POLITECNICO DI MILANO

PhD in ARCHITETTURA, INGEGNERIA DELLE COSTRUZIONI E AMBIENTE COSTRUITO / ARCHITECTURE, BUILT ENVIRONMENT AND CONSTRUCTION ENGINEERING - 41st cycle

THEMATIC Research Field: MR HOLOGRAPHIC APPLICATION TO SUPPORT THE CH CONSERVATION ACTIVITY

Monthly net income of PhDscholarship (max 36 months)
€ 1400.0
In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	This research falls within the field of Cultural Heritage (CH), emphasizing reality-based surveying and the integration of 3D data into Mixed Reality (MR) applications to enhance conservation and maintenance processes. After three years of research, development, and field experimentation, the MR prototype for heritage maintenance—successfully tested at the Milan Cathedral—now serves as a solid foundation for a second research phase focused on scalability, interoperability, and wider operational deployment. The proposed work aims to transform the current solution into an extensible and modular platform, adaptable to various architectural and territorial heritage contexts, while prioritizing the on-site user experience.While the Milan Cathedral remains the main case study, other heritage sites may be integrated. The first research task is to optimize the current MR interface for next-generation devices, identifying and preparing suitable hardware solutions. The second step involves updating and testing the localization system for holographic sensors in large, complex physical environments, expanding on earlier prototypes. Next, the

	project will focus on the integration of advanced point cloud manipulation tools and 2D metric data overlays within the MR environment. These tools will allow users to isolate, annotate, and edit 3D spatial data in real time, enabling precise analyses and targeted interventions even in highly stratified contexts.A crucial development axis will involve connecting the MR system to the Cathedral's emerging Information System and to diverse databases (historical, diagnostic, photographic, maintenance, BIM/GIS), starting with the Milan Cathedral archive. Using dedicated APIs and middleware, the system will access, update, and correlate multi-source data in real time, creating a dynamic and interconnected knowledge ecosystem.The final component foresees close collaboration with fellow researchers to integrate AI capabilities into the MR application. These will support real-time detection of objects and surface characteristics, facilitating spatial localization of deterioration and data-driven maintenance insights.This research seeks to evolve a functional prototype into a scalable, intelligent, and open digital platform, capable of supporting effective, long-term conservation strategies across diverse heritage contexts. By leveraging MR, AI, and integrated data systems, the platform will promote sustainable preservation practices and unlock new potential for informed, spatially aware heritage management.
Methods and techniques that will be developed and used to carry out the research	The study will utilize a multidisciplinary approach to improve the technological, operational, and cognitive performance of the current Mixed Reality system. This phase will introduce new functionalities and integration strategies, emphasizing broader applicability, enhanced data interaction, and intelligent automation, rather than reiterating previous achievements. The investigation will start with the adoption and configuration of emerging MR hardware, focusing on devices that enhance spatial awareness, user comfort, and interaction fidelity. This study will investigate innovative interaction paradigms, such as multimodal input (gestures, voice, gaze), focusing on accessibility and intuitiveness in field conditions across

	various stakeholders. The project aims to enhance MR deployment in complex architectural settings by refining spatial anchoring and registration workflows. This will involve adapting existing positioning algorithms and implementing new localization protocols specifically designed for large-scale, non-uniform heritage spaces. These protocols will guarantee consistent content alignment, even in geometrically irregular or visually obstructed regions. An essential component involves enhancing the system's ability to visualize and analyse dense 3D point cloud data. Interactive point cloud editing tools will be embedded within the MR interface to achieve this goal. Users can extract significant spatial subsets, annotate features in situ, and correlate these with two-dimensional datasets, facilitating comprehensive multi-scale analysis on-site. The project will introduce a flexible data integration layer that can interface with various repositories, including historical archives, diagnostic reports, and existing digital models. The facilitation will occur through the design of interoperable middleware solutions and the establishment of standardized data exchange protocols, which will enhance communication between the MR application and external platforms. The integration of AI-driven visual analysis will facilitate real-time interpretation of surface conditions and object recognition, thereby advancing innovation. Computer vision techniques will facilitate the automated identification of degradation patterns, while advanced machine learning models may aid in predicting material deterioration, thereby enabling preventive conservation strategies. The topic has already been studied and is currently being developed by other PhD researchers. The objective is to modify methods and techniques for real-time holographic applications.
Educational objectives	The project aims to foster interdisciplinary skills at the intersection of architecture, digital technologies, and heritage conservation. It will enhance the ability to design and implement MR-based tools for complex cultural sites. The participant will develop critical thinking on data integration, user-centered design, and AI applications in

	the built environment.
Job opportunities	The project opens up career opportunities in digital heritage, architectural conservation, and immersive technology development. Experience in MR, 3D data processing, and AI-driven analysis is highly sought after in both academia and industry. The interdisciplinary profile developed through this research aligns with emerging roles in smart heritage management and the candidate will be well-positioned to lead innovation in the digital transformation of cultural assets.
Composition of the research group	0 Full Professors 2 Associated Professors 0 Assistant Professors 4 PhD Students
Name of the research directors	Prof. Francesco Fassi

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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents	--

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

Stage and period abroad	
Institution or company where the candidate will spend the period abroad (name and brief description)	
By number of months abroad	0

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
Additional support: **Budget for the research activity (only for positions supported by scholarship):**total amount

Euro 5.707,20 per student.

In detail:

-1styear Euro 1.902,40

-2ndyear Euro 1.902,40

-3rdyear Euro 1.902,40**.**

Additional information about the organization and regultions of ABC-PhD programme can be found in the Regulations for the 41stCycle of ABC-PhD:download is available at link: https://www.dottorato.polimi.it/en/phd-programmes

Additional information about ABC department and ABC-PhD programme:available at link: https://www.dabc.polimi.it/

Desk availability: The ABC department provides non-permanent desks to be temporarily booked in common PhD rooms.