Course guide
270677 - SANS - Statistical Analysis of Networks and Systems

Last modified: 13/07/2022

Unit in charge: Barcelona School of Informatics
Teaching unit: 701 - DAC - Department of Computer Architecture.

Degree: MASTER'S DEGREE IN INNOVATION AND RESEARCH IN INFORMATICS (Syllabus 2012). (Optional subject).

Academic year: 2022 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: JORGE GARCÍA VIDAL

Others: Primer quadrimestre:
JOSE MARIA BARCELÓ ORDINAS - 10
JORGE GARCÍA VIDAL - 10

PRIOR SKILLS

Basic knowledge of probability theory, linear algebra and calculus

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEE2.2. Capability to understand models, problems and algorithms related to computer networks and to design and evaluate algorithms, protocols and systems that process the complexity of computer communications networks.

Generical:
CG4. Capacity for general and technical management of research, development and innovation projects, in companies and technology centers in the field of Informatics Engineering.

Transversal:
CTR5. APPROPIATE ATTITUDE TOWARDS WORK: Capability to be motivated by professional achievement and to face new challenges, to have a broad vision of the possibilities of a career in the field of informatics engineering. Capability to be motivated by quality and continuous improvement, and to act strictly on professional development. Capability to adapt to technological or organizational changes. Capacity for working in absence of information and/or with time and/or resources constraints.

Basic:
CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.

TEACHING METHODOLOGY

Some materials will be posted online. The main results will be explained in the blackboard. Classes with problem solving and application examples.

LEARNING OBJECTIVES OF THE SUBJECT

1.The main goal of the course is to develop in the students quantitative modeling skills, based on probabilistic techniques.

STUDY LOAD

Type	Hours	Percentage
Hours large group	54,0	36.00
Self study	96,0	64.00

Total learning time: 150 h

CONTENTS

Probability models

Description:
Probability axioms, basic combinatorics, random variables, independence and conditional probability, expected values (review, only problems and online material), inequalities (Markov, Chebyshev, Jensen), (weak) Law large numbers, entropy and mutual information. Properties of Gaussian distributions, central limit theorem.

Linear models

Description:
Spectral theorem for symmetric matrices. Positive-definite matrices, quadratic forms. SVD. Curse of dimensionality, High-dimensional spaces. Dimensionality reduction. PCA. Monroe-Penrose pseudo-inverse.

Estimation. Basic Machine Learning techniques for classification and regression

Description:
Maximum likelihood and bayesian estimation. Decision functions, Loss, Risk, Empirical Risk minimization. Approximation and estimation. Bias-variance tradeoff. Classification. Linear regression.

Graphical models and dynamic systems

Description:
Graphical models. Belief propagation. Hidden Markov Models. Kalman filters. Time series

ACTIVITIES

Probability models

Description:
Probability axioms, basic combinatorics, random variables, independence and conditional probability, expected values (review, only problems and online material), inclusion/exclusion, conditional independence, inequalities (Markov, Chebyshev, Jensen), examples: Bernouilli, Binomial, Multinomial, Poisson, (weak) Law large numbers, entropy and mutual information. Density functions, examples: uniform, exponential, Gaussian (review, problems and online material), beta, dirichlet, (eigenvalues/eigenvectors, symmetric, positive definite matrices video), multivariate gaussian, memoryless of exponential distribution. Properties of Gaussian distributions, central limit theorem.

Specific objectives:
1

Related competencies :
CG4. Capacity for general and technical management of research, development and innovation projects, in companies and technology centers in the field of Informatics Engineering.
CEE2.2. Capability to understand models, problems and algorithms related to computer networks and to design and evaluate algorithms, protocols and systems that process the complexity of computer communications networks.
CTR5. APPROPIATE ATTITUDE TOWARDS WORK: Capability to be motivated by professional achievement and to face new challenges, to have a broad vision of the possibilities of a career in the field of informatics engineering. Capability to be motivated by quality and continuous improvement, and to act strictly on professional development. Capability to adapt to technological or organizational changes. Capacity for working in absence of information and/or with time and/or resources constraints.
CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.

Full-or-part-time: 12h
Theory classes: 6h
Practical classes: 6h

Linear models

Description:
Spectral theorem for symmetric matrices. Positive-definite matrices, quadratic forms. SVD. Dimensionality reduction. PCA. Monreo-Penrose pseudo-inverse. Infinite-dimension vector spaces. Continuity of linear operators. Hilbert spaces. Riesz representation theorem.

Specific objectives:
1

Related competencies :
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Full-or-part-time: 12h
Theory classes: 6h
Practical classes: 6h

Estimation. Basic Machine Learning techniques for regression and classification

Description:
Maximum likelihood and bayesian estimation. Linear regression. Bias-variance tradeoff. Classification.

Full-or-part-time: 12h
Theory classes: 6h
Practical classes: 6h

Graphical models & dynamic systems

Description:
Graphical models. Belief propagation. Hidden Markov Models. Kalman filters. Time series.

Specific objectives:
1

Related competencies :
CG4. Capacity for general and technical management of research, development and innovation projects, in companies and technology centers in the field of Informatics Engineering.
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Full-or-part-time: 12h
Theory classes: 6h
Practical classes: 6h

self-evaluating tests

Specific objectives:
1

Related competencies :
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CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.

Full-or-part-time: 18h 30m
Guided activities: 1h 30m
Self study: 17h

self-assesment test T2

Specific objectives:
1

Related competencies :
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CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.

Full-or-part-time: 18h 30m
Guided activities: 1h 30m
Self study: 17h

self assesment test T3

Specific objectives:
1

Related competencies :
CG4. Capacity for general and technical management of research, development and innovation projects, in companies and technology centers in the field of Informatics Engineering.
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CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.

Full-or-part-time: 20h 30m
Guided activities: 1h 30m
Self study: 19h

self assesment test T4

Specific objectives:
1

Related competencies :
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CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.

Full-or-part-time: 20h 30m
Guided activities: 1h 30m
Self study: 19h

Homework1

Full-or-part-time: 4h 30m
Self study: 4h 30m

Homework 2

Full-or-part-time: 6h
Self study: 6h

Homework 3

Full-or-part-time: 6h
Self study: 6h

Homework 4

Full-or-part-time: 6h
Self study: 6h

GRADING SYSTEM

The evaluation is based on the development of several projects. Each of the projects will be evaluated (0=
FM = Sum_i (Wi*Mi)

Where:

Wi = is the weight of each project i = 1, ... N
Mi = is the mark of each project i = 1, ... N

The number of projects may vary over time, but in general, the following projects are foreseen:
* P1 (25%): Basic probability, information theory, and linear algebra,
* P2 (25%): Estimation, ML and Bayesian approaches
* P3 (25%): Understanding Bias-Variance tradeoff
* P4 (25%): Basic regression and classification

BIBLIOGRAPHY

Basic:
- MacKay, D.J.C. Information theory, inference, and learning algorithms. Cambridge University Press, 2003. ISBN 0521642981.
- Feller, W. An introduction to probability theory and its applications. 3rd ed. John Wiley and Sons, 1968. ISBN 0471257117.
- Evans, M.J.; Rosenthal, J.S. Probability and statistics: the science of uncertainty. 2nd ed. W.H. Freeman and Company, 2010. ISBN 9781429224628.
- Bishop, C.M. Pattern recognition and machine learning. New York: Springer, 2006. ISBN 0387310738.
- Blum, Arvim; Hopcroft, John; Kannan, Ravindran. Foundations of data science. Cambridge: Cambridge University Press, 2020. ISBN 9781108485067.

Complementary:
- Rosenthal, J.S. A first look at rigorous probability theory. 2nd ed. Singapore: World Scientific, 2006. ISBN 9812703713.
- Wainwright, M.J.; Jordan, M.I. "Graphical models, exponential families, and variational inference". Foundations and Trends in Machine Learning [on line]. Vol. 1, Nos. 1-2 (2008), pp. 1-305 [Consultation: 24/07/2020]. Available on: https://people.eecs.berkeley.edu/~wainwrig/Papers/WaiJor08_FTML.pdf.

RESOURCES

Hyperlink:
- http://www.inference.phy.cam.ac.uk/mackay/itila/