Syllabus

Optimisation CT5141

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About this document

This is the syllabus document. It gives details such as learning outcomes, timetable, and assessment, and discusses our use of the Blackboard virtual learning environment.

If details mentioned here change, I will post a new version under Blackboard - Information, and an announcement to let you know.

CT5141 Optimisation

This module is an option on the MSc Artificial Intelligence. It runs in Semester 1.

Description. This module covers optimisation – "the science of better". Optimisation is used in a huge variety of applications, including: finding time-saving transport routes; scheduling exams without conflicts; reducing weight and cost in engineering design; designing portfolios of financial investments; finding numerical data models with low expected error; and many more. In this module we will aim to understanding a broad range of applications and a unifying view of the field, and concentrate on two main types of methods: (1) heuristic and metaheuristic optimisation and (2) exact methods for constrained optimisation. In this module we will not cover gradient descent and related methods, as they are covered in machine learning modules available on the MScAI. We will spend time in-class on practical implementations, writing our own optimisation programs from scratch and also using state-of-the-art libraries.

Prerequisites

- Strong programming ability
- Ability to learn Python quickly in parallel, including Numpy and Matplotlib
- Command-line usage
- Good intuition for maths including probability, discrete maths, linear algebra, calculus, statistics

Learning outcomes:

- LO1 – Design and implement a variety of exact, heuristic and metaheuristic algorithms applicable to a variety of domains
- LO2 – Understand objective functions, local/global optima and objective function landscapes
- LO3 – Understand Pareto efficiency, frontiers and dominance
- LO4 – Gain practical knowledge of multiple approaches to optimisation
- LO5 - Explain how to choose one type of algorithm (e.g. exact methods, heuristic methods, multi-objective) and one representation over another for a given problem
- LO6 – Implement customised problem-specific algorithms

Sections

- Introduction Week 1
- Constrained linear optimisation Weeks 2-4
- Black-box optimisation Weeks 5-9
- Constructive heuristics Week 10
- Gradient-based optimisation Week 11
- Summary Week 12

Week-by-week topics (subject to change)

1. Introduction.
2. Linear Programming.
3. Integer programming.
4. Sensitivity analysis.
5. Hill climbing and objective landscapes.
6. Genetic algorithms.
7. Real-valued optimisation: particle swarm and CMA-ES.
8. Combinatorial optimisation.
9. Multi-objective optimisation.
10. Constructive heuristics and hybrids.
11. Gradient-based optimisation.
12. Summary.

A note on gradient descent

Many applications of optimisation arise in machine learning. Often, a numerical objective is formulated as a sum of losses on a dataset, and a gradient can be derived. We will mention gradient descent, but avoid the main ML applications because they are studied in another module.

Concepts

- Representations: vectors of binary, integer, real; permutations, trees, graphs
- Search spaces and landscapes: size, neighbourhoods, local optima, statistics
- Problem structure: linearity, constraints
- Restarts, parallel search, and information transfer
- Pareto efficiency
- Decision-making
- How to choose the right algorithm for a problem

Software

- Excel Solver
- Python
- Google OR-Tools
- CMA-ES
- DEAP

Textbook

Re black-box optimisation (this is available for free (legally) online):

- Sean Luke, *Essentials of Metaheuristics*

Re linear programming:

- Beasley OR-notes
  http://people.brunel.ac.uk/~mastjjb/jeb/or/contents.html

Assessment

- 70% Exam.
- 30% Continuous assessment (details to be confirmed).

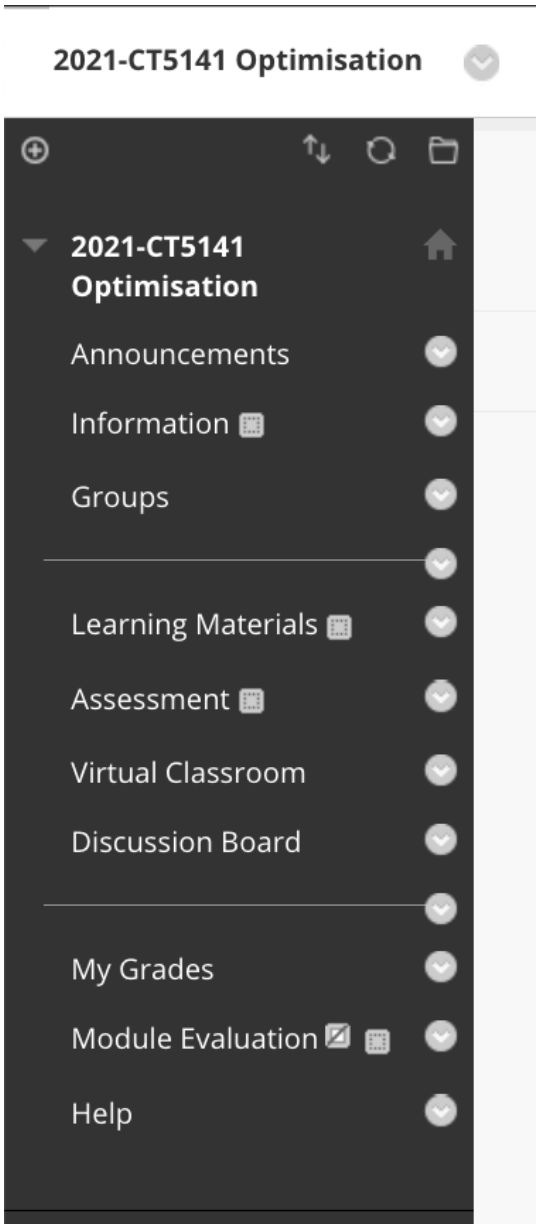
Quizzes

The videos will sometimes contain quizzes. These are just to help you monitor your own understanding and attention while watching. They are not graded.

Ground Rules

- Participation is encouraged. Please tell me when you don't understand something or think I've made a mistake.
- Participation is also the best way to ensure I know who you are when it comes to (e.g.) writing references
- Plagiarism - don't.

Blackboard (aka Bb)



Blackboard (Bb) is our virtual learning environment. The main menu on the left is divided into sections. The most important at the start is the Learning Materials section.
Assignment specs and submissions will be under Assessment. (I'll post an Announcement.)
The Virtual Classroom will be used for the Wednesday online labs and for office hours.

Bb Discussion Board

We will use the Blackboard discussion board for asynchronous, text discussion. If you are thinking of sending email to ask about materials or admin, please post in the discussion board instead! (Unless it is in any way sensitive or personal.) I will receive an email notification.

Trust me, this helps everyone!

You should consider clicking subscribe on the discussion board.

Timetable

MSc in Computer Science (Artificial Intelligence)

1MAI1 Timetable 2022/2023 Year 1, Semester I

Time/Day	Monday	Tuesday	Wednesday	Thursday	Friday
9:00 am	CT5166 Knowledge Graphs Lab: IT102 (J McCrae)	CT5142 AI and Ethics: IT207 (lecturer tbc)	CT561 Systems Modelling & Simulation Lab: IT106 (J Duggan)		
10:00 am	CT5166 Knowledge Graphs Lab: IT102 (J McCrae)	CT5142 AI and Ethics: IT207 (lecturer tbc)	CT5141 Optimisation Lab: IT101 (J McDermott)	CT4100 Information Retrieval: IT125G (C O'Riordan)	CT5141 Optimisation: AC214 (J McDermott)
11:00 am	CT5105 Tools & Techniques for Large Scale Data Analytics: AC214 (M Nickles)			CT4100 Information Retrieval: Dillon Theatre (C O'Riordan)	CT5141 Optimisation Lab: AC214 (J McDermott)
12:00 pm	CT5105 Tools & Techniques for Large Scale Data Analytics: AC214 (M Nickles)				CT5120 Intro to Natural Lang. Processing Lab: IT101 (P Buitelaar/J McCrae)
1:00 pm					CT5120 Intro to Natural Lang. Processing Lab: IT101 (P Buitelaar/J McCrae)
2:00 pm		CT561 Systems Modelling & Simulation: IT125G (J Duggan)		CT5132 Program. & Tools for AI: IT207 (J McDermott)	
3:00 pm	EE445 Digital Signal Processing: ENG 2002	CT561 Systems Modelling & Simulation: IT125G (J Duggan)		CT5132 Program. & Tools for AI: IT207 (J McDermott)	CT5105 Tools & Techniques for Large Scale Data Analytics Lab: IT102 (M Nickles)
4:00 pm	EE445 Digital Signal Processing: ENG 2002		CT5120 Intro to Natural Lang. Processing: Joseph Larmor Theatre (P Buitelaar/J McCrae)	CT5165 Principles of Machine Learning: Charles McMunn Theatre (I Ullah)	CT5105 Tools & Techniques for Large Scale Data Analytics Lab: IT102 (M Nickles)
5:00 pm			CT5120 Intro to Natural Lang. Processing: Joseph Larmor Theatre (P Buitelaar/J McCrae)	CT5165 Principles of Machine Learning: Charles McMunn Theatre (I Ullah)	CT5166 Knowledge Graphs: IT204 (J McCrae)
6:00 pm					CT5166 Knowledge Graphs: IT204 (J McCrae)

Please note that labs will commence when advised by lecturers.

http://www.cs.nuigalway.ie/timetables/

Tuesday 23 August 2022

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Timetable

- Lecture & Lab: Friday 10-12 Room AC214.

The lecture is a "traditional" lecture class (not flipped): you don't have to prepare. You have to pay strong attention and ask intelligent questions in class. Slides will be provided after each class.

The lab is for work on exercises and assignments. It will run approximately every second week. Exercises and solutions will be provided in advance.

Before the Week 1 class, you should read the Syllabus document (which you have now done).