1SC2894 – Evolutionary Games

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Department: DOMINANTE - INFORMATIQUE ET NUMÉRIQUE
Language of instruction: FRANCAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27,00

Description

The theory of evolutionary games is the application of game theory to the study of the evolution of populations in biology and more generally to the study of biological phenomena with applications in many different fields including sociology, anthropology and economics. Evolutionary game theory is based on Darwinian evolution and comprises three main stages: competition (play), natural selection (replicator dynamics) and heredity.
In this context we are interested in genetic algorithms (which are part of evolutionary algorithms) deal with optimization problems and search parameters using bio-inspired operators such as mutation, crossing and selection.

Quarter number

ST2

Prerequisites (in terms of CS courses)

Having attended the ST2 course "Theorie des jeux"

Syllabus

The subject of this EI aims to apply evolutionary algorithms to a bioinformatics problem. The project consists in 1) designing the evolutionary operators; 2) parameterizing the designed operators bearing in mind that several parameters have to be finely tuned to obtain good results and that there is no methodology for this adjustment which must be carried out according to the data and the objective to to reach; 3) to combine them through the execution of an (evolutionary) game in order to obtain a solution approaching as much as possible the fixed objective, knowing that the objective is not necessarily attainable. As a consequence, several parameters for several operators must also be tested in order to improve the proposed solution. For example, the question : "What happens if you re-inject evolution history into operators?" Requires many executions to compare trends.

Class components (lecture, labs, etc.)
Students must be able to organize themselves into working groups in order to segment the work to be done. Two approaches are possible : collaboration or competition. A third way would be to combine the approaches, either at the same time or in different times during the project. What is the capacity of the group to organize itself, to make leaders emerge, to accept its emergence? What is the ability of leaders to bring the group to the desired goal ?

Grading
The evaluation consists of a seminar session where each student's group is going to present the project done

Resources
Development and analysis of genetic algorithms baased optimisation framework through the Python programming language.

Description of the skills acquired at the end of the course
Students will have acquired basic notions for the conception, implantation and solution of an optimization problem trough the methodology of genetic (evolutionary) algorithms

SCIENCE AND ENGINEERING CHALLENGE N°4 COURSES

ST4 – 41 – SYSTEMS MONITORING AND PROGNOSTICS FOR RISK MANAGEMENT

Major : GSI (Grands Systèmes en Interaction)
Language : English
Campus : Paris-Saclay & Metz for one challenge week

Engineer related topic

Today, complex industrial systems are all integrated into risk management processes. These processes aim to prevent serious failures, to limit their effects, and to optimize protection measures or return to service procedures. They encompass fields of expertise that are both numerous and varied, such as applied statistics, management, modeling, simulation, decision support, etc. The general objective of this thematic sequence is to show how specific areas related to information processing (Applied statistics and Signal processing) can be used to contribute to risk management.

Let us take the example of railway, land or air transport systems. The infrastructures, vehicles and devices welcoming users are equipped with a large number of sensors that continuously collect data relating to their state of health. The processing of this monitoring data collected online makes it possible to detect the aging or malfunction of certain components and to update the prognostics of breakdowns or accidents. If problems are detected early enough, we are able to anticipate and adapt maintenance plans and operational modes. We will then speak about predictive maintenance. If the problems are detected too late, we will be more likely to manage a crisis situation and reduce its effects. We will then speak about resilience.

In order to optimize predictive maintenance or resilience strategies upstream, we will use so-called “historical” data collected by the same types of sensors in the past or from additional studies (on similar systems, in the laboratory, etc.). These data will be used to build models and calculate performance indicators such as maintenance costs or return to service times after an accident.

These "online" detection/prognostics and upstream optimization approaches are applicable to other sectors such as manufacturing industry, energy production and distribution, extraction of petroleum resources, etc. It is all the more important in sectors activity requiring a high level of safety, such as nuclear or aeronautics.

Two fundamental questions are addressed in this ST:

• What are the benefits, both economic and in terms of safety, that can be obtained by optimizing predictive maintenance and the resilience of industrial systems and infrastructures?

• What steps need to be considered to establish relevant predictive maintenance and resilience?

Prerequisite

Main statistics and probability courses.

Introductory period: this sequence aims to give a vision of the theme from several angles:

- Introductory lectures on the issue of resilience, risk analysis and predictive maintenance and the associated economic issues
- Highlighting interest in advanced methods for maintenance, risk analysis, diagnosis
- Presentation related to the social, economic and geopolitical environment, in the context of the industry 4.0

Specific course (60 HEE): Systems monitoring and prognostics for risk management

Brief description: Industrial systems monitoring, prognosis and decision-making encompass several areas of expertise, from data analysis to management, including modeling and decision support. The content of this course is designed to be integrated into the thematic sequence: "Information processing for the resilience of systems and infrastructures" and to meet the challenges proposed by industrial partners during the integration week.

The general objective of the course is to show how statistical and data-driven approaches (probabilistic modeling, parametric estimation, hypothesis tests, classification, machine learning, stochastic processes) can contribute to the monitoring of systems, to the prognosis of their failure and decision support for maintenance or risk management in the broad sense.

The first focus is to estimate the probability that a technical system will not fulfill its main function. We present a set of methods which allows:

- to predict the instant of failure for an isolated element, or a set of interconnected elements (called a system),
- to predict online the evolution of a degradation phenomenon based on monitoring data.

The next focus is how the processing of available system health information can help the decision-maker minimizing the delay before resumption of service and the effects of a failure. We present a set of methods which allow:

- to diagnose a failure,

- to evaluate the performance of a maintenance strategy
- to make a decision under uncertainty.

based on historical data and online monitoring data.

Challenge week #1: Algorithms for monitoring and decision of the state of health of aircraft engines. Application to the diagnosis of the oil circuit of a turbojet.

- **In partnership with:** Safran
- **Location :** Paris-Saclay campus

  Brief description: The availability and safety of aircraft have been at the heart of air transport since their creation. Failures, particularly in flight, may result in the aircraft being diverted to an airport other than the destination or delayed on arrival. They can also significantly degrade the engine. The extra costs generated can be significant for the company or the manufacturer. In collaboration with Safran, this integration course focuses on the monitoring of the state of health of aircraft engines by limiting the study, because of the complexity of the general problem, in the case of the oil circuit of a turbojet. The oil circuit plays a vital role in the lubrication of the engine bearings of an aircraft. Several failure modes can lead to a degradation of the lubrication efficiency inducing the damage of the bearing and then the engine and subsequently a stopping of the engine in flight. This has important consequences in economic terms: availability of the engine or repair if the engine is repairable.

  - Failures can occur for example due to leaks or coking (deposits on pipes or sprinklers). One of the paths explored for detecting a failure of this system is to monitor a number of circuit parameters such as pressure or temperature.
  - In this case study, the goal is to be able to detect a drift. The direct use of the pressure is insufficient due to the dispersions of the flight scenarios.
  - The question of finding the influencing parameters on the oil pressure become primordial by means for example of a statistical modeling. Subsequently, algorithms need to be design to follow-up and help the decision process.

Challenge week #2: Flood risk management for an electricity production system

In partnership with: EDF R&D

– **Location :** Paris-Saclay campus

– **Brief description:**

The operator of electricity production facilities EDF's mission is to make the best use of its system, over time, in order to produce the electricity required in its load plan as profitably as possible and in complete safety.

One of the major challenges of risk management in this sector of activity is the forecasting and anticipation of the effects of natural disasters, and more generally, rare events having an impact on the proper functioning of infrastructures. Optimal risk management involves predicting hazards, that is to say initiating events likely to create dysfunctions, analyzing their consequences and implementing barriers to mitigate their effects.

The objective of this project is to reproduce the optimization of a risk management approach on a use case. This involves dimensioning the height of a dike which constitutes a protective barrier against the risk of flooding for a nuclear power plant located along a river.

The risk analysis is carried out on the basis of historical flood data and a physical flow model making it possible to calculate the height of the overflow. Decision-making regarding the height of the dike is optimized from a cost model taking into account investment costs, maintenance costs, and costs in the event of flooding.

Challenge week #3: Application of data analysis for the improvement of steel manufacturing processes

– **In partnership with:** ArcelorMittal

– **Location :** Metz campus

– **Brief description:** Within the ArcelorMittal process center, a transversal department works on measurement and control issues. This department develops solutions for all steel manufacturing processes. The developments concern the instrumentation and the control of the factories as well as the characterization of the products, whether it is surfaces property or materials. A group is dedicated to data analysis algorithms in the framework of developing models for predicting product quality and improving the reliability of manufacturing tools. This last point is very important for the group, a challenge is to be able to anticipate the failures to avoid or limit the stops of the chain of production. These activities are part of the themes of the digital engineering within the framework of industry 4.0, which are flagged as a scientific excellence in the field of data analysis.

The proposed study concerns heating furnaces of a hot rolling mill located in Differdange, Luxembourg. The anomalies that occur from time to time require the stopping of the furnaces. The aim is to predict in advance the failures that will occur based on the analysis of data from temperature sensors. Students will work on data (sensor + labeling of operators) provided by ArcelorMittal. Practical implementation will be done in Matlab, Python or RapidMiner.

Challenge week #4: Data-driven reliability estimation and optimal operation planning for health care equipment.

- **In partnership with:** GE health care
- **Location :** Paris-Saclay campus
- **Brief description :**

Health care equipment in general has high reliability requirements: its failure might directly endanger the lives of patients. At the same time, health care equipment also has high availability requirements: the hospitals in general could not afford too-long downtime as they have to keep serving patients. Understanding the reliability of health care equipment is, thus, an important topic in medical care industries.

In this project, we work with GE Healthcare (GE HC), one of the leading supplier to health care equipment globally. GE HC has to satisfy the high reliability and availability requirements for their products. For this, they have to maintain a large-scale aftersales(service) supply chain supporting over one million systems installed globally in the world. More than 400,000 spare part references, including~10,000 repairable parts are potentially necessary to maintain the installed based (IB). How to effectively manage so many products, while satisfying the high reliability and availability requirements, is, thus, a very challenging problem. At the same time, during the product design, development, and, more importantly, the operation phases, there are a large number of data available. Although these data might be noisy and contain large degree of missing information and uncertainty, they are valuable sources that could provide some insights to the reliability of the products, which could be further used to improve the efficiency of the operation of the after-sale supply chain.

The aim of this project is, then, to provide tools and processes to leverage the reliability information from the data and to enrich decision making process in the operations of the after-sale supply chain. In this project, you will be able to:

- Work with the real dataset provided by GE HC;
- Develop data-driven reliability models for health care equipment, on both the component and system level;
- Experience how to deal with the “imperfectness” of a practical dataset;
- Experience how to improve a current process with the help of data analytics on the reliability data.