

CS-328

**Numerical methods for visual computing and ML**

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Cursus	Sem.	Type
Communication systems	BA3	Opt.
Computer science	BA3	Opt.
HES - IC	H	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Written
Workload	120h
Weeks	14
<b>Hours</b>	<b>4 weekly</b>
Lecture	2 weekly
Exercises	2 weekly
<b>Number of positions</b>	

**Summary**

Visual computing and machine learning are characterized by their reliance on numerical algorithms to process large amounts of information such as images, shapes, and 3D volumes. This course will familiarize students with a range of essential numerical tools to solve practical problems in this area.

**Content**

This course provides a first introduction to the field of numerical analysis with a strong focus on visual computing and machine learning applications. Using examples from computer graphics, deep neural networks, geometry processing, computer vision, and computational photography, students will gain hands-on experience with a range of essential numerical algorithms.

The course will begin with a review of floating point arithmetic and error propagation in numerical computations. Following this, we will study and experiment with several techniques that solve systems of linear and non-linear equations and perform dimensionality reduction. Since many interesting problems cannot be solved exactly, numerical optimization techniques constitute the second major topic of this course. We will take an extensive look at automatic differentiation, the mechanism underlying popular deep learning frameworks such as PyTorch and Tensorflow. The course concludes with a review of numerical methods that introduce randomness to solve problems that would otherwise be intractable.

Students will have the opportunity to gain practical experience with the discussed methods using programming assignments based on Scientific Python.

**Keywords**

Visual computing, machine learning, numerical linear algebra, numerical analysis, optimization, scientific computing

**Learning Prerequisites****Required courses**

MATH-101 (Analysis I) and MATH-111 (Linear Algebra).

**Recommended courses****Important concepts to start the course**

Students are expected to have good familiarity with at least one programming language (e.g. C/C++, Java, Scala, Python, R, Ruby...). The course itself will rely on Python, but this is straightforward to learn while taking the course.

During the first weeks of the semester, there will be tutorial sessions on using Python and Scientific Python.

## Learning Outcomes

By the end of the course, the student must be able to:

- Develop computer programs that use numerical linear algebra and analysis techniques to transform and visualize data.
- Reason about ways of structuring numerical computations efficiently.
- Analyze the numerical stability of programs built on top of floating point arithmetic.
- Recognize numerical problems in visual computing applications and cast them into a form that can be solved or optimized.

## Teaching methods

Lectures, interactive demos, theory and programming exercises

## Expected student activities

Students are expected to study the provided reading material and actively participate in class and in exercise sessions. They will be given both theoretical exercises and a set of hands-on programming assignments.

## Assessment methods

1. Continuous assessment during the semester via project assignments (35%)
2. Final exam (65%)

## Resources

### Bibliography

Slides and other resource will be provided in class.

The course textbook is

*Numerical Algorithms: Methods for Computer Vision, Machine Learning, and Graphics* by Justin Solomon (freely available at the following link: [http://people.csail.mit.edu/jsolomon/share/book/numerical\\_book.pdf](http://people.csail.mit.edu/jsolomon/share/book/numerical_book.pdf))

An optional reference is

*Scientific Computing: An Introductory Survey* (2nd edition) by Michael Heath

### Ressources en bibliothèque

- [Numerical Algorithms: Methods for Computer Vision, Machine Learning, and Graphics / Solomon](#)
- [Scientific Computing: An Introductory Survey / Heath](#)

### Moodle Link

- <https://go.epfl.ch/CS-328>

## Prerequisite for

Although it is not a strict prerequisite, this course is highly recommended for students who wish to pursue studies in the area of Visual Computing, in particular: CS-341 (Introduction to computer graphics), CS-440 (Advanced computer graphics), CS-442 (Computer vision), CS-413 (Computational Photography), CS-444 (Virtual Reality), and CS-445 (Digital 3D geometry processing)