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Photogrammetry and Deep Learning to improve Cultural Heritage records: extracting 3D metric information from historical images

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Summary

The thesis aims to give an analysis and assessment through the extraction of metric information from historical images and to experiment with its potentialities in the heritage field with the aim of valorising historical iconographical documentation.

This thesis deals with historical images stored in historical archives in the heritage context. This documentation has been produced for many other purposes but actually contains something very valuable for Cultural Heritage: data and information. Specifically, the thesis explores how to extract and use dimensional data from historical images for documenting monuments, buildings and groups of buildings that no longer exist or were transformed over time.

This thesis focuses on two kinds of images documentation, historical photographs and film footage from the early 19th century. Concerning the extraction of metric information from historical images, this thesis intends to give an upgrade of the previous studies on this topic using the latest developed technologies. This upgrade is in terms of metric precision provided with the use of classical photogrammetry combined with Deep Learning solutions. The output is a method, suitable for different fields, but experimented with as an application in the heritage context.

In this proposed method Deep Learning is used for the retrieval of primary data used as input material in the standard Structure-from-Motion (SfM) pipeline used to reconstruct lost Cultural Heritage. Object detection Neural Networks were trained to automatically recognise a specific monument in film footage and image collections. Then the images suitable to be processed with photogrammetry are selected from all the frames detected by the Neural Network. The selection is performed according to the camera motions within the scene of the video. Only the shots taken from multiple points of view of the same scene are suitable for the photogrammetric process. In order to process these data and to obtain metrically

certified results, a modification of the algorithms of the standard photogrammetric pipeline was necessary. This purpose was achieved with the use of open-source Structure-from-Motion algorithms and the creation of a specific benchmark to compare the results.

Specifically, this thesis is divided into five Chapter. After the introduction in Chapter 1, Chapter 2 is dedicated to photogrammetry applied to historical images. A classification and a state of the art of historical archives material considering their possible use in metric documentation and thus suitable for photogrammetry is performed. Then, a photogrammetric workflow is proposed to process historical images and the maximum metric quality level reachable by the photogrammetric processing is investigated.

In Chapter 3 the state of the art of Deep Learning applied to Cultural Heritage is presented. In particular, an innovative match-moving method is proposed to improve ways to search for architectural heritage in video material and to reduce the effort of manually examining them by the operator in the archive in terms of efficiency and time.

Chapter 4 is concerned with the description of the case studies analysed and the discussion of the results of the implementation of the method. Two case studies in Paris were chosen: the UNESCO Heritage Tour Saint Jacques and the pavilions of Les Halles of the architect Victor Baltard. These case studies represent two different situations of heritage because the tower was transformed over time but still exists and the pavilions were destroyed in 1971. Thus, it is possible to compare the different results obtained from the implementation of the workflow to the two case studies. To validate the methodology, the workflow was tested also on other case studies and the results are reported: the historical photographs of paintings of Byzantine churches; a Japanese historic building before and after restoration and the temporary architecture of the International Exposition in Turin in 1921 and 1928.

Conclusions and future perspectives of the research will be provided in the final part of the thesis (Chapter 5).