MSc in Bioinformatics for Health Sciences

MAT. Elements of Mathematics

Syllabus Information

Academic Course: 2018/19

Academic Center: 804 - Official Postgraduate Programme in Biomedicine

Study: 8045 – Bioinformatics for Health Sciences - MSc

Subject: 31035 – MAT. Elements of Mathematics

Credits: 5.0

Course: 1st

Teaching languages: English

Teachers: Eduardo Eyras

Teaching Period: 1st term

Presentation

The aim of the course is to provide elementary mathematical tools of general use in data analysis, and also required in more advanced subjects, related to linear algebra and optimization. The work will include theory classes, written exercises and practical classes to solve mathematical problems. This course will require the student a lot of self-study time to grasp the most theoretical concepts and to do the homework to acquire enough knowledge to pass the final exam. Basic understanding of how mathematical proofs work and some practice with basic proofs will be covered in the class.

Associated skills

General competences:

Instrumental:

1. Proficient reading/writing/listening scientific English related to the subject.
2. Ability to analyze the correct mathematical tools for solving a particular problem.
3. Ability to solve with pen and paper basic linear algebra and optimization problems.
4. Knowledge of basic programming to operate with matrices.

Interpersonal:

1. Group work.
2. Ability to solve by yourself a given problem.

Systemic:

1. Analysis, abstraction and synthesis abilities.
2. Ability to search for information
3. Capacity of writing in formal mathematical language and write mathematical proofs

Specific competences:

- To understand the concept of vector space over the real numbers
- To understand the concept of generators, lineal dependence, basis, basis change and dimension
- To understand the concept of linear map and isomorphism
- To understand the concept of diagonalization of matrices
- To understand the concept of scalar product, metric, norm, orthogonality and angles
- To understand the concept of many-valued function
- To understand the concepts of continuity, partial derivatives, directional derivatives, Jacobian and Hessian matrices of a many-valued function, and their relationship with the optimization of a functions
- To understand the concept of Lagrange multipliers, and to master the Lagrange method for optimization with equality constraints
- To master techniques of local and global optimization of many-valued functions, with or without inequality constraints
- To understand techniques of approximate optimization and learn how to work with them

Contents

Block 1: Linear Algebra.

Concepts	**Procedures**
Vector spaces and subspaces	
Linear dependence, system of generators, basis	Basis of a vector space. Change of basis of a vector space.
Linear map, isomorphism	Matrix associated to a linear map in a certain basis. Change of basis of a linear map. Kernel of a linear map. Homogeneous system of linear equations.
Diagonalization of matrices, eigenvectors and eigenvalues.	Eigenvalues and eigenvectors of a linear map. Diagonalizable matrices. Applications. Singular Value Decomposition (SVD) PCA

Block 2: Analytical and approximate optimization

Concepts	**Procedures**
Sets	Open, closed and compact sets.
Many-valued function, continuity	Domain of a many-valued function where it is continuous.
Partial derivatives, directional derivatives, tangent hyperspace.	Partial derivatives of a many-valued function. Directional derivatives of a many-valued function. The tangent hyperplane to a many-valued function.
Critical points, free optimization, second order conditions	Critical points of a many-valued function. Local and global optima of a many-valued function.
Optimization. Method of the Language multiplers	Local and global optima of a many-valued function restricted to an equality constraint. Optimization with inequality constraints
Approximate optimization	Approximate methods of optimization. Example: Support Vector Machines

Teaching methods

- In the classroom: Work in the classroom includes the correct understanding of the theory and practical exercises. Moreover, a more practical work applying the theory to easy problem solving and examples is expected from the student (total 32 hours).

- Outside the classroom: Activities outside the classroom includes the resolution of problem sets (one for each section of the course) and the complete understanding the mathematical proofs studied in class (total 93 hours).

Evaluation

General assessment criteria:

The evaluation will consist on a final exam at the end of the course, worth ~50%, and the evaluation of a problem set delivered during the course, worth ~50%.

Grading system

Grades are between 0 and 10 and an overall 5 is needed to pass

Competence Evaluation	Attainment indicator	Assessment procedure	Scheduling
Instrumental			
1. Proficient reading/writing/ listening scientific English related to the subject	Correct understanding of proposed problem sets, and correct final presentation.	Implicit in the exam and exercises	Progressive
3. Ability to solve with pen and paper basic linear algebra, geometry, optimization and calculus problems.	Correct solution of the proposed execises	Implicit in the exam and problem sets	Progressive
4. Knowledge of office software to write mathematics reports.	High quality report containing the results to the problem sets.	Implicit in the problem sets.	Progressive
Interpersonal			
1. Group work	Ability to do team work both in programming and in preparing final presentation	Implicit in group problem sets.	Progressive
2. Ability to solve by yourself a given problem	Correct answer of set of pen and pencil exercises and examination	Implicit final exam	End of the term

Competence Evaluation	**Attainment indicator**	**Assessment procedure**	**Scheduling**
Systemic			
1. Analysis, abstraction and synthesis abilities	Development of algorithms for proposed problems.	Implicit in problem sets and final exam	Progressive
2. Ability to search for information	Complete final presentation	Implicit in problem sets	Progressive
3. Capacity of writing formal mathematical proofs	Correct formal proofs of the mathematical propositions proposed in the final exam and in the problem sets.	Implicit in problem sets and final exam.	Progressive

Bibliography and Information Resources

- Mathematics for Machine Learning: https://mml-book.github.io/
- Cerdà, J., Linear Functional Analysis. American Mathematical Society, 2010.
- Course on Linear Algebra. Jim Hefferon. Saint Michael's College. USA 2014. http://joshua.smcvt.edu/linearalgebra/
- Calculus For Biologists: A Beginning. Getting Ready For Models and Analyzing Models. James Peterson. Gneural Gnome Press 2008.
- Mathematics for Biologists. Kirsten ten Tusscher and Alexander Panfilov. Theoretical Biology & Bioinformatics. Utrecht University 2011.