Integration of Photonics and Artificial Intelligence for the Analysis and Preservation of Cultural Heritage

Field of Study : Arts and Culture, Information Science and Engineering

SUPERVISORS

	First name	LAST NAME	University	Research Unit
Supervisor	Davide	Rocco	UNIBS	NORA group- DII
Co-Supervisor	Luis Agustin	Hernández	UNIZAR	GRAPHyC group

KEYWORDS

Photonics, artificial intelligence, cultural heritage, metasurface, paintings

ABSTRACT

Cultural heritage, encompassing artifacts such as paintings, is a significant part of human history and identity. However, these artifacts are susceptible to degradation over time due to environmental factors, improper handling, and aging. To carefully analyze, preserve and digitalize these invaluable pieces, innovative approaches are necessary. The integration of photonics and artificial intelligence (AI) offers a promising avenue for non-invasive analysis, condition assessment, and digitalization of paintings. This research proposes to explore the combined use of photonics and AI in analyzing and preserving paintings, with an emphasis on developing advanced methodologies for real-time monitoring and imaging.

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or REA. Neither the European Union nor the granting authority can be held responsible for them.

Research aims and methodology

The major goal of this research project is to design and develop an optical device that can replace the traditional bulky spectral imaging system with great potential application in miniaturization and planarization.

This will be possible by replacing the classical components with their nanoscale counterparts, i.e. by using the so called metasurface. A metasurface is a two-dimensional engineered material composed of an array of subwavelength-sized structures, known as meta-atoms, that are specifically designed to manipulate electromagnetic waves in a highly controlled manner. These structures are often made of metals or dielectrics and can be arranged in various patterns on a surface to achieve desired electromagnetic properties.

Due to the miniaturization offered by metasurface-inspired optical components, the significant reduction in size and weight of the final device, will makes it a promising candidate for applications where compactness, low weight, and robustness are of primary importance such as portable hyper-spectral imaging for in-field scanning of cultural heritage. More broadly, the outcomes of this project paves the way toward better realization of potentials of optical component based on metasurfaces in implementing advanced functional optical and optoelectronic systems for operation under strict constraints.

The complexity and interdisciplinarity of the project require careful planning of the implemented methodologies. An important focus of the project will be on the optical part. The candidate's skills relating to electromagnetic fields and their propagation will be developed and deepened. Numerical simulation tools with different software will be fundamental to become familiar with the proposed problem and to design a prototype of the final device based on metasurfaces. The device design phase will be supported by inverse design and machine learning methods provided by recent developments in artificial intelligence. Finally the designed device will be tested experimentally by conducting detailed studies on selected historical paintings from museum collections, applying the developed photonics-AI techniques to assess their current state and recommend preservation actions. The evaluation of the practicality of the proposed system will be finally addressed.

Relevance and added-value of the proposed research in relation to the current state of knowledge

A common challenge with almost all of the state-of-art hyper-spectral imaging platforms is their compact, robust, and low-weight implementation, limited by the requirement for relatively complicated optical systems and reliance on mostly bulky conventional optical elements. Incorporating metasurfaces into hyperspectral imaging

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or REA. Neither the European Union nor the granting authority can be held responsible for them.

systems represents a significant leap forward in terms of performance, efficiency, and practicality. By enabling miniaturization, higher resolution, improved sensitivity, and cost-effective production, metasurface-enhanced hyperspectral imagers can open up new possibilities for applications ranging from cultural heritage preservation to environmental sensing and medical diagnostics. Hence, this integration represents the main added-value of the proposed research in relation to the current state of knowledge. Furthermore, the use of artificial intelligence could lead to a more performing device than is currently foreseeable with standard design techniques.

Interdisciplinary nature of the research together with the alignment with the CHORAL programme and complementarity expertise of the teams

The presented project is completely aligned with the interdisciplinary nature of the CHORAL programme. On the one hand, the final use of the device under study is to analyze cultural heritage and therefore the skills of the prof. Agustin Hernandez Luis and his research unit are necessary. On the other hand, for the design based on metasurfaces the expertise of the Brescia unit are fundamental for the success of the project.

Output plan including publication and disseminationactivities

The primary channels will be communications at international conferences, workshops, master programs and publication of peer-reviewed papers in international journals. The partners will preferentially target reputable high-impact journals. All publications will be at least green-Open-Access. Team members will attend scientific and industrial conferences in their specific areas, where they will present the whole project's aims and objectives.
Conference participation will be coordinated to cover the largest span of disciplines (artifical intelligence, optics and photonics, cultural heritage) and reach the broadest relevant audience. This dissemination strategy aims at expanding fundamental and applied research in the field.

Estimated schedule

Task	Timeline
Literature Review	5 months
Development of Photonics Techniques	8 months
AI Model Development	8 months
Evaluation and Validation	9 months
Final Report and Dissemination	6 months

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or REA. Neither the European Union nor the granting authority can be held responsible for them.