NATCOR 2024

A National Taught Course Centre in Operational Research

Heuristic Optimisation and Learning

University of Nottingham

08 – 12 April 2024

School of Computer Science, Jubilee Campus

Course Description and Information

1. Contacts

The 5-day NATCOR course on *Heuristic Optimisation and Learning* will be delivered in-person. This is a residential course to take place in the **Jubilee Campus** at the University of Nottingham: www.nottingham.ac.uk/about/campuses/jubileecampus.aspx

The course is mostly delivered by members of the **COL Lab** (www.nottingham.ac.uk/research/groups/col/) in the School of Computer Science with the occasional contribution of some guest lecturers.

Course lead:

> **Dario Landa-Silva** dario.landasilva@nottingham.ac.uk
>
> Please feel free to contact the course lead for questions related to this specific NATCOR course.

Team of Instructors:

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2. Course Outline

Purpose

The Nottingham NATCOR course covers the main techniques for heuristic optimisation algorithms (local search, meta-heuristics, multi-objective heuristics, hyper-heuristics, evolutionary algorithms) as well as an insight into complexity theory, automated configuration of heuristics, automated algorithm design, big data science and machine learning in the context of heuristic optimisation. The course is delivered by experts in the field with strong publication records and experience in the design and deployment of these methods on real-world problems in various business and industry scenarios.

Description

Heuristic Optimisation and Learning are cornerstone methodologies from the disciplines of Operational Research and Computer Science. These methods have been very successful in providing solutions to real-world problems across a wide range of application areas. Heuristic algorithms include a range of techniques from simple 'rules of thumb' to more sophisticated methods inspired on physical and natural processes like

energy flow, evolution, and swarm intelligence. Heuristics can provide good-quality solutions (although not necessarily optimal) in practical computational time to otherwise intractable problems. Heuristics can be applied and tailored to a wide range of optimisation problems. Heuristic algorithms can also be combined with exact optimisation algorithms to form a rich variety of hybrid methodologies capable of performing with high effectiveness and efficiency when tackling complex problems. Big data usually refers to data that has large volume, variety, and complexity so that specialised modern techniques are required to analyse it and extract valuable knowledge from it. With the widespread availability of big data in many research problems and real-world applications, learning from it presents more challenges than traditional data science. There are many facets of big data science including acquisition, storage, computing infrastructure, visualisation, security, privacy, analysis, mining, machine learning etc. There are exciting interactions between big data science, machine learning and optimisation, and one of these is learning from evolutionary algorithms which is one of the topics covered in this course.

The course is suitable for participants from a wide range of backgrounds, from those that are new to optimisation to those that already have knowledge in some of the main topics (optimisation, heuristics, evolutionary computation, big data science, machine learning) but want to learn about the other topics and their interactions. The course is also effective to provide a full picture of heuristic optimisation and its interactions to big data science and machine learning.

In terms of techniques, the course covers a good number of them, giving a comprehensive view of heuristic optimisation and learning. The course starts with a gentle introduction to the fundamentals of optimisation and complexity theory. It then moves to cover key concepts and design principles of constructive and local search heuristics. Then, the course studies some metaheuristic techniques and evolutionary algorithms focusing on the main mechanisms from the single and multi-objective perspectives. This is followed by sessions on hyper-heuristic techniques, their origins, classification, and insights into variants of these methods. The automated configuration of heuristics and automated design of algorithms are also covered. The course also includes sessions on big data science and machine learning as well as some of the links to optimisation with evolutionary algorithms.

In terms of practice, the course describes the application of some of the optimisation and learning techniques covered in the course and others, to tackle real-world problems in areas like air transportation, airport operations, vehicle and personnel operational logistics, energy consumption prediction and others. Practical work with some of the techniques covered is also a feature of the course. Participants are organised in teams to work of various practical tasks where optimisation and learning are applied following the concepts and techniques covered in the course. There are plenty of opportunities for course participants to network and discuss interests and ideas.

Delivery Method

This residential course is planned to be delivered in-person. However, online tools like Microsoft Teams will also be used to enrich the learning experience and communication for course participants. Some course materials will be made available for downloading during the course.

The course will be delivered using a mix of lectures, discussions, and practical work. For some parts of the course, participants will be asked to undertake some tasks individually or in groups and use some freely available or trial software. Emphasis will be put on making the course a rich experience where theory and practical work are blended. In addition to the instructors, there will be teaching assistants to help with managing the course and its logistics.

Pre-requisites

Basics of complexity and optimisation theory as well as computer algorithms and data structures. Some reading material is provided to students a couple of weeks in advance to the start of the course.

Aim

On completion of the course, students should have a working knowledge of the theory, design, implementation, configuration, and application of the main heuristic methods, as well as an insight into their interplay with data science and machine learning in the context of optimisation scenarios.

Learning Outcomes

Understanding of the fundamental theory underlying the main heuristic optimisation methods (e.g. local search, metaheuristics, hyper-heuristics, evolutionary algorithms, etc.). Awareness of the strengths and limitations of different heuristic optimisation methods. Ability to critically evaluate the applicability and quality of different heuristic optimisation methods. Understanding the fundamentals of automated algorithm design in the continuous and discrete spaces. Capability for designing and developing heuristic methods for some optimisation problems. Awareness of some software tools for the rapid prototyping of heuristic optimisation methods. Understanding the fundamentals of data science and machine learning in the context of heuristic optimisation. Awareness of the key concepts in the application of some optimisation techniques to real-world airport and air transportation operations.

Assessment

A few formative assessments throughout the course in the form of quizzes and practical exercises, in addition to a simple summative test at the end of the course.

The summative test at the end of the course is in the format of multiple-choice questions spanning the various topics covered in the course. Undertaking this assessment is a requisite given the mechanism by which the delivery of the course is funded. However, it is emphasised that the degree of difficulty of this summative assessment in moderate. Engaging with the sessions and activities of the course should be sufficient to be able to do well in this assessment.

Previous Runs of the Course

The Nottingham NATCOR course has been delivered every two years since 2010. Each time as a residential course, except in 2020 when it was delivered online using Microsoft Teams due to the covid-19 pandemic. In past runs of the course, the number of participants has been between 50 and 90 and from several countries around the world. The course has attracted participants from diverse academic backgrounds including mathematics, business, computer science, industrial engineering, economics, statistics, operations management, management science, transportation logistics, psychology, etc.

Some comments from previous participants in the course include the following:

"I appreciate the overview of different techniques given in a very organised manner."

"Well organised and loved the real-life applications and case studies addressed; these were my favourite."

"The lectures included a lot of interesting topics and case examples. Lecturers were very experienced and keen to respond our questions."

"The environment between attendees was really good and allowed an understanding of the wide applicability of these methods."

"I have really enjoyed the course. It made me feel a lot more confidence concerning the approach to my research work."

"Overall thoroughly enjoyed, very interesting; most enjoyed the case studies and looking at the research that the lecturers have performed using what we are learning."

"Exceptional organization, sufficient related courses, high level professors and lecturers, valuable, amazing and interesting experience, nice to meet new people and exchange ideas."

"Well-organised in a logical way to connect all the 'knowledge dots' I had before into a clearer picture."

"I really liked the course. It was very well organized and overall, very interesting. I liked how we were going deeper into the topics throughout the week, and mainly how the topics were so connected to the research of the lecturers."

Why to Join the NATCOR Course "Heuristic Optimisation and Learning" at Nottingham?

Since the first edition in 2010, the Nottingham NATCOR course has been delivered every two years with great success. The course has continuously evolved to offer a mix of fundamental knowledge, implementation practice, latest research, and real-world case studies on heuristic optimisation. Each year, the cohort of participants in the course has been a diverse and rich mix of different backgrounds in science, engineering, business, and industry. Participants have been very satisfied overall with the course organisation, topics covered, coherence of the content, practical exercises, and friendly atmosphere that we strive to generate among all course participants and instructors. See some of the comments by previous students in the course here: https://www.natcor.ac.uk/courses/

As part of the course being continuously evolving, big data science and machine learning are now part of the course since 2018. Moreover, following from feedback by previous participants, for this edition in 2024 there is more time allocated to practical sessions throughout the whole week. This will allow participants to dedicate more time to deeper understanding, discussions and working with their peers on implementing some of the techniques covered in the course.

The topics to be covered in "Heuristic Optimisation and Learning" 2024 at Nottingham include:

Introduction to Optimisation
Complexity Theory
Design of Heuristic Algorithms
Hyper-heuristics
Automated Configuration of Optimisation Algorithms
Automated Algorithm Design
Big Data and Machine Learning
Big Data Learning with Evolutionary Algorithms
Optimisation for Air Operations and Air Transportation Problems

Feel free to contact the course lead, Dario Landa-Silva (dario.landasilva at nottingham.ac.uk), should you have any question about this course.

3. Course Timetable

Monday 8th April

12:00 – 13:00	**Registration and Welcome Lunch**
	The Exchange Building
13:00 – 13:30	**Welcome and Introduction**
	Dario Landa-Silva
13:30 – 15:30	**Introduction to Optimisation**
	Jason Atkin
15:30 – 16:00	**Tea/Coffee Break**
	Opportunity for Networking
16:00 – 17:00	**Complexity Theory Part 1**
	Andrew Parkes
17:00 – 17:30	**Practical Challenges**
	Daniel Karapetyan
19:00 – 21:00	**Social Activity**

Tuesday 9th April

09:00 – 10:30	**Complexity Theory Part 2**
	Andrew Parkes
10:30 – 12:00	**Optimisation for Airport Operations**
	Jason Atkin
12:00 – 13:30	**Lunch Break**
	See Suggested Places in Page 8
13:30 – 15:30	**Design of Heuristic Algorithms**
	Dario Landa-Silva
15:30 – 16:00	**Tea/Coffee Break**
	Opportunity for Networking
16:00 – 17:30	**Practical Challenges**
	Daniel Karapetyan / Course Participants
19:00 – 21:00	**Course Dinner**

Wednesday 10th April

09:00 – 11:00	**Hyper-heuristics**
	Ender Ozcan
11:00 – 12:00	**Automated Configuration of Optimisation Algorithms Part 1**
	Manuel Lopez-Ibañez
12:00 – 13:30	**Lunch Break**
	See Suggested Places in Page 8
13:30 – 15:30	**Automated Configuration of Optimisation Algorithms Part 2**
	Manuel Lopez-Ibañez
15:30 – 16:00	**Tea/Coffee Break**
	Opportunity for Networking
16:00 – 17:30	**Practical Challenges**
	Weiyao Meng / Course Participants

Thursday 11th April

09:00 – 10:00	**Practical Challenge**
	Weiyao Meng / Course Participants
10:00 – 12:00	**Automated Algorithm Design**
	Rong Qu
12:00 – 13:30	**Lunch Break**
	See Suggested Places in Page 8
13:30 – 15:30	**Big Data and Machine Learning**
	Isaac Triguero
15:30 – 16:00	**Tea/Coffee Break**
	Opportunity for Networking
16:00 – 17:30	**Practical Challenges**
	Rebecca Tickle / Course Participants

Friday 12th April

09:00 - 10:30	**Big Data Learning with Evolutionary Algorithms**
	Isaac Triguero
10:30 – 12:00	**Approaches for Real World Air Transportation Problems**
	Geert De Maere
12:00 – 14:00	**Lunch Break / Practical Challenges**
	Daniel Karapetyan / Weiyao Meng / Course Participants
14:00 – 15:00	**Course Test, Close**
	Dario Landa-Silva

4. Additional Information

Pre-Course Preparation

The course will be delivered in person but supported with the use of Microsoft Teams to enhance interaction among course participants and instructors. Please download and install the App or use the Teams on your web browser with a Microsoft account. We recommend that you familiarise yourself with the software before the course.

https://www.microsoft.com/en-gb/microsoft-365/microsoft-teams/download-app

Please prepare for having your whole focus on the course when participating in the sessions. Interaction in person and in Teams can complement each other very well if used properly. There will be frequent short breaks and a longer lunch break in each day of the course.

Some instructors might use Teams to gather comments and answer questions during the in-person sessions, please follow their instructions for the use of the chat and other tools like hand raising, etc. during sessions. There will be some general rules that will be communicated at the start of the course to try making this a good experience for participants.

All the Team interactions for all sessions will be delivered in the general channel of the course Teams session. For some parts of the course, participants will be organised in small groups and allocated to separate channels within the Teams session to conduct discussion and other practical work.

More information will be sent to those registered in the course a few days before the start date. This will include a brief survey to gather a bit of the background of each participant so that we can organise various aspects of the course.

Local Information

The course will be delivered in the Jubilee Campus of the University of Nottingham, see detailed maps and directions here:

https://www.nottingham.ac.uk/about/visitorinformation/mapsanddirections/jubileecampus.aspx

An arrival to the Jubilee Campus, students should **go straight to the Lecture Theatre 3 (LT3) in The Exchange Building** (building 2 in the map linked below) for the **REGISTRATION** and **WELCOME LUNCH**.

Map of the Jubilee Campus in PDF format:
https://www.nottingham.ac.uk/sharedresources/documents/mapjubileecampus.pdf

The overnight accommodation for those students that booked it, is located on the **Southwell Hall** (see building B in the map linked below). Access to the Southwell Hall is **only available from 3pm onwards on Monday 8-April**. Bags can be left in the lecture room during the first talks on Monday afternoon. Check in is from the Jubilee welcome point which is based in Newark Hall (see building A in the map linked below).

The booked rooms are single study bedrooms, with private en-suite bathroom facilities. Check in time will start on **Monday 08-April from 3pm** and check out time will be on **Friday 12-April by 10am**. The Hall Manager or Assistant Hall Manager will check in guests and give you a room key from the Hall Reception. Keys are to be handed in to the main reception upon departure and any missing key will be charged for. Guests are asked to always retain their keys. The following is included with the accommodation: full English breakfast, toiletry pack and refreshment tray, complimentary car parking, complimentary WiFi. Amenities in the room include a refreshment tray with kettle, towels and mini toiletries, bedding consisting of duvet and pillows. A booklet with further information on facilities in the Jubilee and other campuses of the University is available in the Team of the course.

Instructions for visitors to access the wireless network on campus are at the following link:
https://www.nottingham.ac.uk/dts/communications/internet-and-web-services/guest-wifi.aspx

The main campus of the university is **University Park Campus**. Students are welcome to enjoy the walks, parks, and gardens in the University's landscaped settings. There are also some food outlets in the University Parks Campus. More details about the campus here:
https://www.nottingham.ac.uk/about/campuses/universityparkcampus.aspx

The opening evening will involve a gathering at a venue (place to be confirmed) where some **social activity** and light dinner will be organised aimed to encourage course participants to know each other. More information will be provided on the day.

In the second evening we will gather somewhere (place to be confirmed) for the **course dinner**. More information will be provided on the day.

Places to Eat

The course will be taking place during the Easter Break which is a period when many University halls and restaurants will be closed in the evening. A light lunch will be provided when you arrive on Monday 08-April as well as food at the two social events taking place during the course (see course timetable above).

Please note, apart from these meals, no other lunch or evening meals will be provided. All other meals will be at your own expense. There are a few places to eat in the Jubilee Campus and around within 15-minute walk or so. These are some suggestions:

In Jubilee Campus: https://www.nottingham.ac.uk/hospitality/cafesbars/jubileecampus.aspx

Around Jubilee Campus: Amigo's Pizza, Best Food Chinese, Domino's Pizza, Doner Box, Hot 9, Mario's Fast Food, Rose and Crown, Sea Fish, Subway, The White Horse Café, Wing Trapp, among others.

Location of water fountains in the Jubilee and other campuses can be seen here: https://www.nottingham.ac.uk/wastenott/resources/resources.aspx

What's On in Nottingham

These are some links where you can find more information about what to do in Nottingham during the days of the course:

https://nottinghampuppetfestival.co.uk/

https://www.justthetonic.com/nottingham-comedy/next-month/

https://www.nottinghamcontemporary.org/whats-on/

https://www.visit-nottinghamshire.co.uk/whats-on