1SC4490 – Statistical analysis of financial markets

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Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES
Language of instruction: ANGLAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27,00

Description

Students in this course will analyze real data from modern financial markets and assess the relevance of time series models or agent-based approach to model this data.

Quarter number
ST4

Prerequisites (in terms of CS courses)
Time Series and Agent-based Models in Finance (ST4 MDS)

Syllabus
Data handling. Reading of scientific articles. Python implementation of time series or agent-based models. Analysis and technical presentation.

List of recent subjects (subjects may differ in 2023):
- *VARMA models for commodities* (BNP Paribas, 2020).
- *Autoregressive models and high-frequency financial data* (FiQuant, CentraleSupelec, 2019, 2020, 2021)
- *Calibration of agent-based models on financial markets* (FiQuant, CentraleSupelec, 2020, 2021, 2022) : build and calibrate agent-based models with methods including generalized methods of moments and Kalman filters ; compare the model behaviour to real financial timeseries.
- *Developing a Bitcoin trading bot* (Cap Gemini, 2020, 2021, 2022) : explore Blockchain time series, model the time series with classical models using AR/MA/ARIMA or GARCH, and neural networks, compare and contrast both approaches and finally propose a trading strategy.
- *French regional electricity load forecasting* (SIA Partners, 2021) : forecast the electricity consumption of several french administrative regions, using multiple years of past observations timeseries, as well as meteorological features.
- *Structural analysis of VAR models in finance* (FiQuant, CentraleSupelec, 2021, 2022) : model financial time series with vector autoregressive models

; analyze dependencies on multiple markets and data (equity or bitcoin, low or high-frequency) using structural analysis.

Class components (lecture, labs, etc.)
Project work in groups of students.

Grading
Oral presentation with detailed technical support.

ST4 – 45 – DIGITAL TWINS FOR EFFICIENT CONSTRUCTIONS AND TRANSPORTATION VEHICLES

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

Engineering problem

The construction, city, and transportation sectors are at the core of the challenges towards reducing the exploitation of natural resources and the release of greenhouse gases into the atmosphere. The high level of performance achieved in these sectors in terms of quality, reliability, and safety of constructions (bridges, buildings, dams…) and vehicles (cars, trains, aircrafts…) designed, built, and operated must continue to be improved while guaranteeing new environmental performance.

These new requirements yield an increasing complexity in the projects. The development of digital tools and the development of databases that contain an ever-increasing amount of information opens new perspectives for better managing this complexity and to eventually improve the economic, social, and environmental performance of the objects produced by the construction and transportation industries. The digital tools developed make it possible, on the one hand, to faithfully reproduce the behavior of these objects in a virtual environment (numerical simulations) and, on the other hand, to share relevant information between the various jobs and fields of expertise solicited throughout their life cycle (specification, design, production, operation / maintenance, recycling). These developments have given rise to the concepts of digital continuity, Building Information Modeling (BIM), or digital twins.

The entire value chain of products developed in the transport and construction sectors is strongly impacted by this digital transformation:

- the possibilities for monitoring the user experience and the state of the product offered by data acquisition and processing make it possible to design products that are evolutive, intelligent, and adaptable to their environment;

- access to databases of the variable actions to which the object will be subjected to (traffic, earthquakes, storms, ageing of materials, etc.) enables a reliability-based design strategy to be adopted, allowing optimized product design;

- digital sharing of information encourages collaborative work (Building Information Modeling - BIM / Product Lifecycle Management - PLM) where the same object can be enriched by various types of expertise;

- the storage of information on developed and exploited products, processed by learning machines, allows the creation of decision support tools based on artificial intelligence.

The main objective of Science and Engineering Challenge is to provide the students with the scientific, technical, and human skills necessary to design, build, and operate construction and transportation vehicles that are efficient on the economic, social, and environmental levels.

Adviced prerequisites

Programming in Matlab or Python, recommended: Continuum Mechanics

Context and issue modules: These modules will make it possible to present the social, economic, environmental, and human challenges of digital transformation in the sectors of the Construction, City, and Transportation major, so that the future engineers understand the driving forces behind it and can put their scientific and technical skills at the service of a digital transformation that respects the humanist values at the core of the CentraleSupélec curriculum. Conferences, round tables, personal notes will raise awareness of the problems of digital transformation, with the associated socio-economic obstacles and aspects, as well as the challenges of transforming professions and working methods (future of work).

Specific course (60 HEE) : Introduction to digital twin

Brief description: The concept of digital twin reflects the mirroring of what exists in the real world and what is modelled in a virtual world. The digital twin contains all the information of the physical system it represents (geometry, electrical, electronic, and thermal networks, embedded software, etc.) as well as algorithms for processing this information by mimicking or predicting its behavior (learning machine, AI, optimization, etc.). It is a technological tool which allows to reinforce the performance of the object it represents, to anticipate its evolutions throughout its life cycle, to plan production or maintenance activities, to make its design evolve within a framework constrained by economic, social, and environmental performance objectives.

This introductory course to digital twin focuses on objects from the construction (building, bridge, etc.) or transportation (vehicle) sectors. Aspects related to information on the geometry, the behavior of the system (mechanical for example) and the external dynamic solicitations (wind, pedestrians, swell...) is presented. The course highlights the fact that the

different sources of information contained in the digital twin are processed by different fields of expertise and different jobs (architect or designer, structural engineer, fluid mechanic...) which each rely on their own tools, methods, and practices.

The main objective of the course is to provide students with the necessary skills to manage the information contained in a digital twin throughout the life cycle of the object it represents.

The students who enroll in this course gain skills to create and enrich the digital twin of a simple physical object from the transportation or construction sectors by modeling its geometry, behavior, and dynamic external actions in a systemic approach. In addition, students are confronted with the difficulties of exchanging relevant information between these different jobs.

Challenge week: Information processing for the design of an engineering structure

- Associated partner: Systra

- Location: Paris-Saclay campus

- Brief description: The aim of this course is to put students in the situation of an engineer in charge of the rehabilitation of a civil engineering structure to bring it into compliance with regulations. More specifically, students will have to propose a rehabilitation plan for a bridge built in a zone where the seismic hazard is revised by a new regulation.

The students are given as a starting point a digital model containing the geometric data and mechanical properties of an existing bridge as well as a specification to bring it into compliance with some new seismic regulations. The partner of the thematic sequence (Systra) plays the role of the client of the rehabilitation study mission in front of teams of 4 to 6 students who will then have to:

- adopt the posture of a design engineer adapted to the collaborative context (identification of the players, understanding of the respective responsibilities / scope of action, adapted communication / respect of a certain protocol);

- analyze and process the geometric and mechanical information from the digital model of the bridge to propose a simplified but relevant mechanical model at the preliminary design stage

- analyze and process statistical information from earthquake databases

- manipulate digital design tools;

- manipulate numerical or analytical tools for modelling mechanical behavior;

- To be part of a process of automating the design of a bridge rehabilitation plan from a database of existing bridges and the development of artificial intelligence.

At the end of the Science and Engineering Challenge, each team presents its seismic bridge rehabilitation project.