240AR022 - Pattern Recognition & Machine Learning

Coordinating unit: 240 - ETSEIB - Barcelona School of Industrial Engineering
Teaching unit: 707 - ESAIL - Department of Automatic Control
Academic year: 2017
Degree: MASTER'S DEGREE IN AUTOMATIC CONTROL AND ROBOTICS (Syllabus 2012). (Teaching unit Compulsory)
MASTER'S DEGREE IN INDUSTRIAL ENGINEERING (Syllabus 2014). (Teaching unit Optional)
ECTS credits: 6
Teaching languages: English

Teaching staff
Coordinator: ANDREU CATALA MALLOFRE
Others: CECILIO ANGULO
RAUL BENITEZ

Degree competences to which the subject contributes

Specific:
4. The student will be able to model, formulate and solve problems of control, taking into account its uncertainty, by Fuzzy logic based controllers.
5. The student will be able to select and program pattern recognition methods and learning based on the type of problem, after distinguishing if the situation so requires

Generical:
1. Ability to conduct research, development and innovation in the field of systems engineering, control and robotics, and as to direct the development of engineering solutions in new or unfamiliar environments, linking creativity, innovation and transfer of technology
2. Ability to reason and act based on the so-called culture of safety and sustainability

3. Have adequate mathematical skills, analytical, scientific, instrumental, technological, and management information.

Transversal:
6. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.
7. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.
8. ENTREPRENEURSHIP AND INNOVATION: Being aware of and understanding how companies are organised and the principles that govern their activity, and being able to understand employment regulations and the relationships between planning, industrial and commercial strategies, quality and profit.

Teaching methodology
The methodology of the course combines master classes, laboratory sessions and autonomous learning through the development of problem assignments, scientific papers analysis and projects development.

Learning objectives of the subject

Learning Outcomes:
At the end of the course the student should be able:
- To identify, select and implement machine learning, selection of features, and pattern recognition methods according to the problem's characteristics
To suitably represent the structured spatiotemporal information
- To use numerical methods for optimization, machine learning algorithms and pattern recognition systems by considering conventional software packages.

Mandatory Contents:
- Linear models for clustering, classification, and regression.
- Artificial neural networks, support vector machines and kernel methods.
- Learning by demonstration and graphical models.
- Continuous latent variables and sequential data.

1. Support Vector Machines and Kernel methods
2. Learning by demonstration
3. Graphical models
4. Latent continuous variables methods
5. Sequential data
6. Model combination

**Study load**

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours medium group: 27h</th>
<th>18.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours small group: 27h</td>
<td>18.00%</td>
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<tr>
<td></td>
<td>Self study: 96h</td>
<td>64.00%</td>
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### Introductory concepts

**Description:**
This topic will deal with:
- Probability Theory
- Decision Theory

**Related activities:**
Master class

**Specific objectives:**
CB1, CB2, CB3, CG1, CG3, CG8, CT3, CT5, CT6, CT7, CE3, CE11

<table>
<thead>
<tr>
<th>Learning time: 6h</th>
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</thead>
<tbody>
<tr>
<td>Theory classes: 2h</td>
</tr>
<tr>
<td>Practical classes: 0h</td>
</tr>
<tr>
<td>Self study: 4h</td>
</tr>
</tbody>
</table>

### Clustering, regression and classification of linear models

**Description:**
This topic deals with:
- Clustering models
- Linear basis Function models for regression
- Discriminant Functions
- Classification Probabilistic models

**Related activities:**
Master class, troubleshooting and independent learning through exercises

**Specific objectives:**
CB1, CB2, CB3, CG1, CG3, CG8, CT3, CT5, CT6, CT7, CE3, CE11

<table>
<thead>
<tr>
<th>Learning time: 14h</th>
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<tbody>
<tr>
<td>Theory classes: 2h</td>
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<tr>
<td>Practical classes: 2h</td>
</tr>
<tr>
<td>Self study: 10h</td>
</tr>
</tbody>
</table>
### Artificial Neural Networks

**Learning time:** 16h  
Theory classes: 4h  
Practical classes: 2h  
Self study: 10h

**Description:**  
This topic deals with:  
- Perceptron  
- NN structure and learning  
- Feedforward NN and Back Propagation  
- Radial Basis Functions  
- Regularization of NN

**Related activities:**  
Master class, troubleshooting and independent learning through exercises

**Specific objectives:**  
CB1, CB2, CB3, CG1, CG3, CG8, CT3, CT5, CT6, CT7, CE3, CE11

### Support Vector Machines and Kernel methods

**Learning time:** 16h  
Theory classes: 4h  
Practical classes: 2h  
Self study: 10h

**Description:**  
This topic deals with:  
- Statistical Learning Theory  
- Kernel trick

**Related activities:**  
Master class, troubleshooting and independent learning through exercises

**Specific objectives:**  
CB1, CB2, CB3, CG1, CG3, CG8, CT3, CT5, CT6, CT7, CE3, CE11
### Learning by demonstration

**Learning time:** 18h  
- Theory classes: 4h  
- Practical classes: 4h  
- Self study: 10h

**Description:**
This topic deals with:
- Reinforcement Learning
- Applications in robotics

**Related activities:**
Master class, troubleshooting and independent learning through exercises

**Specific objectives:**
CB1, CB2, CB3, CG1, CG3, CG8, CT3, CT5, CT6, CT7, CE3, CE11

### Graphical models

**Learning time:** 16h  
- Theory classes: 4h  
- Practical classes: 2h  
- Self study: 10h

**Description:**
This topic deals with:
- Bayesian networks
- Mixture models and the EM algorithm

**Related activities:**
Master class, troubleshooting and independent learning through exercises

**Specific objectives:**
CB1, CB2, CB3, CG1, CG3, CG8, CT3, CT5, CT6, CT7, CE3, CE11
<table>
<thead>
<tr>
<th>Latent continuous variables methods</th>
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Theory classes: 2h</td>
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<tr>
<td>This topic deals with:</td>
<td>Practical classes: 4h</td>
</tr>
<tr>
<td>· Principal Component Analysis (PCA)</td>
<td>Self study: 10h</td>
</tr>
<tr>
<td>· Feature extraction and dimensionality reduction</td>
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<tr>
<td>· Independent Component Analysis (ICA)</td>
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<td><strong>Related activities:</strong></td>
<td></td>
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<tr>
<td>Master class, troubleshooting and independent learning through exercises</td>
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<tr>
<td><strong>Specific objectives:</strong></td>
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<td>CB1, CB2, CB3, CG1, CG3, CG8, CT3, CT5, CT6, CT7, CE3, CE11</td>
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<table>
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<tr>
<th>Sequential data</th>
<th>Learning time: 16h</th>
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Theory classes: 4h</td>
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<tr>
<td>This topic deals with:</td>
<td>Practical classes: 2h</td>
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<tr>
<td>· Hidden Markov Models (HHM)</td>
<td>Self study: 10h</td>
</tr>
<tr>
<td>· Linear dynamical systems (LDS)</td>
<td></td>
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<tr>
<td><strong>Related activities:</strong></td>
<td></td>
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<tr>
<td>Master class, troubleshooting and independent learning through exercises</td>
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<tr>
<td><strong>Specific objectives:</strong></td>
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<td>CB1, CB2, CB3, CG1, CG3, CG8, CT3, CT5, CT6, CT7, CE3, CE11</td>
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The evaluation system will consist of the following elements:

- E1. Paper-based exams (40%)
- E2. Questions, test, exercises, short reports (25%)
- E3. Project report (35%)
- E4. Re-evaluation, equivalent to E1 (40%)

**Qualification system**

**Model combination**

<table>
<thead>
<tr>
<th>Description:</th>
<th>Learning time: 12h</th>
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<tr>
<td>This topic deals with:</td>
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<tr>
<td>· Mixture of models</td>
<td>Practical classes: 2h</td>
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<tr>
<td>· Data fusion</td>
<td>Self study: 10h</td>
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**Related activities:**
Master class, troubleshooting and independent learning through exercises

**Specific objectives:**
CB1, CB2, CB3, CG1, CG3, CG8, CT3, CT5, CT6, CT7, CE3, CE11

**Bibliography**

**Basic:**