Title:	Practical Machine Learning APPROVED
Long Title:	Practical Machine Learning

Module Code:	COMP9061

Credits:	5

NFQ Level:	Expert

Field of Study:	Computer Science

Valid From:	Semester 1 - 2018/19 (September 2018)

Module Delivered In	no programmes

Module Coordinator:	TIM HORGAN

Module Author:	Ted Scully

Module Description:	Machine learning provides a means by which programs can infer new knowledge from observational data. This module will provide a comprehensive foundation in the theory, application and implementation of machine learning techniques. The module focuses on supervised and unsupervised learning algorithms, specifically classification and clustering techniques.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Develop a machine learning algorithm for solving a real-world problem.
LO2	Perform pre-processing and model selection for machine learning models.
LO3	Select and apply appropriate classification algorithms to datasets from a specific application domain.
LO4	Evaluate the accuracy of machine learning models using best practice techniques.

Pre-requisite learning
Module Recommendations *This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).*
No recommendations listed
Incompatible Modules *These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed
Requirements *This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.*
No requirements listed
Co-Requisites
No Co Requisites listed

Module Content & Assessment

Indicative Content
Pre-processing and Model Selection Application of pre-processing techniques such as outlier detection, feature selection, imputation of missing data, encoding, normalization, etc. Model selection using hyper parameter optimization.
Evaluation Best practice evaluation techniques such as precision, recall, confusion matrices and ROC curves. Debugging algorithms using validation and learning curves. Cross fold validation.
Classification Algorithms Classification algorithms such as decision trees, ensemble technique (bagging and boosting), support vector machines, instance-based algorithms, naïve bayes, bayesian networks, etc.
Unsupervised Algorithms Overview of unsupervised learning techniques. Example applications of clustering techniques. Introduction to algorithms such as k-means, k-median, dbscan and hierarchical clustering techniques. Optimization and distortion cost function. Random initialization and methods of selecting number of clusters. Silhouette plots.
Case Study Design and implementation of a relevant case study such as a recommender system.

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	Develop a machine learning model for a real-world problem and perform a comprehensive analysis.	1	50.0	Week 9
Project	Perform a comparative analysis of a range of machine learning classification algorithms applied to a dataset from an application domain. Standard pre-processing and model selection techniques should be applied and the performance should be comprehensively evaluated. Findings should be documented.	2,3,4	50.0	Week 13

No End of Module Formal Examination

Reassessment Requirement
Coursework Only *This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.*

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Delivers the concepts and theories underpinning the learning outcomes.	2.0	Every Week	2.00
Lab	Application of learning to case studies and project work.	2.0	Every Week	2.00
Independent Learning	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Delivers the concepts and theories underpinning the learning outcomes.	2.0	Every Week	2.00
Lab	Application of learning to case studies and project work.	2.0	Every Week	2.00
Independent Learning	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Module Resources

Recommended Book Resources

- **Sebastian Raschka 2015, *Python Machine Learning*, 2nd Ed., Packt [ISBN: 9781783555130]**
- **John Hearty 2016, *Advanced Machine Learning with Python*, 1st Ed., Packt Publishing [ISBN: 9781784398637]**

Supplementary Book Resources

- **Ethem Alpaydin 2016, *Machine Learning: The New AI*, 1st Ed. [ISBN: 9780262529518]**
- **Peter Flach 2012, *Machine Learning: The Art and Science of Algorithms that Make Sense of Data*, 1st Ed., Cambridge University Press [ISBN: 9781107422223]**

Recommended Article/Paper Resources

- **Pedro Domingos 2012, *A Few Useful Things to Know about Machine Learning*, Communications of the ACM, 55**
  http://homes.cs.washington.edu/~pedrod/papers/cacm12.pdf

Other Resources

- **Website: *Kaggle: Data Science***
  https://www.kaggle.com
- **Website: *Scikit-Learn***
  http://scikit-learn.org/stable/

Title:	Knowledge Representation APPROVED
Long Title:	Knowledge Representation
Module Code:	COMP9016
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	no programmes
Module Coordinator:	TIM HORGAN
Module Author:	Ruairi OReilly
Module Description:	Knowledge representation and reasoning (KR) is a field of AI that focuses on the representation of domain specific knowledge in a form that can be utilised by computer systems. Knowledge representations within a domain are often conceived as formalisms, a description of something in formal mathematical or logical terms. This module will introduce students to methodologies for the visualisation and interpretation of domain specific knowledge and the translation of interpretations into KR formalisms. It will provide the student with an appreciation of how to evaluate the suitability of knowledge representation schemes, balance competing features/requirements and make informed decisions when designing KR formalisms. The module will also focus on the application of KR to appropriate real world problems such as the semantic web, time-series indexing and temporal abstraction of expert knowledge.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Appraise domain specific formalisms used in knowledge representation schemes.
LO2	Compare and contrast current knowledge representation approaches integrated in systems relevant to AI.
LO3	Select, apply and evaluate a knowledge representation scheme for a specified domain.
LO4	Design and implement KR formalisms for a real world time series data set.
LO5	Interpret, critique and communicate the suitability of data visualisation techniques used in conjunction with the design of KR formalisms and the analysis of the resulting output.

Pre-requisite learning
Module Recommendations *This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).*
No recommendations listed
Incompatible Modules *These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed
Requirements *This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.*

Module Content & Assessment

Indicative Content
Introduction Central role of knowledge representation; desired properties of representation schemes; overview of representation schemes including, e.g., logic, frames, neural networks, common-sense knowledge; the frame problem in logic.
Formalism Propositional and predicate logic; syntax and semantics; rules of inference; logical consequence and proof; logic as knowledge representation formalism; unification; resolution theorem proving.
Knowledge Representation formalisms, semantic nets, systems architectures, frames rules and ontologies; automated reasoning, inference engines, theorem provers and classifiers; roles within KR frameworks, ontology engineering.
Knowledge Representation vrs Data Representation Temporal reasoning and abstraction; change, causality and actions described in terms of time, decision analysis, spatial–temporal reasoning; time series representation, symbolic representation, discrete wavelet transform, discrete fourier transform; dimensionality reduction; comparison of data mining tasks (clustering, classification, indexing), upper and lower bounds, distance measures.
Data Visualisation Data visualisation theory - targeting appropriate visual elements on a page, mapping values in the data domain to visual domain, human visualisation interaction - adding computation steering to visualisations. Charts, Plots & Layouts - graphical representations of data: Line Charts, Area Charts, Bubble Charts, Bar Charts, Scatterplots, Scaling Data, Axes, Geomapping.
Discussion Topics For example, semantic web and natural language processing, expert systems; knowledge-based systems - acquisition and representation; indexing time series at scale.

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	Detail and critically evaluate a knowledge representation scheme, its utilisation of formalisms and relevance to Artificial Intelligence.	1,2,3	30.0	Week 8
Practical/Skills Evaluation	In class lab e.g. design, develop and implement a KR formalism for a specified problem domain.	1,2,3,4	25.0	Week 11
Project	Design, develop and deploy a KR solution for a real world problem domain. e.g. a system for automating the interpretation of biomedical data requires a KR scheme that enables the translation of data such that the integrity of all domain specific information is maintained. Provide a rationale for the chosen visualisation approach taken at both the design and analysis stage.	1,2,3,4,5	45.0	Sem End

No End of Module Formal Examination

Reassessment Requirement
Coursework Only *This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.*

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lecture underpinning learning outcomes.	2.0	Every Week	2.00
Lab	Lab supporting content delivered.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lecture underpinning learning outcomes.	2.0	Every Week	2.00
Lab	Lab supporting content delivered.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Module Resources

Recommended Book Resources

- **R. Brachman & H. Levesque H 2004, *Knowledge Representation and Reasoning*, 1st Ed Ed., Morgan Kaufmann [ISBN: ISBN 1558609326, ISBN-13: 9781558609327]**
- **S. Russell & P. Norvig 2003, *Artificial Intelligence A Modern Approach*, 2nd Ed Ed., Prentice-Hall [ISBN: S. RUSSELL & P. NORVIG, ARTIFICIAL INTELLIGENCE A]**

Supplementary Book Resources

- **Michael Gelfond, Yulia Kahl 2014, *Knowledge Representation, Reasoning, and the Design of Intelligent Agents: The Answer-Set Programming Approach*, 1 Ed., Cambridge University Press [ISBN: 978110702956]**

This module does not have any article/paper resources

Other Resources

- **website: *IEEE***
  http://www.ieee.org
- **website: *Jeff Heaton***
  http://www.heatonresearch.com
- **website: Prof. Eamonn Keogh *UCR Time Series Classification Archive***
  http://www.cs.ucr.edu/~eamonn/time_serie s_data/
- **website: Prof. Yuval Shahar *Temporal Abstraction***
  http://www.ise.bgu.ac.il/faculty/shahar/

Title:	Metaheuristic Optimisation APPROVED
Long Title:	Metaheuristic Optimisation

Module Code:	COMP9058
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	1 programme(s)
Module Coordinator:	TIM HORGAN
Module Author:	Alejandro Arbelaez
Module Description:	This module explores techniques for the analysis and design of efficient techniques to solve real-life problems. In this module the learner will be introduced to the complexity of solving hard combinatorial problems, i.e., recognise and prove NP-hard problems. Additionally, the module covers effective and efficient meta-heuristic techniques to tackle complex decision problems, especially combinatorial optimisation problems.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Categorise a real-life problem with respect to its computational complexity.
LO2	Assess the benefits and limitations of meta-heuristics to solve NP-hard problems.
LO3	Solve an NP-hard problem with meta-heuristics to find a satisfactory lower-bound solution.
LO4	Analyse the average performance of a randomised algorithm to solve an NP-hard problem
LO5	Apply nature-inspired and local search meta-heuristics to solve real-life problems.

Pre-requisite learning
Module Recommendations *This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).*
No recommendations listed
Incompatible Modules *These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed
Requirements *This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.*
No requirements listed
Co-Requisites
No Co Requisites listed

Module Content & Assessment

Indicative Content
Computational Complexity Theory Complexity classes (P, NP, NP-complete, and NP-hard); P vs. NP; polynomial-time reductions to prove NP-completeness; tractability and intractability; the no free lunch theorem.
Population-based meta-heuristics Mainstream population-based meta-algorithms such as: evolutionary and genetic algorithms, estimation of distribution algorithms (EDAs); ant-colony optimization, particle swarm optimization, and artificial bee colony algorithm
Single solution-based meta-heuristics Application of standard local search techniques such as: neighborhood search, variable neighborhood search, hill climbing, simulated annealing, and Tabu search; global Vs. local optimum solutions
Randomised Algorithms Las Vegas and Monte Carlo algorithms; k-opt and Lin-Kernighan algorithms; random walk; randomised search trees; randomised sorting.
Performance of randomised algorithms Random variables and their properties; average case-runtime of Las Vegas algorithms; runtime distributions of las Vegas algorithm; evaluate and compare randomised algorithms.
Applications Applying population-based and single solution-based meta-heuristics to solve real-world problems , e.g., assignment problem, Boolean satisfiability problem, traveling salesman problem, and knapsack problem

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	In this project the students will be given a problem and they will have to show that the problem is NP-complete and implement a population-based meta-heuristic, to solve the problem and critically evaluate the performance the solution.	1,2,3	50.0	Week 6
Project	In this project the students will be given a real-life problem and the students will have to implement a single solution-based metaheuristic to solve the problem and critically evaluate the performance of the solution	3,4,5	50.0	Sem End

No End of Module Formal Examination

Reassessment Requirement
Coursework Only *This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.*

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Presentation of theory.	2.0	Every Week	2.00
Lab	Lab supporting lectures.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Presentation of theory.	2.0	Every Week	2.00
Lab	Lab supporting lectures.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Module Resources

Recommended Book Resources

- **Stuart Russell and Peter Norvig 2016, *Artificial Intelligence: A Modern Approach*, Pearson Education Limited [ISBN: 9781292153964]**
- **El-Ghazali Talbi 2009, *Metaheuristics: From Design to Implementation*, John Wiley & Sons [ISBN: 978-0-470-278]**
- **Xin-She Yang 2010, *Nature-Inspired Metaheuristic Algorithms*, 2 Ed., Luniver Press [ISBN: 9781905986286]**

Supplementary Book Resources

- **Steve S. Skiena 2009, *The Algorithm Design Manual*, 2nd Edition Ed., Springer [ISBN: 9781848000698]**
- **Holger H. Hoos and Thomas Stützle 2004, *Stochastic Local Search: Foundations & Applications*, Morgan Kaufmann [ISBN: 978-149330373]**
- **Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, 2009 2009, *Introduction to Algorithms*, 3rd Edition Ed., MIT Press [ISBN: 9780262033848]**

Supplementary Article/Paper Resources

- **Holger H. Hoos and Thomas Stutzle 1998, *Evaluating Las Vegas Algorithms: Pitfalls and Remedies*, Proceedings of the Fourteenth Conference on Uncertainty in Artificial Intelligence**
- **Stephen A. Cook 1971, *The Complexity of Theorem-Proving Procedures*, Proceedings of the Third Annual ACM Symposium on Theory of Computing**
- **Keld Helsgaun 2009, *General k-opt submoves for the Lin-Kernighan TSP heuristic*, Math. Program. Comput, 1**
- **Charlotte Truchet, Alejandro Arbelaez, Florian Richoux, Philippe Codognet 2016, *Estimating parallel runtimes for randomized algorithms in constraint solving*, Journal Of Heuristics, 22**

Other Resources

- **Website: *Design and Analysis of Algorithms***
  https://ocw.mit.edu/courses/electrical-e ngineering-and-computer-science/6-046j-d esign-and-analysis-of-algorithms-spring- 2012/index.htm
- **Website: Professor Michael Mitzenmacher*Data Structures and Algorithms***
  http://www.fas.harvard.edu/~libcs124/cs1 24/
- **Website: David Eppstein*Design and Analysis of Algorithms***
  https://www.ics.uci.edu/~eppstein/161/

Title:	Big Data Processing APPROVED
Long Title:	Big Data Processing
Module Code:	COMP9062
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	no programmes
Module Coordinator:	TIM HORGAN
Module Author:	Ignacio Castineiras
Module Description:	Data is now being generated at an unprecedented rate. The volume, velocity and variety of the data that is being produced means that traditional database architectures are no longer suitable to store, manage and analyse such data. As a result, organisations are now using distributed systems where parts of the data are stored in distributed databases and managed and analysed by distributed algorithms. In this module, students will be introduced to distributed architectures, frameworks and algorithms to store, manage and analyse large-scale datasets. As part of this module, students will learn not only how to deal with static data but also data in motion performing real-time data analytics.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Appraise how the velocity, volume and variety of data will impact how data is stored, managed and analysed.
LO2	Survey the different tools that constitute a big data framework.
LO3	Process large-scale temporal, geospatial, text and graph datasets using descriptive and analytical tools.
LO4	Design and develop a machine learning algorithm for performing large scale distributed computation.

Pre-requisite learning
Module Recommendations *This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).*
No recommendations listed
Incompatible Modules *These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed
Requirements *This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.*
No requirements listed
Co-Requisites

Module Content & Assessment

Indicative Content
The Big Data Revolution. Data storage and data process: Historical evolution. New infrastructure, data models and processing techniques required to deal with big data. Main challenges: Capture, store, search, analyse and visualise the data.
Distributed Computing. Sequential vs. non-sequential computation. Parallel, concurrent and distributed computing: definition and differences. A sequential vs a distributed framework for processing large-scale datasets: Efficiency, resiliency, scalability. Process communication: Asynchronous message passing, message inbox, priority policies, time-limits. Process planner: Dependent process via links, fault tolerance via monitors and state notification. Actors and Streams.
Big Data Framework. Dataset characterisation: Variety, velocity and volume. Data Framework ecosystem overview: Tools to ingest, store, analyse and manage data. Data integration: Extracting, transforming and loading relational and non-relational data. Distributed File system: Cluster components and roles.
Large-Scale Distributed Computation. Map-sort-reduce process: Data processing, Key/value-based communication, Standard I/O file streaming. Spark: Core, Shell, DataSets and DataFrames. Eager and Lazy evaluation. Resilient Distributed Datasets: Transformations and actions, basic API. Distributed Processing and Persistence: RDD partitions and job execution. Spark streaming: Offline vs on-line data processing. Advantages and disadvantages of Spark streaming. Architecture and application flow for Spark streaming. Applications: Text, temporal and geospatial data processing.
Machine Learning for Large-Scale Distributed Computation. Algorithmic design for parallel computing environments: K-means clustering, Decision trees and random forests, graph processing, neural nets, recommender systems. Spark MLlib: Survey of existing algorithms for parallel analysis of large data sets.

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	Complete an analytics project by performing a comprehensive analysis of different offline datasets by applying appropriate technologies e.g. MapReduce and Spark. Produce a report comparing and contrasting both approaches in terms of their expressiveness and efficiency.	1,2,3	50.0	Week 8
Project	Perform descriptive and predictive analytics over different off-line and online-based data sets by applying distributed machine learning algorithms. Design and implement at least one of the algorithms proposed.	3,4	50.0	Week 13

No End of Module Formal Examination

Reassessment Requirement

Coursework Only
This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lecture deliverying theory underpinning learning outcomes	2.0	Every Week	2.00
Lab	Practical computer-based lab supporting learning outcomes	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lecture deliverying theory underpinning learning outcomes	2.0	Every Week	2.00
Lab	Practical computer-based lab supporting learning outcomes	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Module Resources

Recommended Book Resources

- **Ofer Mendelevitch, Casey Stella and Douglas Eadline. 2017, *Practical Data Science with Hadoop and Spark : Designing and Building Effective Analytics at Scale*, Pearson Education [ISBN: 9780134024141]**
- **Nick Pentreath 2015, *Machine Learning with Spark*, PACKT Publishing [ISBN: 9781783288519]**

Supplementary Book Resources

- **Joe Armstrong 2013, *Programming Erlang*, Pragmatic Bookshelf [ISBN: 9781937785536]**
- **Srinath Perera and Thilina Gunarathne 2013, *Hadoop MapReduce Cookbook*, PACKT Publishing [ISBN: 9781849517294]**

This module does not have any article/paper resources

Other Resources

- **Website: *Hadoop Cloudera Map-Reduce documentation***
  https://www.cloudera.com/documentation/e nterprise/5-5-x/categories/hub_mapreduce .html
- **Website: *Hadoop Cloudera Spark documentation***
  https://www.cloudera.com/documentation/e nterprise/5-5-x/categories/hub_spark.htm l

Title:	Research Practice & Ethics APPROVED
Long Title:	Research Practice & Ethics
Module Code:	COMP9011
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	2 programme(s)
Module Coordinator:	TIM HORGAN
Module Author:	Donna OShea
Module Description:	The purpose of this module is to introduce students to the tools and techniques for doing research. In addition, students will examine the concept of research integrity and ethics applied to their field of study. On completion of this module students will develop a research proposal outlining the context of the topic, its research aims, objectives, methodologies, work plan, ethical considerations etc. This proposal will then be developed further in an implementation phase.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Develop a research proposal defining the project aims, objectives and research methodology that will be applied to the research project.
LO2	Review the current state of the art in the topic related to the proposed research outlining the contribution the research will make to the general field.
LO3	Evaluate the main research integrity and ethical considerations that need to be considered in the proposed project.
LO4	Develop a project schedule and plan that considers the identified research integrity and ethical considerations.
LO5	Communicate effectively the idea and contribution of the proposed research project.

Pre-requisite learning

Module Recommendations
This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).

13405	COMP9011	Research Practice & Ethics

Incompatible Modules
These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.

No incompatible modules listed

Co-requisite Modules

No Co-requisite modules listed

Requirements
This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.

No requirements listed

Co-Requisites

Module Content & Assessment

Indicative Content
Research Methods and Methodologies Definitions. Knowledge kinds and interrelationships. Empirical Research. Basic Research. Applied Research. Practical Research. Action Research. Parameters of research. Kinds of research: qualitative, descriptive and experimental. Applying research methodologies to computing, software and software development. Case studies and examples.
Research and Research Strategies Constitution of research papers. Standards. Search strategies including: web, library, inter-library loan, databases such as IEEE and ACM, search engines. Literature review and systematic literature review.
Research Planning Issues within a research project that relate specifically to computing/software projects including: problem definition, software planning, specification and system definition, choosing environments for development, timing issues relating to the software process, prototyping, iteration, risk evaluation, slippage, performance issues, evaluations and conclusions.
Research Documentation Documentation appropriate to research and the programme specifications. This includes research proposal documentation, report documentation, research paper formats and citation formats.
Ethics for Computer Scientists Ethics in Information & communication technology. Ethics, privacy and information security. Computer Ethics. Cyber ethics. Social, regulation and legal issues. Ethical design. Impact of IoT on ethics - environment monitoring and data collection. Impact of AI on ethics. Posthuman era, machine ethics, unintended consequences. Case studies - Facebook Mood Manipulation Experiments, Internet of Things, Google Maps.
Research Ethics & integrity Human subjects - ethical, legal, social and political issues. Research ethics committee in CIT. Categories of research ethics - questionnaires/surveys for adults versus children. Consent.

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Essay	The student will propose an initial research topic and will define some initial context behind the idea. In addition, the student will define some preliminary research aims and objectives. The student will then be expected to present their idea with the aim of effectively communicating the broad research topic and context.	1,2	40.0	Week 9
Other	The student will develop the research proposal detailing fully the idea and relevant state of the art, aims, objective, methodologies, work plan schedule and ethical issues that need to be considered. The student may also be required to present their proposal.	1,2,3,4,5	60.0	Sem End

No End of Module Formal Examination

Reassessment Requirement
Coursework Only *This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.*

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lecture delivering theory underpinning learning outcomes.	2.0	Every Week	2.00
Lab	Practical to develop individual proposal.	1.0	Every Week	1.00
Independent & Directed Learning (Non-contact)	Independent Study.	4.0	Every Week	4.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	3.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lecture delivering theory underpinning learning outcomes.	2.0	Every Week	2.00
Lab	Practical to develop individual proposal.	1.0	Every Week	1.00
Independent & Directed Learning (Non-contact)	Independent Study.	4.0	Every Week	4.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	3.00

Module Resources

Recommended Book Resources

- Martyn Denscombe 2014, *The Good Research Guide*, 5 Ed., Open University Press, McGraw-Hill Education [ISBN: 9780335264704]

Supplementary Book Resources

- Steven J. Taylor, Robert Bogdan, Marjorie DeVault 2016, *Introduction to Qualitative Research Methods: A Guidebook and Resource*, 4 Ed., Wiley [ISBN: 9781118767214]
- Prabhat Pandey, Meenu Mishra Pandey 2015, *Research Methodology: Tools and Techniques*, 1 Ed., Bridge Center [ISBN: 9786069350270]
- James D. Lester 2014, *Writing Research Papers: A Complete Guide*, 15 Ed., Pearson [ISBN: 9780321952950]
- K. Schwalbe 2011, *Information Technology Project Management*, 6 Ed., Cengage Learning [ISBN: 9781111221751]
- Dennis Lock 2007, *Project management*, Gower Aldershot [ISBN: 978-0566087721]
- Nick Bostrom 2016, *Superintelligence: Paths, Dangers, Strategies*, OUP Oxford [ISBN: 9780198739838]

Recommended Article/Paper Resources

- Shaw, M. 2003, *Writing Good Software Engineering Research Papers*, Proceeding of the 25th International Conference on Software Engineering: IEEE Computer Society, 726-736
- Nick Bostrom, Eliezer Yudkowsky 2014, *The Ethics of Artificial Intelligence*, The Cambridge handbook of artificial intelligence, 316-3
  https://intelligence.org/files/EthicsofAI.pdf
- Francine Berman and Vinton G. Cerf 2017, *Social and Ethical Behavior in the Internet of Things*, Communications of the ACM, 60(2)
  http://www.cs.rpi.edu/~bermaf/Berman+Cerf_IoT.pdf

Supplementary Article/Paper Resources

- Nick Bostrom 2009, *The Future of Humanity*, New Waves in Philosophy of Technology
  https://nickbostrom.com/papers/future.html

Other Resources

- Website: *APA reference style: Tightening up you citations.*
  http://linguistics.byu.edu/faculty/henri chsenl/APA/APA11.html
- Website: Henrichsen, L. et al. 2007, *Taming the Research Beast*
  http://linguistics.byu.edu/faculty/henri chsenl/ResearchMethods/
- Website: The Atlantic 2014, *Everything We Know About Facebook's Secret Mood Manipulation Experiment*
  https://www.theatlantic.com/technology/a rchive/2014/06/everything-we-know-about-facebooks-secret-mood-manipulation-exper iment/373648/
- Website: Berkman Klein Centre for Internet & Society at Harvard University *Ethics and Governance of Artificial Intelligence*
  https://cyber.harvard.edu/research/ai?pa ge=2

Title:	Computer Simulation & Analysis APPROVED
Long Title:	Computer Simulation & Analysis

Module Code:	COMP9063
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	no programmes
Module Coordinator:	TIM HORGAN
Module Author:	DIRK PESCH

Module Description:	Computer simulation is widely used as a tool to design, implement, and analyse models of real-world systems in a computer. Computer simulation is used if an analytical (mathematical) analysis of the system model is too complicated or requires a level of abstraction that simplifies the model too much. It is also used if building the real system is not feasible or too expensive but an analysis of its behaviour or performance is required before real-world implementation. This module introduces the student to the principles of computer simulation and analysis. A specific emphasis is put on stochastic simulation approaches, that is computer simulation driven by random numbers. These occur in many real-world use cases such as computer and communication networks, traffic and transportation systems, thermodynamic systems and many others.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Critically evaluate the applications of computer simulation and modelling techniques and approaches used in computer simulation.
LO2	Appraise random number generation techniques available for the stochastic simulation of a particular system model.
LO3	Evaluate and apply a computer simulation modelling technique with the aim of modelling a real world system.
LO4	Design a computer simulation and select the most appropriate tool to implement the computer simulation.
LO5	Analyse the behaviour or performance of a computer simulation using statistical evaluation techniques.

Pre-requisite learning
Module Recommendations *This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).*
No recommendations listed
Incompatible Modules *These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed

Module Content & Assessment

Indicative Content
Introduction Why computer simulation; modelling approaches used in computer simulation; simulation techniques and approaches; overview of simulation tools and languages; use case examples.
Random Number generation Techniques for pseudo random number generation; testing randomness of pseudo random number generation; selecting random distributions and processes to model system properties; techniques for generation of random variates;
Analysis Simulation output data analysis; Statistical evaluation methods; output data analysis of a single system; comparison of multiple systems; reliability testing, significance sampling, variance reduction techniques
Computer simulation modelling techniques Description and discussion of stochastic simulation techniques; Monte Carlo simulation and examples; numerical and dynamic simulation modelling and examples. Discrete event and agent based simulation modelling; stochastic discrete event simulation. Building valid, credible and appropriately detailed simulation models; model verification approaches.
Simulation languages and tools Detailed review, discussion and application of of selected computer simulation tools/languages; Choice of SimPy, CNCL, OpenModelica, Matlab, Omnett++, Arena, ns3, netsim, SUMO, and others; Example implementations of use cases in one or more of the selected tools

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	In this assignment the student may be expected to apply their understanding of random number generation and statistical evaluation and use an appropriate simulation tool to model and simulate a simple real world problem. Students may also be required to write a report evaluating and justifying their choice of techniques used.	1,2,3	40.0	Week 6
Project	In this project students may be expected to model a real world problem or set of problems and design, implement and evaluate their performance in a computer simulation. Students may also be required to write a report evaluating and justifying their choice of technique used.	1,2,3,4,5	60.0	Sem End

No End of Module Formal Examination

Reassessment Requirement

Coursework Only
This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lecture underpinning learning outcomes of module.	2.0	Every Week	2.00
Lab	Lab to support theoretical content delivered in class.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lecture underpinning learning outcomes of module.	2.0	Every Week	2.00
Lab	Lab to support theoretical content delivered in class.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Module Resources

Recommended Book Resources

- **Averill M. Law 2015, *Simulation Modeling and Analysis*, 5th Ed., McGraw Hill Intl [ISBN: 9781259254383]**

Supplementary Book Resources

- **Sheldon M. Ross 2006, *Simulation*, 4th Ed., Elsevier Science [ISBN: 9780125980630]**
- **V. P. Singh 2008, *System Modeling and Simulation*, New Age International [ISBN: 9788122423860]**
- **B. K. Choi, D.H. Kang 2013, *Modeling and Simulation of Discrete Event Systems*, Wiley [ISBN: 9781118386996]**

Recommended Article/Paper Resources

- **Farhad Azadivar 1992, *A tutorial on simulation optimization*, Proceedings of the 24th conference on Winter simulation (WSC '92) http://dx.doi.org/10.1145/167293.167332**
- **C. M. Macal and M. J. North 2005, *Tutorial on agent-based modeling and simulation*, Proceedings of the Winter Simulation Conference, 2005 http://dx.doi.org/10.1109/WSC.2005.1574234**
- **Jack P. C. Kleijnen, Susan M. Sanchez, Thomas W. Lucas, and Thomas M. Cioppa *State-of-the-Art Review: A User's Guide to the Brave New World of Designing Simulation Experiments*, INFORMS Journal on Computing, 17:3, 2005 https://doi.org/10.1287/ijoc.1050.0136**

Other Resources

- **Website: *Computer Simulation Software* https://en.wikipedia.org/wiki/List_of_co mputer_simulation_software**

Title:	AI for Sustainability APPROVED
Long Title:	AI for Sustainability
Module Code:	COMP9064
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	no programmes
Module Coordinator:	TIM HORGAN
Module Author:	Laura Climent
Module Description:	Computing and artificial intelligence can play an important role in addressing critical sustainability challenges faced by present and future generations. The goal of this module is to introduce students to a range of sustainability challenges and to computational methods in Artificial Intelligence (AI) that deal with such sustainability challenges. In this module the students will be able to identify real-life applications in which the use of the planet's resources can be minimized. In addition, students will learn how to solve such sustainability problems via computational models and techniques from the field of AI.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Identify a wide range of real-life sustainability problems from various application areas.
LO2	Identify the main features of sustainability problems, including their resources to minimize.
LO3	Model real-life sustainability problems as graphs and as optimization models.
LO4	Apply graph theory algorithms to solve the real-life sustainability problems modelled.
LO5	Apply dynamic programming techniques in order to solve a range of sustainability problems.

Pre-requisite learning
Module Recommendations *This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).*
No recommendations listed
Incompatible Modules *These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed
Requirements *This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.*
No requirements listed
Co-Requisites
No Co Requisites listed

Module Content & Assessment

Indicative Content
Introduction to Computational Sustainability Introduction to real-life sustainability problems. Real-life applications where the minimization of resources impact the sustainability of our planet. Modelling computational sustainability problems as optimization problems. Explanation of the features of computational sustainability problems. Introducing the concept of best solution according to certain criterion/criteria such as minimising costs, energy, resources, etc.
Graphs Algorithms for Sustainability Problems Graph main concepts (sub-graph, path, cycle, connection) and categories (directed, weighted). Modelling real-life sustainability problems as graphs. Graph algorithms: topological sorting, connectivity, minimum spanning tree (Prim's algorithm and Kruskal's algorithm), shortest path (Dijkstra's algorithm), network flow. Travelling salesman problem.
Dynamic Programming Algorithms for Sustainability Problems Decreasing recursive design (top-down approach) vs. increasing iterative design (bottom-up approach). Applications: Graphs, resource allocation problems, cutting problems, etc.
Applications to Real-life Sustainability Problems: Analysis, modelling and solving of real-life sustainability problems. For instance, the forestry harvesting problem can be modelled as a cutting problem and solved with dynamic programming; the network design problem can be modelled as a graph and be solved with minimum spanning trees; finding the shortest path from a source to certain destination can be modelled as graph and can be solved with specific algorithms for graphs, etc.

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	For a given case study of a sustainability problem, the student would be expected to model it as a graph and solve it by implementing specific algorithms for graphs.	1,2,3,4	50.0	Week 8
Project	For a given case study of a sustainability problem, the student would be expected to model it and solve it by implementing dynamic programming algorithms.	1,2,3,5	50.0	Sem End

No End of Module Formal Examination

Reassessment Requirement

Coursework Only
This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Presentation of theory.	2.0	Every Week	2.00
Lab	Lab supporting lectures.	2.0	Every Week	2.00
Independent Learning	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Presentation of theory.	2.0	Every Week	2.00
Lab	Lab supporting lectures.	2.0	Every Week	2.00
Independent Learning	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Module Resources

Recommended Book Resources

- **William Kocay, Donald L. Kreher 2016, *Graphs, Algorithms, and Optimization*, Second Edition Ed. [ISBN: 9781482251166]**
- **Art Lew, Holger Mauch 2006, *Dynamic Programming: A Computational Tool*, Springer [ISBN: 3540370137]**

Supplementary Book Resources

- **Jörg Lässig, Kristian Kersting, Katharina Morik 2016, *Computational Sustainability*, Springer [ISBN: 978-3-319-318]**

Recommended Article/Paper Resources

- **P Kilkki, U Väisänen *Determination of the optimum cutting policy for the forest stand by means of dynamic programming.***
- **A Arbelaez, D Mehta, B O'Sullivan, L Quesada *A Constraint-Based Local Search for Edge Disjoint Rooted Distance-Constrained Minimum Spanning Tree Problem.***

Other Resources

- **Website: *What artificial intelligence means for sustainability?* https://www.greenbiz.com/article/what-ar tificial-intelligence-means-sustainabili ty**
- **Website: *Artificial Intelligence for Computational Sustainability: A Lab Companion/Introduction* https://en.wikibooks.org/wiki/Artificial_Intelligence_for_Computational_Sustaina bility:_A_Lab_Companion/Introduction#The_Special_Place_of_AI_in_Computational_Su stainability**

Title:	Recommender Systems APPROVED
Long Title:	Recommender Systems
Module Code:	COMP9065
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	no programmes
Module Coordinator:	TIM HORGAN
Module Author:	Diarmuid Grimes
Module Description:	AI-based recommender systems are widely used across a broad range of domains including e-commerce, marketing, movie/music recommendations, etc. In this applied module, learners will focus on a number of case studies and will develop recommender systems for these specific problem domains. The module will demonstrate how to analyse a problem domain and subsequently design, implement and integrate into an appropriate recommender system, with a focus on collaborative, content-based filtering and hybrid recommender systems. Students will develop and evaluate their own recommender system for a real-world case study.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Assess the use of recommender systems across a range of daily life applications and the challenges in developing a fine-tuned recommender system.
LO2	Critically assess and select a recommender system for a given problem.
LO3	Design a recommender system applying either a content-based or collaborative filtering approach.
LO4	Develop and implement recommender systems using open source tools.
LO5	Evaluate the performance of different recommender systems on a sample dataset.

Pre-requisite learning
Module Recommendations *This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).*
No recommendations listed
Incompatible Modules *These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed
Requirements *This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.*
No requirements listed
Co-Requisites

Module Content & Assessment

Indicative Content
Introduction to recommender systems History of recommender systems and their usee in the e-services industry. Information search and retrieval, filtering and personalising data content. Recommender system model - items, users and transactions. Item/user categorisation and characterisation. Utility matrices.
General recommender system approaches Introduction to content-based filtering, collaborative filtering, data mining methods, context-aware methods (demographics, temporal, location, knowledge-based). Development of content-based filtering techniques. High-level architecture. Item similarity and user profiles.
Collaborative filtering General framework. User similarity. Matrix factorisation, alternating least squares, neighbourhood-based methods. Challenges associated with collaborative filtering, and possible solutions: cold-start, data sparsity, etc. Hybrid collaborative filtering and content-based filtering methods: Combining content-based and collaborative filtering in order to overcome disadvantages of both.
Tools and applications Using open source tools to build and evaluate content-based and collaborative filtering recommender systems. Application domains. Recommender systems will be built for two test cases using widely-studied datasets.
Evaluating recommender systems Data sampling techniques. Offline and online evaluation of recommendation system performance and scalability, parameter tuning and calibration. Metrics for evaluation of recommendation quality: Prediction accuracy, rank accuracy. Recommendation system properties such as diversity, robustness, serendipity. Security for recommendation systems: limiting influence of malicious users.

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	The student will design and implement a recommender system for a sample data set, and produce a report outlining the steps taken and the basis for their choice of recommender system approach.	1,2,3,4	40.0	Week 8
Project	The student will design and implement two recommender systems on a dataset. The student will produce a report comparing and contrasting the performance of the two methods in terms of both accuracy and recommender system properties.	2,3,4,5	60.0	Sem End

No End of Module Formal Examination

Reassessment Requirement

Coursework Only
This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lectures delivering theory underpinning learning outcomes.	2.0	Every Week	2.00
Lab	Practical to develop recommender system.	2.0	Every Week	2.00
Independent Learning	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lecture delivering theory underpinning learning outcomes.	2.0	Every Week	2.00
Lab	Practical to develop recommender system.	2.0	Every Week	2.00
Independent Learning	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Module Resources

Recommended Book Resources

- **Charu C. Aggarwal 2016, *Recommender Systems: The Textbook*, Springer [ISBN: 9783319296579]**

Supplementary Book Resources

- **Dietmar Jannach, Markus Zanker, Alexander Felfernig, Gerhard Friedrich 2010, *Recommender Systems: An Introduction*, Cambridge University Press [ISBN: 9780521493369]**
- **Francesco Ricci, Lior Rokach, Bracha Shapira 2015, *Recommender Systems Handbook*, 2 Ed., 28, Springer [ISBN: 9781489976376]**

This module does not have any article/paper resources

Other Resources

- **Website: *List of recommender systems***
  https://github.com/grahamjenson/list_of_recommender_systems

Title:	Natural Language Processing APPROVED
Long Title:	Natural Language Processing
Module Code:	COMP9066
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	no programmes
Module Coordinator:	TIM HORGAN
Module Author:	Ted Scully
Module Description:	Natural language processing (NLP) is a set of statistical and machine learning techniques applied to the analysis and synthesis of natural language and speech. This module will provide learners with a comprehensive introduction to the theory underpinning NLP and will also equip learners with the knowledge to implement and apply NLP algorithms and techniques to real-world problems such as sentiment analysis.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Apply and evaluate a language modelling technique such as n-grams to a natural language processing problem.
LO2	Compare and contrast the use of parsing techniques for context-free grammar problems.
LO3	Develop and evaluate a document classification model using machine learning techniques.
LO4	Implement a machine translation model for real-world data and assesses it's performance.

Pre-requisite learning
Module Recommendations *This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).*
No recommendations listed
Incompatible Modules *These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed
Requirements *This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.*
No requirements listed
Co-Requisites
No Co Requisites listed

Module Content & Assessment

Indicative Content
Language Modelling Introduction to natural language processing and language models. N-gram modelling, The Markov assumption and maximum likelihood estimation. Evaluating language models, perplexity, generalization, smoothing techniques and dealing with unknown words. Hidden Markov models and part-of-speech tagging.
Parsing for NLP Context free grammar. Syntactic parsing. Structural, attachment and coordination ambiguity. Handling structural ambiguities using the CKY algorithm. Statistical parsing, probabilistic context free grammars for disambiguation. Learning PCFG rule probabilities. Dependency Parsing. Dependency grammars and typed dependency structure.
Machine Learning Document classification using machine learning techniques such as naive bayes (mutli-nomial and bernoulli models), support vector machines, logistic regression and neural networks (embedding dense word vectors).
Machine Translation (MT) Introduction to linguistic knowledge. Rule-based MT (transfer-based MT and inter-lingual MT. Statistical MT (word and phrase-based translation). Neural MT and vector-based representations. MT evaluation metrics (WER, BLEU and TER).

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	Build a language model by applying a relevant modelling techniques. Produce a report that critically analyses the performance of the model.	1,2	35.0	Week 7
Project	Develop a document classification model for a case study project and perform a comprehensive evaluation of its performance.	3	30.0	Week 9
Project	Implement a machine translation model such as a neural model with vector-based representations. Assess the performance of model using standard techniques such as WER.	4	35.0	Week 12

No End of Module Formal Examination

Reassessment Requirement
Coursework Only *This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.*

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Delivers the concepts and theories underpinning the learning outcomes.	2.0	Every Week	2.00
Lab	Application of learning to case studies and project work.	2.0	Every Week	2.00
Independent Learning	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Delivers the concepts and theories underpinning the learning outcomes.	2.0	Every Week	2.00
Lab	Application of learning to case studies and project work.	2.0	Every Week	2.00
Independent Learning	Student undertakes independent study. Student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Module Resources

Recommended Book Resources

- **N. Hardeniya J. Perkins, D. Chopra, N. Joshi, I. Mathur 2016, *Natural Language Processing: Python and NLTK*, 1st Ed., Packt Publishing [ISBN: 9781787285101]**
- **L. Hobson. H. Cole, H. Hannes 2017, *Natural Language Processing in Action: Understanding, analyzing, and generating text with Python*, 1st Ed., Manning Publications [ISBN: 9781617294631]**

Supplementary Book Resources

- **C. Manning 1999, *Foundations of Statistical Natural Language Processing*, 4th Ed., MIT Press [ISBN: 9780262133609]**

Recommended Article/Paper Resources

- **E. Cambria, B. White 2014, *Jumping NLP Curves: A Review of Natural Language Processing Research*, IEEE Computational Intelligence Magazine, 9 http://ieeexplore.ieee.org/document/6786458/**

Supplementary Article/Paper Resources

- **J. Lafferty, A. McCallum, F. Pereira 2001, *Conditional Random Fields: Probabilistic Models for Segmenting and Labeling Sequence Data*, International Conference on Machine Learning http://repository.upenn.edu/cgi/viewcontent.cgi?article=1162&context=cis_pap ers**

This module does not have any other resources

Title:	Deep Learning APPROVED
Long Title:	Deep Learning
Module Code:	COMP9067
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	no programmes
Module Coordinator:	TIM HORGAN
Module Author:	Ted Scully
Module Description:	Deep learning techniques, which are a subfield of machine learning, has led to significant advances in challenging real-world problems such as natural language processing and image recognition. This module focuses on equipping students with both the theoretical and practical skills that will enable them to build and apply deep learning models to real-world problems.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Implement and evaluate a gradient descent-based machine learning algorithm.
LO2	Build, train and apply deep neural networks to problems such as computer vision.
LO3	Perform hyperparameter optimization, regularization and optimization for deep learning networks.
LO4	Create convolutional neural network models and apply to image datasets.
LO5	Build and train Recurrent Neural Networks (RNNs).

Pre-requisite learning
Module Recommendations *This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).*
No recommendations listed
Incompatible Modules *These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed
Requirements *This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.*
No requirements listed
Co-Requisites
No Co Requisites listed

Module Content & Assessment

Indicative Content
Regression and Gradient Descent. Introduction to linear regression and gradient descent. Multiple linear regression and metrics for evaluating regression models. Logistic regression and activation functions. Using a vectorized implementation.
Build and evaluate deep neural networks. Build and train shallow neural networks. Forward and backward propagation. Key parameters for neural networks. Create and train a fully connect deep learning model. Initialization, L2 and dropout regularization, gradient checking and batch normalization. Convergence algorithms. Best-practice for evaluating performance and analyzing for bias and variance.
Convolutional neural network. Overview of convolutional neural networks. Methodology for stacking layers in a deep network to address multi-class image classification problems. Object detection and the YOLO algorithm. Deep residual learning for image recognition.
Recurrent Neural Networks (RNNs). The basic recurrent unit (Elman unit) and LSTM (long short-term memory) unit. Overview of the GRU (gated recurrent unit). Build and train recurrent neural networks. Approaches for mitigating the vanishing gradient problem.

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	Perform a comparative analysis between a basic gradient descent-based machine learning model and a deep learning neural network applied to a dataset from a specific application domain.	1,2,3	50.0	Week 7
Project	Build and train a convolutional or recurrent neural network and apply to a dataset from a specific application domain. A comprehensive evaluation should be completed.	4,5	50.0	Week 13

No End of Module Formal Examination

Reassessment Requirement
Coursework Only *This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.*

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Delivers the concepts and theories underpinning the learning outcomes.	2.0	Every Week	2.00
Lab	Application of learning to case studies and project work.	2.0	Every Week	2.00
Independent Learning	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Delivers the concepts and theories underpinning the learning outcomes.	2.0	Every Week	2.00
Lab	Application of learning to case studies and project work.	2.0	Every Week	2.00
Independent Learning	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Module Resources

Recommended Book Resources

- **I. Goodfellow , Y. Bengio, A. Courville 2017, *Deep Learning (Adaptive Computation and Machine Learning series)*, 1st Ed., MIT Press [ISBN: 9780262035613]**

Supplementary Book Resources

- **T. Laville 2017, *Deep Learning for Beginners: Concepts, Techniques and Tools*, 1st Ed., CreateSpace Independent Publishing [ISBN: 9781979311182]**
- **F. Chollet 2017, *Deep Learning with Python*, 1st Ed., Manning Publications [ISBN: 9781617294433]**

Recommended Article/Paper Resources

- **S. Ioffe, C. Szegedy 2015, *Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift*, International Conference on Machine Learning**
- **K. He, X. Zhang, S. Ren, J. Sun 2016, *Deep Residual Learning for Image Recognition*, IEEE Conference on Computer Vision and Pattern Recognition (CVPR)**

Other Resources

- **Website: TensorFlow *https://www.tensorflow.org/***
- **Website: Theano *http://deeplearning.net/software/theano/***
- **Website: Caffee *http://caffe.berkeleyvision.org/***

Title:	Decision Analytics APPROVED
Long Title:	Decision Analytics
Module Code:	COMP9057
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	2 programme(s)
Module Coordinator:	TIM HORGAN
Module Author:	Laura Climent
Module Description:	Many real-world problems require the optimization of an objective function while satisfying underlying constraints. In this module, students will learn how to model real-world optimization problems. They will also learn to select and apply appropriate optimization algorithms, which find optimal solutions via decision making.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Assess a wide range of real-world problems, which can be solved through the application of decision analytics.
LO2	Model a variety of real-world problems, identifying their main characteristics as constraint satisfaction and optimisation problems.
LO3	Apply constraint programming algorithms to solve real-world problems.
LO4	Apply linear programming algorithms to solve real-world optimisation problems.
LO5	Evaluate an algorithm to determine its soundness and completeness for a particular optimisation problem.

Pre-requisite learning
Module Recommendations *This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).*
No recommendations listed
Incompatible Modules *These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed
Requirements *This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.*
No requirements listed
Co-Requisites
No Co Requisites listed

Module Content & Assessment

Indicative Content
Introduction Introduction to real-life optimisation problems. Overview of the application of decision analytics in order to obtain the best solution according to certain criterion/criteria such as minimising costs, maximising benefits, etc. Explanation of the features of combinatorial optimisation.
Applications to Real-life Problems Analysis and solving of combinatorial optimization problems such as vehicle routing problem, scheduling problems, cutting stock problem, bin packing problem, etc.
Modelling & Constraint Programming Modelling real-life problems as Constraint Satisfaction Problems. Explanation of Constraint Propagation techniques such as: node-consistency, arc-consistency and path-consistency. As well as the explanation of backtracking algorithms and algorithms that combine search and constraint propagation such as: Maintaining Arc Consistency (MAC). Extension of the Constraint Satisfaction Problems to Constraint Satisfaction and Optimisation Problems. Branch & Bound algorithm for identifying optimal solutions and Boolean Satisfiability.
Soundness and Completeness Explanation of the concepts of soundness and completeness by providing several examples of algorithms of each type. Explanation of the advantages and disadvantages of complete/incomplete algorithms and the more appropriate scenarios of applicability for each type.
Optimisation Basic properties of Linear Programming problems. Linear Programming formulation and solving methods. Explanation of Integer Programming and Mixed Integer Programming.

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	For a given case study, the student would be expected to model a constraint satisfaction and optimisation problem and also implement an algorithm from Constraint Programming.	1,2,3,5	50.0	Week 8
Project	For a given case study, the student would be expected to model a constraint satisfaction and optimisation problem, implement the model and solve it with Linear Programming.	1,2,4,5	50.0	Week 13

No End of Module Formal Examination

Reassessment Requirement
Coursework Only *This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.*

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Presentation of theory.	2.0	Every Week	2.00
Lab	Lab supporting lectures.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Presentation of theory.	2.0	Every Week	2.00
Lab	Lab supporting lectures.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Module Resources

Recommended Book Resources

- **Thomas H. Cormen , Charles E. Leiserson , Ronald L. Rivest , Clifford Stein 2009, *Introduction to Algorithms*, MIT Press [ISBN: 9780262533058]**

Supplementary Book Resources

- **Francesca Rossi 2006, *Handbook of Constraint Programming (Foundations of Artificial Intelligence)*, Elsevier Science [ISBN: 9780444527264]**
- **Frederick S. Hillier 2014, *Introduction to Operations Research*, McGraw-Hill Education [ISBN: 9781259253188]**

Recommended Article/Paper Resources

- **Du, Ding-Zhu, and Panos M. Pardalos, eds. 2013, *Handbook of combinatorial optimisation: supplement*, Springer Science & Business Media, Vol. 1.**

Supplementary Article/Paper Resources

- **Laura Climent, Richard J. Wallace, Miguel A. Salido, Federico Barber 2014, *Robustness and Stability in Constraint Programming under Dynamism and Uncertainty*, Journal of Artificial Intelligence Research, 49, 49-78**
  https://www.jair.org/media/4126/live-4126-7626-jair.pdf

Other Resources

- **Website: *Global Optimization Test Problems***
  http://www.mat.univie.ac.at/~neum/glopt/ test.html
- **Website: *Discrete Optimization Coursera***
  https://www.coursera.org/learn/discrete- optimization
- **Website: *IBM ILOG CPLEX Optimization Studio***
  https://www.ibm.com/jm-en/marketplace/ib m-ilog-cplex

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Cork Institute of Technology

COMP9068: AI Research Project
(Semester:2 Mandatory)

Title:	AI Research Project APPROVED
Long Title:	AI Research Project
Module Code:	COMP9068
Credits:	15
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	no programmes
Module Coordinator:	TIM HORGAN
Module Author:	Donna OShea
Module Description:	In this module the learner is expected to undertake independent study. As part of this self-directed learning the student will employ various research methods and will develop and implement their proposed and approved project applied to the field of Artificial Intelligence (AI). The student will be expected to disseminate the research work and research outcomes through an oral presentation, poster presentation and submission of a dissertation.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Plan and implement self directed learning to further knowledge and understanding of an unfamiliar and/or ill defined problem applied to the field of Artificial Intelligence (AI).
LO2	Establish a contribution to the development of knowledge in the specific discipline.
LO3	Apply appropriate written and oral communication skills and synthesise the research work in the form of presentation, abstracts, executive summaries, technical papers and a dissertation.
LO4	Prepare a dissertation that details and evaluates the work undertaken and justifies the conclusions reached.

Pre-requisite learning

Module Recommendations
This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).

13405	COMP9011	Research Practice & Ethics

Incompatible Modules
These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.

No incompatible modules listed

Co-requisite Modules

No Co-requisite modules listed

Requirements
This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.

No requirements listed

Co-Requisites

No Co Requisites listed

Module Content & Assessment

Indicative Content
Content A mandatory requirement of the programme is the development of a research project in an area that complements the student's continuing professional development. Prior to taking this module, the student will have selected their research question which will be further developed, investigated and implemented as part this module. Considerable latitude, will be given to the student in the choice of subject material and medium for the project, thereby allowing assessment of selectivity and creativity. The project is used to assess: the learner's initiative; ability to learn autonomously and to conduct research; range of know-how and skill; the judgement exercised by the learner in approaching the brief; level of analysis and synthesis leading to conclusions. Creative competences and the ability to organise material are tested in the oral presentation and report.
General Supervised self directed learning that addresses the learning outcomes, draws on the overall curriculum content and critically evaluates a specific research problem.
Oral and poster presentation Disseminate the research work and outcomes and communicate effectively, through oral and poster presentations. This will include an in-depth question and answer session.
Dissertation Present a dissertation which communicates and disseminates the research work undertaken and the research outcomes developed. The dissertation should include the analysis undertaken, results of the work and how this work contributes to furthering knowledge in the specific field of research. The learner must demonstrate a deep and fundamental understanding of the specific research problem addressed.

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Written Report	Submit a mid term report and present their work summarising the workplan with the aim of demonstrating project progress and deliverables achieved and intended scientific contribution to the field of study (attendance at interview may be required).	1,2,3	20.0	Week 6
Written Report	Dissertation submission outlining the topic, research question and methodology, project, findings and plan. The student will also be expected to demonstrate their project through a presentation and/or demonstration.	1,2,3,4	80.0	Sem End

No End of Module Formal Examination

Reassessment Requirement
Coursework Only *This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.*

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecturer-Supervised Learning (Contact)	Weekly meeting with project supervisor.	0.5	Every Week	0.50
Tutorial	Research Project - Class Workshop.	0.5	Every Week	0.50
Independent & Directed Learning (Non-contact)	Project work and independent learning.	20.0	Every Week	20.00
			Total Hours	21.00
			Total Weekly Learner Workload	21.00
			Total Weekly Contact Hours	1.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecturer-Supervised Learning (Contact)	Weekly meeting with project supervisor.	0.5	Every Week	0.50
Tutorial	Research Project - Class Workshop.	0.5	Every Week	0.50
Independent & Directed Learning (Non-contact)	Project work and independent learning	20.0	Every Week	20.00
			Total Hours	21.00
			Total Weekly Learner Workload	21.00
			Total Weekly Contact Hours	1.00

Module Resources

Recommended Book Resources

- **Martyn Denscombe 2010, *The Good Research Guide*, 4 Ed., Open University Press [ISBN: 978-0335241385]**
- **J.A. Sharp, K. Howard 2002, *The Management of a Student Research Project*, 3 Ed., Gower Publishing [ISBN: 0-566-08490-2]**
- **W. Strunk Jr., E. White, R. Angell 2000, *The Elements of Style*, 4 Ed., Pearson Higher Education [ISBN: 0-205-30902-X]**

Supplementary Book Resources

- **Robert K. Yin (Editor) 2013, *Case Study Research: Design and Methods*, 5th Ed., Sage Publications**
- **Turabian, K. 2013, *manual for writers of research papers, theses, and dissertations: Chicago style for students and researchers*, University of Chicago Press**
- **Levin, P. 2011, *Excellent Dissertations, Student Friendly Guides*, Open University Press [ISBN: 0335238610]**
- **Dennis Lock 2007, *Project management*, Gower Aldershot [ISBN: 978-0566087721]**
- **J. Henry 2003, *Software Project Management: A Real-World Guide to Success*, Addison-Wesley [ISBN: 0-201-75865-2]**

Recommended Article/Paper Resources

- **Halpern, J. W. 1998, *Getting in deep: Using qualitative research in business and technical communication*, 2(2)**
- **Rude, C. D. *Mapping the Research Questions in Technical Communication*, Journal of Business and Technical Communication, Jan 2009**

Other Resources

- **Website: *Developing a Thesis***
  http://writingcenter.fas.harvard.edu/pag es/developing-thesis

Institiúid Teicneolaíochta Chorcaí
Cork Institute of Technology

COMP9069: Robotics & Autonomous Systems
(Semester:2 Elective)

Title:	Robotics & Autonomous Systems APPROVED
Long Title:	Robotics & Autonomous Systems
Module Code:	COMP9069
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	no programmes
Module Coordinator:	TIM HORGAN
Module Author:	Sean McSweeney
Module Description:	The application of reinforcement learning to robotics and autonomous systems has the potential to transform many industries such as manufacturing, construction and logistics. Traditional robotics design requires highly controlled more-or-less stationary environments for correct operation, the integration of reinforcement learning into robotic systems is allowing robots to overcome this constraint and thus operate in unconstrained environments. Reinforcement learning in these systems results in robots that can modify behaviour with changing environmental conditions, continuously improve operation and adapt to system failures. This module will focus on the application of reinforcement learning to both articulated systems (e.g. robotic arms and walking robots) and autonomous systems (e.g. quad-copters and rovers).

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Develop and simulate models for articulated and autonomous robotic systems.
LO2	Evaluate the applicability of reinforcement learning in robotics.
LO3	Adapt reinforcement learning algorithms to robotic motion control and autonomous applications.
LO4	Appraise the application of deep reinforcement learning to robotic systems.

Pre-requisite learning
Module Recommendations *This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).*
No recommendations listed
Incompatible Modules *These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed
Requirements *This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.*
No requirements listed
Co-Requisites

Module Content & Assessment

Indicative Content
Modelling and Simulating Robots and Autonomous Systems Spatial descriptions and transformations, forward kinematics, inverse kinematics, jacobian matrices, modelling non-rigid robots, autonomous system kinematics. Uncertainty in robotic models. Simulation and programming tools and environments such as V-REP, ROS, Gazebo.
Reinforcement Learning Elements of RL, Finite Markov Decision Processes, Policies and Value Functions, Partially Observable MDPs, Inverse Reinforcement Learning, Bellman Equations, Optimal Value Functions, Model Based vs Model Free Algorithms, Dynamic Programming, Monte Carlo Methods, Temporal-Difference Prediction and Q Learning.
Reinforcement Learning in Robotic Systems Searching for parametric motor primitives, adapting parametric motor primitives to changing conditions, control prioritisation for motor primitives. Autonomous systems map building, localisation, path planning, obstacle avoidance and navigation in dynamic environments.
Deep Reinforcement Learning in Robotics Radial Basis Function Artificial Neural Networks, Policy Gradient, TD Lambda, and Deep Q-Learning applications in robotic systems. Usage of OpenAI Gym, Tensorflow.

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	Project developing a simulation model of an articulated or autonomous robotic system and evaluating of the fidelity of the model developed.	1,2	40.0	Week 7
Project	Project applying reinforcement learning to robotic or autonomous system, iterating and evaluating the methodology applied to environmental and system changes.	3,4	60.0	Sem End

No End of Module Formal Examination

Reassessment Requirement
Coursework Only *This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.*

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lecture delivering theory underpinning learning outcomes.	2.0	Every Week	2.00
Lab	Practical computer-based lab supporting learning outcomes.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Independent & directed learning	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Lecture delivering theory underpinning learning outcomes.	2.0	Every Week	2.00
Lab	Practical computer-based lab supporting learning outcomes.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Independent & directed learning	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Module Resources

Recommended Book Resources

- **Sutton, Richard S and Barto, Andrew G 1998, *Reinforcement learning: An introduction*, MIT press Cambridge [ISBN: 9780262193986]**

Supplementary Book Resources

- **Jens Kober and Jan Peters 2014, *Learning Motor Skills From Algorithms to Robot Experiments*, Springer International Publishing [ISBN: 9783319031941]**
- **Todd Hester 2013, *TEXPLORE: Temporal Difference Reinforcement Learning for Robots and Time-Constrained Domains*, Springer International Publishing [ISBN: 9783319011677]**

Recommended Article/Paper Resources

- **Kober, Jens and Bagnell, J Andrew and Peters, Jan 2013, *Reinforcement learning in robotics: A survey*, The International Journal of Robotics Research, 32, no 11, pp 1238-1274**
- **Cully, Antoine and Clune, Jeff and Tarapore, Danesh and Mouret, Jean-Baptiste 2015, *Robots that can adapt like animals*, Nature Research, 521, pp 503-507**
- **Ijspeert, Auke Jan 2008, *Central pattern generators for locomotion control in animals and robots: a review*, Elsevier Journal on Neural networks, Vol 21, No 4, pp 642-653**

Supplementary Article/Paper Resources

- **Chatzilygeroudis, Konstantinos and Rama, Roberto and Kaushik, Rituraj and Goepp, Dorian and Vassiliades, Vassilis and Mouret, Jean-Baptiste 2017, *Black-Box Data-efficient Policy Search for Robotics*, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)**
- **Cutler, Mark and How, Jonathan P 2015, *Efficient reinforcement learning for robots using informative simulated priors*, IEEE International Conference on Robotics and Automation (ICRA), pp 2605-2612**
- **Abbeel, Pieter and Coates, Adam and Quigley, Morgan and Ng, Andrew Y 2007, *An application of reinforcement learning to aerobatic helicopter flight*, Advances in neural information processing systems, pp 1-8**

Other Resources

- **Website: 2017*Curated List of Reinforcement Learning Applications in Robotics* https://github.com/Phylliade/awesome-mac hine-learning-robotics**
- **Website: 2017*Curated List of Reinforcement Learning Resources* https://github.com/aikorea/awesome-rl#bo oks**
- **Website: 2017*Curated list of open source robotics simulators and libraries.* https://github.com/jslee02/awesome-robot ics-libraries**

Title:	Planning & Scheduling APPROVED
Long Title:	Planning & Scheduling
Module Code:	COMP9070
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	no programmes
Module Coordinator:	TIM HORGAN
Module Author:	Alejandro Arbelaez
Module Description:	Planning and scheduling are emerging areas derived from Artificial intelligence with important applications areas ranging from process planning and space mission control to scheduling work rosters for aircraft crews. In this module, the learner will be introduced to the theory of planning and scheduling and the challenges behind co-operative approaches applied to the field. Furthermore, this module will explore current state-of-the-art techniques to solve complex planning and scheduling problems.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Assess the benefits and limitations of complete and incomplete heuristics to solve planning and scheduling problems.
LO2	Categorize planning and scheduling problems with respect to their computational complexity.
LO3	Design and implement a solution to a real-world planning problem.
LO4	Analyse the performance of planning and scheduling heuristics to solve real world problems.
LO5	Design and implement a planning and scheduling solution that can deal with incomplete or uncertain information and operate in dynamic environments.

Pre-requisite learning
Module Recommendations *This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).*
No recommendations listed
Incompatible Modules *These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed
Requirements *This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.*
No requirements listed
Co-Requisites
No Co Requisites listed

Module Content & Assessment

Indicative Content
Introduction Introduction and overview of complex real-world problems that are solvable using planning and scheduling techniques. Problems such as school timetabling, staff allocation, airline scheduling etc.
Classical planning Formalisation of planning problems and logic-based representations for discrete planning, i.e., set representation and first-order logic
Planning algorithms Mainstream classical planning algorithms such as: Forward State-Space Search, Breadth-First Search, Uniform-Cost Search, A*. Encoding the planning problem into a set of SAT (Boolean Satisfiability) and CSP (Constraint Satisfaction Problems) problems
Scheduling problems Classical scheduling problems such as: single and multiple machine scheduling (identical Vs. different), the job-shop problem, flow Shops, and open Shops, staff allocation, school timetabling, airline scheduling, etc
Scheduling algorithms Exact or complete algorithms to find optimal solutions, e.g., mixed integer programming, constraint programming, and dynamic programming for scheduling; Incomplete heuristic algorithms to find near-optimal solutions, e.g., First-come first-served (FIFS), first-in first-out (FIFO), Shortest Job First (SJF), Round Robin (RR) scheduling, etc
Planning and scheduling with uncertainty Predictive-reactive scheduling to repair solutions after an unexpected event; proactive-reactive robust planning & scheduling that incorporate a degree of disruption or unexpected events

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	In this project the students will be given an planning problem and the students will have to implement heuristic solution to tackle the problem.	1,2,3	40.0	Week 6
Project	In this project the students will be given an scheduling problem with and without uncertainty and the students will have to implement heuristic solution to tackle the problem and critically evaluate the performance of their solution	1,2,3,4,5	60.0	Sem End

No End of Module Formal Examination

Reassessment Requirement
Coursework Only *This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.*

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Presentation of theory	2.0	Every Week	2.00
Lab	Lab supporting lectures	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Presentation of theory	2.0	Every Week	2.00
Lab	Lab supporting lectures	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Module Resources

Recommended Book Resources

- **Michael L. Pinedo 2016, *Scheduling: Theory, Algorithms, and Systems*, 5 Ed., Springer [ISBN: 3319265784]**
- **Stuart Russell and Peter Norvig 2016, *Artificial Intelligence: A Modern Approach*, 3 Ed., 10, 11, Prentice Hall [ISBN: 1292153962]**

Supplementary Book Resources

- **Malik Ghallab, Dana Nau and Paolo Traverso 2004, *Automated Planning and Acting*, Cambridge University [ISBN: 9781107037274]**
- **Jussi Rintanen/Armin Biere, Marijn Heule, Hans van Maaren, Toby Walsh 20, *Handbook of Satisfiability*, 15, IOS Press 2009 [ISBN: 978-1-58603-9]**
- **Philippe Baptiste, Philippe Laborie, Claude Le Pape, Wim Nuijten/Francesca Rossi Peter van Beek Toby Walsh 2006, *Handbook of Constraint Programming*, 1 Ed., 22, Elsevier Science [ISBN: 9780444527264]**

Supplementary Article/Paper Resources

- **Laura Climent, Richard J. Wallace, Miguel A. Salido, Federico Barber 2014, *Robustness and Stability in Constraint Programming under Dynamism and Uncertainty*, Journal of Artificial Intelligence Research, 49, 49--7**
  https://doi.org/10.1613/jair.4126

Other Resources

- **Website: *Planning & Scheduling (Charles University)***
  https://ktiml.mff.cuni.cz/~bartak/planov ani/index.html
- **Website: *AI Planning, Execution, and Learning (Carnegie Mellon University)***
  http://www.cs.cmu.edu/~reids/planning/
- **Website: *Planning and Scheduling Methodologies (University of Porto)***
  https://paginas.fe.up.pt/~lpreis/mpe0910 /

Title:	Fraud and Anomaly Detection APPROVED
Long Title:	Fraud and Anomaly Detection
Module Code:	COMP9071
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2018/19 (September 2018)
Module Delivered In	no programmes
Module Coordinator:	TIM HORGAN
Module Author:	Samane Abdi
Module Description:	Anomaly detection is the process of identifying unusual patterns of events, observations, or a set of data which do not conform to an expected normal behaviour. This module will provide learners with a comprehensive introduction to the theory underpinning anomaly detection and will also equip learners with the knowledge to effectively apply a range of anomaly detection techniques (such as clustering and rule-based algorithms) to real-world problems such as fraud detection.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Apply statistical algorithms to anomaly detection for a specific application domain.
LO2	Compare the performance of a range of classification-based machine learning algorithms to anomaly detection problems.
LO3	Implement a clustering based anomaly detection.
LO4	Develop an online model for anomaly detection over big-data streams.

Pre-requisite learning
Module Recommendations *This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).*
No recommendations listed
Incompatible Modules *These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed
Requirements *This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.*
No requirements listed
Co-Requisites
No Co Requisites listed

Module Content & Assessment

Indicative Content
Statistical Techniques Overview and application of a range of parametric and non-parametric statistical techniques for anomaly detection such as change point detection, Gaussian mixture models and hidden Markov models.
Classification Models Anomaly detection using a range of relevant machine learning classification techniques such as neural networks, SVMs, rule-based algorithms, ensembles techniques, distance-based and density-based algorithms.
Unsupervised Model and Evaluation Application of unsupervised models to anomaly detection problems such as LOF, COF, LOCI and CBLOF. The role of dimensionality reduction techniques such as PCA and feature selection. Best practice evaluation techniques such as F1 scores and ROC curves.
Anomaly Detection at Scale Implement and deploy a model for real-time anomaly detection in a big data environment using Spark Streaming and MLlib for an application domain.

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	Perform a comparative analysis of a range of statistical techniques versus classification models to detect anomalies. Standard methodologies should be applied and the performance should be comprehensively evaluated.	1,2	50.0	Week 7
Project	By employing appropriate research methods, the student is expected to apply the unsupervised techniques to Implement and deploy a model for real-time anomaly detection in a big data environment.	3,4	50.0	Week 13

No End of Module Formal Examination

Reassessment Requirement
Coursework Only *This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.*

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Delivers the concepts and theories underpinning the learning outcomes.	2.0	Every Week	2.00
Lab	Application of learning to case studies and project work.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Workload: Part Time				
WorkLoad Type	*WorkLoad Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Delivers the concepts and theories underpinning the learning outcomes.	2.0	Every Week	2.00
Lab	Application of learning to case studies and project work.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Student undertakes independent study. The student reads recommended papers and practices implementation.	3.0	Every Week	3.00
			Total Hours	7.00
			Total Weekly Learner Workload	7.00
			Total Weekly Contact Hours	4.00

Module Resources

Recommended Book Resources

- **Sumeet Dua, Xian Du 2011, *Data Mining and Machine Learning in Cybersecurity*, Auerbach Publications [ISBN: 978-143983942]**

Supplementary Book Resources

- **Ted Dunning, Ellen Friedman 2013, *Practical Machine Learning: A New Look at Anomaly Detection*, 1 Ed., O'Reilly Media [ISBN: 978-149191160]**

Recommended Article/Paper Resources

- **ACM Digital Library 2009, *Anomaly detection: A survey*, ACM Computing Surveys (CSUR)**

Other Resources

- **Website: *Anomaly Detection***
  https://www.statistics.com/anomaly-detec tion/
- **Website: *Machine Learning***
  https://www.coursera.org/learn/machine-l earning