

## Engineering Tripos Part IIB, 4M17: Practical Optimisation, 2023-24

### Module Leader

[Prof. Geoff Parks](#) [1]

### Lecturers

[Prof. Garth Wells and Prof. Geoff Parks](#) [2]

### Timing and Structure

Michaelmas Term. 13 lectures + 3 coursework sessions. Assessment: 100% coursework. Lectures will be recorded.

### Prerequisites

3M1

### Aims

The aims of the course are to:

- Teach some of the basic optimisation methods used to tackle difficult, real-world optimisation problems.
- Teach means of assessing the tractability of nonlinear optimisation problems.
- Develop an appreciation of practical issues associated with the implementation of optimisation methods.
- Provide experience in applying such methods on challenging problems and in assessing and comparing the performance of different algorithms.

### Objectives

As specific objectives, by the end of the course students should be able to:

- Understand the basic mathematics underlying linear and convex optimisation.
- Be able to write and benchmark simple algorithms to solve a convex optimisation problem.
- Understand the technique of Markov-Chain Monte Carlo simulation, and apply it to solve a Travelling Salesman Problem.
- Understand the ways in which different heuristic and stochastic optimisation methods work and the circumstances in which they are likely to perform well or badly.
- Understand the principles of multiobjective optimization and the benefits of approaching real-world optimisation problems from a multiobjective perspective.

### Content

- Introduction (what is Practical Optimisation?)
- Approximately solving  $Ax=b$  (various methods of norm minimization of residuals that lead to LP or convex problems)
- Geometry of polyhedral and convex sets (review of the simplex method; introduction to algorithmic complexity)

- Duality theory and its applications
- Unconstrained optimisation
- Important convex relaxations in cardinality problems
- Circumstances in which 'methods of last resort' are needed
- Simulated Annealing: basic concepts, solution representation and generation, the annealing schedule, enhancements and modifications
- Genetic Algorithms: basic concepts, solution representation, selection, crossover, mutation
- Tabu Search: basic concepts, solution representation, local search, intensification, diversification
- Multiobjective Optimization: archiving, multiobjective simulated annealing, multiobjective genetic algorithms
- Case Study: multiobjective optimization of pressurised water reactor reload cores

## Coursework

Coursework	Format
<p><b>Coursework activity #1:</b> <i>Investigation of a moderate size Linear Regression problem with various norm and regularization approximations</i></p> <p><u>Learning objective:</u></p> <ul style="list-style-type: none"> <li>• convert a regression problem into a linear program and solve it with linprog</li> <li>• program a simple line search algorithm and experiment the impact of smoothness on convergence rate.</li> <li>• understand how different norms affect the solution of an approximation problem.</li> </ul>	<p>Individual</p> <p>anonymou</p>
<p><b>Coursework activity #2:</b> <i>Investigation of the performance of two stochastic optimization methods on a hard problem</i></p> <p><u>Learning objective:</u></p> <ul style="list-style-type: none"> <li>• gain experience in applying stochastic optimisation methods to challenging problems</li> <li>• explore and analyse the variation in optimiser performance as algorithm control parameters are modified</li> <li>• compare and analyse the performance of different optimisation methods on challenging problems</li> </ul>	<p>Individual</p> <p>anonymou</p>

## Booklists

Please refer to the Booklist for Part IIB Courses for references to this module, this can be found on the associated Moodle course.

## Examination Guidelines

Please refer to [Form & conduct of the examinations](#) [3].

## UK-SPEC

This syllabus contributes to the following areas of the [UK-SPEC](#) [4] standard:

[Toggle display of UK-SPEC areas.](#)

## Intellectual Abilities

### Knowledge and Understanding

### Practical skills

## **Engineering Analysis (E)**

### **Underpinning Science and Mathematics and associated engineering disciplines**

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#### **Links**

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[2] <mailto:gnw20@cam.ac.uk>, [gtp10@cam.ac.uk](mailto:gtp10@cam.ac.uk)

[3] <https://teaching24-25.eng.cam.ac.uk/content/form-conduct-examinations>

[4] <https://teaching24-25.eng.cam.ac.uk/content/uk-spec>