# CS416-15 Optimisation Methods

## 23/24

**Department**
Computer Science
**Level**
Undergraduate Level 4
**Module leader**
Marcin Jurdzinski
**Credit value**
15
**Module duration**
10 weeks
**Assessment**
Multiple
**Study location**
University of Warwick main campus, Coventry

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## Description

## Introductory description

At their core, many real-world problems involve optimisation problems that are complex and challenging, and they require principled mathematical and algorithmic solutions. Companies such as Google and Facebook use powerful algorithmic primitives such as gradient descent to solve a host of challenging problems. These primitives in turn are based on a beautiful mathematical theory developed in the context of convex and discrete optimisation.

## Module aims

The aim is to learn the mathematical and algorithmic foundations underpinning optimization problems that are ubiquitous in applications in machine learning, data analysis, and scientific computing.

There are several interrelated aims of this module:
(1) to expose students to optimisation methods that have found significant applications,
(2) to develop a toolkit of mathematical methods that can be used to tackle real-world problems, and
(3) to rigorously analyse these methods.

## Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

Some of the following topics will be discussed. The selection of topics may vary from year to year.

Convex optimisation methods and their applications. Gradient descent, the multiplicative weights update method, the Frank-Wolfe gradient descent algorithm.
Discrete and combinatorial optimisation methods and their applications. Submodular functions, submodular minimisation via the ellipsoid method and gradient descent. Submodular maximisation via the Greedy algorithm.
Algorithms for linear algebra and their applications. The power method, singular value decompositions, principal component analysis, spectral clustering, least squares and linear regression.

## Learning outcomes

By the end of the module, students should be able to:

- Learn mathematical tools from convex optimisation, discrete and combinatorial, and linear algebra.
- Learn optimisation methods that are widely used in applications.
- Understand the mathematical theory behind these optimisation methods.
- Implement optimisation methods and apply them to real-world problems.

## Indicative reading list

Reading lists can be found in Talis

Specific reading list for the module

## Subject specific skills

1. Learn basic optimisation methods which are ubiquitous in applications in machine learning, data analysis and scientific computing.
2. Strengthen the mathematical background in analysis and algebra.
3. Learn how to analyse optimisation methods with mathematical rigor.
4. Get programming experience by developing these methods in software and see different scenarios of application

## Transferable skills

1. Develop analytical thinking by working with mathematical concepts.
2. Develop research & problem solving skills, particularly for mathematical problems. Students are exposed to some paradigms of optimisation, and later they develop their own approach to solve problems.
3. Communication skills - Learn how to express themselves with mathematical precision.

## Study

## Study time

| Type | Required |
|---|---|
| Lectures | 20 sessions of 1 hour (13%) |
| Seminars | 10 sessions of 1 hour (7%) |
| Practical classes | 10 sessions of 1 hour (7%) |
| Private study | 110 hours (73%) |
| Total | 150 hours |

## Private study description

Private study and revision.

## Costs

No further costs have been identified for this module.

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## Assessment

You do not need to pass all assessment components to pass the module.

Students can register for this module without taking any assessment.

### Assessment group D4

| | Weighting | Study time | Eligible for self-certification |
|---|---|---|---|
| Practical Assignment 1<br>Lab Exercise | 15% | | Yes (extension) |
| Practical assignment 2<br>Lab Exercise | 15% | | Yes (extension) |
| In-person Examination<br>CS416 exam | 70% | | No |

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- Answerbook Pink (12 page)
- Students may use a calculator

### Assessment group R2

| | Weighting | Study time | Eligible for self-certification |
|---|---|---|---|
| In-person Examination<br>CS416 resit examinations | 100% | | No |

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- Answerbook Pink (12 page)
- Students may use a calculator

### Feedback on assessment

- Individual written feedback
- Group feedback in seminars

Past exam papers for CS416

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## Availability

### Pre-requisites

We shall assume the standard general background that 3rd year Computer Science and Discrete Mathematics students have.

## Courses

This module is Optional for:

- Year 5 of UCSA-G504 MEng Computer Science (with intercalated year)
- Year 4 of UCSA-G503 Undergraduate Computer Science MEng

This module is Option list B for:

- Year 4 of UCSA-G4G3 Undergraduate Discrete Mathematics
- Year 5 of UCSA-G4G4 Undergraduate Discrete Mathematics (with Intercalated Year)