Universitat Autònoma de Barcelona

**2017/2018**

# Pattern Analysis and Recognition

Code: 43340
ECTS Credits: 6

| Degree | Type | Year | Semester |
|---|---|---|---|
| 4314660 Computer Engineering | OB | 1 | 2 |

## Contact

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## Use of languages

Principal working language: english (eng)

## Prerequisites

Programming in Python.

Good level of English.

Basic understanding of linear algebra, integration and derivation, and the concept of probability

The subject of Pattern Analysis and Recognition follows in the line of related undergraduate courses on e.g. artificial intelligence, reasoning, machine learning, computer vision, where basics of pattern analysis and recognition have been introduced. Although the course is designed to build up from a minimum amount of prior knowledge, exposure to these topics would be beneficial for the students.

## Objectives and Contextualisation

The focus of this course, apart from providing the theoretical basis of pattern analysis and recognition, is to demonstrate the tools and methodologies required for applying the received knowledge in real-life problems, and build up experience in a practical application sense.

The course will introduce the basics of a number of themes in different detail. A subset of these themes will be worked further through the development of project work. This structure allows the course to cover the issue of pattern recognition in considerable breadth through the lectures, introducing a number of concepts and methodologies, while at the same time it allows the students to acquire more in-depth experience with a subset of the themes examined through the practical work. In parallel, the course demands the students to work both autonomously to learn and expand their knowledge on the basis of the material introduced, as well as in teams to develop the practical work required.

In particular the following objectives are set for students attending this course:

- To develop a scientific way of thinking and acquire critical reasoning skills
- To develop their teamwork skills and work cooperatively in a group
- To develop their individual learning skills
- To build a good understanding of basic data analysis concepts such as normalization, regularization, probability.
- To have a working knowledge of various methodologies for regression and classification, including Bayesian Classification, Clustering, Support Vector Machines, Nearest Neighbour Search, and Neural Networks.

- To acquire basic knowledge of structural pattern recognition, graph based methods and graphical models.
- To build the ability to develop and evaluate pattern recognition systems apply them to solving real-world problems.

## Skills

- Analyse the information needs of a particular environment and carry out all stages in the construction of an information system.
- Apply mathematical, statistical and artificial-intelligence methods to model, design and develop applications, services, intelligent systems and knowledge-based systems.
- Communicate orally and in writing in English.
- Define and communicate results, guaranteeing high levels of performance and quality.
- Direct work on computer systems, complying with current rules and guidelines and safeguarding the quality of the service.
- Display a capacity for general and technical management and management of research, development and innovation projects in companies and technology centres, in the field of computer engineering.
- Integrate knowledge and use it to make judgements in complex situations, with incomplete information, while keeping in mind social and ethical responsibilities.
- Launch, lead and manage manufacturing processes for computer hardware, safeguarding persons and goods and overseeing product quality and certification
- Lead, plan and supervise multidisciplinary teams
- Oversee, manage, audit and certify the quality of computing developments, processes, systems, services, applications and products.
- Propose, calculate and design products, processes and installations in all areas of computer engineering.
- Undertake mathematical modelling, calculation and simulation in technological centres and engineering companies, especially in research, development and innovation tasks in all areas related to computer engineering.
- Use acquired knowledge as a basis for originality in the application of ideas, often in a research context.

## Learning outcomes

1. Choose the learnt techniques and train them to resolve a particular data-mining project.
2. Communicate orally and in writing in English.
3. Define and communicate results, guaranteeing high levels of performance and quality.
4. Direct work on computer systems, complying with current rules and guidelines and safeguarding the quality of the service.
5. Display a capacity for general and technical management and management of research, development and innovation projects in companies and technology centres, in the field of computer engineering.
6. Identify the best representations that can be defined for solving both analysis problems and pattern-recognition problems.
7. Identify the best representations that can be defined for solving pattern-recognition problems.
8. Integrate knowledge and use it to make judgements in complex situations, with incomplete information, while keeping in mind social and ethical responsibilities.
9. Launch, lead and manage manufacturing processes for computer hardware, safeguarding persons and goods and overseeing product quality and certification
10. Lead, plan and supervise multidisciplinary teams
11. Model, design, develop and evaluate a solution to a particular problem of pattern-recognition.
12. Propose, calculate and design products, processes and installations in all areas of computer engineering.
13. Undertake mathematical modelling, calculation and simulation in technological centres and engineering companies, especially in research, development and innovation tasks in all areas related to computer engineering.
14. Use acquired knowledge as a basis for originality in the application of ideas, often in a research context.

## Content

**Theme 1 - Basic Concepts**

- Linear Regression
- Normalization
- Logistic Regression
- Reguralization, bias-variance demomposition, Sparsity, sparse methods
- Subspace methods, dimensionality reduction (PCA, whitening, ZCA, LDA)
- Metric learning and Nearest Neighbour Search

**Theme 2 - Bayesian Perspective**

- Probabilities
- Bayesian Decision Theory
- Bayes' theorem
- Bayesian classification
- Bayesian Interpretation of linear regression

**Theme 3 - Clustering**

- K-means clustering
- Gaussian Mixture models
- Expectation Maximisation

**Theme 4 - Kernel methods**

- Kernel methods
- Support Vector Machines
- Support Vector Regression

**Theme 5 - Neural networks**

- Perceptron algorithm
- Neural network architectures
- Backpropagation
- Deep Neural Networks
- Convolutional Neural Networks
- Softmax

**Theme 6 - Advanced Topics**

- Structural Pattern Recognition
- Ensemble Networks
- Graphical Models

## Methodology

The learning process will be based on 2 types of activities: lectures focused on theoretical background and the development of a practical project.

THEORETICAL LECTURES

During these class sessions, the contents of the course will be presented and discussed. The students will be provided with digital material and bibliographic references. The lectures apart from offering a sound theoretical background, will cover all material necessary to develop the course project. All material necessary to follow the theoretical lectures will be provided through the "Campus Virtual" online platform.

PROJECT DEVELOPMENT

The students will be required to develop a project throughout the course. The projects will be the result of teamwork, where small groups of students will be formed in the beginning of the course and work together throughout the course duration.

The project will have the form of a practical solution to a given problem, where the groups will be required to make use of the knowledge acquired during the course, and produce a software solution (code) and a written report. The groups will have the obligation to present their work at the end of the course.

The development of the project will be guided through follow-up sessions every two weeks. During these sessions the requirements for the next stage of the project will be discussed and the students will have a chance to present progress up to date, expose problems, and discuss possible solutions with the teaching staff. Apart from the bi-weekly follow-up sessions, the students are expected to make use of the contact hours with the teaching staff to discuss open questions throughout the course.

The project will be structured in three parts, covering the following knowledge areas:

1. Regression, regularization and dimensionality reduction
2. Feature extraction and Nearest Neighbour
3. Support Vector Machines / Neural Networks

Each part will have a duration of about4-5weeks and willresult to a course deliverable.

## Activities

| Title | Hours | ECTS | Learning outcomes |
|---|---|---|---|
| **Type: Directed** | | | |
| Lectures | 26 | 1.04 | 2, 8, 13, 14 |
| Project sessions | 19 | 0.76 | 1, 2, 3, 6, 7, 8, 10, 11, 12, 13, 14 |
| **Type: Supervised** | | | |
| Project Follow Up | 7 | 0.28 | 2, 6, 7, 8, 10, 14 |
| **Type: Autonomous** | | | |
| Individual study | 45 | 1.8 | 1, 5, 6, 7, 11, 13 |
| Project development | 45 | 1.8 | 1, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14 |

## Evaluation

The evaluation of the student will be done in a continuous process that will take into account the evaluation of the project results, the participation of the students during the lecture and project sessions, and the final exam.

The **deliverables** expected are as follows:

D.1.1 Partial Report and Code (group) #1 (**PR1**)

D.1.2 Partial Report and Code (group) #2 (**PR2**)

D.1.3 Final Project Report and Code (group) (**PR3**)

The **evaluation activities** foreseen are:

E.2.1 Project Defence (group and individual) (**PD**)

E.2.2 Final Examination (individual) (**FE**)

The final grade will be calculated in the following manner:

**FINAL GRADE** = 0.1 * **PR1** + 0.1 * **PR2** + 0.1 * **PR3** + 0.3 * **PD** + 0.4 * **FE**

The minimum grade for each of the deliverables and evaluation activities is 5.

The grade of 4.5 will appear in the student's record in the case that the final grade calculation yields a grade greater or equal to 5, but the student has not reached the minimum requirement in one of the evaluation activities.

Active participation and positive contributions during the classes will result to a rounding of decimal points upwards. In order to opt for a "Matricula d'Honor" it is necessary to have demonstrated an active participation.

The partial reports of the project will be every 4-5 weeks. All deliverables are obligatory.

Any late submission of any of the project deliverables will be evaluated if and only if it takes place before the subsequent project deliverable due date, while the maximum grade awarded in such a cases will be limited to 7/10.

In the case of failing any of the project deliverables, the group will havethe opportunity to resubmit a corrected version of the deliverable, before the day of the final exam.

A no-show in the final exam (FE) implies a "no-show" in the qualification record.

There will be a recovery examination that will permit students to obtain a pass on the theoretical part of the course in the case they have failed the final examination (FE). The date of the recovery examination will be proposed by the School.

All examinations will be adjusted according to the calendar of the School. The due dates for project deliverables will be published on the online platform of the course and are subject to scheduling changes to adapt to any possible incidence. Any changes will be announced through the online platform which is understood to be the principal mechanism for information exchange between the teaching staff and the students.

Without prejudice to other disciplinary action deemed appropriate, and in agreement with the academic regulations in force, any irregularities committed by a student that may lead to an alteration of the final qualification will be graded with a zero (0). For example, plagiarism, copying, etc, during an evaluation activity will involve immediate failure of the activity with a zero (0). In such an incident, the evaluation activities will be indicated with the failing reason, and will not be recoverable. If it is necessary to pass any of these evaluation activities to pass the course, this course will be failed directly, without the opportunity to recover in the same year.

## Evaluation activities

| Title | Weighting | Hours | ECTS | Learning outcomes |
|---|---|---|---|---|
| Final Examination | 0.4 | 2 | 0.08 | 1, 2, 6, 7, 8, 11, 14 |
| Project defence | 0.3 | 6 | 0.24 | 2, 3, 5, 10, 12, 13 |
| Project Deliverables | 0.3 | 0 | 0 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 |

## Bibliography

**The principal references for this course are:**

"Pattern Recognition and Machine Learning (Information Science and Statistics)", C. Bishop, Springer, 2007

"Pattern Classification", R. Duda, P. Hart, D. Stork, 2nd edition, Wiley-Blackwell, 2000

"Artificial Intelligence: A Modern Approach", S. Russell, P. Norvig, 3rd edition, Pearson, 2013

"Deep Learning", I. Goodfellow, Y. Bengio, A. Courville

**Related Web resources:**

Stanford's Machine Learning Course, Coursera, https://www.coursera.org/course/ml

Andrew Ng's course on Neural Networks and Deep Learning, https://www.coursera.org/learn/neural-networks-deep-learning

Machine Learning Summer School Lectures, Video Lectures, http://videolectures.net/mlss09uk_cambridge/

Michael Nielsen, "Neural Networks and Deep Learning", free online book, Jan 2016, http://neuralnetworksanddeeplearning.com/index.html

Ian Goodfellow, YoshuaBengio, and Aaron Courville, "Deep Learning", MIT Press, 2016, http://www.deeplearningbook.org/

Andrea Vedaldi and Andrew Zisserman, "VCC Convolutional Neural Network Practical", http://www.robots.ox.ac.uk/~vgg/practicals/cnn/

CS231n: Convolutional Neural Networks for Visual Recognition, http://cs231n.stanford.edu/

Geoffrey Hinton, Neural Networks for Machine Learning, Coursera, https://www.coursera.org/learn/neural-networks