction and switching criteria to alternative apps or technologies (wanted versus needed apps) – focus will be on mhealth-related Apps

Project 2: We developed a framework to consider quantitative analysis and sense making of mhealth App logdata analysis. This project will expand this work to also include qualitative factors for a more integrated decision support framework

7.5 Unjani clinics M&E tool

Co-supervisor: TBD

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? Yes – approx. R40,000 p.a.

Description of topic:

Project 1: We develop a Monitoring and Evaluation framework and dashboard for Unjani clinics to serve as a monitoring tool but also to help develop the business case for the programme to gain future funding - for more information about Unjani please see their website of their programme <https://www.unjaniclinic.co.za/>.

Project 2: We want to develop a project where satellite images of the location and surrounding environment of Unjani clinics will be analysed to help identify success factors of the clinics.

7.6 The adoption of Health technology innovations: Long term adoption of wearables

Co-supervisor: Dr Euodia Vermeulen

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? Yes

Are bursaries offered for this topic? Yes – approx. R80,000 p.a.

Description of topic:

The initial uptake and adoption of wearables (specifically, fitness trackers, activity trackers, or smart watches) may be influenced by a multitude of internal and external factors. The long-term adoption of wearables may be even more complex than the initial motivation for uptake and have implications for health monitoring. There is a need to explore and analyse the factors that drive long-term adoption of wearables in a South African population. A mixed-method study based on technology uptake and adoption theorems is suggested with a survey-type data collection tool to find factors that influence individual's sustained adoption of wearables.

8 Prof Martin Nieuwoudt (IBE)

Faculty: Engineering

Email address: mnieuwoudt@sun.ac.za, martin.nieuwoudt@gmail.com

Research areas: Medical IoT, Machine Learning for Biomedical Imaging, Biostatistics, Global Health and Epidemiology

8.1 The development of sensors to monitor wastewater

Co-supervisor: Prof Rob Warren, Prof Willem Perold

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? No

Are bursaries offered for this topic? TBD

Description of topic:

This project will build on prior work that has been done at the MRC and also by the Biosensors group in the Department of Electrical & Electronic Engineering.

8.2 Miniaturisation of the process of DNA extraction using microfluidics and electrical devices

Co-supervisor: Prof Rob Warren, Prof Willem Perold

Is it suitable for a MEngSc (Structured) research assignment? No

Is it suitable for a MEngSc (Research) thesis? Yes

Is it suitable for a PhD in Biomedical Engineering? No

Are bursaries offered for this topic? TBD

Description of topic:

This project will build on prior work done by Prof Nieuwoudt and Prof Warren's master's students in the domains of microfluidics and conductive DNA biochemistry.