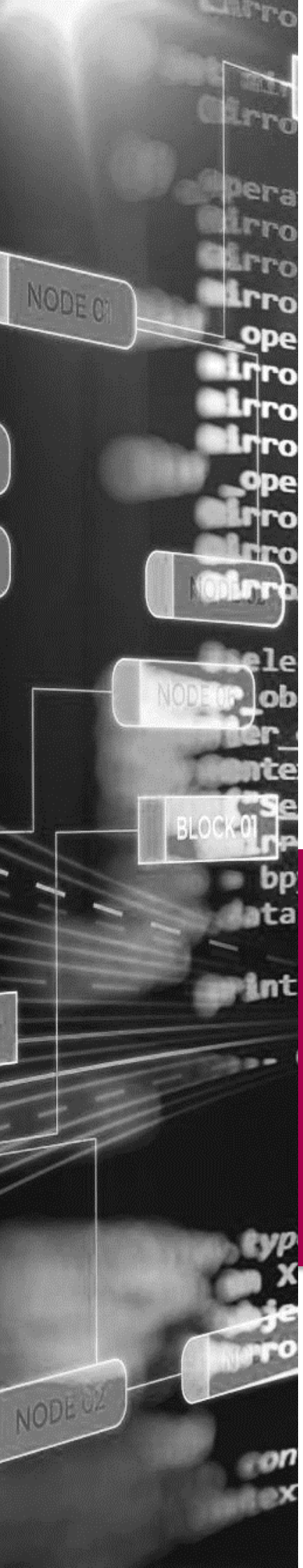

ENSEA

Beyond Engineering

Signal Processing and Artificial Intelligence

Graduate/Master Program

ENSEA – Semester 9 SIA - French-Taught

Edition 2023

Signal Processing and Artificial Intelligence
ENSEA - SIA 3rd Year Academic Track

Level	**Second year of Master's Degree/Graduate/Semester 9**		
Period	Fall semester (September to January)		
Language of tuition	French		
ECTS	30		
Courses	Code	Course	ECTS
	SIA_1	**Signal Processing [Composed of:]**	**6**
	SIA_3600	Advanced Signal Processing Methods	
	SIA_3602	Audio	
	SIA_2	**Digital and Image Processing [Composed of:]**	**6**
	SIA_3601	Advanced digital processing	
	SIA_3603	Images and Video Processing	
	SIA_3	**Artificial Intelligence [Composed of]**	3
	SIA_3611	Machine Learning	
	SIA_4	**Deep Learning and Hardware [Composed of:]**	**5**
	SIA_3607	Hardware for Signal Processing	
	SIA_3612	Deep learning for visual recognition	
	SIA_5	**Project [Composed of:]**	**5**
	SIA_3620	Project	
	SIA_3630	Conferences	
	SH-3EME	**Humanities [Composed of:]**	**5**
	DSH_3000	Responsible and sustainable management of human resources in a complex environment	
	DSH_3060	English	
	DSH_3061	FLE (French for foreigners) or Spanish or German	

Signal Processing and Artificial Intelligence
ENSEA - SIA 3rd Year Academic Track

SIA_1 Signal Processing (6 ECTS)

SIA_3600 Advanced Signal Processing Methods (Lectures: 20h / Tutorial classes: 12h / Lab: 16h)

Upon completion of this course, students will be familiar with signal processing tools that they can use to analyze and extract key parameters of a signal from observations. Offline and adaptive methods will be considered. They will implement them in the context of acoustic echo cancellation (audio conferencing) and data compression.

In particular, they will be able to:

Design an estimator without a priori (Maximum likelihood, EM algorithm) and analyze its performance (Cramer-Rao boundary),

Design a hypothesis test detector;

Apply it to non-destructive testing,

Design an estimation with a priori (Bayesian estimation, maximum a posteriori, linear regression),

In the linear case, design a filter minimizing the squared error (optimal Wiener filter, finite order Wiener filter) and

Implement an adaptive filter (LMS, NLMS, RLS algorithm); apply it to acoustic echo cancellation, or li-near prediction,

Implementation of a Kalman filter.

The practical work will concern source separation with applications such as cocktail party, acoustic echo cancellation, or texture estimation.

SIA_3602 Audio (Lectures: 12h / Tutorial classes: 8h / Lab: 16h)

The objective of this course is to present a range of the most recent technologies for the acquisition, automated processing and restitution of audio-frequency signals, in particular signals carrying musical information. The intended applications concern both consumer multimedia and professional production systems.

Acoustics: sound sources, propagation and radiation, speech, music and harmony, ...

Psychoacoustics and lossy compression such as MP3,

Audio processing chain: technological aspects and performances, lines, synchronization, pre-amplification, dithering, interconnection standards,

Architectures for digital audio signal processing: specialized processors, Codec, ALSA, I2S, SAI

Production and post-production: equalization, multi-band dynamic processors, noise reduction, spatialization, ...Digital music signal processing: specific Fourier transforms, source separation methods, P-SOLA, audio descriptors

Music Information Retrieval and Machine Learning: chord recognition, musical genre recognition, automatic synthesis and composition, ...

SIA_2 Digital and Image Processing (6 ECTS)

SIA_3601 Advanced digital processing (Lectures: 18h / Tutorial classes: 12h / Lab: 12h)

Multimedia signal compression standards (MP3, JPEG, MPEG) use signal decomposition and reconstruction techniques. The compression is carried out at the level of the decomposition signals, with in particular a quantization stage. These techniques must provide a perfect or near-perfect reconstruction in the absence of any compression. Quantization must take into account constraints such as the transmission channel rate or the desired distortion after reconstruction. This course presents the theoretical basis of these techniques, with an emphasis on perfect reconstruction systems. It also presents the principles of signal quantization modelling.

- Orthogonal transforms
- Multi-rate signal processing, bank of filters
- Orthogonal and bi-orthogonal wavelets
- Modelling the quantization of signals

SIA_3603 Images and Video Processing (Lectures: 12h / Tutorial classes: 8h / Lab: 16h)

This course presents the basics of image and video processing. It reviews the notions of digital signal processing specific to images and videos, as well as the perceptual aspects related to them. These notions are then applied to well known domains such as image or video compression, primitive extraction, image watermarking, etc. The goal of this course is to allow the student to acquire and master the tools present in an image or video processing chain.

- Direct Image Processing: contrast, smoothing, gradients, in-painting
- Processing through decomposition and related applications
- Image compression and related standards: PNG, GIF, JPEG, JPEG2000
- Video compression and related standards: MPEG-1, MPEG-2, MPEG2000, H264

SIA_3 Artificial Intelligence (3 ECTS)

SIA_3611 Machine Learning (Lectures: 16h / Tutorial classes: 14h / Lab: 16h)
This course introduces the fundamental concepts, theory and algorithmic ideas of machine learning. It provides the student with a foundation for applying machine learning techniques to real-world problems or for researching the development of new machine learning algorithms and methods. It also provides the foundation for several other data science courses, including deep learning. Specifically, the course focuses on the main techniques of supervised, unsupervised, and reinforcement-based machine learning. The following will be developed:

- Clustering: centroid-based, density-based, and distribution-based algorithms, agglomerative hierarchical clustering, expectation maximization for soft clustering.
- Linear regression: simple and multiple regression analyses, least squares method, maximum true likelihood estimation.
- Discriminative and generative classifiers: logistic regression, naive Bayes classifier, K-nearest neighbors, support vector machines, decision trees, random forests.
- Performance metrics, hyperparameter tuning and performance estimation protocols: ROC and AUC curves, cross-validation, nested cross-validation, bootstrapping, overfitting and model selection.
- Feature selection: forward-backward search, lasso, orthogonal matching search.
- Markov decision processes and dynamic programming: Bellman equations, policy iteration, value iteration.
- Monte Carlo methods: prediction and control variable.
- Temporal difference learning: Q-learning, deep Q-learning.

SIA_4 Deep Learning and Hardware (5 ECTS)

SIA_3607 Hardware for Signal Processing (Lectures: 4h / Tutorial classes: -h / Lab: 16h)

The implementation of algorithms processing large volumes of data is usually done using server-based solutions. However, the training phases of deep learning algorithms have a particularly high carbon footprint. Moreover, embedded algorithms, especially for IoT, rely on hardware implementations subject to severe power constraints. The objective of this course is therefore to make students aware of the hardware solutions currently available, their performance, their practical implementation, their respective roles in the prototyping stages and their ecological implications. Various targets can be considered, among which a particular target that students will be invited to choose according to their project topic (see SIA_3720). The practical sessions will allow students to become familiar with the design practices and treatments specific to the objective.

SIA_3612 Deep learning for visual recognition (Lectures: 12h / Tutorial classes: 6h / Lab: 16h)

Computer vision has become omnipresent in our society, with applications in image searching, mapping, medicine, drones, autonomous cars, and so on. Visual recognition tasks such as image classification, localization and detection are at the heart of these applications. Recent developments in deep neural network approaches (deep learning) have greatly advanced the performance of these visual recognition systems.

The following topics will be covered during this course:

Learning algorithms (backpropagation, dropout, batch normalization, transfer learning...)

Deep learning architectures for visual recognition tasks: Convolution Networks (ConvNet: AlexNet, ResNet, VGG,...), Recurrent Networks (RNN), Generative Models (PixelCNN, Generative Adversarial Networks - GAN,...),

Deep Compression,...

Case studies from research, image classification, image generation, object detection, image style change (DeepDream), semantic segmentation, etc. will illustrate these topics.

SIA_5 Project (5 ECTS)

SIA_3620 Project (Lectures: -h / Tutorial classes: -h / Lab: 68h)
This course offers students the opportunity to carry out a synthesis of the courses followed during the semester. They will have to achieve a bibliographical study, determine the objectives to be reached, plan the tasks to be carried out, achieve, identify the additional skills they will have to acquire and propose methodological solutions, to organize a working schedule and division within the frame of collective project, validate the main steps previously defined, regularly inform the supervisors of their project's progress, and finally present at the end of semester a functional production.
With regard to the hardware implementation of the algorithms in connection with SIA_3707, the training will focus on the choice of the target and of the particular
technical solutions planned in order to obtain, for example, the best compromise between efficiency and carbon footprint for server-based implementation or to optimize integration on an embedded target.

SIA_3630 Conferences (Lectures: 10h / Tutorial classes: -h / Lab: -h)
Several lectures will be given by specialists of the field, industrial engineers or researchers, to present flagship applications in the fields of artificial intelligence, specific data processing (audio, video, image…) or multipurpose techniques (remote sensing, robotics, etc.). The themes may vary from one year to the next according to the evolution of techniques and availability of lecturers.

SH_3EME Humanities (5 ECTS)

DSH_3000 Responsible and sustainable management of human resources in a complex environment

(Lectures: 16h / Tutorial classes: 6h / Lab: -h)

The course presents the evolution of organizations in a complex environment (team management, corporate culture in a multicultural context, professional project through the dynamics and management of evolutions). It emphasizes the strategic role of human resources management in a CSR context (Quality of Life at Work - OHS) in order to prepare engineering students (guided by the 26000 standard) for their role as project managers, project leaders or employees of a project team.

It introduces the notions of labor law that are essential for engineers (employment contracts, expatriation, work environment in the company) by integrating the social and societal concerns of the company.

The practical courses allow, through an edutainment approach (or in the form of a serious game):

- to implement an HRM that values responsibility and ethics (Remuneration, Training, Skills management, Health and Safety at work).
- Identify good practices to implement a CSR policy.

DSH_3060 English (Lectures: -h / Tutorial classes: 24h / Lab: -h)

The objective of the third-year courses is to make the students able to work in English and have a good command of the language.

The goal is achieving a professional use and to reach, at least, a B2 level requested do obtain the degree.

Two third-year options are grouped together for English courses. Level groups can be formed. The students will be able to work on different aspects of life professional (communication in different settings, in the office, abroad, in seminars, through writing, orally, case studies...), by carrying out work groups and putting in practice the knowledge they have acquired throughout their training.

DSH_3061 FLE (French for foreigners) (Lectures: -h / Tutorial classes: 24h / Lab: -h)

The main goal of this class is training the foreign students through communication fundamentals for everyday life, proposing them an introduction to French culture and civilization and more advanced knowledge in order to work in a French company during the final internship period.