MA398-15 Matrix Analysis & Algorithms

21/22

Department
Warwick Mathematics Institute
Level
Undergraduate Level 3
Module leader
Radu Cimpeanu
Credit value
15
Module duration
10 weeks
Assessment
Multiple
Study location
University of Warwick main campus, Coventry

Description

Introductory description

Many large scale problems arising in data analysis and scientific computing require efficient solutions to systems of
linear equations, least-squares problems, and eigenvalue problems. The module is based around understanding the
mathematical principles underlying the design and the analysis of effective methods and algorithms to solve these
types of challenges. It involves an interplay between mathematical analysis and computing, including programming
aspects, validation and result analysis.

[Module web page]

Module aims

Understanding how to construct algorithms for solving problems central in numerical linear algebra and how to
analyse them with respect to accuracy and computational cost. Selecting, evaluating and

characterising findings when
applying both analytical and numerical methods to practical problems of interest.

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.

Many large scale problems arising in data analysis and scientific computing require efficient solutions to systems of
linear equations, least-squares problems, and eigenvalue problems. The module is based around understanding the
mathematical principles underlying the design and the analysis of effective methods and algorithms to solve these
types of challenges. Key concepts include matrix decompositions, factorisations, direct and iterative system solvers.
They are supported by fundamental aspects related to floating point arithmetic, computational cost analysis, stability
and convergence, with examples such as image compression and operating in data-rich environments. Incursions into
ideas from high performance computing will also feed into the material in order to inform about modern software
engineering practices in academia and beyond. This module is suitable for students in joint degrees with Mathematics, as well as associated departments such as (but not limited to) Computer Science, Physics and Statistics.

Learning outcomes

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

- explain concepts and ideas related to matrix factorisations as the theoretical basis for algorithms,
- assess algorithms with respect to computational cost, conditioning of problems and stability of algorithms,
- demonstrate theoretical concepts using numerical software tools,
- compare different (competing) numerical methodologies and critically evaluate bottlenecks in algorithmic design for real-world applications.

Indicative reading list

AM Stuart and J Voss, Matrix Analysis and Algorithms, script.
G Golub and C van Loan, Matrix Computations, 3. ed., Johns Hopkins Univ. Press, London 1996.
NJ Higham, Accuracy and Stability of Numerical Algorithms, SIAM 1996.
RA Horn and CR Johnson, Matrix Analysis, Cambridge University Press 1985.
D Kincaid and W Cheney, Numerical Analysis, 3. ed., AMS 2002.
LN Trefethen and D Bau, Numerical Linear Algebra, SIAM 1997.

Interdisciplinary

The module sits naturally between mathematics, computer science and elements from related disciplines such as
physics, biology or image processing.

Subject specific skills

Discrete mathematical analysis, algorithmic construction, cost and error analysis, concepts in numerical methods for a
range of applied problems in mathematical sciences.

Transferable skills

Informed problem solving, software development, creative solution analysis, project management, critical thinking, application-oriented solution strategy design, programming language expertise.

Study

Study time

Type	Required
Lectures	30 sessions of 1 hour (20%)
Tutorials	9 sessions of 1 hour (6%)
Private study	111 hours (74%)
Total	150 hours

Private study description

Each assignment should take approximately 8h to complete, in line with its weight in the overall module assessment.
Several hours of preparation (software installation, any debugging e.g. using support classes) will also likely be
necessary. Lecture preparation (20h), engaging with online material (20h), participation in optional seminar
discussions (10h) and work on formative elements (15-20h, be they pen and paper based or programming) is
anticipated to fill up the rest of the independent learning time, though many of the above offer checkpoints in terms of lectures, support classes or TA-run support classes.

Costs

No further costs have been identified for this module.

Assessment

You must pass all assessment components to pass the module.

Students can register for this module without taking any assessment.

Assessment group D2

	Weighting	Study time	Eligible for self-certification
Assignment	15%		No

Three assignments (posted in weeks 2, 5 and 8), with feedback provided within 2 weeks from submission, so as to enable feedforward into the following assignment and ultimately study. These
will consist of 70% theoretical work (theorem proving and application) and 30% implementation, data visualisation and interpretation, with a final component attributed to brief discussions about the wider implications of the material.

	Weighting	Study time	Eligible for self-certification
In-person Examination	85%		No

Pen and paper work only, with a combination of theoretical content (theorem proving, comparisons etc.), application to particular examples (or finding counterexamples), filling in or improving provided algorithmic scaffolding, as well as critical assessment of provided results. The precise format depends on the nature of the assessment (online versus in person).

- Answerbook Gold (24 page)

Assessment group R

	Weighting	Study time	Eligible for self-certification
In-person Examination - Resit	100%		No

Pen and paper work only, with a combination of theoretical content (theorem proving, comparisons etc.), application to particular examples (or finding counterexamples), filling in or improving provided algorithmic scaffolding, as well as critical assessment of provided results. The precise format depends on the nature of the assessment (online versus in person).

- Answerbook Gold (24 page)

Feedback on assessment

Formative assessments (exercise sheets, 3x during the term), as well as lecture materials are discussed in Q&A sessions with the module leader, as well as in support classes with the TA.

Timely feedback will be provided after each summative assessment (assignment sheets, 3x during the term) such that
it can be incorporated in the developing study process. This will include comments on both mathematical and good
programming practice, such that the outcomes can propagate beyond the level of the module itself.

Past exam papers for MA398

Availability

Pre-requisites

MA106 Linear Algebra and (to a lesser extent) MA259 Multivariable Calculus are sufficient in terms of core 1st and
2nd year modules within Mathematics. Helpful but not mandatory is some knowledge of numerical concepts such as
accuracy, iteration processes, and stability as provided in MA228 Numerical Analysis or MA261 Differential Equations:
Modelling and Numerics.

To take this module, you must have passed:

- All of
  - MA106-12 Linear Algebra

Courses

This module is Optional for:

- Year 1 of TMAA-G1PD Postgraduate Taught Interdisciplinary Mathematics (Diploma plus MSc)
- Year 1 of TMAA-G1PC Postgraduate Taught Mathematics (Diploma plus MSc)
- Year 3 of UCSA-G4G1 Undergraduate Discrete Mathematics
- Year 3 of UCSA-G4G3 Undergraduate Discrete Mathematics
- Year 4 of UCSA-G4G2 Undergraduate Discrete Mathematics with Intercalated Year
- USTA-G300 Undergraduate Master of Mathematics,Operational Research,Statistics and Economics
  - Year 3 of G300 Mathematics, Operational Research, Statistics and Economics
  - Year 4 of G300 Mathematics, Operational Research, Statistics and Economics

This module is Core option list B for:

- Year 3 of UMAA-GV17 Undergraduate Mathematics and Philosophy
- Year 3 of UMAA-GV19 Undergraduate Mathematics and Philosophy with Specialism in Logic and Foundations

This module is Core option list D for:

- Year 4 of UMAA-GV19 Undergraduate Mathematics and Philosophy with Specialism in Logic and Foundations

This module is Option list A for:

- TMAA-G1PD Postgraduate Taught Interdisciplinary Mathematics (Diploma plus MSc)
    - Year 1 of G1PD Interdisciplinary Mathematics (Diploma plus MSc)
    - Year 2 of G1PD Interdisciplinary Mathematics (Diploma plus MSc)
- Year 1 of TMAA-G1P0 Postgraduate Taught Mathematics
- TMAA-G1PC Postgraduate Taught Mathematics (Diploma plus MSc)
    - Year 1 of G1PC Mathematics (Diploma plus MSc)
    - Year 2 of G1PC Mathematics (Diploma plus MSc)
- UMAA-G105 Undergraduate Master of Mathematics (with Intercalated Year)
    - Year 3 of G105 Mathematics (MMath) with Intercalated Year
    - Year 5 of G105 Mathematics (MMath) with Intercalated Year
- Year 3 of UMAA-G100 Undergraduate Mathematics (BSc)
- UMAA-G103 Undergraduate Mathematics (MMath)
    - Year 3 of G100 Mathematics
    - Year 3 of G103 Mathematics (MMath)
    - Year 4 of G103 Mathematics (MMath)
- UMAA-G106 Undergraduate Mathematics (MMath) with Study in Europe
    - Year 3 of G106 Mathematics (MMath) with Study in Europe
    - Year 4 of G106 Mathematics (MMath) with Study in Europe
- Year 3 of UPXA-FG33 Undergraduate Mathematics and Physics (BSc MMathPhys)
- Year 3 of UPXA-GF13 Undergraduate Mathematics and Physics (BSc)
- UPXA-FG31 Undergraduate Mathematics and Physics (MMathPhys)
    - Year 3 of GF13 Mathematics and Physics
    - Year 3 of FG31 Mathematics and Physics (MMathPhys)
- Year 4 of UPXA-GF14 Undergraduate Mathematics and Physics (with Intercalated Year)
- Year 4 of USTA-G1G3 Undergraduate Mathematics and Statistics (BSc MMathStat)
- Year 5 of USTA-G1G4 Undergraduate Mathematics and Statistics (BSc MMathStat) (with Intercalated Year)
- Year 4 of UMAA-G101 Undergraduate Mathematics with Intercalated Year
- Year 3 of USTA-Y602 Undergraduate Mathematics,Operational Research,Statistics and Economics

This module is Option list B for:

- Year 1 of TMAA-G1PE Master of Advanced Study in Mathematical Sciences
- Year 3 of USTA-G1G3 Undergraduate Mathematics and Statistics (BSc MMathStat)
- Year 4 of USTA-G1G4 Undergraduate Mathematics and Statistics (BSc MMathStat) (with Intercalated Year)

- Year 3 of USTA-GG14 Undergraduate Mathematics and Statistics (BSc)
- Year 4 of USTA-GG17 Undergraduate Mathematics and Statistics (with Intercalated Year)

This module is Option list E for:

- USTA-G300 Undergraduate Master of Mathematics,Operational Research,Statistics and Economics
  - Year 3 of G30D Master of Maths, Op.Res, Stats & Economics (Statistics with Mathematics Stream)
  - Year 4 of G30D Master of Maths, Op.Res, Stats & Economics (Statistics with Mathematics Stream)
- USTA-G301 Undergraduate Master of Mathematics,Operational Research,Statistics and Economics (with Intercalated
  - Year 3 of G30H Master of Maths, Op.Res, Stats & Economics (Statistics with Mathematics Stream)
  - Year 4 of G30H Master of Maths, Op.Res, Stats & Economics (Statistics with Mathematics Stream)
  - Year 5 of G30H Master of Maths, Op.Res, Stats & Economics (Statistics with Mathematics Stream)