

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)

Course objectives: To provide the tools for the analysis and extraction of parameters of observation-based signal. To provide the theoretical basics of multimedia data compression techniques.

- Without A Priori Estimation: Cramer Rao bound, Maximum likelihood, E-M algorithm
- A Priori Estimation: Principle of Bayesian estimation, Maximum A Posteriori estimation (MAP), Minimum Mean Square Error estimation (MMSE)
- Linear Case
- Principle of Orthogonality (Wiener-Hopf), Optimal Wiener filter, finite-order Wiener filter (matrix characterization, Least Mean Square, Normalized Least Mean Square and Recursive Mean Square algorithm). Application to acoustic echo cancelling.

I/O management

- Application to compression or adaptive line enhancer (LMS algorithm, NLMS, RLS), connection with the AR modelling: connection between estimation and random processes modelling, Levinson algorithm, the autocorrelation and covariance methods. Application to spectral estimation.
- Kalman filter (state model, principle of Kalman filter, Kalman gain)
- Markov Chain Modelling: Markov Chain Monte Carlo method.

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

Course objectives: To present the basics of signal acquisition, processing, transmission, storage and broadcast of audio signals. To present the basics of image and video processing. To introduce the theoretical knowledge required for content-based analysis systems.

- Basics of Acoustics: sound sources, propagation and radiation, stereo sound, speech, music and harmony, scale
- Audio Signal Chain: Technical details: lines, synchronization, pre-amplification, dithering, Firewire/MIDI/DAT standards.
- Architectures for Audio Digital Signal Processing: Codec, ALSA, I2S, SAI,
- Psychoacoustics and lossy compression: MP3
- Digital Signal Processing for post-production: equalization, multiband dynamic range processors, convolution reverb, noise reduction, spatialization
- Music Information Retrieval and Machine Learning: chord recognition, musical genre, synthesis and automatic composition
- Digital Signal processing for music: P-SOLA, source separation methods, audio descriptors

SIA_2 Digital and Image Processing (6 ECTS)

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

- 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)

- 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 (5 ECTS)

SIA_3611 Machine Learning (Lectures: 14h / Tutorial classes: 10h / Lab: 12h)

- Supervised learning: Regression vs classification, curse of dimensionality, kernel methods, regularization, generative approaches (Bayesian, HMM sequential models, decision boundary) and discriminant (linear discriminant analysis, support vector)
- Neural Network/Deep learning: Multi-layer, perceptron, loss, non-linear functions, Backpropagation, SGD, ADAM(AX), ConvNet, RNN, GRU, LSTM, auto-encoder
- Unsupervised learning: hierarchical methods (K-means, Fuzzy K-means, EM and GMM algorithms) and non-hierarchical (ascending, descending)
- Applications: frameworks (pandas, sklearn, keras, tensorflow), typical test data sets, evaluation of performances

SIA_3612 Deep learning for visual recognition (Lectures: 10h / Tutorial classes: 8h / Lab: 16h)

- Learning algorithms (backpropagation, dropout, batch normalization, transfer learning)
- Deep learning architectures for visual recognition: ConvNet (AlexNet, ResNet, VGG), RNN, Generative models (PixelCNN, Generative Adversarial Networks), Deep Compression

SIA_4 Hardware for Signal Processing (3 ECTS)

SIA_3607 Hardware for Signal Processing (Lectures: 6h / Tutorial classes: -h / Lab: 24h)

- Real-time operating system: Task, Inter-task communication, interruption management, input-output layer (DMA, Serial bus)
- Network Architecture: OSI architecture, level 2,3,4 protocols, application protocol, socket communication
- Hardware architecture for signal processing: Harman and Von Neumann architectures, fixed-point and floating-point processors, DSP, SHARC. CPLD, FPGA.
- Methodology for system design for DSP and FPGAs: VHDL description, modeling, synthesis and implementation, with applications to Digital Radios for FPGA platforms (real-time CORDIC algorithm). C language and Assembly language for signal processing on SHARC, with applications to real-time digital filtering (IIR and FIR). Low-level code optimization for speed and size on DSP: loop design, instructions ordering, using specific assembly language instructions for parallelism purposes, managing stack and memory.
- The objective of the FPGA part of the Practical Work sessions is the conception of a frequency demodulator demonstrator for an FM receiver using an original method based on the CORDIC algorithm. After a quick introduction to the algorithm using high-level programming languages, students are invited to deploy the proposed solution in VHDL on a DE1-SoC target.

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 Human Resources Management and International Management (Lectures: 16h / Tutorial classes: 6h / Lab: -h)

This transversal training offers:

- an awareness of labor law specifically for the engineer: employment contract, expatriation, working environment in the company
- managerial aspects dealt within a multicultural context such as team management, corporate culture, professional projects...
- accounting aspects: employee cost versus human capital.

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 to 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.