

Course guide

230382 - AI2OT - Artificial Intelligence and Internet of Things (Iot)

Last modified: 11/04/2025

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 744 - ENTEL - Department of Network Engineering.

Degree: MASTER'S DEGREE IN ELECTRONIC ENGINEERING (Syllabus 2013). (Optional subject).
MASTER'S DEGREE IN TELECOMMUNICATIONS ENGINEERING (Syllabus 2013). (Optional subject).
MASTER'S DEGREE IN ADVANCED TELECOMMUNICATION TECHNOLOGIES (Syllabus 2019). (Optional subject).
MASTER'S DEGREE IN ELECTRONIC ENGINEERING (Syllabus 2022). (Optional subject).

Academic year: 2025 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: JOSE PARADELLS ASPAS

Others:

PRIOR SKILLS

Basic understanding of Artificial Intelligence, microprocessors and sensors

REQUIREMENTS

No specific subject if the student fulfils the capabilities indicated (basics on neural networks, microprocessors and electronic sensors)

TEACHING METHODOLOGY

The seminar combines the introduction of basic theoretical concepts with practical aspects. The seminar uses a free available platform (edgeimpulse.com) that allows to build a IoT node with processing at the endpoint. The course will follow all the steps starting from the definition of the problem to solve to the validation of the results. It will start with the selection of the device (IoT node), selection of sensors. Later data acquisition will follow and features extraction. At this point we will be able to select the neural network. With the dataset ready and the network defined training becomes the following step. Once the training is done we will perform validation and optimisation to assure the model is small enough to be executed on a microprocessor. The final step will consist on integration of the neural network in a real node and to demonstrate its functionality. The idea is every student should be able to perform all the steps using a device provided by the subject.

LEARNING OBJECTIVES OF THE SUBJECT

The student, at the end of the course should be able to understand the key aspects for building solutions based on artificial intelligence, and being able to build them by themselves. Aspects as data acquisition, dataset creation, data augmentation, tagging, feature extraction, neural networks model, training, optimisation and validation are going to be presented and used. The usage of artificial intelligence for a IoT device will allow to see all the elements related to the use of artificial intelligence but at small scale (relaxing the computational requirements) and being aware of the hardware restrictions and the need of optimisations.

STUDY LOAD

Type	Hours	Percentage
Hours small group	8,0	10.67
Hours large group	16,0	21.33
Self study	51,0	68.00

Total learning time: 75 h

CONTENTS

An introduction to Artificial Intelligence (AI) and the Internet of Things (IoT) and development platform presentation

Description:

The artificial Intelligence has been associated to complex problems and heavy computing executed on the cloud. The data feeding is also adjusted to this, in the sense that sensors generate data that has to be transported and stored on the cloud. At present it has been seen that the processing is not needed to be done in the cloud, it can be done close to the source (edge computing) or even at the sensor itself (endpoint computing). This last approach reduces the communication needs and the latency and it is feasible nowadays thanks to improvement on microprocessors and artificial intelligence models

A presentation will be made of the development platforms and specifically of the one that will be used in the course (edgeimpulse.com)

Specific objectives:

Know the state of the art of artificial intelligence for low performance devices (microprocessors)

Related activities:

Slide presentation

Full-or-part-time: 7h

Theory classes: 3h

Self study : 4h

Examples of use of Artificial Intelligence in the IoT device.

Description:

Examples of the use of artificial intelligence in the IoT can now be found. These range from preventive maintenance, using vibrations, intrusion detection, recognition of commands by voice or gestures to the implementation of synthetic sensors. The latter are based on capturing complex information such as sound or image and generating more basic information such as a poorly turned off faucet or a people counter.

Specific objectives:

Know the applications of artificial intelligence in the Internet of things

Related activities:

Devise possible new use cases that can be implemented by the student during the seminar

Full-or-part-time: 7h

Theory classes: 3h

Self study : 4h

Data acquisition and actuation

Description:

A neural network can be seen as a black box that, given inputs (information from sensors), offers results that can be shown to the user with a screen or through actions (actions). Input information can be provided by many different types of sensors, from as simple as a presence detector (delivers 0s or 1s) to a camera (image sequence of $N \times M$ pixels of different colors). The results can generate an action such as turning on a light, closing a door, activating an alarm or giving a textual (display) or sound (loudspeaker) response. In this session of the seminar we will dedicate ourselves to presenting the data generation elements (sensors) and actuation elements (actuators).

Specific objectives:

Sensor and actuator identification to carry out the project identified by the student

Related activities:

Analysis of the different sensors and actuators and the different types of data they use

Full-or-part-time: 11h

Theory classes: 2h

Laboratory classes: 1h

Self study : 8h

Feature extraction

Description:

The data offered by the sensors may not have the format to be processed by a neural network. In order to facilitate this process, in some cases we proceed to what is called feature extraction. It consists of processing the data and distilling others that, without losing relevant information for decision making, can be processed more easily by existing neural network models. Feature extraction can be very relevant since in some cases it requires a higher computational complexity than that associated with that required to obtain an inference from the neural network. A typical example is sound-based data.

Specific objectives:

Identify data transformation and its impact on computational cost and loss of accuracy

Related activities:

Decide if it is necessary to transform the project data and see how it can be done

Full-or-part-time: 7h

Theory classes: 1h

Laboratory classes: 2h

Self study : 4h

Neural network selection

Description:

Neural networks can present different levels with different relationships between levels and different operations in each of the levels. They can be sequential or they can have feedback. The combination of the different elements allows for solutions that better capture the variability of the input data or that require fewer operations and memory consumption. In this session, the aim is to review the different layers and connections, giving indications about the goodness of certain combinations to treat certain problems.

Specific objectives:

To understand the neuronal network to be used and implications of its modification

Related activities:

To analyse the possible modifications of the proposed neuronal network

Full-or-part-time: 7h

Theory classes: 2h

Laboratory classes: 1h

Self study : 4h

Training, validation and optimization

Description:

A neural network must be trained so that it can infer conclusions with new data that we can offer it. This training can be associated as learning through experiences. The training is performed as a minimization of the error of a complex function and is based on training data and test or validation data. The training may require more or fewer iterations and may have different ways of searching for the minimum of the error function.

Once you have a trained network, you can evaluate to what extent performance is degraded by simplifying it by removing links between levels, removing nodes or reducing the resolution of the values handled by the network.

Specific objectives:

To understand available options for training and the optimización possibilities

Related activities:

Study the impact of the different training options

Full-or-part-time: 9h

Theory classes: 2h

Laboratory classes: 1h

Self study : 6h

Deployment and usage of the developed solution

Description:

The designed neural network must be usable on an IoT device. To do this, it must be able to receive data from the device's sensors and must be able to generate responses (actions). The neural network must be deployed on the device and code must be added to implement the action. To simplify this deployment, an Arduino programming environment will be used. The solution running on the IoT node will be verified in a real use environment

Specific objectives:

Relate the black box that represents a neural network to the data input and the inference output on an IoT node

Related activities:

Programming neural network input and output

Full-or-part-time: 9h

Theory classes: 1h

Laboratory classes: 2h

Self study : 6h

Presentation of project done and results

Description:

On the last day of class each student will present to the rest of the class their project and the results obtained in a real demonstration

Specific objectives:

Be able, in a few minutes, to explain the motivation of the project, the solution adopted and the results

Related activities:

Prepare a speech of a few minutes summarizing the work done during the seminar

Full-or-part-time: 18h

Theory classes: 2h

Laboratory classes: 1h

Self study : 15h

GRADING SYSTEM

Three elements will be used for evaluation

- 1.- Class participation: 20%
- 2.- Project idea and development: 30%
- 3.- Project performance and documentation (including a video): 50%

BIBLIOGRAPHY

Basic:

- Warden, Pete; Situnayake, Daniel. Tinyml: machine learning with tensorflow lite on arduino and ultra-low-power microcontrollers [on line]. Beijing: O'Reilly, 2020 [Consultation: 16/02/2022]. Available on: <https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=5995898>. ISBN 9781492051992.
- Warden, Pete. "Why the future of machine learning is tiny". Pete Warden's blog [on line]. June 11, 2018 [Consultation: 26/01/2022]. Available on: <https://petewarden.com/2018/06/11/why-the-future-of-machine-learning-is-tiny/>.
- Laput, Gierard. "Synthetic Sensors : towards general-purpose sensing". web Gierad.com [on line]. 2017 [Consultation: 26/01/2022]. Available on: <https://www.gierad.com/projects/supersensor/>.
- Torras, Jordi. Python deep learning : introducción práctica con Keras y TensorFlow 2. Barcelona: Marcombo, 2020. ISBN 9788426728289.
- "Edge Impulse". Edge Impulse documentation [on line]. [2021] [Consultation: 26/01/2022]. Available on: <https://docs.edgeimpulse.com/docs>.
- Shore, Chris. "Transforming endpoints with artificial intelligence". web ARM [on line]. 2021 [Consultation: 26/01/2022]. Available on: <https://armkeil.blob.core.windows.net/developer/Files/pdf/white-paper/arm-transforming-iot-endpoints-whitepaper.pdf>.
- Merenda, Massimo; Porcaro, Carlo; Iero, Demetrio. "Edge machine learning for AI-enabled IoT devices: a review". Sensors [on line]. 20(9), 2533 [Consultation: 26/01/2022]. Available on: <https://doi.org/10.3390/s20092533>.
- Martins, Franck. "AI Edge Computing : new paradigm for IoT". web ST [on line]. 2018 [Consultation: 26/01/2022]. Available on: <https://tuit.cat/jgmxm>.

Complementary:

- Murshed, M.G. Sarwar [et al.]. "Machine learning at the network edge: a survey". ACM Computing Surveys [on line]. Volume 54, Issue 8 [Consultation: 26/01/2022]. Available on: <https://dl-acm-org.recursos.biblioteca.upc.edu/doi/10.1145/3469029>.

RESOURCES

Computer material:

- Nom recurs. Personal notebook computer that the student should bring to class
- Entorn de programació. IDE Arduino
- Dispositiu IoT. An student will have available, for the teaching period of the subject one of the following devices: nano 33 BLE sense or ESP-CAM

Hyperlink:

- Entorn de desenvolupament web. Development platform. EdgeImpulse.com