Call for PhD applications

Title: Automatic classification of photographic images for spatio-temporal monitoring of restoration sites

Grant: Fondation des Sciences du Patrimoine (Cultural Heritage Foundation)

Abstract
Over the last decade, a large number of digital documentation projects have demonstrated the potential of image-based modeling (photo modeling, photogrammetry, ...) of heritage objects in the context of documentation, conservation and restoration. The inclusion of these emerging methods in the daily monitoring of the activities of a heritage restoration site (context in which hundreds of photographs per day can be acquired by multiple actors and according to several observation and analysis needs) raises new questions at the intersection of big data management and of the semantic enrichment and the automatic classification of this data, for the purpose of searching by content similarity. This PhD project has the ambition to introduce a disruptive approach for the massive processing of large collections of photographs, distributed in space and time. This project is part of the CNRS and French Ministry of Culture scientific workcamp for the restoration of Notre-Dame de Paris and, in particular, within the framework of a working group in charge of building a "digital ecosystem" capable of evolving as the studies progress, by progressively centralizing the resources collected, produced, analyzed and interpreted by the scientists and professionals involved in the restoration workcamp. Through interactions with the working groups involved in this scientific work site (wood/charpente, stone, stained glass, metals, structure, acoustics, heritage emotions, etc.), the problem of automatic indexing of masses of photographs will be addressed by combining several complementary 2D/3D semantic enrichment methods.

Keywords : heritage science, computer vision, content-based retrieval, multimodal data analytics, data semantics.

State of the art
Over the past decade, the emergence of a large number of digital documentation projects has demonstrated the potential of digitizing heritage artifacts at different scales. In particular, the use of 3D digitization technologies (and digital imagery in the broadest sense) in the framework of cultural heritage documentation programs has led to the emergence of a new generation of graphic supports, useful for multiple purposes: archaeological analysis, monitoring of deterioration phenomena, dissemination and representation of historical knowledge, etc. The use of 3D digitization technologies in the context of cultural heritage documentation programs has led to the development of a new generation of graphic supports, useful for multiple purposes: archaeological analysis, monitoring of deterioration phenomena, dissemination and representation of historical knowledge, etc. 3D Reality-capture is now considered as the field of technological research based on the use of sensors [Remondino et al., 2010]. In this framework, thanks to the progress of photogrammetry and computer vision, the last ten years have been characterized by an impressive growth of image-based 3D reconstruction approaches [Vu et al., 2009; Wenzel et al., 2012; Rupnik et al., 2017].

The inclusion of these new methods of digital documentation in the daily monitoring of the activities of a heritage restoration site (a context in which hundreds of photographs per day can be acquired by multiple actors and according to several observation and analysis needs) raises new questions at the intersection between big data management and the semantic enrichment and the automatic classification of this data for the purpose of searching by content similarity. Indeed, any observation and analysis of a material, a shape or a space in the field of heritage restoration frequently implies the identification of similarity metrics for comparison, indexing, interpretation and classification of shapes as phenomena to be studied. The confrontation of this daily need for memorization, analysis and categorization, with the most recent advances in digital sciences applied to heritage documentation, highlights three complementary issues.

First of all, the measures of similarity between various 'digital objects', which has been an active research area for several years, from the introduction of image analysis techniques by computer vision to the more recent approaches of 3D model analysis by algorithmic geometry. These methods provide today good results for the applications of indexing and recognition of multimedia objects [Baltrušaitis et al., 2019] [Ma et al, 2021], and their application to the field of cultural heritage [Biasotti et al., 2015].

Next, the management of heterogeneous digital contents, relying mainly on formal structures (thesauri, ontologies, etc.) capable of describing in an univocal manner implicit and explicit conceptual elements (as well as their interrelationships) [Doerr, 2002] mobilized in the documentation of heritage artifacts, including in the specific field of conservation-restoration [Bannour et al., 2018].

Finally, methods to enrich representations of forms and spaces with descriptive attributes: from methods for linking semantic tags to 3D representations [Havemann et al., 2008], to approaches for organizing heterogeneous data sets around a morphological description [Manferdini et al., 2008]. Moreover, the joint analysis of spatial and temporal data has become of particular importance for the study of transformations or evolution of objects [Krauß and Tian, 2020], for the temporal distribution of categorized events, as well as for the distribution of spatio-temporal data [Belussi et al., 2018].

Several works of the MAP laboratory (CNRS/Ministry of Culture) have focused on the intersection of these three issues by introducing approaches for the semantic structuring of multidimensional representation sets for the documentation and conservation of cultural heritage [De Luca et al. 2011, Manuel et al. 2014, Messaoudi et al. 2017].

Objectives

The current degree of spread of personal digital cameras, combined with the increasing acquisition of photogrammetry skills within the community of scientists and heritage professionals, makes it possible today to envisage the collaborative (and participative) construction of image corpora and digital models capable of documenting (and also mapping) the daily activities of a restoration site.

This PhD project has the ambition to introduce a breakthrough methodological approach for the massive processing of large collections of photographs through the integration of recent methods of computer vision, image indexing and semantic structuring of heterogeneous data. In particular, the questions of spatial and temporal distribution of photographs will be addressed in conjunction with that of content-based indexing. First of all by exploiting the projective relationship between images and the three-dimensional scenes reconstructed from these images [Manuel A. 2016], as a propagation path for sets of semantic attributes collected by labelling and annotation methods. Then, by evaluating the potential of monomodal [Gominski et al., 2019] [Ma et al, 2021] and multimodal [Piasco et al., 2018; Piasco et al., 2021] image matching and indexing machine learning methods in scenarios of analysis of complex transformations at the scale of monumental architecture. By crossing these methods, we will try to identify approaches for the automatic semantic enrichment of spatialized and temporally distributed images, but also of point clouds resulting from photogrammetric correlation calculations, in particular

through classification approaches [Poux, 2019] likely to take into account several sets of descriptors (morphological, visual, temporal, ...).

In the domain of semantic description and indexing of heterogeneous data, we will explore in particular graph embedding approaches [Trsedya et al. 2019] to introduce modular similarity measures in heterogeneous RDF semantic graphs. These graphs combine the conceptual level properties and relationships of the objects of study, including features related to restoration-conservation [Bannour et al. 2018], with the spatiotemporal and visual relationships extracted with the methods mentioned above.

The software implementation of the methods designed during this PhD could be based on the integration and/or extension of several software modules (developed in recent years by the three laboratories involved in the project) concerning image matching and 3D point cloud generation by photogrammetry, 2D/3D annotation based on descriptive attributes and reading levels organized around terminological structures, interactive visualization of multi-dimensional representations within web interfaces.

Experimental framework

While being oriented towards the introduction of reproducible methods and tools to be used in the field of documentation, conservation and restoration of cultural heritage in the broad sense, this PhD project is part of the CNRS and the French Ministry of Culture's scientific project for the restoration of Notre-Dame de Paris and, in particular, within the framework of the working group on "digital data" (www.notre-dame.science).

Several tens of thousands of photographic images, point clouds and 3D models documenting the cathedral in several temporal states (before, after fire and during restoration) are available to the scientific site and will be exploitable within the framework of this PhD project.

Candidate profile

For this highly interdisciplinary PhD topic, applications are expected from several disciplinary sectors in the domain of Information and Communication Sciences and Technologies, with, if possible, experiences in digital applications to heritage documentation.

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Remuneration: 35k euros gross/year

Application procedure
To apply, send a PDF document (a single file) including:
- Detailed Curriculum Vitae
- Cover letter
- Diploma (giving access to a PhD thesis registration) and Master's grades (M2)
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Start date of the PhD: to be defined between spring and fall 2021

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