ERASMUS+ International PhD Summer School 2025

- Mathematics and Machine Learning for image analysis -
3 June – 11 June 2025

1 Overview

The Summer School aims to tackle cross-cutting mathematical approaches to **imaging sciences** and **machine/deep learning**, essential for young PhD students/researchers interested in discovering the fascinating connections between these disciplines. The school aims at providing the students with both the theoretical and applied foundations of the mathematics of machine learning for imaging with an overview to challenging applications.

The summer school consists of four teaching blocks, each focusing on a specific topic and taught by a different lecturer and a preliminary teaching block (3 hours) on Tuesday 3th of June for a short introduction on machine learning, an alignment abacus to allow students to follow subsequent advanced courses. This will be in blended format, the lecturer in presence at the Department of Mathematics. Each of the other 4 blocks (6 hours each) is complemented by a lab session (2 hours) and/or exercise session (2 hours). To complements these sessions, seminars given by experts in imaging and covering a wide range of applications will be organized. The final blended session with exams will be organized one week after the conclusion of the school. The total number of hours will be 42 split over two consecutive weeks.

A certificate of attendance and number of 4 ECTS will be assigned.

2 Organizers, Lecturers and ERASMUS+ Partners

The school will be organized by the University of Bologna and co-organized by the scientific committee of the MIVA (Matematica delle Immagini, della vision visione e loro applicazioni) UMI group.

2.1 Organizing committee

- Luca Calatroni, CR CNRS, Laboratoire I3S, UCA, Sophia-Antipolis, France, **e-mail**: calatroni@i3s.unice.fr
- Marco Donatelli, Dipartimento di Scienza e Alta Tecnologia, Università degli Studi dell'Insubria, Italy, **e-mail**: marco.donatelli@uninsubria.it
- Alessandro Lanza, Department of Mathematics, University of Bologna, Bologna, Italy, **e-mail**: mailto:alessandro.lanza2@unibo.it

- Serena Morigi, Department of Mathematics, University of Bologna, Bologna, Italy, **e-mail**: serena.morigi@unibo.it

- Marco Prato, Dipartimento di Scienze Fisiche, Informatiche e Matematiche Università di Modena e Reggio Emilia, Italy **e-mail**: marco.prato@unimore.it

- Matteo Santacesaria, Department of Mathematics, University of Genoa, Italy,**e-mail**: matteo.santacesaria@unige.it

2.2 Lecturers

- **Lecturer:** Thomas Pock,
  Affiliation: Graz University of Technology, Graz, Austria
  e-mail: pock@icg.tugraz.at

- **Lecturer:** Martin Benning,
  Affiliation: University College London, London, United Kingdom
  e-mail: martin.benning@ucl.ac.uk

- **Lecturer:** Andreas Hauptmann,
  Affiliation: University of Oulu, Oulu, Finland
  e-mail: Andreas.Hauptmann@oulu.fi

- **Lecturer:** Marcelo Pereyra,
  Affiliation: Heriot-Watt University, Edinburgh, United Kingdom
  e-mail: m.pereyra@hw.ac.uk

2.3 ERASMUS+ International PhD Summer School partners

The Summer School is organized in the framework of Blended Intensive Programmes (BIPs) under the bilateral agreement between the University partners of the Program Erasmus+ 2021 − 27 KA131 Learning Mobility of Individuals (diri.erasmusbip@unibo.it).

List of Partners in the bilateral agreement:

- Centrale Supélec-Université Paris-Saclay, Paris, Prof. Jean-Christophe Pesquet, jcpesquet-pro@gmail.com, FRANCE

- Université Paul Sabatier Toulouse II, Prof. Jean-Denis Durou yvain.queau@enseeiht.fr , FRANCE

- University of Graz, Prof. Kristian Bredies, Kristian.bredies@uni-graz.at, AUSTRIA

- Tampereen yliopisto, Prof. Alessandro Foi, alessandro.foi@tuni.fi, FINLAND

- Slovenská technická univerzita v Bratislave, Prof. Karol Mikula, karol.mikula@gmail.com, SLOVAKIA

- National University of Science and Technology POLITEHNICA Bucharest, Prof. Ion Necoara, i.necoara@yahoo.com ROMANIA

- Helsingin yliopisto, Prof. Samuli Siltanen samuli.siltanen@iki.fi, FINLAND
- Université Côte d'Azur (UCA), Sophia-Antipolis, Prof. Luca Calatroni, calatroni@i3s.unice.fr FRANCE
- Universität Hamburg, Hamburg, Prof. Martin Burger, martin.burger@uni-hamburg.de, GERMANY
- KTH Royal Institute of Technology Stockholm, Prof. Ozan Öktem, ozan@kth.se SWEDEN
- University of Copenhagen, Prof. François Lauze, francois@diku.dk DENMARK

3 Practical information

Following the success of the previous editions (link to the 2023 edition), (link to the 2024 edition) the proposed summer school is expected to attract about 80 graduate students, III University Cycle.

- The **dates are 3/06 − 11/06 2024** (spread over two weeks), but they may be subject to changes in case major conferences/events on analogous topics should happen at the same time.
- The summer school will take place at the **Department of Mathematics, University of Bologna, Bologna, Italy (UNIBO)**. Many services are available specifically for students: student residences, snack bars, an interdisciplinary library, study rooms open all day and at weekends, and scientific-technological laboratories.
- The lecture room is located at the Plesso Belmeloro, via Andreatta 8, for the morning session and at the Department of Mathematics, UNIBO, Bologna P.zza Porta San Donato 5, for the afternoon session. The classroom is equipped with free University WIFI system, it has a capacity for 90 students, see Fig.1, an ICT Laboratory will be available for a total of 100 student's workstations. WifiLab is a wireless network to access the Department of Mathematics virtual labs.
- Coffee breaks will be served by a catering service and the lunches will be offered at the University canteen; students, organizers and lecturers will have meals together so as to favour the informal discussion and the scientific exchange.
- To encourage interactions between students and lecturers/organizers, during the weekend a one day trip to Rimini/Ravenna will be organized as well as a social dinner in Bologna. Furthermore, a two-hour **Poster contest** will be organized during the second week of the school.
- The summer school has dedicated webpages which contain slides, codes, exercises as well as news and day-by-day scheduling (link to the PhD summer school).
- There are several flights from/to Bologna international airport as well as several trains connecting Bologna with many large Italian cities.



Figure 1: (left) UNIBO CamPlus entrance; (center) classroom; (right) ICT Lab.

4 Intended Audience

The summer school will be designed for PhD students, as well as early career researchers (e.g. post-docs) with background in applied mathematics, computer science, engineering or physics.

We will pay particular attention to ensuring equal opportunities of access to the summer school, without discrimination of sex, ethnicity, religion or income. A possible selection due to the capacity of the classrooms will be based mainly on merit and the interest to the topics covered by the summer school.

5 Courses

The summer school will cover the following topics:

- **Teaching unit 1**: Getting started: **Introductory Machine Learning** (Blended): basic tools for theoretical understanding and practical use of the main supervised and unsupervised learning algorithms.**Lecturer**: *Prof. ????*
- **Teaching unit 2**: **Applications of inverse problems in imaging**: learned iterative reconstructions for large-scale and/or nonlinear inverse problems from a practical point of view. Combining analytical and data driven methods for industrial and medical applications.**Lecturer**: *Prof. Andreas Hauptmann*
- **Teaching unit 3**: **Optimization-based machine learning for computational imaging Lecturer**: *Prof. Thomas Pock*
- **Teaching unit 4**: **Bayesian imaging methods** we could start from a suitably introductory level which we would tailor to these specific cohort of PhD students, and then go quickly towards modern techniques based on diffusion processes and machine learning, which I would illustrate on challenges inferences such as uncertainty quantification, hypothesis testing, model self-calibration, model selection without ground truth, etc.**Lecturer**: *Prof. M. Pereyra.*
- **Teaching unit 5**: **Regularisation theory coupled with machine learning Lecturer**:*Prof. M. Benning*
- **Teaching unit 6**: Final Evaluation (blended form).

In addition to this teaching units, the following activities will be organized:

- **Scientific seminars** given by experts working in industrial sectors working on topics such as biomedical imaging, cultural heritage, HPC, medical imaging.
- **Computing imaging lab. activities**. **Instructors**: MIVA-UMI Staff.

5.1 Examination

During the examination day, students will gather together on an online platform to work collectively and/or individually on specific assignments integrated in the blended intensive programme and evaluate the overall learning outcomes. The examination will be organized in a virtual form, one week after the end of the summer school.

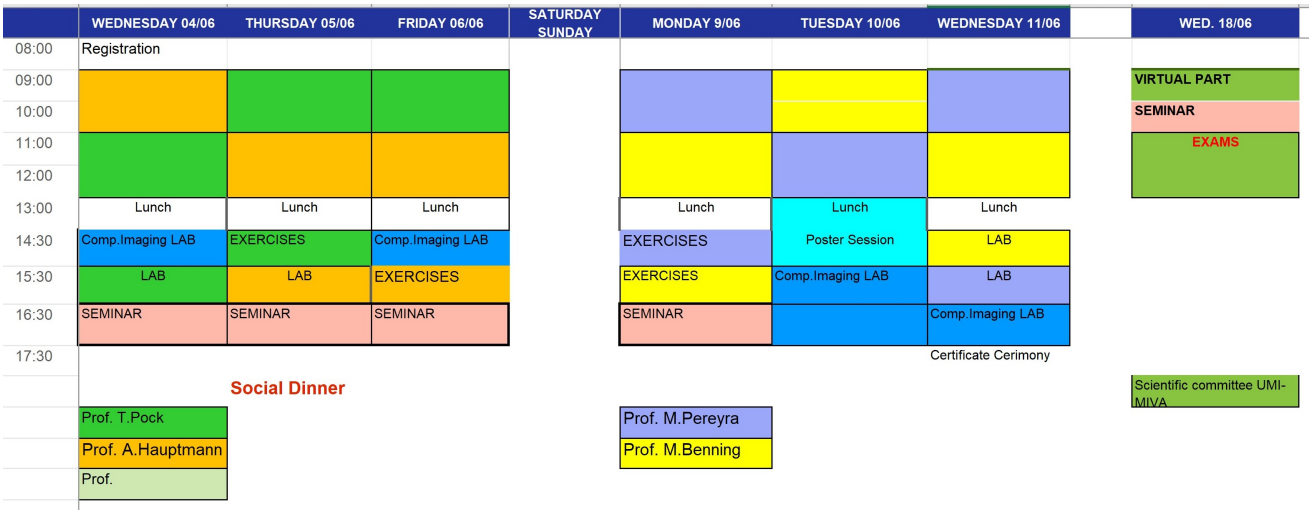

Figure 2: Tentative schedule.

5.2 Schedule

A tentative day-by-day schedule of activities is illustrated in Fig.2.

6 Funding

A bilateral agreement under the ERASMUS+ BIP program with the partner countries must be signed: it will allow to allocate scholarships for incoming students from the countries in Section 2.3, as well as to cover the expenses for all the invited lecturers from the different countries. Incoming applicant students (at least 5 from each partner sites, for a total number of at least 15) will be asked to apply through their university systems for an ERASMUS scholarship which will cover their travel expenses and a per-day cost.

Registration is free ,but mandatory for all the students. Catering service will cover the lunches and coffee breaks. Expenses will be partially covered by the University of Bologna (6000 Euro from Blended Intensive Programmes (BIPs) funds awarded for organization of courses).