MICROSCOM: Erasmus Mundus Joint Master in Advanced Microscopy with Artificial Intelligence

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ABSTRACT

MICROSCOM is an Erasmus Mundus Design Measure project awarded by the European Commission to establish a two-year International Master's programme in Advanced Microscopy with Artificial Intelligence (MICROSCOM), what is called Erasmus Mundus Joint Master (EMJM). The EMJM MICROSCOM programme will be the first of its kind to comprehensively address all aspects of the computational microscopy field, including a thorough understanding of microscopy principles, methods, and techniques, as well as software and hardware development and integration. It will also cover the incorporation of artificial intelligence (AI) techniques and edge computing, along with practical projects focused on real-world problems. The EMJM will be administered by a consortium of Higher Education Institutions (HEIs) from Ireland, Spain and the United Kingdom, in conjunction with international partners from academia and industry who possess specialised expertise to oversee MSc Thesis.

Keywords: International Master Degree, Erasmus Mundus Master, Education, Advanced Microscopy, Artificial Intelligence, Computational Microscopy

1. INTRODUCTION

An Erasmus Mundus Master is a collaborative and international Master's programme provided by European universities and higher education institutions, and occasionally by other affiliated nations. The European Union funds these programmes, both students and participating institutions, through the Erasmus Mundus programme, offering students exceptional opportunities to pursue advanced studies in various disciplines across multiple higher education institutions in different countries. Students enrolled in an Erasmus Mundus Master programme are given the chance to obtain either a joint degree or multiple degrees from the institutions involved. This allows them to gain an international educational experience and develop an intercultural perspective in their chosen field of study.

Students of an Erasmus Mundus Master programme are obligated to relocate to various educational institutions in different countries throughout the program's duration. By participating in this programme, students can gain valuable insights from studying in various international and cultural settings, while also accessing the specialised knowledge and resources offered by each partner institution. Transferring between institutions can additionally enhance the development of international professional and personal connections, thereby enhancing the overall global educational experience for the student.

Here we present the MICROSCOM project[1] funded as part of the Erasmus Mundus programme. The main goal of the Erasmus Mundus Design Measure (EMDM) project called MICROSCOM is to develop a collaborative European Master's Programme. The International Master will provide a joint degree in *'Advanced Microscopy with Artificial Intelligence'*. We aim to launch a unique two-year international master's focused on computational microscopy and its applications. Computational microscopy involves the creation of software and hardware to

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improve the entire process of acquiring and analysing microscopic image data. This pioneering program will provide comprehensive education covering all facets of computational microscopy. Thus the main objective is to educate proficient individuals in the field of computational microscopy who will possess a thorough knowledge of: a) the fundamental principles, methodologies, and techniques of microscopy; b) artificial intelligence (AI) techniques for building AI models and use of image processing tools applied to microscopy; and c) the development and integration of customised hardware.

The specific objectives are: i) develop a curriculum in computational microscopy to guarantee high academic standards; ii) to foster interdisciplinary collaborations and forge partnerships between leading academic institutions and companies in the field of computational microscopy and its practical implementations; iii) to establish procedures for student selection, admission criteria, standard student services, administrative and financial oversight, and policies regarding joint degrees; and iv) to establish and create strategies to guarantee the program's prominence and long-term viability.

Currently, there is no Master programme that covers this field comprehensively, considering the three mentioned areas. This shortcoming will be addressed by the MICROSCOM project, which will cover the entirety of the digital microscopy life cycle, as well as practical projects tackling real-world problems.

2. METHODS

The Erasmus Master Degree that will be developed as part of the MICROSCOM project will consist of 120 ECTS (European Credit Transfer and Accumulation System) credits. This will include 30 credits earned at each Higher Education Institution (HEI) involved in the programme, as well as an additional 30 credits for the final Master's thesis conducted in collaboration with other institutions, including companies and research intritutions. The Higher Education Institutions involved in this collaboration are University College Dublin (UCD), Universidad de Castilla-La Mancha (UCLM) and University of Glasgow (UofG).

The Master's programme will be accessible to undergraduate students hailing from STEM disciplines and any country in the world. STEM disciplines encompass academic fields that pertain to Science, Technology, Engineering, and Mathematics. STEM areas cover a broad spectrum of academic disciplines, such as biology, physics, computer science, electrical engineering, chemistry, mathematics, and more. Europe has promoted STEM education and careers through various initiatives. An example is the AutoSTEM project, which is part of the Erasmus programme. This project uses automata to introduce STEM concepts and skills to young children in various subject areas, such as measurement, power transfer, mechanics, numbers, creativity, and comprehension.[2]

Prior to admission to the Master's programme, a rigorous selection process will be conducted. Upon admission to the Master's programme, students are required to earn 30 ECTS credits at each institution within the first 3 semesters of the programme. Students will be encouraged to transfer to different HEIs. During the last semester, students have the option to either return to one of the HEIs or pursue placements and complete their final master's project at a company or research centre. During the summer, specifically at the conclusion of the 2nd semester in June and before the start of the 3rd semester in September, students will be required to participate in a two-week summer school. Additionally, they will be expected to engage in an 8 to 9-week period of placement at a collaborating institution affiliated with the Master's programme. This collaborating institution may be either a company or a research centre.

The master's program will be launched in February 2025, with the student selection phase concluding in July 2025. The programme will officially begin in September 2025.

Open Call

At present, we are in the process of establishing an external consortium consisting of 33 institutions, including universities, research centres, and companies. There is still room for collaboration, so we are launching a public invitation for collaboration with all institutions that may have an interest in accommodating Master's students for a duration of 2 to 5 months as part of their placement and/or for the completion of their final Master's project. Additionally, we welcome sponsorship and participation in various events organized within the Master's program, such as workshops, summer schools, and conferences. The European Commission will fully finance the internship, including providing financial support to the host institutions for their supervision. Interested institutions are required to send an email to the corresponding author.

Overview

The Master's programme will cover both theoretical and practical content and develop problem solving skills and competencies in the field of computational microscopy. The three primary modules will consist of: a) Instruction on microscopy principles at UDC; b) Education on image processing and artificial intelligence techniques at UCLM; and c) Training on customised hardware development and integration at UofG. Figure 1 provides a comprehensive overview of these modules.

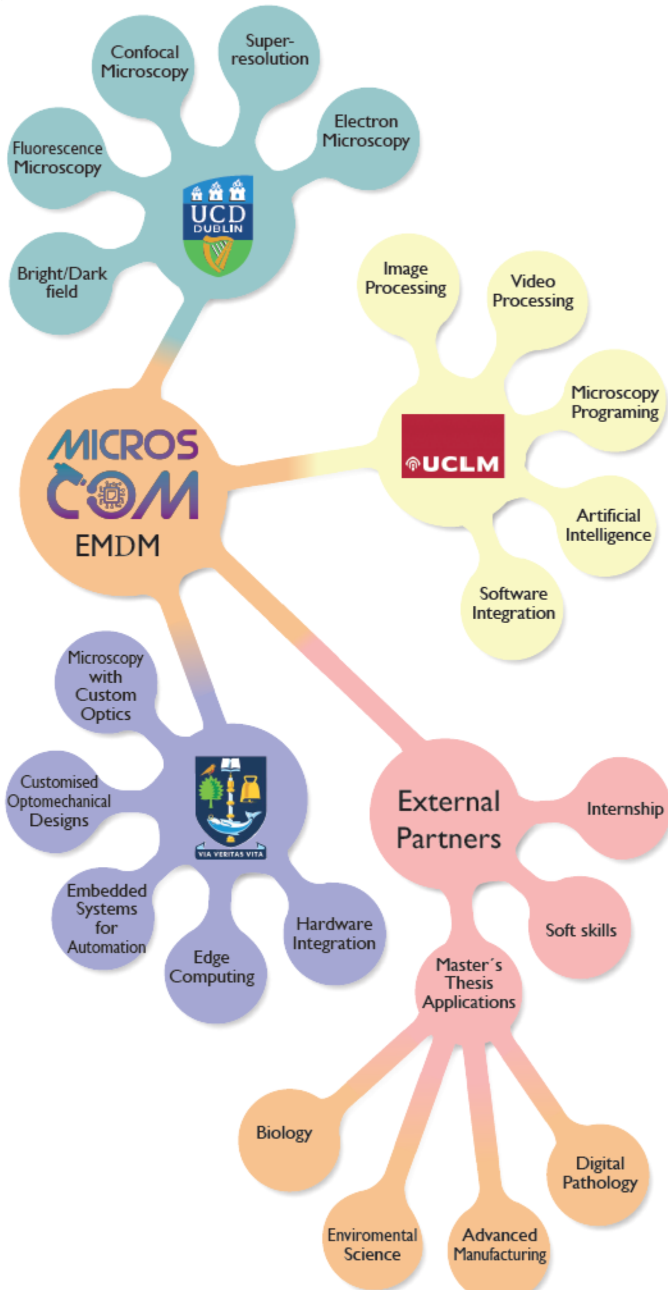

Figure 1: Overview of the Erasmus Mundus Master's modules to be proposed under the MICROSCOM EMDM

The students will receive specialized training in research methodology by completing a Master's Final Project that will enable them to develop a research project to be implemented in several international settings. External

Internships will focus on gaining a deeper understanding of the practical aspects of computational microscopy.

Microscopy is essential in a variety of areas and disciplines, and its application extends to a wide range of scientific and technological fields. Figure 2 shows a visual representation of computational microscopy and a selection of its applications. All images are owned by the authors and have been created as a result of their projects. These are just some of the areas in which microscopic imaging plays a fundamental role:

1. Biology: For studying cellular structure, tissue functioning, microbiology, genetics, among others.
2. Physics: For studying phenomena at small scales, such as atomic and molecular structure, and for investigating properties of materials under extreme conditions.
3. Engineering: For designing and inspecting microelectronic devices, small-scale mechanical components, and advanced materials.
4. Environmental Science: For analyzing samples of soils, waters, and microorganisms, as well as studying the ecology of microbial communities and environmental pollution.
5. Medicine: For the purpose of disease diagnosis, the examination of tissue and cell samples, as well as the monitoring of medical treatments.
6. Materials Science and Nanotechnology: For analyzing the structure and properties of materials at micro and nanoscales, crucial for the development of new materials and enabling advancements in fields such as electronics, medicine, and energy.
7. Chemistry: For visualizing chemical reactions at the molecular level and observing the structure and composition of chemical compounds.
8. Geology: For investigating the structure of minerals and rocks, as well as studying geological processes at microscopic scales.
9. Archaeology: For examining artifacts and archaeological samples at a microscopic level, which can reveal information about their origin, manufacture, and preservation.

Professional Outcomes

According to certain media outlets and experts, there will be a significant demand for STEM jobs in the labour market. STEM professionals commonly possess traits such as innovation, practicality, and logical reasoning. The central aspect of this educational model emphasises the capacity to generate new ideas, create and find solutions to problems in a creative manner, which will be required by the future professions. Various European initiatives have actively encouraged STEM education and professions in Europe.

In this particular, possessing a master's degree in computational microscopy and practical expertise in its diverse applications is essential for a broad spectrum of professional prospects, both at the user at developed level. Proficiency in microscopic techniques, as well as in developing and using image processing tools, including the application of artificial intelligence for analysing microscopic images, along with knowledge and experience in custom optomechanical design, particularly for microscopy hardware integration, is essential and highly valued in diverse professional and academic settings. Some of these professional settings and outcomes are:

1. Biomedical Engineering: In companies and research centers dedicated to developing medical devices and biomedical technologies, where microscopic image processing is employed in designing and evaluating medical devices and diagnostic systems.
2. Biomedical Research: In medical research laboratories and healthcare centers, where microscopic image processing is essential for analyzing biological samples, diagnosing diseases, and researching medical treatments.

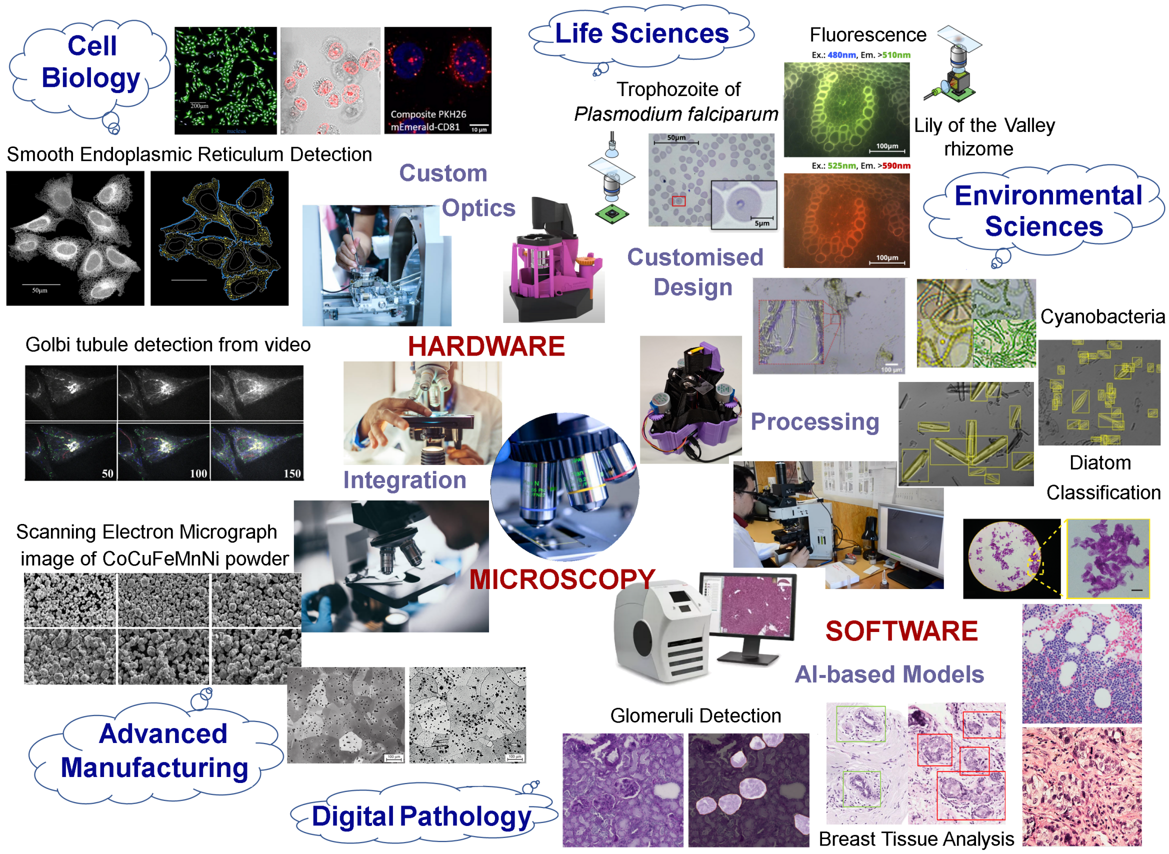

Figure 2: Graphical overview of computational microscopy and some of its applications

3. Microscopy Industry: In companies manufacturing microscopy equipment and image analysis software, where knowledge in image processing and data analysis is essential for developing new products and technologies.

4. Advanced Microscopy Systems Development: Understanding customized optomechanical design allows for the creation of specialized microscopy systems tailored to specific research needs. This expertise ensures the development of high-performance imaging setups optimized for various applications, such as super-resolution microscopy or live-cell imaging.

5. Data Science and Artificial Intelligence: In companies and organizations involved in data analysis and developing artificial intelligence algorithms, where knowledge in image processing can be applied in biomedical image analysis, pattern recognition, and other related fields.

6. Medical Diagnosis: In clinical laboratories and medical research centers, where computational microscopy is employed for disease diagnosis, cancer cell detection, analysis of biological samples, among others.

7. Portable and Point-of-Care Diagnostics: The integration of edge computing and hardware into portable microscopy devices facilitates the development of point-of-care diagnostic tools. These tools can deliver rapid and accurate analysis of biological samples in remote or resource-limited settings, supporting healthcare delivery and disease management.

8. Smart Microscopy Devices for Industry: Customized optomechanical design, combined with edge computing and hardware integration, enables the development of smart microscopy devices for industrial applications. These devices can incorporate advanced imaging capabilities, such as defect detection in manufacturing processes or quality control in semiconductor fabrication, improving productivity and product quality.

9. Materials and Nanotechnology Industry: In companies developing and manufacturing new materials and devices at the nano scale, where computational microscopy is used to investigate and control material properties at atomic and molecular levels.
10. Materials Science Research: In research laboratories and materials development companies, where microscopic image processing is used to analyze the structure and properties of materials at micro and nano scales, as well as investigate manufacturing processes and material characterization.
11. Pharmaceutical and Biotechnology Industry: In companies involved in drug discovery, medical device development, and related technologies, where computational microscopy is used for drug discovery, protein structure research, characterization of biomedical materials, among others.
12. Semiconductor and Electronics Industry: In companies manufacturing electronic components and microelectronic devices, where computational microscopy is crucial for the design, characterization, and quality control of devices at micro and nanometer scales.
13. Academic Research: At universities and research centers, where new techniques and technologies in the field of computational microscopy are developed to advance scientific knowledge in areas such as biology, medicine, materials science, physics, among others.
14. Research and Development Companies: In companies across various sectors conducting research and development of new technologies, where computational microscopy is used for material characterization, designing innovative products, and process optimization.

These are just a few examples where proficiency or training in computational microscopy would be necessary. Overall, the specialised knowledge in computational microscopy improves innovation and productivity in a wide range of fields, including biomedical research and industrial manufacturing. The applications of computational microscopy encompass a broad spectrum of fields and industrial sectors where the observation and analysis of samples at micro and nano scales are crucial.

3. CONCLUSIONS

In summary, this article outlines the proposal for the MICROSCOM project, funded as part of the Erasmus Mundus program, to develop an international master's program focused on computational microscopy and its applications. The International Master will provide a joint degreen in 'Advanced Microscopy with Artificial Intelligence'. The significance of possessing a master's degree in computational microscopy and practical expertise in this domain is emphasised for a wide range of career opportunities.

Currently, 33 institutions have already expressed their interest in participating, but there is still room for collaboration. Therefore, we present an open call to encourage and invite this collaboration. We extend an invitation to institutions to engage in hosting Master's students for placements and final projects, as well as participating in the Master's program events and sponsoring the Master's program. The European Commission will fully fund these opportunities, offering financial support to host institutions for supervision. Institutions that are interested are advised to contact the corresponding author for more information.

The proposed Master's programme will comprise 120 ECTS credits and provide study opportunities at UCD (Dublin, Ireland), UCLM (Ciudad Real, Spain) and UofG (Glasgow, United Kingdom) and several placement over different countries all around the world. The significance of internships in companies and research centres is underscored, along with the importance of collaborating with external institutions for project development. The Master programme will be launched in February 2025, with the selection of students being finalized in June 2025 and the official start of the Mastercourses taking place in September 2025.

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