MATHEMATICS FOR DATA MANAGEMENT AND ANALYSIS

BACHELOR IN DATA AND BUSINESS ANALYTICS
Professor: MARCO CASERTA
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Academic year: 19-20
Degree course: SECOND
Semester: 1º
Category: BASIC
Number of credits: 6.0
Language: English

PREREQUISITES
Basic Algebra. Optimization for functions of one and more variables.
SUBJECT DESCRIPTION
This course provides a modern introduction to the mathematics behind data analysis. A certain degree of understanding of linear algebra and optimization are of paramount importance to attain a mastery of data and business analytics. This course will provide the opportunity to learn the fundamental mathematical notions behind data science and machine learning. In a modern fashion, we approach the field with special emphasis on the use of a computing language. We will explore the different techniques and develop little chunks of codes using python and jupyter notebooks.
OBJECTIVES AND SKILLS

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. Demonstrate the ability to use a software to conduct basic data analyses.
METHODOLOGY
The course is articulated on a mix of lectures and computer-based sessions. During the lectures, we will first motivate the need of theoretical tools by means of a real-world example. Next, the relevant theory will be presented. During the lab sessions, the students will be asked to address a challenging real-world problem and to employ the tools developed in class to analyze the problem, model it, attain a solution, and interpret it in the context of the underlying real-world problem.
<table>
<thead>
<tr>
<th>Teaching methodology</th>
<th>Weighting</th>
<th>Estimated time a student should dedicate to prepare for and participate in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lectures</td>
<td>30.0 %</td>
<td>45 hours</td>
</tr>
<tr>
<td>Discussions</td>
<td>10.0 %</td>
<td>15 hours</td>
</tr>
<tr>
<td>Exercises</td>
<td>40.0 %</td>
<td>60 hours</td>
</tr>
<tr>
<td>Group work</td>
<td>0.0 %</td>
<td>0 hours</td>
</tr>
<tr>
<td>Other individual studying</td>
<td>20.0 %</td>
<td>30 hours</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100.0 %</td>
<td>150 hours</td>
</tr>
</tbody>
</table>
PROGRAM

The number in parenthesis below are referred to chapters and paragraphs of the bibliographic items (described in the “Bibliography” section of this syllabus.) Note that:

- Items marked with “L” are referred to portions of book 1 in the Bibliography.
- Items marked with “S” are referred to portions of book 2 in the Bibliography.
- Items marked with “DM” are referred to portions of book 3 in the Bibliography.

BLOCK 1 : LOGIC AND PROOFS

SESSIONS 1 - 3

- Propositional logic, truth tables, logical Equivalence, deduction (DM-3.1)
- Direct proof, proof by contrapositive, proof by contradiction, proof by (counter)example (DM-3.2)
- Induction and recursion (DM-2.5)

BLOCK 2 : LINEAR ALGEBRA

SESSION 4

- Introduction to Colaboratory: https://colab.research.google.com/notebooks/welcome.ipynb#recent=true
- Overview of Colaboratory Features: https://colab.research.google.com/notebooks/basic_features_overview.ipynb
- External Data Input and Output: Connection with Google Drive: https://colab.research.google.com/notebooks/io.ipynb

SESSIONS 5 - 6

- Linear models in Economics and Engineering (L-1.1)
- Introduction to Vectors and Matrices (L-1.3, L-1.4 -- S-1.2, S-1.3)
- Solving linear equations via elimination (L-1.5 -- S-2.2, S-2.3)

SESSIONS 7 - 8

- Matrix Algebra: The inverse of a matrix, matrix factorization (L-2.2, L-2.5 -- S-2.5, S-2.6)
- Determinants: Properties of Determinants, Cramer’s rule, volumes (L-3.1, L-3.2, L-3.3 -- S-5.1, S-5.3)

17th June 2019
SESSIONS 9 - 11
- Vector Spaces Subspaces: Null space, row space, column space (L-4.1, L-4.2 -- S-3.1, S-3.2)
  Independence, basis, and dimensions (L-4.3, L-4.5 -- S-3.4, S-3.5)
  Application: Markov Chain and Google PageRank

SESSIONS 12 - 14
- Eigenvalues and Eigenvectors Introduction: Difference equation of a dynamic system
  Characteristic equation (L-5.2 -- S-6.1)
  Diagonalization (L-5.3 -- S-6.2)
  Eigenvectors and linear transformations (L-5.4 -- S-8.1, S-8.2)

SESSION 15
Midterm Exam (details provided in class)

SESSIONS 16 - 18
- Differential equations Introduction
  Systems of differential equations (L-5.7 -- S-6.3)

SESSIONS 19 - 21
- Orthogonality and Least Squares Inner product, length, orthogonal vectors (L-6.1 -- S-4.1)
  Projections (L-6.3 -- S-4.2)
  The least squares problem and its applications (L-6.6, L-6.7, L-6.8 -- S-4.3)

SESSIONS 22 - 23
- Singular Value Decomposition Image processing by linear algebra: Principal component analysis (L-7.5 -- S-7.3, S-7.4)

BLOCK 3: OPTIMIZATION - LINEAR PROGRAMMING

SESSIONS 24 - 28
- Introduction: Location Problems and/or other LP examples (L-9.3)
- Geometric method (L-9.2)
- The simplex method (L-9.3 -- S-10.4)
- Duality (L-9.4)
- Lagrangean problem and Karush-Kuhn-Tucker conditions
- Exercises

SESSION 29
Wrap-up Session

17th June 2019
SESSION 30
Final Exam (details provided in class)
BIBLIOGRAPHY
Compulsory Bibliography:

# EVALUATION CRITERIA

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Percentage</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance and Participation</td>
<td>10 %</td>
<td>See comments below.</td>
</tr>
<tr>
<td>Quizzes</td>
<td>20 %</td>
<td>Paper and computer-based tests.</td>
</tr>
<tr>
<td>Midterm Exam</td>
<td>30 %</td>
<td>Held in class.</td>
</tr>
<tr>
<td>Final Exam</td>
<td>40 %</td>
<td>Held on last day of class.</td>
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</table>

## 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. Quizzes

At the beginning of some sessions, you will be given a short quiz based on required readings and exercises for the session. Quizzes will be announced in advance. 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.

## C. Mid-term and final exams
There will be one mid-term and one final exam. For these exams, you must bring your own computer. Both the midterm and the final are computer-based, and will require familiarity with the computing environment used during the lectures (python and colaboratory.)

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.

**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-swits) 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: Midterm 40%, final 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.
Marco Caserta received his Ph.D. in Industrial Engineering and Operations Research from the University of Illinois (USA), after earning a MSc in Management Engineering from the Politecnico di Milano (Italy). He is currently a professor at IE University as well as an associate professor at the IE Business School. He teaches optimization related courses to graduate students within the International MBA and the PhD programs.

His main research interest is concentrated on the design and development of metaheuristic-based algorithms for very large scale real-world optimization problems, with a special focus on logistics, telecommunication and transportation related problems. He has published a number of papers in journals in the area of operations research/management science.

**OTHER INFORMATION**

**Office Hours**
Please, send an email to mcaserta@faculty.ie.edu to schedule an appointment in advance.

**Attendance**
Attendance at all scheduled classes is mandatory and essential for success in the course. If you miss class for any reason, you are responsible for getting notes from classmates.

**Students with Special Needs**
To request academic accommodations due to a special need, please contact Rafif Srour via email at: Rafif.Srour@ie.edu.

**Student Privacy Statement**
At times, students may disclose personal information through class discussions. It is expected that all members of the class will respect the privacy of their classmates. This means that the information disclosed in the class will not be repeated or discussed with other students outside of the course.

**Decisions about Grades**
Decisions about grades are made very carefully, and are final at the end of the course. If you have questions regarding a certain grade or you would like to receive personal feedback, you must request a meeting with me to discuss grades on specific assignments before the last class of the course. Any disputes regarding grades must be resolved before the final exam. “Extra credit” or makeup assignments will not be granted.

**ACADEMIC INTEGRITY**

Unless you are specifically instructed to work with other students in a group, all of your assignments, papers, projects, presentations, and any work assigned must reflect your own work and thinking.

**What is academic integrity?** When you do the right thing even though no one is watching. The core values of integrity, both academic and otherwise include: honesty, fairness, respect, responsibility, and trust. Academic Integrity requires that all students within Instituto de Empresa (IE) act in accordance with these values in the conduct of their academic work, and that they follow the rules and regulations concerning the accepted conduct, practices and procedures of academic research and writing. Academic Integrity violations are defined as Cheating, Plagiarism or other violations of academic ethics.
Cheating and plagiarism are very serious offenses governed by the IE student code of conduct. Any student found cheating or plagiarizing on any assignment or component of this course will at a minimum receive a “0” on the affected assignment. Moreover, the student will also be referred to the University Judicial System for further action. Additional penalties could include a note on your transcript, failing the class, or expulsion from the university.

It is important to note that, while the list below is comprehensive, it should not be considered exhaustive.

**Cheating includes:**

- An act or attempt to give, receive, share, or utilize unauthorized information or unauthorized assistance at any time for assignments, papers, projects, presentations, tests or examinations. Students are permitted to mentor and/or assist other students with assignments by providing insight and/or advice. However, students must not allow other students to copy their work, nor will students be permitted to copy the work of other students. Students must acknowledge when they have received assistance from others.
- Failure to follow rules on assignments, papers, projects, presentations, tests or examinations as provided by the course professor and/or as stipulated by IE.
- Unauthorized co-operation or collaboration.
- Tampering with official documents, including electronic records.
- The impersonation of a student on presentations, exercises, tests or an examination. This includes logging onto any electronic course management tool or program (e.g. Black Board, etc.) using someone else’s login and password.

**Plagiarism includes:**

- Using the work of others and attempting to present it as your own. For example, using phrases or passages from books, articles, newspapers, or the internet and not referencing them properly in your document. This includes using information from others without citing it, misrepresentation of cited work, and misuse of quotation marks.
- Submitting an assignment or paper that is highly similar to what someone else has written (i.e., minimal changes in wording, or where the sentences are similar, but in a different order).
- You don’t have to commit “word for word” copying to plagiarize – you can also plagiarize if you turn in something that is “thought for thought” the same as someone else.

**Other violations of academic ethics include:**

- Not acknowledging that your work or any part thereof has been submitted for credit elsewhere.
- Misleading or false statements regarding work completed.
- Knowingly aiding or abetting anyone in committing any form of an Academic Integrity violation.
CODE OF CONDUCT IN CLASS

1. **Be on time**: Students arriving more than 5 minutes late will be marked as “Absent”. Only students that notify in advance in writing that they will be late for a specific session may be granted an exception (at the discretion of the professor).

2. **If applicable, bring your name card and strictly follow the seating chart**: It helps faculty members and fellow students learn your names.

3. **Do not leave the room during the lecture**: Students are not allowed to leave the room during lectures. If a student leaves the room during lectures, he/she will not be allowed to re-enter and, therefore, will be marked as “Absent”. Only students that notify that they have a special reason to leave the session early will be granted an exception (at the discretion of the professor).

4. **Do not engage in side conversation**: As a sign of respect toward the person presenting the lecture (the teacher as well as fellow students), side conversations are not allowed. If you have a question, raise your hand and ask it. If you do not want to ask it during the lecture, feel free to approach your teacher after class. If a student is disrupting the flow of the lecture, he/she will be asked to leave the classroom and, consequently, will be marked as “Absent”.

5. **Use your laptop for course-related purposes only**: The use of laptops during lectures must be authorized by the professor. The use of Social Media or accessing any type of content not related to the lecture is penalized. The student will be asked to leave the room and, consequently, will be marked as “Absent”.

6. **No cellular phones**: IE University implements a “Phone-free Classroom” policy and, therefore, the use of phones, tablets, etc. is forbidden inside the classroom. Failing to abide by this rule entails expulsion from the room and will be counted as one absence.

7. **Escalation policy: 1/3/5**: Items 4, 5, and 6 above entail expulsion from the classroom and the consequent marking of the student as “Absent.” IE University implements an “escalation policy”: The first time a student is asked to leave the room for disciplinary reasons (as per items 4, 5, and 6 above), the student will incur one absence, the second time it will count as three absences, and from the third time onward, any expulsion from the classroom due to disciplinary issues will entail 5 absences.