MATHEMATICS FOR DATA MANAGEMENT AND ANALYSIS

Bachelor in Data and Business Analytics BDBA SEP-2023
MDMA-DBA.2.M.A

Area Data Science

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Degree course: SECOND

Number of credits: 6.0

Semester: 1º

Category: BASIC

Language: English

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Dr. David Gordo Gómez is a seasoned professional with a strong background in machine learning, data science, and statistical modeling. He holds a PhD and MSc in Theoretical Physics from the Autonomous University of Madrid and a Bachelor's degree in Physics from the Universidad de Salamanca. He has a strong background in theoretical particle physics and has conducted research in this field, utilizing large data sets generated by the Large Hadron Collider at CERN, Switzerland.

As the Co-founder and CEO of Komorebi AI, Dr. Gordo Gómez brings a wealth of expertise in developing real-world solutions using machine learning and data science techniques. He has a track record of solving complex problems related to data analysis and has extensive experience machine learning. He is focused on exploring frontier techniques in natural language processing and computer vision, and their applications to industrial problems.

In addition to his leadership role at Komorebi AI, Dr. Gordo Gómez is also a sought-after educator, serving as a lecturer in in programming and Machine Learning at IE University and IE Business School.
He has a passion for imparting his knowledge and skills, and regularly teaches programming, natural language processing, and reinforcement learning in the Executive and MSc in Data Science programs at the Madrid Internet of Things Institute (MIOTI).

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SUBJECT DESCRIPTION

This course provides a comprehensive introduction to the fundamental mathematical concepts and techniques essential for effective data management and analysis, with a specific emphasis on linear algebra. This course equips learners with the necessary mathematical foundation to manipulate and analyze data efficiently.

The course begins by exploring the fundamental concepts of linear algebra, such as vectors, matrices, and systems of linear equations. Students will delve into the properties and operations of vectors and matrices, including vector spaces, matrix multiplication, determinants, and inverses. Through practical exercises, students will develop a solid understanding of these key linear algebra concepts.

Furthermore, the course delves into advanced topics in linear algebra that are particularly relevant for data analysis. Students will explore eigenvectors, eigenvalues and orthogonality. These are the base for concepts such as singular value decomposition (SVD), data compression, image recognition, and recommendation systems. Additionally, the course introduces concepts from linear regression, providing students with the tools to perform regression analysis and make predictions based on data.

Throughout the course, students will have the opportunity to apply their knowledge to practical, real-world scenarios through hands-on exercises and projects. By the end of the course, students will have gained a solid foundation in linear algebra and its applications to data management and analysis, equipping them with essential skills for success in the rapidly evolving field of data science.

LEARNING OBJECTIVES

The goal of this course is to introduce students to quantitative and qualitative methodologies in order to provide them with the necessary tools for conducting basic empirical research. This course will enhance the student's ability to think critically and scientifically about everyday issues and problems. Specifically, this course is designed to achieve several objectives:

1. Develop the ability to think critically about real-world problems, including how such problems can be modeled using simple mathematical tools.
2. Learn how to deal with basic concepts of linear algebra and optimization.
3. Understand how these concepts are the foundation of modern data management and analysis techniques.

TEACHING METHODOLOGY

IE University teaching method is defined by its collaborative, active, and applied nature. Students actively participate in the whole process to build their knowledge and sharpen their skills. Professor's main role is to lead and guide students to achieve the learning objectives of the course. This is done by engaging in a diverse range of teaching techniques and different types of learning activities such as the following:

Learning Activity	**Weighting**	**Estimated time a student should dedicate to prepare for and participate in**
Lectures	40.0 %	60.0 hours
Discussions	3.33 %	5.0 hours

Exercises in class, Asynchronous sessions, Field Work	30.0 %	45.0 hours
Group work	10.0 %	15.0 hours
Individual studying	16.67 %	25.0 hours
TOTAL	100.0 %	150.0 hours

PROGRAM

SESSION 1 (LIVE IN-PERSON)

INTRODUCTION

- Presentation of the course.
- Introduction to Linear Algebra.
- Linear Models in Economics and Engineering and systems of linear equations.

SESSION 2 (LIVE IN-PERSON)

LINEAR EQUATIONS

- Linear systems of equations and the corresponding augmented matrix.
- Solving linear systems using Gauss elimination algorithm.

SESSION 3 (LIVE IN-PERSON)

LINEAR EQUATIONS

- Characterization of the solution set of a linear system.

SESSION 4 (LIVE IN-PERSON)

LINEAR EQUATIONS

- Problem session about linear systems of equations.

SESSION 5 (LIVE IN-PERSON)

MATRICES

- Special matrices, operations with matrices and matrix multiplication.

SESSION 6 (LIVE IN-PERSON)

MATRICES

- Applications of matrix multiplication. Problem session about matrix multiplication.

SESSION 7 (LIVE IN-PERSON)

Group activities/exercises: Computations with matrices using the computer.

SESSION 8 (LIVE IN-PERSON)

INVERSE OF A MATRIX

- Invertibility and existence of solutions to linear systems of equations.Gauss-Jordan algorithm to find the inverse of a matrix, matrix factorization.

SESSION 9 (LIVE IN-PERSON)

INVERSE OF A MATRIX

- Invertibility and existence of solutions to linear systems of equations.
  Gauss-Jordan algorithm to find the inverse of a matrix, matrix factorization.

SESSION 10 (LIVE IN-PERSON)

INVERSE OF A MATRIX

- Problem session on operations with matrices.

SESSION 11 (LIVE IN-PERSON)

DETERMINANTS

- The determinant of a matrix.

SESSION 12 (LIVE IN-PERSON)

DETERMINANTS

- Properties of the determinant and relationship with the inverse of a matrix.

SESSION 13 (LIVE IN-PERSON)

DETERMINANTS

- Problem session on determinants.

SESSION 14 (LIVE IN-PERSON)

INTERMEDIATE QUIZ 1

SESSION 15 (LIVE IN-PERSON)

VECTOR SUBSPACES

- The euclidean vector space: vectors and subspaces.

SESSION 16 (LIVE IN-PERSON)

VECTOR SUBSPACES

- Notable examples of subspaces: Null space, row space and column space of a matrix. Linear transformations.

SESSION 17 (LIVE IN-PERSON)

VECTOR SUBSPACES

- Linear independence.
- The concept of dimension
- Dimension of the subspaces associated with a matrix

SESSION 18 (LIVE IN-PERSON)

VECTOR SUBSPACES

- Problem session about vector spaces.

SESSION 19 (LIVE IN-PERSON)

EIGENVALUES AND EIGENVECTORS

- Definition of Eigenvalues and Eigenvectors.
- The characteristic equation.

SESSION 20 (LIVE IN-PERSON)

EIGENVALUES AND EIGENVECTORS

- Diagonalization.
- Analysis of some applications of eigenvalues.

SESSION 21 (LIVE IN-PERSON)

EIGENVALUES AND EIGENVECTORS

- Problem session about eigenvalues and eigenvectors.

SESSION 22 (LIVE IN-PERSON)

Group activities/exercises: Applications of Eigenvalues and Eigenvectors

SESSION 23 (LIVE IN-PERSON)

ORTHOGONALITY

- Inner Product, length and orthogonal vector
- Orthogonal complement.

SESSION 24 (LIVE IN-PERSON)

ORTHOGONALITY

- Orthogonal Projection and the Gram-Schmidt algorithm.

SESSION 25 (LIVE IN-PERSON)

ORTHOGONALITY

- The least squares problem and applications to machine learning.

SESSION 26 (LIVE IN-PERSON)

ORTHOGONALITY

- Problem session on inner product and orthogonality.

SESSION 27 (LIVE IN-PERSON)

Group activities/exercises: Applications of Inner Product and Orthogonality and Least Squares

SESSION 28 (LIVE IN-PERSON)

INTERMEDIATE QUIZ 2

SESSION 29 (LIVE IN-PERSON)

Wrap-up session.

SESSION 30 (LIVE IN-PERSON)

Final Exam

EVALUATION CRITERIA

A. Class participation and discussion

Class participation will be evaluated based on the following criteria:

- Quality (not quantity) of your participation in class discussion: The most important dimension of participation concerns what it is that you are saying. A high quality comment reveals depth of insight, rigorous use of case evidence, consistency of argument, and realism. Frequency refers to the attainment of a threshold quantity of contributions that is sufficient for making a reliable assessment of comment quality. The logic is simple: if contributions are too few, one cannot reliably assess the quality of your remarks. However, once threshold quantity has been achieved, simply increasing the number of times you talk does not automatically improve your evaluation. Beyond the threshold, it is the quality of your comments that must improve. In particular, one must be especially careful that in claiming more than a fair share of “airtime”, quality is not sacrificed for quantity. Finally, your attempts at participation should not be such that the instructor has to “go looking for you”. You should be attempting to get into the debate on a regular basis.

You might want to avoid being classified as one of the following types of students:

- Repeaters, i.e., students that, consciously or unconsciously, make comments that are really just repeats/rephrasing of what has already been said (by other students, or you). This wastes time and adds nothing to learning.
- Ramblers, i.e., students that take a lot of time to say simple things or they may tell long personal/professional stories, or they roam into topics that are not relevant, or simply make low-quality comments just to participate. They waste valuable time and prevent other students from being able to participate.
- Students that have been distracted (by Facebook, etc.) or who have stopped paying attention and then, later on, when they realized they have missed a term or concept, they ask you about

it.

B. Intermediate Quizzes

During two sessions, you will be given a quiz based on the content taught on the previous sessions. Quizzes can be either computer-based or paper-based and are typically composed of a few questions, aimed at ensuring that every student has a basic understanding of the material covered in class in the previous sessions. **Each of the two quizzes will account for 15% of the global grade.**

C. Final exam

There will be one final exam. In order to pass the course, you need a **minimum grade of 3.5 in the final exam**. If your grade in the final exam does not reach the threshold value of 3.5, you will fail the course, even in the case in which your weighted average (computed using the table above) exceeds 5.0.

D. Group Activities

During each of the group activity sessions, we will explore applications and exercises of the concepts covered in the previous sessions. Groups will be created at the beginning of the course, and all members of the group will receive the same grade.

criteria	percentage	Learning Objectives	Comments
Final Exam	40 %		Held during last session.
Intermediate Quizzes	30 %		Held during two F2F sessions.
Group Activities	20 %		Explained in each of the group activity sessions.
Class Participation	10 %		

RE-SIT / RE-TAKE POLICY

Each student has 4 chances to pass any given course distributed over two consecutive academic years: ordinary call exams and extraordinary call exams (re-sits) in June/July.

Students who do not comply with the 70% attendance rule during the semester will fail both calls for this Academic Year (ordinary and extraordinary) and have to re-take the course (i.e., re-enroll) in the next Academic Year.

Evaluation criteria will be subject to the following rules:

- Students failing the course in the ordinary call (during the semester) will have to re-sit the exam in June / July (except those not complying with the attendance rule, who will not have that opportunity and must directly re-enroll in the course on the next Academic Year).
- The extraordinary call exams in June / July (re-sits) require your physical presence at the campus you are enrolled in (Segovia or Madrid). There is no possibility to change the date, location or format of any exam, under any circumstances. Dates and location of the June / July re-sit exams will be posted in advance. Please take this into consideration when planning your summer.
- The June / July re-sit exam will consist of a comprehensive exam. Your final grade for the course will depend on the performance in this exam only; continuous evaluation over the semester will not be taken into consideration. Students will have to achieve the minimum passing grade of 5 and the maximum grade will be capped at 8.0 (out of 10.0) – i.e., “notable” in the in the re-sit exam.
- Re-takers: Students who failed the subject on a previous Academic Year and are now re-

enrolled as re-takers in a course. The evaluation criteria for them as re-takers in the course during that semester (ordinary call of that Academic Year) are as follows: Quizzes 40%, final exam 60% (there is no continuous evaluation for re-takers). In order to pass, a minimum of 3.5 in the final exam is required. The maximum grade that may be obtained in the retake exam (3rd call) is 10.0 (out of 10.0).

After ordinary and extraordinary call exams are graded by the professor, you will have a possibility to attend a review session for that exam and course grade. Please be available to attend the session in order to clarify any concerns you might have regarding your exam. Your professor will inform you about the time and place of the review session.

- Students failing more than 18 ECTS credits after the June-July re-sits will be asked to leave the Program. Please, make sure to prepare yourself well for the exams in order to pass your failed subjects.
- In case you decide to skip the opportunity to re-sit for an exam during the June / July extraordinary call, you will need to enroll in that course again for the next Academic Year as a re-taker and pay the corresponding extra cost. As you know, students have a total of 4 allowed calls to pass a given subject or course, in order to remain in the program.

BIBLIOGRAPHY

Compulsory

- Lay, Lay, McDonald. (2021). *Linear Algebra and Its Applications.* 6th. Pearson. ISBN 9781292351216 (Printed)

This book provides a modern elementary introduction to linear algebra.

Recommended

- Strang. (2016). *Introduction to Linear Algebra.* 5. SIAM. ISBN 9780980232776 (Printed)

This provides an advanced introduction to linear algebra, and is accompanied by a set of video lectures of the author, available at: https://ocw.mit.edu/courses/mathematics/18-06-linear-algebra-spring-2010/video-lectures/

- Howard Anton & Chris Rorres. (2014). *Elementary Linear Algebra with Supplemental Applications.* 11th. Wiley. ISBN 9781118677452 (Printed)

Elementary Linear Algebra 11th edition gives an elementary treatment of linear algebra that is suitable for a first course for undergraduate students. The aim is to present the fundamentals of linear algebra in the clearest possible way; pedagogy is the main consideration. Calculus is not a prerequisite, but there are clearly labeled exercises and examples (which can be omitted without loss of continuity) for students who have studied calculus.

BEHAVIOR RULES

Please, check the University's Code of Conduct here. The Program Director may provide further indications.

ATTENDANCE POLICY

Please, check the University's Attendance Policy here. The Program Director may provide further indications.

ETHICAL POLICY

Please, check the University's Ethics Code here. The Program Director may provide further indications.