ANX-PR/CL/001-01
LEARNING GUIDE

SUBJECT
93001072 - Machine Learning Lab

DEGREE PROGRAMME
09AQ - Master Universitario en Ingenieria de Telecomunicacion

ACADEMIC YEAR & SEMESTER
2020/21 - Semester 1
Index

Learning guide

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1. Description

1.1. Subject details

<table>
<thead>
<tr>
<th>Name of the subject</th>
<th>93001072 - Machine Learning Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of credits</td>
<td>4.5 ECTS</td>
</tr>
<tr>
<td>Type</td>
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<td>Academic year of the programme</td>
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</tr>
<tr>
<td>Semester of tuition</td>
<td>Semester 3</td>
</tr>
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<td>September-January</td>
</tr>
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<td>Tuition languages</td>
<td>English</td>
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<td>Degree programme</td>
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</tr>
<tr>
<td>Centre</td>
<td>09 - Escuela Tecnica Superior de Ingenieros de Telecomunicacion</td>
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<tr>
<td>Academic year</td>
<td>2020-21</td>
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</table>

2. Faculty

2.1. Faculty members with subject teaching role

<table>
<thead>
<tr>
<th>Name and surname</th>
<th>Office/Room</th>
<th>Email</th>
<th>Tutoring hours *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luis Alfonso Hernandez Gomez (Subject coordinator)</td>
<td>C-330</td>
<td><a href="mailto:luisalfonso.hernandez@upm.es">luisalfonso.hernandez@upm.es</a></td>
<td>Sin horario.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Appointment arranged by email</td>
</tr>
<tr>
<td>Eduardo Lopez Gonzalo</td>
<td>C-330</td>
<td><a href="mailto:eduardo.lopez@upm.es">eduardo.lopez@upm.es</a></td>
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</tr>
<tr>
<td></td>
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<td>Appointment arranged by email</td>
</tr>
</tbody>
</table>

* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.
3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

The subject - recommended (passed), are not defined.

3.2. Other recommended learning outcomes

- It is highly recommended to follow this course simultaneously with the subject Predictive and Descriptive Learning unless you have a theoretical background in Machine Learning and Deep Learning

- Previous exposure to a programming language, such as MATLAB, R or Python

4. Skills and learning outcomes *

4.1. Skills to be learned

CG1 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación.

CG2 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio.

CG4 - Que los estudiantes sepan comunicar sus conclusiones ¿y los conocimientos y razones últimas que las sustentan? a públicos especializados y no especializados de un modo claro y sin ambigüedades.

CG5 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo.

CT1 - Capacidad para comprender los contenidos de clases magistrales, conferencias y seminarios en lengua inglesa.
CT3 - Capacidad para adoptar soluciones creativas que satisfagan adecuadamente las diferentes necesidades planteadas.

CT4 - Capacidad para trabajar de forma efectiva como individuo, organizando y planificando su propio trabajo, de forma independiente o como miembro de un equipo.

CT5 - Capacidad para gestionar la información, identificando las fuentes necesarias, los principales tipos de documentos técnicos y científicos, de una manera adecuada y eficiente.

4.2. Learning outcomes

RA305 - Capability to design, develop and evaluate machine-learning techniques for a wide range of application areas

* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

5. Brief description of the subject and syllabus

5.1. Brief description of the subject

In this laboratory students will learn how to apply the variety of Machine Learning methods presented in the Predictive and Descriptive Learning course to practical scenarios. Students will practice using scientifically-oriented processing environments and most common programming languages and machine learning libraries (TensorFlow, Keras, Python scikit-learn, ML libraries in R).

Along the course students will address practical problems on the application of the variety of Machine Learning methods presented in the Predictive and Descriptive Learning course. Experimental activities will cover both predictive or supervised learning (from classical linear and logistic regression or random forest and SVM to Deep Learning -Feed-forward, Convolutional Networks, Recurrent Networks) and descriptive or unsupervised prevision learning (principal component analysis, t-SNE and cluster analysis). Several realistic and practical scenarios and use cases will be addressed (as those proposed in Kaggle competition, www.kaggle.com). Students will practice using scientifically-oriented languages and cloud environments, mainly working with Python and R languages. Through all lab activities students will have to gain practice on model accuracy using cross-validation and on how to draw precise conclusions and valuable interpretations from machine learning results and models.

The students will acquire the skill to apply the variety of Machine Learning methods on to practical scenarios. Main course outcome will be to consolidate the theoretical study of machine learning techniques along this Master
Programme. Through hands-on experience case studies students will learn how to select and accurately assess the performance evaluation of machine learning methods. They will also acquire solid criteria on what could be best model for a given data and task as well to be able to draw precise conclusions and interpretations from experimental results. By the end of the course, students should be able to:

- Understand how to apply the most used models and techniques for predictive and descriptive learning to different real scenarios.

- Design a proper experimental methodology for accurately assessing and gaining knowledge from the use of each one of the different machine learning techniques.

- Work with both scientifically-oriented processing environments and cluster computing frameworks for big data processing that can be used in a wide range of applications in science and industry.

5.2. Syllabus

1. Introduction to Machine Learning Lab
   1.1. Designing a Machine Learning System
   1.2. Introducing Python for DataScience and Machine Learning

2. Linear Regression
   2.1. Developing interpretable Linear Regression models

3. Classification
   3.1. Developing and understanding Logistic Regression models

4. Resampling methods
   4.1. Using Cross-Validation and Bootstrap

5. Tree-Based Methods
   5.1. Decision trees, Bagging, Random Forests and Boosting

6. Support Vector Machines
   6.1. Kernels and Support Vector Machines

7. Descriptive Learning
   7.1. Principal Components Analysis, t-SNE, K-means and Hierarchical Clustering
8. Introduction to Deep Learning

8.1. Simple Neural Network in TensorFlow (Basic Deep Learning Design Methodology)

8.2. Feed-Forward Neural Networks (TensorFlow and Keras)

8.3. Convolutional Networks for Images and Signals (TensorFlow and Keras)

8.4. Recurrent Neural Networks: Signal and Natural Language Processing use cases (Keras)

8.5. Advanced Deep Learning architectures

9. Building Machine Learning Pipelines
## 6. Schedule

### 6.1. Subject schedule*

<table>
<thead>
<tr>
<th>Week</th>
<th>Face-to-face classroom activities</th>
<th>Face-to-face laboratory activities</th>
<th>Distant / On-line</th>
<th>Assessment activities</th>
</tr>
</thead>
</table>
| 1    | Introduction to Machine Learning Systems  
Duration: 03:00  
Lecture | Introduction to Machine Learning Systems  
Duration: 03:00  
Lecture |  |  |
| 2    | Linear and Logistic Regression Models  
Duration: 03:00  
Laboratory assignments | Linear and Logistic Regression Models  
Duration: 03:00  
Laboratory assignments |  |  |
| 3    | Linear and Logistic Regression Models  
Duration: 03:00  
Laboratory assignments | Linear and Logistic Regression Models  
Duration: 03:00  
Laboratory assignments |  |  |
| 4    | Resampling methods  
Duration: 03:00  
Laboratory assignments | Resampling methods  
Duration: 03:00  
Laboratory assignments |  |  |
| 5    | Tree-based models  
Duration: 03:00  
Laboratory assignments | Tree-based models  
Duration: 03:00  
Laboratory assignments |  |  |
| 6    | Support Vector Machines  
Duration: 03:00  
Laboratory assignments | Support Vector Machines  
Duration: 03:00  
Laboratory assignments |  |  |
| 7    | Descriptive Learning  
Duration: 03:00  
Laboratory assignments | Descriptive Learning  
Duration: 03:00  
Laboratory assignments |  |  |
| 8    | Python for DataScience and Machine Learning  
Duration: 03:00  
Laboratory assignments | Python for DataScience and Machine Learning  
Duration: 03:00  
Laboratory assignments |  |  |
| 9    | Review: Developing Machine Learning models  
Duration: 03:00  
Laboratory assignments | Review: Developing Machine Learning models  
Duration: 03:00  
Laboratory assignments | Evaluation: Developing Machine Learning models  
Individual presentation  
Continuous assessment  
Not Presental  
Duration: 00:10 |  |
| 10   | Feed-forward Networks in TensorFlow and Keras  
Duration: 03:00  
Laboratory assignments | Feed-forward Networks in TensorFlow and Keras  
Duration: 03:00  
Laboratory assignments |  |  |
| 11   | Convolutional Networks for Images and Signals  
Duration: 03:00  
Laboratory assignments | Convolutional Networks for Images and Signals  
Duration: 03:00  
Laboratory assignments |  |  |
| 12   | RNN for Signals and NLP  
Duration: 03:00  
Laboratory assignments | RNN for Signals and NLP  
Duration: 03:00  
Laboratory assignments |  |  |
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<thead>
<tr>
<th></th>
<th>Pipelines and Advanced Deep Learning</th>
<th>Duration: 03:00</th>
<th>Laboratory assignments</th>
<th>Pipelines and Advanced Deep Learning</th>
<th>Duration: 03:00</th>
<th>Laboratory assignments</th>
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<td>17</td>
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<td>Final project evaluation</td>
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<td>Group presentation</td>
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<td>Continuous assessment</td>
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<td></td>
<td>Duration: 00:15</td>
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<td></td>
<td>Final project evaluation</td>
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<td>Evaluation: Developing Machine</td>
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<td>Individual presentation</td>
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<td>Not Presential</td>
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<td>Final examination</td>
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<tr>
<td></td>
<td>Duration: 00:10</td>
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<tr>
<td></td>
<td>Final project evaluation</td>
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<td>Group presentation</td>
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<td>Duration: 00:15</td>
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</table>

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

* The schedule is based on an a priori planning of the subject; it might be modified during the academic year, especially considering the COVID19 evolution.
## 7. Activities and assessment criteria

### 7.1. Assessment activities

#### 7.1.1. Continuous assessment

<table>
<thead>
<tr>
<th>Week</th>
<th>Description</th>
<th>Modality</th>
<th>Type</th>
<th>Duration</th>
<th>Weight</th>
<th>Minimum grade</th>
<th>Evaluated skills</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Evaluation: Developing Machine Learning models</td>
<td>Individual presentation</td>
<td>No Presential</td>
<td>00:10</td>
<td>40%</td>
<td>/ 10</td>
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<td>17</td>
<td>Final project evaluation</td>
<td>Group presentation</td>
<td>No Presential</td>
<td>00:15</td>
<td>60%</td>
<td>/ 10</td>
<td>CG4, CT4, CT1, CT5, CG2, CG5, CG1</td>
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</table>

#### 7.1.2. Final examination

<table>
<thead>
<tr>
<th>Week</th>
<th>Description</th>
<th>Modality</th>
<th>Type</th>
<th>Duration</th>
<th>Weight</th>
<th>Minimum grade</th>
<th>Evaluated skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Evaluation: Developing Machine Learning models</td>
<td>Individual presentation</td>
<td>No Presential</td>
<td>00:10</td>
<td>40%</td>
<td>/ 10</td>
<td>CT4, CT1, CT5, CG2, CG5, CG1, CG4, CT3</td>
</tr>
<tr>
<td>17</td>
<td>Final project evaluation</td>
<td>Group presentation</td>
<td>No Presential</td>
<td>00:15</td>
<td>60%</td>
<td>/ 10</td>
<td>CG4, CT4, CT1, CT5, CG2, CG5, CG1</td>
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7.1.3. Referred (re-sit) examination

<table>
<thead>
<tr>
<th>Description</th>
<th>Modality</th>
<th>Type</th>
<th>Duration</th>
<th>Weight</th>
<th>Minimum grade</th>
<th>Evaluated skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation: Developing Machine Learning models</td>
<td>Individual presentation</td>
<td>Face-to-face</td>
<td>00:10</td>
<td>40%</td>
<td>/ 10</td>
<td>CT3 CT4 CT5 CG1 CG2 CG4 CG5 CT1</td>
</tr>
<tr>
<td>Final project evaluation</td>
<td>Group presentation</td>
<td>Face-to-face</td>
<td>00:15</td>
<td>60%</td>
<td>/ 10</td>
<td>CT3 CT4 CT5 CG1 CG2 CG4 CG5 CT1</td>
</tr>
</tbody>
</table>

7.2. Assessment criteria

Students will be qualified through continuous evaluation by default. According to the Normativa de Evaluación del Aprendizaje de la Universidad Politécnica de Madrid, students willing to renounce to continuous evaluation must complete the Moodle task entitled "Renounce to continuous evaluation" before the fourth week of the semester (deadline will be announced in Moodle).

Evaluation will assess if students have acquired all the competences of the subject. Thus, evaluation through final assessment will be carried out considering all the evaluation techniques used in continuous evaluation (EX, ET, TG, etc.), and will be celebrated in the exam period approved by Junta de Escuela for the current academic semester and year. Evaluation activities that assess learning outcomes that cannot be evaluated through a single exam can be carried out along the semester.

Extraordinary examination will be carried out exclusively by the final assessment method.

Continuous assessment will consist of:
- Individual presentations to demonstrate skills in developing machine learning models will be made by mid-
semester (40% of final grade).

- A final collaborative project will be developed to be evaluated by the end of the semester. Evaluation will cover
both individual achievements in Machine Learning, and more specifically Deep Learning models, as well as the
development of teamwork skills, as this is one of the learning objectives for the course (final project assessment will
represent 60% of the final grade).

**Final assessment:**

Those students that have renounced to continuous evaluation should address a final examination including both
individual presentations to demonstrate skills in developing machine learning models (40% of final grade) and their
final collaborative project covering machine learning and deep learning models (60% of the final grade).

**Extraordinary examination:**

Extraordinary examination consists of an individual presentations to demonstrate skills in developing machine
learning models (40% of final grade) and a final collaborative project focused on machine learning and deep
learning models (60% of the final grade).

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**8. Teaching resources**

**8.1. Teaching resources for the subject**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Notes</th>
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</table>
9. Other information

9.1. Other information about the subject

For on-line learning activities we will use UPM Moodle platform and tools. Moodle, GutHub and Youtube will be the environments to share specific course materials. Specific communication frameworks such as Skype for Business or Microsoft Teams could be used allowing UPM students to interact with instructors.

The increasing relevance of technological developments based on Machine Learning makes this course an educational activity directed to contribute to Goal 4.4 in Sustainable Development Goals (SDGs) 2030 United Nations Agenda, empowering our students with relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship.
Through approaching practical scenarios in our Lab, students will develop relevant skills and in-depth knowledge on the impact of different Machine Learning techniques on different fields as health, environmental monitoring, smart energy management, or finance. This will help them to become more aware of how technology can contribute to several SDGs goals: end poverty (Goal 1), promote well-being (Goal 2), and promote sustainable management of water, energy, economic growth and industrialization (Goals 5, 6, 7, and 8) as well as to reduce inequality among countries (Goal 10).

Also, due to the relevance of using machine learning to extract value from data in a broad range of economic sectors, the course will also contribute to SDG Goal 17 (Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development) in particular working on systemic issues on Data monitoring and accountability (17.18 and 17.19).