Subject: Multimedia Signal Processing
Code: 18489
Institution: Escuela Politécnica Superior
Degree: Telecommunication Technologies and Services Engineering
Level: Graduate
Type: Sound and Image specialty
ECTS: 6

1. COURSE TITLE

Multimedia Signal Processing

1.1. Course number

18489

1.2. Course area

Sound and Image

1.3. Course type

Specific Technology Training in Sound and Image

1.4. Course level

Graduate

1.5. Year

3º

1.6. Semester

2º

1.7. Credit allotment

6

1.8. Prerequisites

Multimedia Signal Processing (MSP) belongs to the *Specific Technology Training in Sound and Image* of the Telecommunication Technologies and Services Engineering degree. It is one of the two panoramic subjects of this specific training.

The *Specific Technology Training in Sound and Image* comprises 8 subjects from the third and fourth years of the degree:

- Audio and Video Systems and Services
- Acoustic Engineering
- Multimedia Signal Processing
- Video Technologies
- Audio Technologies
- Visual Signal Processing
- Voice and Audio Signal Treatment
- Digital Television

This subject is based on concepts presented in previous subjects, in particular:

- *Probability and Statistics*, which is part of the Core Course Module, taken in the first semester of the second year.
- *Linear Systems*, which is part of the Core Course Module, taken in the first semester of the second year.
- *Digital Signal Processing*, which is part of the Training Module to the Telecommunications Branch, taken in the first semester of the third year.

In order to take this subject (MSP) it is necessary to be familiar with the use of basic mathematical tools such as the trigonometric functions, complex number operations, and basic integration. It is also a requirement to understand all aspects related to random variable and statistical distributions (learnt in Probability and Statistics).

Very important concepts learnt in the subjects Linear Systems and Digital Signal Processing are the representation of linear systems using their impulse response and their frequency response, the continuous Fourier transform in the time domain, and the sampling and reconstruction of signals to go from the continuous to the discrete domain and vice versa.

1.9. Minimum attendance requirement

1.10. Faculty data

Add @uam.es to all the email addresses below.

Theory:

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1.11. Course objectives

Multimedia Signal Processing (MSP) is an introductory subject focused on advanced multimedia signal processing. The subject is structured in two parts. The first one, which comprises the first two units, goes in depth into different signal processing concepts studied in previous years, generalizing them to multidimensional (in terms of space and time) signals. In particular the students will become familiar with aspects related to lineal systems, frequency analysis, sampling, interpolation, multidimensional transformations, etc. The second part of the course is focused on Machine Learning and pattern recognition techniques and it comprises the last four units: 3) introduction to Machine Learning; 4) supervised learning (giving special attention to the Neural Networks and the Support Vector Machines); 5) unsupervised learning (with special attention to the k-means algorithm); and 6) one last unit where the students will learn how to put in practice the different techniques analysed during the course.

During the course there will be several practice sessions aimed to reinforce the concepts studied during the theory classes and to learn how to use different computational tools that are of great help in the design and analysis of analogue and digital systems.

The competency covered by this course is:

SI1: Capacity to build, exploit and manage uptake services and applications, analogical and digital treatment, encoding, transportation, representation, processing, storage, reproduction, management and presentation of audio-visual services and multimedia information.

At the end of each unit, the student should be capable of:

UNIT BY UNIT SPECIFIC OBJECTIVES	
UNIT 1.- Multidimensional Signals and Systems	
1.1.	Apply to multidimensional signals the different expressions that characterize the lineal and invariant systems.
1.2.	Interpret the frequency components of a multidimensional signal.
1.3.	Understand the basic concepts of the reticule theory which serves as the basis for the sampling of multidimensional signals.
1.4.	Apply basic filters to multidimensional signals.
1.5.	Apply multivariate interpolation techniques to regular structures.
1.6.	Learn the basic techniques for the quantification of multidimensional signals, and in particular those applied to images.
UNIT 2.- Multidimensional Frequency Analysis	
2.1.	Learn the matrix expressions that define a 1D lineal discrete transform, as well as the basic concepts associated to this type of transform.
2.2.	Learn the matrix expressions that define a 2D lineal discrete transform, as well as the basic concepts associated to this type of transform.
2.3.	Study the details and applications of the most used transforms in the field of signal processing (Fourier, sine, cosine).
2.4.	Be able to interpret the transformed domains according to the transform functions, in order to analyze the initial data.
2.5.	Understand the fundamentals of the wavelets transforms.
UNIT 3.- Machine Learning, what do machines think about?	
3.1.	Understand the difference between supervised and unsupervised learning. Become familiar with concepts such as regression and classification.
3.2.	Be able to solve simple lineal regression problems and understand in which cases it should be used.
3.3.	Be able to solve multivariate lineal regression problems and understand in which cases it should be used.
3.4.	Understand the difference between lineal and logistic regression. Become familiar with the most popular logistic regression algorithms, being able to apply them to

	solve simple problems
3.5.	Understand the importance of regularization and learn the most important strategies to carry it out.
UNIT 4.- Supervised learning: Neural Networks and SVMs	
4.1.	Learn practical applications of the supervised learning. Understand the difference between parametric and non-parametric algorithms.
4.2.	Learn the basic concepts about Neural Networks, their origin and their application areas, as well as the most important representation methods.
4.3.	Become familiar with the most important training algorithms for neural networks and in particular with the back-propagation algorithm. Be able to program a simple neural network and apply it to a classification problem.
4.4.	Understand the fundamentals of the Support Vector Machines and their application areas, as well as the importance of correctly selecting their basic parameters.
4.5.	Apply the SVMs to solve complex regression problems.
UNIT 5.- Unsupervised learning: clustering and dimensionality reduction	
5.1.	Understand the importance of unsupervised learning and its application areas.
5.2.	Become familiar with the k-means algorithm as a classic approach to solve the clustering problem and be able to apply it to simple problems.
5.3.	Become familiar with the Expectation Maximization (EM) algorithm as an advanced approach to solve the clustering problem and be able to apply it to simple problems.
5.4.	Understand why the dimensionality reduction is very important in certain problems and learn to different strategies to carry it out: PCA and subset selection.
UNIT 6.- Using Machine Learning	
6.1.	Learn some basic guidelines to put in practice the different Machine Learning techniques studied during the course and to know which of them is better fitted for a given problem.
6.2.	Learn the basic design parameters that define a Machine Learning system.
6.3.	Understand the basic concepts related to biometrics as a real-world pattern recognition problem which has been partially solved using Machine Learning techniques. Be able to implement a basic face recognition system.

1.12. Course contents

UNIT 1: Multidimensional signals and systems.
UNIT 2: Multidimensional Frequency Analysis.
UNIT 3: Machine Learning, what do machines think about?
UNIT 4: Supervised learning: Neural Networks and SVMs
UNIT 5: Unsupervised learning: clustering and dimensionality reduction
UNIT 6: Using Machine Learning

1. **Multidimensional signals and systems.**
    - 1.1. Frequency interpretation of multidimensional signals.
    - 1.2. Sampling of multidimensional signals.
    - 1.3. Discrete multidimensional signals interpolation.
    - 1.4. Quantification of multidimensional signals.

    PRACTICE SESSION 1: Images in MATLAB.
    PRACTICE SESSION 2: Systems LSI.
    PRACTICE SESSION 3: Interpolation.

2. **Multidimensional Frequency Analysis.**
    - 2.1. Unidimensional discrete transforms.
    - 2.2. Bidimensional discrete transforms.
    - 2.3. Fourier, cosine and sine discrete transforms.
    - 2.4. Introduction to the wavelet analysis.

    PRACTICE SESSION 4: Bidimensional discrete transforms.

3. **Machine Learning, what do machines think about?**
    - 3.1. Introduction: supervised vs unsupervised learning
    - 3.2. Lineal regression (simple).
    - 3.3. Multivariate lineal regression (multiple).
    - 3.4. Logistic regression.
    - 3.5. Regularization.

    PRACTICE SESSION 5: Regression.

4. **Supervised learning: neural networks and SVMs**
    - 4.1. Introduction
    - 4.2. Neural Networks: representation.
    - 4.3. Neural Networks: training.
    - 4.4. The SVMs (Support Vector Machines).
    - 4.5. Regression using SVMs.

    PRACTICE SESSION 6: Neural Networks.

5. **Unsupervised learning: clustering and dimensionality reduction**
    - 5.1. Introduction.
    - 5.2. K-means clustering.
    - 5.3. EM algorithm (Expectation Maximization).
    - 5.4. Dimensionality reduction: PCA (Principal Component Analysis) vs Subset Selection.

6. **Using Machine Learning**
    6.1. Advice to use Machine Learning.
    6.2. Design of a Machine Learning system.
    6.3. A practical application of Machine Learning: Biometrics.

    PRACTICE SESSION 7: Face recognition.

1.13. Course bibliography

Basic references:

1. A.K. Jain, "Fundamentals of Digital Image Processing", Prentice Hall, 2005.
2. R.C. Gonzalez, R.E: Woods, "Digital Image Processing", 2ª Ed, Prentice Hall, 2002.
3. Sergios Theodoridis, Konstantinos Koutroumbas, "Pattern Recognition", 4th ed., Academic Press, 2009.

Additional readings:

4. R.C. Gonzalez, "Digital Image Processing using MATLAB", Prentice Hall, 2004.
5. Cristopher M. Bishop, "Pattern Recognition and Machine Learning", 8th ed., Springer Science + Business Media (LLC), 2009.

Other readings:

6. Richard O. Duda, Peter E. Hart, David G. Stork, "Pattern Classification", 2nd ed., John Wiley and Sons, 2001.
7. Ethem Alpaydin, "Introduction to Machine Learning", 1st ed., MIT Press, 2004.