2SC8094 – Non-invasive extraction of the fetal electrocardiogram

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Language of instruction: FRANCAIS
Campus: CAMPUS DE METZ
Workload (HEE): 80
On-site hours (HPE): 48,00

Description
The project, which is part of the ST7-Optimization "Source separation for optimal use of signals", will focus on a source separation issue raised by a client partner: INSERM in Nancy.

Non-invasive fetal electrocardiography (NI-FECG) represents an alternative fetal monitoring technique to traditional Doppler ultrasound, which is non-invasive. However, despite significant advances in adult ECG signal processing over the past decades, analysis of NI-FECG remains difficult and largely unexplored. This is mainly due to the relatively low signal-to-noise ratio of the FECG compared to the maternal ECG, which overlaps in both time and frequency.

The problem therefore consists in finding one or more data representation spaces well suited to the problem of fetal ECG extraction. It will be a question of applying and testing one or more methods starting from an article which reviews recent advances in research on NI-FECG, in particular: databases accessible to the public, techniques of NI-FECG extraction for fetal heart rate assessment and morphology analysis, NI-FECG simulators, and methodology and statistics to assess the performance of extraction algorithms.

Quarter number
ST7

Prerequisites (in terms of CS courses)
Probability 1A (CIP-EDP, 1SL1000),
Signal processing ST4 (1CC4000)
Statistics, Machine learning and Data processing ST4 (1CC5000),
Digital environment, computer and programming SG1 (1CC1000).

Syllabus
Evaluation and implementation of non-invasive fetal ECG extraction algorithms, based on the article by Joachim Behar et al. “A practical guide to non-invasive fetal electrocardiogram extraction and analysis”, Physiol. Meas. 37, 2016.

Class components (lecture, labs, etc.)
This teaching is done in the form of a project.

Throughout the duration of the project, students will be asked to keep an up-to-date "laboratory notebook" specifying in a few lines for each experiment or test carried out, its motivations, the results obtained, the source codes and the data used. During the last week dedicated to the project, students will be asked to:

- provide a project report; and
- to carry out a defense in the presence of the partner.

A progress update on the project with reading of the "laboratory notebook" and the provisional version of the report will take place regularly.

Grading
Skills will be assessed:

- in continuous control at the advancement points, the "laboratory notebook" reading and the draft report reading (individual note CC);
- during the final defense (individual note S).

In addition, the quality of the deliverables: final report, "laboratory notebook" and commented source codes, will be evaluated (note QL). Final score = CC/3 + S/2 + QL/6.

In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final defense.

The assessment of skills is specified in the paragraph "Description of acquired skills"

Course support, bibliography
Joachim Behar, Fernando Andreotti, Sebastian Zaunseder, Julien Oster and Gari D Clifford, “A practical guide to non-invasive fœtal electrocardiogram extraction and analysis”, Physiological Measurement, 37, R1 – R35, 2016.

Resources

80 HEE (48 HEE) of project carried out in groups of students.

Learning outcomes covered on the course

At the end of this course, students will be able to:
- represent and decompose electrocardiograms in an "optimal" way;
- fit a model to data;
- use a programming language to effectively implement a data processing algorithm.

Description of the skills acquired at the end of the course

C4 : Have a sense of value creation for his company and his customers (assessed during project monitoring)
C6 : Be operational, responsible, and innovative in the digital world (assessed throughout the project)
C7 : Know how to convince (evaluated during the follow-up, during the defense and in the deliverables)
C8 : Lead a project, a team (evaluated by laboratory notebooks)

ST7 – 81 – ADDITIVE MANUFACTURING DESIGN

Dominante : CVT (Construction, City and Transportation)
Langue d'enseignement : English
Campus où le cours est proposé : Paris-Saclay

Engineering problem

Since its inception, additive manufacturing has proven to be a fundamental change in manufacturing processes, allowing total customization and artisanal quality at the cost and precision of a modern industrialized process. However, it is a young process, and therefore, not yet fully mastered. The mechanical properties of the parts produced are often unpredictable, severely limiting their use in high-end applications. This is why the development of methods (analytical and numerical) capable of predicting the final characteristics of the part by optimizing the design process seems a necessity.

The sequence focuses on the optimization of the design by additive manufacturing:
- Optimal choice of material and microstructure;
- Optimization of geometry with respect to multiphysical constraints;
- Optimization of process parameters (printing path, laser power, powder characteristics...)
- Evaluation of the economic and social stakes of FA compared to standard processes (manufacturing time, cost of materials, labor employed, environmental compatibility...)

This design presents a major challenge due to the multiphysical nature of the additive manufacturing process (thermal, mechanical, electromagnetic, metallurgical, phase change) and poses a multiscale problem both in space and in time (evolutionary nature of the process).

Advised prerequisites

It is advisable to have taken the SPI course "Mechanics of Continuous Media" and at least one of the following courses: Materials, Transfer Science, Thermodynamics.

Context and issue modules:
These modules include lectures, a study-case and a mini-project, aimed at presenting the problem, the social and economic stakes and making a simple object using 3D printing.

Specific course (60 HEE): *Multiphysics coupling*

Brief Description: This course will address the concepts and issues of multiphysics coupling in a broad sense. The following topics, among others, will be covered during the course:

- Strong - weak coupling
- Coupling of different formulations
- Coupling of different scales

Then we will focus on particular couplings, of interest for additive manufacturing:
- Laser on powder: electro-thermal coupling
- Powder bed melting: discrete-continuous, solid-fluid and thermo-mechanical coupling
- Cooling phase: aerothermal-mechanical coupling

The course will end with a reflection on the mechanics of the final part (residual stress, porosity, microstructure...).
A strong emphasis is placed on practice through tutorials and a case study on the multiphysics simulation software COMSOL. The acquired skills are evaluated by the case study.

Projects:

Brief description: The sequence is built around various projects carried out by the CVT major. The students, in groups of 5 maximum, will have to answer a problem proposed by their industrial partner around the design of a part in additive manufacturing. This may involve optimizing its geometry, thinking about its design, designing a system for a given use, analyzing the performance of the part designed by additive manufacturing, etc. Most of the topics involve finite element simulation on COMSOL or on the software of the students' choice. Some topics may involve experimental work.

All projects should follow the following steps:
- Step 1: Getting to know the subject
- Step 2: Simplified representation of the studied part to arrive at a first solution
- Step 3: Optimization of the system in a given parameter space
- Step 4: Analysis of the cost-benefit of the proposed solution compared to an initial or classical solution.

All these projects are gathered in 3 thematic groups:

Project n°1: *Optimization of aeronautical parts in metallic additive manufacturing*.
Associated partner: SafranTech - **Location:** Paris-Saclay

Project n°2: *Optimization of parts for the biomedical industry using polymer additive manufacturing*.
Associate partner: Biomodex **- Location:** Paris-Saclay

Project n°3: *Optimization of civil engineering structures using concrete additive manufacturing*.
Associate partner: XTreee **- Location:** Paris-Saclay