Academic Year/course: 2021/22

69701 - Biostatistics and numerical simulation in biomedical engineering

Syllabus Information

Academic Year: 2021/22
Subject: 69701 - Bioestadística y simulación numérica en ingeniería biomédica
Faculty / School: 110 - Escuela de Ingeniería y Arquitectura
Degree: 633 -
ECTS: 6.0
Year: 2 and 1
Semester: First semester
Subject Type: Compulsory
Module:

1. General information

1.1. Aims of the course

Both, the course and its expected outcomes are aimed at the following targets:

Biostatistics provides the necessary tools for the quantitative assessment of uncertainty in data as well as the knowledge of common statistical techniques in the biomedical context.
Students learn to recognise cases where single or multi-population procedures are useful along with the application of parametric or non-parametric techniques.

Regression models in observational studies are also introduced. Students learn how to predict future values, providing error estimates for such predictions.
The usual techniques for survival data analysis and the methods for comparison of risk in patients under different treatments are part of this course.
At the end of the course students are able to cope with the analysis of a database using the appropriate software.

At the same time, the course should lead the student to know a wide range of numerical techniques that will allow him/her to choose the most appropriate one for a specific problem in the field of Biomedical Engineering. It will also provide them with the necessary knowledge to implement these methods in their own or commercial software. It is also important that that the student understands the possibilities and limitations of these techniques.

Consequently, the overall objective of the course is that the student knows, understands and knows how to use a set of numerical tools to obtain approximate solutions to the problems in the field of Biomedical Engineering, both in the statistical field, as well as in the field of mechanics of continuous media.

The foregoing objectives follow some of the Sustainable Development Goals and (SDGs) adopted as part of the 2030 Agenda dor Sustainable Development and certain specific aims. Thus the learnig goals of this course make the student be competent to get closer to them.

- Goal 3: Ensure healthy lives and promote well-being for all at all ages

Target 3.B Support the research and development of vaccines and medicines for the communicable and noncommunicable diseases that primarily affect developing countries, provide access to affordable essential medicines and vaccines, in accordance with the Doha Declaration on the TRIPS Agreement and Public Health, which affirms the right of developing countries to use to the full the provisions in the Agreement on Trade Related Aspects of Intellectual Property Rights regarding flexibilities to protect public health, and, in particular, provide access to medicines for all.

- Goal 8: Decent work and economic growth

Target 8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors

- Goal 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation

Target 9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities

Target 9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending

- Goal 12: Ensure sustainable consumption and production patterns

Target 12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse

1.2. Context and importance of this course in the degree

Biostatistics and Numerical Methods is a compulsory course in the Master's Degree in Biomedical Engineering.

The teaching of of both subjects focuses on the basic statistical and mathematical tools that are used in other courses of the master's degree. It is addressed to Biomedical Engineering.

This course aims to adapt the tools and techniques available in Statistics and Engineering to the biomedical field. In recent years these techniques have undergone spectacular development, becoming one of the fundamental tools in many fields of bioengineering (computational modelling, solving complex problems, obtaining approximate solutions, adjusting experimental data, etc.).

1.3. Recommendations to take this course

This subject is mandatory and it is tought at a basic level. It can be taken by students from both technical and biomedical areas with no further requirements other than basic Probability and Statistics at the level of an undergraduate degree.

The instructors of the course are in the areas of Mechanics of Continuous Media and Theory of Structures and Statistics and Operations Research.

2. Learning goals

2.1. Competences

Upon successful completion of the course, students are able to:

Get and understand knowledge providing the basis or opportunity for original development and/or application of ideas, often in a research context. [CB.6]

Apply the acquired knowledge and problem-solving skills in new or not well-known environments within broader (or multidisciplinary) contexts related to their area of study. [CB.7]

Integrate knowledge, facing the complexity of formulating judgements based on information that being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgements. [CB.8]

Communicate their conclusions and the ultimate knowledge and reasons that support them to specialised and non-specialised audiences in a clear and unambiguous way. [CB.9]

Get the learning skills that will enable them to keep on studying in a way that will be largely self-directed or autonomous. [CB.10]

Be able to use the techniques, skills and tools of engineering necessary for the problem solving in the biomedical and biological field (CG.2).

Be able to continuous learning and develop autonomous learning strategies (CG.4).

Be able to manage and use bibliography, documentation, legislation, databases, along with specific software and hardware for biomedical engineering (CG.5).

Be able to interpret observational or experimental biomedical data, to characterise the relationships between them and to evaluate hypotheses on them by means of appropriate statistical tests (CE.1).

Be able to apply, evaluate and interpret the most widely used statistics in biomedical research, epidemiology and clinical studies, evaluating the performance of diagnostic and prognostic indices (CE.2).

Be able to understand and apply methods of algebra, geometry, differential and integral calculus and optimisation to design and evaluate solutions to problems that may arise in the field of Biomedical Engineering (CE.3).

Be able to use and appraise computer tools for statistical calculation and numerical simulation in the field of Biomedical Engineering (CE.4).

2.2. Learning goals

Requirements to pass this course:

Students should be able to interpret observational or experimental data from biomedical origin, getting their information and the relationships between them. They should know how evaluate hypotheses in the presence of variability.

Capability to understand the methods for hypotheses testing on means, variances and proportions, related to quantitative or categorical biomedical data. Knowledge on how to apply the appropriate test depending on the characteristics of the data, interpreting their results.

Students should be able to determine relationships between variables in observational studies. They know the procedures for model building and their corresponding validation to explain these relationships, as well as the most relevant techniques of multivariate analysis.

Capability to understand and interpret the most widely used terminology and statistics in epidemiology and clinical studies, including those referring to frequency of occurrence, risk and survival analysis and diagnostic or predictive capacity.

Know the methods of numerical interpolation, differentiation and integration.

To know the least squares adjustment technique and optimisation techniques.

To know the methods of numerical resolution of equations and systems of differential equations of biological systems. Applications to initial value and boundary problems.

Know the methods for the numerical solution of partial differential equations describing biological systems.

Be able to choose the most appropriate numerical technique (finite elements, finite differences, finite volumes) for solving each type of problem within the framework of Biomedical Engineering.

Know how to handle, at user level, numerical calculation programmes (Matlab), as well as how to develop simple algorithms in these codes.

Know how to handle, at user level, general finite element codes (Abaqus) and solve simple problems in the field of Biomedical Engineering.

2.3. Importance of learning goals

Many biomedical problems usually lead to working hypotheses whose verification can only be stated on the basis of statistical results. The corresponding analysis is based on information collected from observational databases, often large, or arising from experimentation. Statistical methods are right the procedure for extracting the relevant information contained therein, recognising patterns or relationships between variables of interest.

On the other hand, reviewing bibliography is part of the research activity. The results appearing in those references are based on statistical analysis, tests significancy or statistical models, so that it is necessary to interpret them properly or assess their relevance for the research itself.

In addition, this subject will provide the student with the basic knowledge necessary to be able to use numerical techniques in the field of Biomedical Engineering. This knowledge will be necessary in subsequent optional subjects with a strong computational character, such as: "Modelling the Behaviour of Musculoskeletal Tissues", "Biomechanics and Biomaterials" or "Design of Prostheses and Implants using Computational Tools".

3. Assessment (1st and 2nd call)

3.1. Assessment tasks (description of tasks, marking system and assessment criteria)

To pass the course, it will be necessary to get a grade equal to or higher than 5 in both, Biostatistics and Numerical Methods. If a score equal to or higher than 5 is obtained only in one of the two parts, Biostatistics and Numerical Methods, the student will only take the exam of the pending part in the September exam.

The activities to be carried out for the assessment of Biostatistics are:

Written test on data analysis (30% of the final qualification). The student must obtain a minimum total score of 5 points out of 10 in the final exam. There will be an overall test in each of the two possible rounds, on the dates and at times determined by the School.

Academic work (15% of the final qualification). The assessment of the tutored work, both the report presented as well as the adequacy and originality of the proposed solution will be taken into account.

Assessment of laboratory practice (5% of the final qualification).

The activities to be carried out for the evaluation of the Numerical Methods part will be:

Subject exam (time available: 1 hour): Minimum exam, multiple choice (multiple choice, four answers with penalties for failures). Marking from 0 to 10. (The grade of this test will represent 30% of the final qualification).

Subject Work: The work will consist of the implementation of a numerical technique for solving simple problems. The implementation may be carried out in numerical or symbolic solving programs (Matlab). The grade of this test will represent 15% of the final qualification. Total time of dedication: 20 hours.

Evaluation of laboratory practices (5% of the final qualification).

There will be an overall test in each of the two possible rounds, on the dates and at times determined by the School.

4. Methodology, learning tasks, syllabus and resources

4.1. Methodological overview

The proposed methodology aims at encouraging student continuous work. The course begins reviewing basic statistical concepts such as estimation, hypothesis testing, and p-values. Non-parametric tests along with tests for categorical data and survival analysis are also presented. The association between variables is analyzed by means of regression models. The

course focuses on simple linear regression as well as on generalized linear models, logistic regression and survival regression models. A wide range of teaching and learning tasks are implemented, such as
Lectures, where the general principles of the course -theory with illustrative examples- are presented to the whole student group.
Computer lab sessions, where students deal with both data analysis and modelling of real events by means of specific statistical software.
For the Numerical Methods section, the learning process provides the students with a set of numerical techniques and tools that can help them in the future to solve diverse problems based in partial deferential equations, which are essential in the Bioengineering field. Similarly to the previous section, in lectures there is a revision of the fundamental equations of the continuum mechanics to give a step ahead to the most extended numerical techniques for the solution of such type of problems. In practice sessions the students can consolidate those concepts previously seen in lectures, under the teacher's supervision.

4.2. Learning tasks

The course includes the following learning tasks:

Section 1. Biostatistics
A01 Lectures (10 hours). The teacher presents the main concepts and techniques to be developed in the computer room.
A03 Computer Lab sessions(20 hours). Students are enabled to use specific software for the different. statistical procedures.
A05 Assignment. Each student develops an individual task regarding the use of statistical procedures in biomedical data. Students can choose data-bases they are particularly interested in or, alternatively, data-bases provided by the instructor. In the latter case it will correspond to a published research article containing statistical techniques. In either case a written report is mandatory.
A06 Tutorials. Personal assistance to students aiming at reviewing and discussing the topics presented in class.
A08 Assessment. A set of written tests and reports that the student has to complete along the course. The grading system is described in point 4 of this guide.

Section 2. Numerical Simulation
A01 Lectures (24 hours). The teacher will present the basic fundamental concepts needed for the development of the course objectives in the lecture room.
A03 Computer Lab sessions (6 hours). The main objective of these sessions is to learn and practice the use of specific software for the solution of differential equation problems in order to consolidate the theoretical techniques previously seen in the lectures.
A05 Assignments. The student has to implement practical code in MatLab to reproduce a bioengineering problem using the learned numerical techniques.
A06 Tutorials. The students can receive personal assistance by the teachers to review and/or discuss the topics presented in class.
A08 Assessment. A set of written tests and reports that the student has to complete along the course. The grading system is described in point 4 of this guide.

4.3. Syllabus

The course will address the following topics:

Section 1. Biostatistics
1. Introduction
1.1. Exploratory data analysis.
1.2. Review of basic concepts on estimation, confidence intervals, hypothesis testing, goodness-of- fit tests.
Topic 2. Parametric and non-parametric tests for one or several samples.
2.1. Tests for normal distributions, ANOVA, multiple comparisons.
2.2. Non-parametric tests: One-sample sign, one-sample Wilcoxon, Mann-Whitney, Kruskal-Wallis.
Topic 3. Regression models
3.1. Simple linear regression, model building and checking, Box-Cox transformation, prediction.
3.2. Generalized Linear model, covariates and factors, covariance analysis, variance decomposition, ANOVA, automatic model building.
3.3. Linear model with multivarite response, MANOVA.
Topic 4. Models for categoric data.
4.1. Contingency tables
4.2. Logistic regression models, log-linear models.
Topic 5. Suvival data analysis.
5.1. Measures of risk and survival. Censor data. Kaplan-Meier estimator
5.2. Parametric models: Weibull.
5.3. Semiparametric models: proportional hazard model.

Section 2. Numerical Methods
Topic 1. Introduction.
Topic 2. The basic equations of continuum mechanics.
Topic 3. Numerical methods.
Topic 4. Finite differences Method (FDM).
Topic 5. Finite Element Method (FEM).
Topic 6. Finite Volume Method (FVM).

4.4. Course planning and calendar

Further information concerning the timetable, classroom, office hours, assessment dates and other details regarding this course, will be provided on the first day of class or please refer to the EINA website (http://eina.unizar.es).

4.5. Bibliography and recommended resources

http://psfunizar10.unizar.es/br13/egAsignaturas.php?codigo=69701