Université de Limoges

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ACSYON

Master of Applied Mathematics

http://www.unilim.fr/acsyon

Key points of the training

- This master's degree in Applied Mathematics prepares students for a career as an Engineer or a Researcher in the rapidly expanding field of Scientific Computing.
- Cutting edge companies and research laboratories need more and more specialists able to develop and to apply innovative mathematical methods to solve increasingly complex problems.
- The two years of ACSYON graduate program respond to this challenge.
- ACSYON focuses on applications of Mathematics where the University of Limoges has a leading expertise and strong research track records: optimization and variational analysis, nonsmooth dynamics, numerical optimization, symbolic-numeric computation, mathematical methods for control theory, semi-algebraic optimization, PDEs and shape optimization.
- Most instructors are researchers at XLIM laboratory of the University of Limoges and the French National Center for Scientific Research (CNRS).
- An important part of the training period is done on individual projects, case studies and practical works on computers. This is an essential part of the training occuring during the second year.
- The last semester of the second year is devoted to an internship of 4 to 6 months. This work, chosen to fit in with the professional aspirations of the student, can be carried out in a private company or in a public research laboratory in France or aboard.

Training organization

According to the **European Credit Transfer System** (ECTS), a two years master's program is worth **120 ECTS** (60 ECTS per year).

First year of the master (M1)

- Eight courses are delivered in English and **online** (distance learning) by the University of Limoges. The online courses are MOOC-like and use a Moodle platform (community-sciences.unilim.fr). Each course is worth **3 ECTS**. The whole on-line courses = **24 ECTS**. All these courses are in English.
- The reminder of **36 ECTS** are delivered either:
    - On-site at the University of Limoges, the other courses are shared with the master CRYTIS MATHS.
    - In a **partner university**, with which an **agreement** is established.
      At the present time, our partners are : University of Pisa (Italy), University of Quy Nhon (Vietnam),University of Sfax (Tunisia), University of Bodo (Burkina Faso), Lebanese University (Lebanon), University of Settat (Morocco).
    - At ENSIL-ENSCI for students from this engineering school from Limoges.

Second year of the master (M2)

- There are two semesters. Each semester is worth **30 ECTS**. The first semester on-site at the University of Limoges. All courses are in English. The students live in Limoges during this period (September to January). The second semester is an internship either in a French or foreign research laboratory or in a private compagny.

Teaching units

M1 – First semester 1 (S1) – September → January

- **Convex analysis** (3 ECTS – online)
  Convexity plays a key role in optimization. This course is an introduction to basic concepts of convex analysis.

    - Basic convexity concepts in finite dimension
    - Topological properties of convex sets
    - Separation of convex sets
    - Convex functions

- **Optimization** (3 ECTS – online)
  This is a view on optimality conditions of the first and second order in unconstrained and constrained optimization.

    - Unconstrained Optimization

- Constrained Optimization – Case of linear constraints
- Constrained Optimization – General case
- Lagrangian Duality

- **Practical Optimization** (3 ECTS – online)
  The goal is to learn how to effectively solve an optimization problem. We will see how to modelize an optimization problem and to compute an optimal solution in concrete situations. A modeling language and efficient solvers for optimization will be widely used.

  - Introduction to optimization and modeling languages (soft. AMPL)
  - Unconstrained problems and least-squares problems (soft. MINOS, SNOPT)
  - Linear programming (soft. CPLEX, XPRESS)
  - Constrained optimization (soft. SNOPT, KNITRO, IPOPT)

- **Introduction to differential equations** (3 ECTS – online)
  Differential equations are evident tools for of applied mathematics for modelization. This course is on some basics about ordinary and partial differential equations.

  - Ordinary differential equations
  - Partial differential equations

M1 – Second semester (S2) - February → June

- **Symbolic analysis** (3 ECTS – online)
  In this course we will see how computer algebra can be used in analysis to give controlled approximation or even exact solutions to some problems. We will cover functional equations with a focus on non singular linear ordinary differential equations. We will also see the case of computation of rational approximations of complex or singular functions and divergent series.

  - Numbers, polynomials and power series
  - Power series and differential equations
  - Effective analytic functions and evaluation
  - Power series and local solution of more general functional equations

- **Introduction to numerical analysis of PDE** (3 ECTS – online)
  We will see some numerical methods to solve partial differential equations.

  - Introduction to PDE
  - Finite difference method
  - Finite element method

- **Dynamical systems** (3 ECTS – online)

  - Introduction to applied dynamical systems
  - Lyapounov stability
  - Invariance principle
  - Attractivity results

- Application to problems in control theory

- **Semidefinite optimization** (3 ECTS – online)
  The main goal of the course is to present Semidefinite Optimization, the convex optimization problem of minimizing a linear function over the cone of positive semidefinite symmetric matrices. We discuss the theory and the application of semidefinite optimization with examples e.g. from control theory and combinatorial optimization. We use solvers implemented in Matlab to solve instances of this problem in practice.

  - Symmetric matrices and the positive semidefinite cone
  - Semidefinite optimization and linear matrix inequalities (duality, optimality conditions, algorithms)
  - Applications of semidefinite optimization (combinatorics, control theory)
  - Practical experiments with SDP solvers under Matlab (SeDuMi, SDPT3)

M2 – First semester (S3) - September → January

- **Linear and nonlinear optimization** (6 ECTS – onsite)
  This course is about the algorithms to solve optimization problems. We will review and study in detail some numerical methods to solve linear and nonlinear optimization problems with continuous and/or integer variables.

  - Review of optimality conditions with and without constraints
  - Unconstrained optimization methods : Conjugate gradient algorithm, Newtonian methods, line search and trust region techniques
  - Linear programming (LP), simplex method, interior point methods, complexity
  - Quadratic optimization
  - Constrained optimization methods : SQP, primal-dual interior-point methods
  - Integer linear programming
  - Mixed integer nonlinear optimization
  - Semi-definite programming and application to combinatorial optimization
  - Large scale optimization and machine learning

- **Nonsmooth dynamics and applications** (4 ECTS - onsite)

  - Mathematical formalism (differential inclusions, evolution variational inequalities, complementarity problems, sweeping process)
  - Applications in mechanical and electrical engineering
  - Lyapounov stability of nonsmooth systems
  - Discretization and numerical simulation (time-stepping, event-driven, LCP solvers, SICONOS platform).

- **Optimal control** (4 ECTS - on-site)
  This course is an introduction to optimal control theory. The objective is to learn the basics allowing to study and solve simple examples of optimal control problems. For this purpose, we will provide some existence and controllability results, and of course we will state the Pontryagin Maximum Principle that allows to solve explicitly a large number of basic examples. Some numerical solvings will be performed in Practical Works.

  - Introduction
  - Cauchy-Lipschitz theory with Carathéodory dynamics
  - Pontryagin maximum principle
  - Controllability and observability
  - Existence results
  - Linear-quadratic theory

- **PDE constrained optimization** (4 ECTS – onsite)
  The goal is to learn how to solve an optimization problem with PDE constraints. We will see how to model some concrete situations as a PDE constraints optimization problem and how to study these problems theoretically and numerically. To this aims we give some reminder on practical tools in functional analysis, optimization and PDE. Then, we'll learn how these tools may become involved in order to solve PDE constraints optimization problems.

  - Reminder on theoretical functional analysis
  - Reminder on practical functional analysis
  - Practical tools for PDE
  - Practical tools for optimization
  - PDE constrained optimization

- **Symbolic-numeric computation** (4 ECTS – onsite)
  In this lectures, we will develop some tools taking profit from both numerical analysis and computer algebra to design algorithms. It allows to treat problems that none of the two approaches can treat alone, as approximate greatest common divisors, rational interpolation or numeric approximation of algebraic special functions.

  - Introduction to symbolic-numeric computation. Floating-point numbers, error analysis.
  - Elements of numerical linear algebra : linear systems and conditioning, matrix factorizations, eigenvalue computation, structured matrices, FFT.
  - Singular value decomposition : statement and proof of existence, geometrical interpretation, Eckart-Young theorem, applications (least squares, image compression and reconstruction…)
  - Univariate polynomials : rootfinding techniques, multiplication via evaluation/interpolation, resultant matrices, exact and approximate gcd.

- **Semi-algebraic optimization** (4 ECTS – onsite)
  The course provides an introduction to methods and algorithms for solving the general semialgebraic optimization problem, that is, computing the infimum of a polynomial

function subject to polynomial equations and inequalities. We will discuss theoretical tools and use the software Gloptipoly to solve this problem in practice.

- Positive polynomials and certificates of positivity via semidefinite programming
- The semialgebraic optimization problem and its SD-Relaxations
- Moments and the moment problem
- Practical experiments with soft. Matlab and Gloptipoly

- **Asymptotic analysis and singular perturbation theory** (4 ECTS – onsite)
  The aim of this course is to provide an introduction to the theory of asymptotic analysis starting from the basic definitions and concepts and ultimately focusing on asymptotic and perturbation methods of solving systems of differential equations depending on a small parameter.
  - Introduction to perturbation theory
  - Asymptotic expansions
  - Asymptotic expansion of integrals
  - Asymptotic solutions of linear differential equations near singularities
  - Perturbation theory of ordinary differential equations

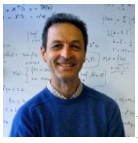
M2 – Second semester (S4) - February → July

- **Internship** (30ECTS)
  The duration of the internship is between 4 to 6 months. It can be done in a research laboratory or in a public or private company, in France or in a foreign country. At the end of the internship, the student submit a report, which is evaluated by two referees. Then the student defends his report in front of a jury of members of the pedagogical team.

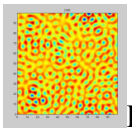
Faculty

FACULTY MEMBERS


Samir ADLY, Professor, Variational analysis


Paul ARMAND, Professor, Numerical optimization


Moulay BARKATOU, Professor, Computer algebra

 Loïc BOURDIN, Associate professor, Optimal control

 Noureddine IGBIDA, Professor, Partial differential equations

 Simone NALDI, Associate professor, Semi-algebraic optimization

 Olivier RUATTA, Associate professor, Symbolic-numeric computation

TEACHING VISITORS

 Vincent ACARY, Researcher at INRIA, non-smooth dynamical systems

 Fabien CAUBET, Associated professor at IMT Toulouse, shape optimization

 Sonia CAFIERI, Professor at ENAC Toulouse, Mixed Integer Nonlinear Optim.

 Nicolas COUELLAN, Professor at IMT Toulouse, Machine learning

 Stef GRAILLAT, Professor at Paris 6, Symbolic-Numeric Computation

 Didier HENRION, Researcher at LAAS, Semi-algebraic optimization

 Bernard MOURRAIN, Researcher at INRIA, Geometric modeling

Admission Requirements

First year of the master (M1):

- The candidates must have previously completed an undergraduate Licence level diploma (European LMD) or an equivalent degree such as Bachelor's degree in Science (BSc) or in Engineering (Beng) that includes courses in pure and applied mathematics.
- English language proficiency required.

Second year of the master (M2):

- Students who have acquired 60 ECTS at Master Level of the European system LMD (or equivalent) and can demonstrate skills and knowledge equivalent to the first year of ACSYON may directly join the second year.
- English language proficiency mandatory.

Application procedures

Before any administrative procedure, student interested by the master must contact directly those responsible of the master. All applicants must supply the following documents:

- Detailed and complete curriculum vitae
- Academic transcripts from the most recently completed semester or year. Transcripts in languages other than English or French must be accompanied by an English or French translation provided by the institution issuing the transcript or by a certified translator.
- Letters of recommendation. Applicants are required to ask at least two instructors familiar with their work to send letters of recommendation on letterhead with original signatures.
- Motivation essay. Applicants should submit a statement of no more than one page outlining their general academic interests and their reasons for applying to ACSYON.
- In addition, applicants whose mother tongue is not English and who have not completed an undergraduate or graduate degree from a recognized foreign institution where English is the language of instruction are required to submit documented proof of competency in oral and written English.

VERY IMPORTANT

- **For foreign students whose country of residence joins CAMPUS France** must submit their applications on CAMPUS France before **March 20**.
  List of countries: Algeria, Argentina, Benin, Brazil, Burkina Faso, Cameroon, Chile, China, Colombia, Comoros, Congo, Côte d'Ivoire, Egypt, Gabon, Guinea, India, Indonesia, Iran, Japan, Lebanon, Madagascar, Mali, Mauritania, Mauritius, Mexico, Morocco, Peru, Russia, Senegal, Singapore, South Korea, Syria, Taiwan, Togo, Tunisia, Turkey, United States, Vietnam.

- **For other students apply online* until May 18**
  * http://candidatures2.unilim.fr:8080/ecandidat

After your application is reviewed by the teaching committee and successful, you will receive the instructions to make your administrative registration file.

- For any administrative information, contact Master's Office « Scolarité – Bureau des Masters » msciences@unilim.fr Faculté des Sciences et Techniques 123, avenue Albert Thomas 87060 Limoges (FRANCE) tél : +33 (0)5 55 45 74 02.
- Other informations are available on the website of the Sciences et Technology Faculty.

Studying in Limoges

- Limoges city is the regional capital of the Limousin region. With a population of nearly 200,000, this city combines the advantages of a large city, but with an excellent quality of life and a moderate living cost.
- With 14,000 students, the University of Limoges is a dynamic and innovative university. The University of Limoges is firmly committed to its international outlook policy, welcoming many foreign students and researchers.
- Limoges can be easily reached by car from Paris in about 4 hours via A20 highway.
- You can also take the train from Paris Austerlitz station to reach in less than 3 hours the Gare de Limoges, the famous railway station, architectural masterpiece and symbol of the city.
- The International Airport of Limoges is directly connnected to several major European cities such as London, Paris and Lyon.
- The public transport (STCL) consists of a network of 28 bus lines of which 5 lines of trolleybus.
- There are numerous accommodation facilities for students at reasonable prices. The International Office and the CROUS can help you to find suitable housing.

Any relevant information related to the studies in our city of Limoges can be found on the webpage of Limoges University (www.unilim.fr).

Contact info

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