WESTERN SYDNEY UNIVERSITY

School of Computing, Engineering and Mathematics

Summer Scholarship Research Program 2019

Project Lists

Project 34: Assisted Biomedical images selection & annotation

Supervisor(s): Gaetano Gargiulo (Principal Supervisor)
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Project description

Annotation of biomedical images, particularly the selection of relevant frames/images within a full scan such as CT, MRI and Ultrasound is a full manual process. A full manual process is fine for single exams where a technician selects the best image/frame to be submitted to the referring specialist for diagnosis. Unfortunately, the manual process is laborious and time consuming hence, not suitable for research. Usually, for research purposes, processing of images is performed in Matlab while selection of images may be operated using proprietary video/images editors, with this project we aim to integrate image/frame selection and annotation (i.e. physiological parameter visualized) into the image process framework.

The intern working closely with the supervisors will produce a graphical user interface to enable importing of videos/large image collection, playback at selected speed (including by frame), frame/image selection, annotation and integration of existing image processing techniques provided by the supervisors.

Project Aims

This project aims to provide a better tool for assisted biomedical images selection. The principal aim of this project is to program a Matlab Graphical User Interface (GUI) that will aid expert in selecting frames from videos (i.e. Ultrasound scan, CT-scan) and or specific images from large collections.

The proposed GUI will be then used to facilitate the supervisors joint research in biomedical image processing. Specifically, for this project the intern will work with cardiac ultrasound scan movies selecting frames related to specific phases of cardiac cycle.

The ideal GUI will be also able to run basic pre-processing programs such as average of images, edge detection and colour-space conversion.

Project Methods

This project required application of standard programming methods and standard programming "good practice" i.e. documented source code, instruction manuals.

Opportunity for Skill Development

- Biomedical Engineering
- Advanced signal and image processing
- Advanced Matlab programming
- Graphical user interfaces

Students are required to have the following skills/meet the following pre-requisite(s) to apply

Advanced Matlab programming skills.

Project 35: States tracking and change detection in time critical severity monitoring

Supervisor(s): Yi Guo (Principal Supervisor)

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Project description

Time-dependence is key in early recognition of these lethal diseases, which rapidly attack vulnerable tissues such as the brain and myocardium, and the window for essential intervention may often be measured in minutes. International guidelines mandate intravenous antibiotics in sepsis within one hour of clinical contact. Entire health systems have been redesigned to allow for rapid clot lysis or clot retrieval in stroke, and for immediate transfer for emergency angioplasty in myocardial infarction. However, we rely on insensitive, late-changing clinical signs to diagnose these life-threatening illnesses, and to determine the need for intervention.

Compensation for illness is mediated by the sympathetic nervous system (SNS), which is part of the integrated regulatory machinery keeping body functions in a steady-state equilibrium. These control systems are activated very early in the processes of compensation for disease, and directly monitoring this control might signal the earliest signs of time-dependent disease.

Pulse oximetry (PO) is a ubiquitous monitoring modality, alongside continuous electrocardiogram (ECG) recording. PO relies on the relative absorption of red / infrared light, as haemoglobin changes in colour in proportion to its saturation with oxygen. A by-product is the photoplethysmogram (PPG), similar to the arterial pressure waveform, giving a non-invasive measure of cardiovascular function. Spectral analysis of the PPG demonstrates oscillations with a prominent low-frequency component seen at approximately 0.1Hz; cross-spectral coherence analysis demonstrated that low-frequency (LF) PPG fluctuations (0.04–0.15 Hz) had the highest coherence with arterial pressure and muscle sympathetic nerve activity (MSNA), strongly suggesting that this peak is likely to represent SNS control of the vasculature. Similar work using ECG demonstrated a similar low-frequency peak in the interbeat or R-R variability, once again highly likely to represent SNS control over the heart.

Pilot studies have shown that photoplethysmogram (PPG), continuous electrocardiogram (ECG) and heart rate variability (HRV), in the cross-spectra of these signals in the frequency domain, appear to discriminate between potentially critically ill patients and those less unwell, and to do so at a time when there is no evidence of specific pathology; secondly, they do so at a point where there is no physiological evidence of deterioration. This project is to perform adequately powered studies to demonstrate the sufficiency of the diagnostic power of these non-invasive techniques.

Project Aims

Develop an analytic and diagnostic methodology allowing the recognition of critically ill patients with time-dependent conditions at an early stage, potentially resulting in novel life-saving tools by non-invasive techniques such as pulse oximetry waveform (photoplethysmography / PPG) and electrocardiogram / heart rate variability (ECG / HRV) data on patients at Liverpool Hospital Emergency Department (LVHED).

Project Methods

Physiological data mainly photoplethysmogram (PPG) / electrocardiogram (ECG) waveforms will be collected in Liverpool Hospital Emergency Department (LVHED) patients suffering from chest pain, sepsis and haemorrhage, simultaneously collecting detailed and granular clinical and outcome data from medical records. The project is a collaboration with South Western Emergency Research Institute (SWERI) where there are currently multiple studies in the LVHED patient group, giving unparalleled access to these patients in this academic ED, which sees 90,000 patients each year.

Patients will be investigated relevant to necessary interventions such as surgery, angioplasty, or antibiotic and inotrope use with admission to intensive care, as well as in-hospital and 30-day mortality. PPG / ECG / HRV for the above clinical, patient-based outcomes will be analysed to recognise the pattern of several severity states in critically ill patients so that a warning system for early detection can be designed. Machine learning techniques including manifold learning and pattern recognition on dynamic systems, will be applied to accelerate the discovery of useful patterns for early warning and to suggest optimum times for intervention.

Opportunity for Skill Development

The student will be able to develop experience on a full cycle of a data science project and learn the techniques that will be used in this project and also the experience of modelling if necessary.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

The student should have analytics programming skills (R/Matlab/Python), predicive modelling or more broadly skills in data science area.

Project 36: Mad Veterinarian: From recreational puzzles to abstract pure Mathematics

Supervisor(s): Professor Roozbeh Hazrat (Principal Supervisor)

Supervisor(s) contact information: r.hazrat@westernsydney.edu.au

Project description

As Alfred North Whitehead put it: "the paradox is now fully established that the utmost abstractions are the true weapons with which to control our thought of concrete fact".

This project starts with a puzzle about three transmogrifying machines that are able to transform an object to other objects (e.g. to transform a cat to a dog and a rat; hence the name Mad Vet experiment). The idea is to associate an abstract mathematical object to this scenario and explore the problem within this abstract system. Namely, corresponding to any Mad Vet scenario there is a naturally defined semigroup (an abstract mathematical object) which may or may not be a group. Our first main goal is to help the student to gain some intuition about when a given semigroup is actually a group; to this end, we work with a number of not-so-run-of-the-mill examples involving these algebraic structures.

Our second main goal is to illustrate a practice common in mathematics: namely, answering a question in one area by recasting it in another area, answering the recast question there, and then using that result to answer the original question. There are numerous examples of such powerful cross-disciplinary pollination.

The project aroused from my research in the structure of monoids. There are very interesting open questions related to this problem. This is a beautiful subject which is at the same time quite accessible to undergraduate students.

Project Aims

- To introduce the student to the world of pure mathematics
- To enhance student's ability to work on an open ended problem, mostly on their own
- To enhance the student's problem solving skills
- To enhance student's communication skills and active participations in achiving a common goal
- To pave the way (and encourage) the student to continue Postgrad studies (prefarably at our CRM centre)

Project Methods

This is a theoretical project and the student starts by looking at the required literature in Mathematics with a close collaboration with the supervisor. The student then starts looking at a specific problem which arises out of the setting of the Mad Vet puzzle. Along the way the student work closely with the supervisor. There will be weekly meeting at CRM where the student describes their findings on the board, allowing for enhancing the student's communication skills and the collaboration work. The student will write down the results in Tex format, and will present them using Beamer at the end of the eight week. If there are any new results obtained, they will be submitted for publication.

Opportunity for Skill Development

The student will become familiar with the research culture and how it is to conduct research if they decide to continue as a Postgraduate student. The project allows student to develop their problem solving skills, to work on their own on an open ended problem and to be able to interact with other researchers (mainly the supervisor) to work on a common project. Besides acquiring knowledge in one branch of pure mathematics, the ultimate goal of the project is to develop student's critical thinking and their independence in understanding the unfamiliar subjects and concepts. As for my motivation, I found that supervising students is one of the most satisfying things anyone in higher education can do. I have observed (and experienced with my own advisor) that research students would go on to become lifelong collaborators with the supervisor.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

The student needs to have a good basis on Discrete Maths and possibly has passed the unit Abstract Algebra. Above all, the student is required to be passionate about Mathematics!

Project 37: Making Unexpected Discoveries in Astronomical Images using a Saliency Model Convolutional Autoencoder

Supervisor(s): Professor Ray Norris (Principal Supervisor)
Dr Nicholas Tothill (Second Supervisor)

Supervisor(s) contact information: Ray.Norris@westernsydney.edu.au
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Project description

The rapidly increasing volume and complexity of astronomical data have ushered in a new era of big-data astronomy which has increased the demand for Machine Learning (ML) solutions. In this era, the sheer amount of image data produced with modern instruments and has resulted in a significant data deluge. Furthermore, the morphologies of objects captured in these astronomical images are highly complex and challenging to classify due to their intricate and indiscrete nature. Additionally, major astronomical discoveries are often unplanned and found in the unexpected, making unsupervised ML highly desirable by operating with few assumptions and without labelled training data.

Although unsupervised learning is powerful, few methods offer any insight into which features result in an input image being classified as anomalous. This limitation has given rise to saliency analysis systems which aim to detect features in an image that stand apart from the rest of the visual field and training set. In this project we aim to produce a convolutional autoencoder implementation of saliency detection similar to the network implemented in C Xia, et al. (2016) to 1) identify anomalous features in astronomical images and 2) rank images globally within an astronomical dataset based on the detected magnitude and number of anomalous features present within each image.

Successful completion of the project will provide the field with a powerful new approach to data exploration and anomaly detection. The expected speed and effectiveness of this method based on prior results (Ralph et al. 2019) indicates excellent scalability and holds implications for use on large future surveys, large-scale instruments such as the Square Kilometre Array (SKA) and in other big-data analysis applications.

Project Aims

The aims of this project are as follows:

- Design and Implementation of a convolutional autoencoder for saliency detection
- Ingestion of optical or radio astronomical images
- Preliminary determination of how well the convolutional autoencoder functions for saliency detection in astronomical images
- Generation of an “anomalous image” catalogue for further study

Project Methods

1. Design the autoencoder network based on the current state of the art found in the student's literature review using Google Tensorflow in Python
2. Define preliminary architecture refinement and hyper-parameter optimisation
3. Develop a basic system to load images from the selected data set
4. Augment the dataset with random rotations
5. Segment images during network operation using the saliency Basic implementation image sub-sampling or "sliding windows"
6. Train the network using selected input data
7. Conduct a basic qualitative or quantitative performance evaluation of global image anomaly detection and local anomalous feature extraction
8. Validate using labelled datasets
9. Generate an anomaly rank for input dataset

Opportunity for Skill Development

Throughout this project, the student will gain a sound understanding of the principles of machine learning from a statistical and algorithmic perspective, including the fundamentals of neural network design in Google Tensorflow. Additionally, the student will gain experience in image processing using the OpenCV3 Python library. Finally, the student will learn the fundamentals of astronomical imaging and big-data processing. The student can also expect to gain experience in writing a journal article based on the project results.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

Students are recommended to have a basic understanding of programming and computer vision. Python is ideal, and Google Tensorflow experience desirable. Students from science, computing, and engineering are encouraged to apply.

Project 38: Next Generation of Recycled Concrete: CO2 Concrete

Supervisor(s): Professor Vivian Tam (Principal Supervisor)
Associate Professor Khoa Le (Second Supervisor)

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Project description

Greenhouse-gas-emission is one of the most impacting environmental issues in today's society. Greenhouse gases are known to absorb infrared radiation in the atmosphere. The most common greenhouse gases emitted by human activities are carbon dioxide (CO2) of about 77% according to data from United States Environmental Protection Agency [1]. The rapidly-increasing trend in global CO2 emissions (about 23.64% since 1990), particularly since the early nineties has led to the generation of about 50,000 metric tonnes of CO2-equivalent in the whole world for 2010. Although Australian national greenhouse-gas-emission slightly increased in 2011 due to the strong international demand for Australian services following the global economic crisis recovery [2], Australia's annual greenhouse-gas-emission for 2014-2015 achieved the second lowest greenhouse-gas-emission level since 2000 [3]. Designing high-grade recycled concrete with low life-cycle cost and greenhouse-gas-emission for buildings will solve one of the pressing issues in Australia in providing a single national reporting framework for energy and greenhouse-gas-emission [4].

However, there are problems in introducing recycled concrete. In particular, the deficiency of strength exhibited by recycled concrete does not permit it to surpass natural concrete in mainstream practical usage [5]. Recent reviews on the effects of incorporating recycled aggregate on the carbon-conditioning behaviour of concrete have shown that carbon-conditioning can successfully improve the strength and volume stability of recycled aggregate and reduce water absorption, porosity and free calcium oxide [6-9]. There are different approaches to carbon-conditioning for either recycled aggregate [10-12] or recycled concrete [13]; however, carbon-conditioning for recycled concrete limits its practical value.

For carbon-conditioning recycled aggregate, an exposer produces a carbon-conditioned recycled aggregate which is denser and less porous with a reduced amount of water absorbency and generates a superior bond matrix because of an enhanced chemical reaction and effective space filling within the matrix [11, 14]. Recycled aggregate is however not yet used in the mainstream concrete production even though (i) it is cheaper than other recycling alternatives, (ii) it can generate an appropriate physical quality, mechanical quality and (iii) it is practical for commercial use. Additional research must also be conducted to fully discover carbon-conditioned recycled aggregate's potential. This will show that carbon-conditioned recycled concrete can be as strong as the normal concrete and hence can be suitable for high-grade applications. This will not only create new

material for structural purposes but also resolve greenhouse-gas-emission and concrete wastage and storage problems in Australia. Even though proposing carbon-conditioned recycled concrete for high-grade applications is innovative, there are problems which must be addressed before it can be used:

- Setting up efficient and effective carbon-conditioned recycled aggregate and carbon-conditioned recycled concrete production processes
- Improving strength and durability of carbon-conditioned recycled concrete and promoting carbon-conditioned recycled concrete be used for high-grade structural applications
- Lowering life-cycle cost and greenhouse-gas-emission of the new material

Project Aims

Aim 1. Performing carbon-conditioning for recycled aggregate using pressurized CO2 (Task 1). This Aim has been performed around the world to date but not comprehensive because only three variables are used. More than three variables are employed in this research;

Aim 2. Experimenting carbon-conditioned recycled concrete and investigating its properties for high-grade structural applications (Task 2); and

Aim 3. Analysing life-cycle cost and greenhouse-gas-emission from material production to demolition processes with and without using the new material (Task 3).

Project Methods

Task 1: Carbon-conditioned recycled aggregate using pressurised CO2

Previous researchers have limitedly conducted experimental work with only two to three variables. It is thus necessary that comprehensive experimental work with more than three variables on chamber pressure and duration to be conducted so that data can be used in the subsequent tasks. Carbon-conditioning will be performed in a pressurised chamber in which CO2 of 99.5% purity is injected at certain pressure points and duration. The gas pressure is regulated to ensure a continuous supply of CO2 to the chamber. The mass of recycled aggregate is chronographically recorded, representing CO2 uptake by the recycled aggregate samples. Data of various gas-pressure points and time intervals in the carbon-conditioned recycled aggregate production are collected and studied in this task. Properties of carbon-conditioned recycled aggregate, normal recycled aggregate and natural aggregate will be studied and compared using 23 experiments under seven main testing groups: i) particle size distribution, ii) particle density, iii) porosity and absorption, iv) particle shape, v) strength and toughness: ten percent fine value and aggregate impact value, vi) chemical composition: chloride and sulphate contents; and vii) microstructure: Scanning Electronic Microscopy analysis.

Task 2: Experiments on carbon-conditioned recycled concrete characteristics

Properties of carbon-conditioned recycled concrete, normal recycled concrete and natural concrete will be studied and compared. Different carbon-conditioned recycled aggregate replacement percentages, various chamber pressure and duration data in the production of carbon-conditioned recycled aggregate, water-to-cement ratios, aggregate-to-cement

ratios and new mixing techniques are also experimented to create different types of carbon-conditioned recycled concrete. Detailed testing on different carbon-conditioned recycled concrete characteristics is conducted in the laboratory. Ten major possible factors affecting recycled concrete characteristics are: i) workability; ii) density; iii) strength; iv) rigidity: static modulus of elasticity; v) deformation: shrinkage and creep; vi) chemical composition: chloride and sulphate contents; vii) permeability: water, air and chloride permeability; viii) carbonation depth; ix) microstructure: Scanning Electron Microscopy analysis; and x) stress-strain relationship under uniaxial loading. In addition, the suitability of different carbon-conditioned recycled concrete types for high-grade structural applications is also assessed.

Task 3: Life-cycle cost and greenhouse-gas-emission analyses

Life-cycle cost and greenhouse-gas-emission analyses of building production and demolition processes with and without using the carbon-conditioned recycled aggregate and carbon-conditioned recycled concrete are performed by systematically adding the required cost and greenhouse-gas-emission in each process. It should be noted that individual cost and greenhouse-gas-emission items may be difficult to estimate because of various inter-woven processes. Interviews with project managers will be conducted to justify cost and greenhouse-gas-emission items if necessary. From the supervisors' initial studies, it can be suggested that using carbon-conditioned recycled aggregate and carbon-conditioned recycled concrete lowers life-cycle cost and lessens greenhouse-gas-emission, yielding a more economical and greener living environment. For normal production and demolition processes of raw material, greenhouse-gas-emission occurs at various stages such as sourcing raw material, manufacturing cement, manufacturing concrete, constructing and operating buildings and demolition.

Opportunity for Skill Development

The student undertaking this project can gain knowledge on the importance of research and identifying research gaps in the construction engineering industry. Experimental work of recycled aggregate and recycled concrete conducted in this project can also help the student understanding research methodologies. These are necessary in developing and improving research skills for Higher Degree Research (HDR) in which the student may be interested for further study.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

Students in any stage of Bachelor of Engineering and Bachelor of Construction Management are suitable for this project.

Project 39: Strengthening cement by silk

Supervisor(s): Ee Loon Tan (Principal Supervisor)
Dr Yingyan Zhang (Second Supervisor)

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Project description

Concrete is brittle materials. It has high compressive strength but low tensile strength. In order to overcome this shortcoming, concrete is usually reinforced by steel. With the development of nanotechnology, new materials have been used in cement to improve its mechanical property with the aim to replace steel in the concrete. Recently, silk has been found to be stronger than steel in tensile strength. It has been used to produce strong and flexible electronic devices. In this project, we will have the first attempt to use silk in concrete to see whether silk is better than steel in improving the material properties of concrete. Furthermore, silk is biological material, which is eco-friendly. Therefore, if silk can replace steel as the new construction material, it will bring huge environmental benefits and help to tackle climate change.

The two Year 2 students will work closely with supervisors to the following topics:

1. Critical literature review about the present research status of new concrete.
2. The properties of silk and its potential in the application of civil engineering.
3. Conduct experimental test (mainly tension test) to see whether silk can improve the material properties of concrete.

Project Aims

1. Critical literature review about the present research status of new concrete.
2. The properties of silk and its potential in the application of civil engineering.
3. Conduct experimental test (mainly tension test) to see whether silk can improve the material properties of concrete

Project Methods

1. Critical literature review to understand the current research prospective in the new-concrete.
2. Experimental test for cement reinforced concrete by silk:
   - Preparing materials for concrete mixing
   - Preparing test specimens (Cylindrical moulds)
   - Mixing concrete using builder concrete mixer
   - Testing the test specimens
   - Using a computer program (Excel) to process raw experimental data

Opportunity for Skill Development

In the project, the student is trained to perform critical literature review (critical thinking), project management, report writing, and carried out experimental testing.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

Strong background of Mechanics of Materials.

Project 40: Green Concrete – Geopolymer Concrete

Supervisor(s): Dr Ee Loon Tan (Principal Supervisor)

Supervisor(s) contact information: e.tan@westernsydney.edu.au

Project description

An environmental issue that has become a major concern of today's society is the emission of greenhouse gases such carbon dioxide CO2 into the Earth's atmosphere. Widespread global warming caused by CO2 emission continues to threat the existence of human and ecological environment. Among the major industries that are heavy consumer of natural resources and emitter of CO2 into atmosphere, the cement industry is one of the top leading culprits of anthropogenic climate change emissions due to the energy consumed during extraction, processing and transportation of the natural resources. Consequently, there is an increase in awareness to engage in new technologies that are sustainable and meets the current demand for concrete for infrastructure development world-wide. Thus, to tackle the presented situation, one suitable solution is to utilise fly ash based geopolymer concrete (GPC) that has proved to totally replace the usage of cement in the concrete.

The word "Geopolymer" was first used by Davidovits in 1978, to define the minerals binder with chemical composition closely related to zeolites that has polymeric Si-O-Al framework structure. Geopolymers are also referred to as alkali-activated aluminosilicate binders. This is due to polycondensation of silica and alumina precursors and high alkali content to develop concrete strength as compare to ordinary cement concrete where pozzolanic reaction depends on the presence of calcium for developing strength. According to research, geopolymer concrete mixes based on Australian geopolymer products indicates potential of a 44-64% reduction in carbon emission in comparison to cement based concrete. Hence, geopolymer concrete has a great potential to reduce the effect of CO2 emission and can play an active role in being the leading concrete product for infrastructure developments around the world.

However, despite proven to exhibit desirable mechanical properties geopolymer concrete has not been utilised in larger structural applications because relatively high curing temperatures are beneficial for overcoming the activation barrier of the fly ash. This has become a major setback for geopolymer concrete to be considered as a potential replacement for ordinary cement concrete. Therefore, this project aims to develop a fly ash based geopolymer concrete that can be cured at ambient temperatures for cast-in-applications. The project is designed to carry out series of experimental investigations to provide valuable information on the mechanical behaviour of the concrete.

Project Aims

The primary aim of the project is to develop a full compressive stress-strain model for fly ash based green concrete. The objectives of the project are as listed:

- Preparing, mixing and pouring new concrete
- Carrying out experimental tests in laboratory
- Analysing and summarising experimental data

Project Methods

The project is designed to carry a series of experimental testing of the concrete test specimens. To complete the project following methods are to be adopted:

- Preparing materials for concrete mixing
- Preparing test specimens (Cylindrical moulds)
- Mixing concrete using builder concrete mixer
- Testing the specimens using MTS 5000 kN compression machine
- Using a computer program (Excel) to process raw experimental data

Opportunity for Skill Development

A range of skills and experience may be developed during the course of the project. These skills are as follows but not limited to:

- Comprehend large volume of information
- Develop skills to effectively arrange and evaluate data
- Perform effectively under pressure and meet deadlines
- Develop skills to present information in academic format
- Work in a collaborative atmosphere
- Gaining practical knowledge

Students are required to have the following skills/meet the following pre-requisite(s) to apply

Strong background of Mechanics of Materials.

Project 41: Two degree of freedom prosthetic hand

Supervisor(s): Hui Xie (Principal Supervisor)
Gaetano Gargiulo (Second Supervisor)

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Project description

Two degree of freedom hand prosthesis are usually very expensive and out of reach from the majority of amputees. With this project we aim to close the gap between amputees and access to a fully functional electromechanical prosthesis device. Exploiting the latest low-cost manufacture process such as direct 3D-printing and low cost embedded computing platform such as Arduino we intend to reduce the costs for a two degrees of freedom (wrist rotation and hand grasp function) thousands times i.e. below $200.

Project Aims

- Total bill of material below $200
- Single actuator two degrees of freedom prosthesis

Project Methods

- Critical analysis of low cost manufacture of mechanical parts and components
- Low computational load closed-loop actuator control
- Real-time Biomedical signal processing (muscle contraction signal) evaluation and review

Opportunity for Skill Development

- CAD (mechanical and printed circuit board)
- Biomedical engineering
- Embedded system

Project 42: Automated Negotiation for Autonomous Driving

Supervisor(s): Dongmo Zhang (Principal Supervisor)
Dave de Jonge (Second Supervisor)

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Project description

Over the last decade, research on autonomous vehicles (AVs) has made revolutionary progress, which brings us hope of safer, more convenient and efficient means of transportation. An autonomous vehicle system is an integration of many technologies, including computer vision, graphical processing, navigation, sensor technologies and so on. Most significantly, the recent advance of machine learning technologies enables a self-driving car to learn to drive in any complex road situations with millions of accumulated driving hours, which are way higher than any experienced human driver can reach. However, driving is not a purely technical job but involves complicated social activities, which could be hard to learn from experience. For instance, if two cars meet in a narrow road or a long bridge on which only one car can go through, how do the cars decide which one should reverse to give way to the other? Many of such a situation requires direct interaction among vehicles, vehicles and infrastructures, or vehicles and authorities. Such demands push the research on AVs to a different direction from machine learning with regards to communication, negotiation and cooperation among autonomous vehicles. Unfortunately, the studies along this direction is far from adequate. The primary goal of this project is to design and implement automated negotiation protocols for autonomous vehicles to negotiate each other when they meet unexpected road situations. The research will be based on simulations using the well-known robot simulation system Gazebo. Each robot acts as an autonomous vehicle and road traffic can then be simulated as a multi-robot system. We will design a few specific unusual road situations, such as road with blocked lines, junction without traffic control or totally blocked traffic jams. The task of the project is to investigate negotiation protocols for robots to interact each other and resolve traffic jams by themselves without external intervention. We will design and implement different negotiation protocols to compare their effectiveness and efficiency.

Project Aims

The aims of this project are:

- Set up a multi-robot system under Gazebo for testing automated negotiation protocols
- Design and implement in Gazebo at least three specific road situations that can likely lead to traffic jams.
- Design and implement different automated negotiation protocols so that robots can interact each other based on the protocols.
- Design and implement negotiation strategies for robots to resolve traffic jams under given negotiation protocols.

Project Methods

Description of negotiation protocols will be based on the concept of road graph, a novel method we recently introduced for representing roads and traffic (published in PRICAI-2019). With the concept of road graph, we can then describe various traffic-related elements, such as traffic flow, traffic-control protocols, vehicle information and vehicle management processes. By using the facilities of Gazebo, we can implement a set of road situations in 3D model. Robots can run in any of such a road situation. Programming of robot will be based on Robot Operating System (ROS) running in Linux. Either C++ or Python can be used. We prefer to use Python because it is simpler and more existing libraries to use. For the testing traffic situations with only two vehicles involved, beside simulations in Gazebo, we can also use TutleBot robots we currently have.

Opportunity for Skill Development

The student who undertakes this project will have a chance to learn the frontier technologies of autonomous vehicles, intelligent robotics and automated negotiation. The student can work with HDR students and get help from them to learn robot programming and run Gazebo simulations. By conducting this project, the student can also develop their research skills for Higher Degree Research and programming/system development skills for industry jobs.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

Students in year 2 or 3 of Bachelor of Computer Science, Bachelor of Computer Science (Advanced) and Bachelor of Information and Communication Technology (Advanced) with excellent programming skills are suitable for this project.

Project 43: Fatigue life analysis of coronary stents

Supervisor(s): Dr Leo Zhang (Principal Supervisor)
Prof Richard Yang (Second Supervisor)

Supervisor(s) contact information: Leo.Zhang@westernsydney.edu.au
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Project description

Cardiovascular diseases are one of the leading causes of death in developed countries due to lifestyle and an increasingly ageing population. Cardiovascular stents are commonly used for unblocking coronary arteries occluded by the presence of plaque. The most commonly used stents in clinic nowadays are balloon-expandable metallic stents. Despite the significant success in stent treatments, there still exists a considerable risk of failure due to high elastoplastic deformation of stents experienced in deployment. Furthermore, stents could also cause sizeable vessel injuries and subsequent tissue remodelling which ultimately lead to re-narrowing of the artery, a phenomenon known as restenosis. To understand the stent characteristics, finite element analysis (FEA) has been extensively used to quantify the biomechanical characteristics for the balloon-expandable stent system. The project will improve the design performance of stents for enhancing the deployment outcome and clinic success.

Project Aims

This project aims to further explore the multiobjective design of arterial stents in a nondeterministic context. Nonlinear finite element simulation will be performed for biomechanical analysis in the course of stent deployment. A multiobjective robust optimization will be conducted by taking into account biological and surgical uncertainties, specifically referring to the random variation in plaque geometry and stent misplacement, respectively. It provides a more accurate stent design for clinical applications.

Project Methods

In this project, a multiobjective robust optimisation procedure will be applied to address the issue of stent design involving uncertainties and mechanical behaviours of stents by using various performance criteria, such as reduction in dog-boning, foreshortening and radial elastic recoil. The optimal stent design model would be manufactured by using the feasibility of metal-based additive manufacturing technology.

Opportunity for Skill Development

Problem-solving and critical thinking skills: This project will develop student's ability to define problems clearly, develop testable hypotheses, find the appropriate solutions to problems.

Computer-aided engineering skills: Student will learn to use finite element analysis software. The student will use the finite element method to solve problems while understanding the fundamentals and theory of finite element analysis and design optimisation.

Communication skills: student will improve this skill through the meeting with supervisors. Students will present information in a clear and organised manner. Write the report in a scientifically appropriate style.

Project 44: Customised Total Knee Replacement Implant by Metal Additive Manufacturing

Supervisor(s): Dr Leo Zhang (Principal Supervisor)
Prof Richard Yang (Second Supervisor)

Supervisor(s) contact information: Leo.Zhang@westernsydney.edu.au
R.Yang@westernsydney.edu.au

Project description

Total knee arthroplasty is an increasingly common procedure for the treatment of severe knee end-stage osteoarthritis. In an increasingly ageing population such as Australia, this is essential as the risk of osteoarthritis sharply increases with age. Total knee replacement (TKR) is also an effective treatment for people with severe physical injury, resulting from accidents, or chronic stress injuries related to repeated physical activity. The most frequently cited reasons for TKR surgery are osteoarthritis, chronic pain and impaired movement.

The incidence of TKR surgery has risen dramatically since the technique was first developed in the 1960s. The incidence is projected to continue increasing at a much faster rate than other orthopaedic surgeries. However, there are still many issues surrounding their design based on various retrospective clinical studies. The research provides more thorough mechanical insight into the role of implant design parameters for knee replacement surgeries.

Additive manufacturing (AM) is becoming popular due to its unique ability to fabricate geometrically complex structures. As one class of metal additive manufacturing technique, powder bed fusion has attracted considerable attention in customised implants or prostheses application. It is a very effective and essential technique for the realisation of such implant or prosthetic structures.

Project Aims

This project will use the latest techniques in FEA to find the most influential geometric parameter in the implant structure and optimise the implant design by varying the dimension of the critical geometric factor. The optimal design of the implant will be manufactured by using metal-based additive manufacturing technology.

Project Methods

The application of finite element analysis has allowed for highly accurate analyses of the physical behaviour of extremely complex, organic structures, such as the human knee. In this project, an anatomically realistic model has been created from CT scan data of a healthy knee. After performing a total knee replacement virtually on SolidWorks, the model will be simulated using finite element analysis in an attempt to replicate a physiological loading condition on a knee.

Opportunity for Skill Development

Problem-solving and critical thinking skills: This project will develop student's ability to define problems clearly, develop testable hypotheses, find the appropriate solutions to problems.

Computer-aided engineering skills: Student will learn to use finite element analysis software. The student will use the finite element method to solve problems while understanding the fundamentals and theory of finite element analysis and design optimisation.

Communication skills: student will improve this skill through the meeting with supervisors. Students will present information in a clear and organised manner. Write the report in a scientifically appropriate style.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

N/A.

Project 45: La Draga: Virtual Reality in History Reconstruction

Supervisor(s): Anton Bogdanovych (Principal Supervisor)
Tomas Trescak (Second Supervisor)

Supervisor(s) contact information: a.bogdanovych@westernsydney.edu.au
t.trescak@westernsydney.edu.au

Project description

La Draga is a significant historic site in Spain. It's one of the best preserved early Neolithic settlements. In the past we have worked with a group of Spanish archaeologists and as a part of a funded project we have created a Virtual Reality reconstruction of the La Draga site based on the results of archaeological excavations. The site has also been populated with a group of avatars. In the second (unfunded) part of the project the task for the student will be to create an interactive Virtual Reality experience (mini-game) within the existing simulation. The mini-game will be used by museum visitors. A video showing the current state of the La Draga prototype can be seen here: https://www.youtube.com/watch?v=rBHRvmVR530

Project Aims

Develop an interactive Virtual Reality game about La Draga for museum visitors.

Project Methods

- In collaboration with the supervisors, the student will design a game concept document.
- Based on the concept document the student will then use the Unity framework to build an interactive game.
- Once the game is completed the student will help designing a study for museum visitors interacting with the game.

Opportunity for Skill Development

The student will learn developing an interactive Virtual Reality game using the Unity package. The student will also learn how to develop a concept document and will be involved in designing a user study for a museum.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

Strong programming skills and basic knowledge of Unity

Project 46: Literature review on damage to aircraft composite structures caused by directed-energy weapons

Supervisor(s): A/Prof Yixia (Sarah) Zhang (Principal Supervisor)
Dr John Wang (Second Supervisor)

Supervisor(s) contact information: Sarah.zhang@westernsydney.edu.au
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Project description

This research aims to conduct a literature review on damage to aircraft composite structures caused by directed-energy weapons, focusing on the experimental studies.
The purpose of this literature review is to provide knowledge that would assist design of experiment to assess laser weapons damage to aircraft composite structures. These experiments will focus on evaluation of the residual strength of composite structures subject to laser weapon damage. This will report the state of the development of the knowledge and methods used in this area and this study will form the background and provide guidance on the methods and research for a potential defence fund application.

Contents of the literature review:

- Brief overview of directed-energy weapons in general and more detailed review of leaser weapons
- Laser weapons that typically used against unmanned aircraft and helicopters
- The damage mechanism of laser weapons to composite structures
- Typical laser weapon damage to aircraft composite structures
- Experimental assessment of laser weapon damage to aircraft composite structures

Project Aims

This research aims to conduct a literature review on damage to aircraft composite structures caused by directed-energy weapons, focusing on the experimental studies.

The purpose of this literature review is to provide knowledge that would assist design of experiment to assess laser weapons damage to aircraft composite structures. This will report the state of the development of the knowledge and methods used in this area and this study will form the background and provide guidance on the methods and research for a potential defence fund application.

Project Methods

Intensive and comprehensive literature review will be conducted to achieve the aim of this project. The student will be trained the method to do a literature review and technical writing and then apply these skills to conduct the review and write up a report.

Opportunity for Skill Development

Via this project, the student will be trained the method to do a literature review, a very important method and step for conducting research. The student will also be trained on technical writing for scientific report and it is expected the writing ability of the student is improved significantly via this project.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

- Knowledge and background from Mechanical Engineering
- Good academic records
- Good writing skills
- Good communication skills
- Quick learner and hard worker