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Processing historical photographs and film footage with Photogrammetry and Artificial Intelligence for Cultural Heritage documentation and virtual reconstruction

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Abstract

The specific objective of this thesis is to offer an excursion through the metric potentialities of different data available in historical archives, by considering the essential role of photogrammetry. The aim is to explore how metric information about buildings which no longer exist or transformed over time could be extracted from old photographs and videos of different quality, for their 3D virtual reconstruction analysing the material stored in historical archives to support researchers and experts in historical research of Cultural Heritage.

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.

Besides the processing of historical photograph, photogrammetry is combined with Artificial Intelligence 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.

Key Words: Computer Vision, 3D Reconstruction, Motion Tracking, Object Recognition, Machine Learning, Image and Video Processing, Cultural Heritage.

1 Introduction

Documenting Cultural Heritage through the extraction of 3D measures with photogrammetry is fundamental for the conservation of the memory of the past. However, when the heritage has been lost the only way to recover this information is the use of historical images from archives.

Historical photographs and film footage in many cases represents the only remaining traces of Cultural Heritage that has been lost or changed over time. Photogrammetry is a powerful technique to process these materials and to document the heritage transformations, but its implementation is technically challenging due to the difficulty in finding the historical data suitable to be processed. This research aims

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to examine the possibility to extract metric information of historic buildings from historical photographs and film footage for their 3D virtual reconstruction.

To reach this objective, two issues are analysed: the availability of historical archives material, often made difficult by an enormous quantity of unorganized data on historic heritage, and the limitations in processing historical photographs and film footage by the presence of characteristics that make difficult to implement photogrammetry.

In recent years, there has been an increasing interest in the digitalization of Cultural Heritage collections. Thanks to the launch of large campaigns of digitization by several institutional and private entities, billions of documents are now available through online tools. Creating new tools for the final user of these data is an appealing research topic especially in the Artificial Intelligence domain. With Machine Learning, tasks like the processing of these great amounts of data and the reduction of human effort can be made automatic and therefore more efficient. In fact, the volume, the size and the variety of historical data lead to some critical factors. The most important is concerned the manpower needed to organize and search the documents. To solve this problem the application of Machine Learning gives opportunities to enhance historical archives and retrieval of heritage information. The major problem with historical images is the availability of material of different types with low image quality, a total lack of camera parameter knowledge, and damage due to improper storage, whereas the problem with historical film footage is that was not shot to be used for 3D reconstruction. In the majority of cases, it consists in movies, amateur videos or cinematographic reports and there is no way of knowing what kind of camera and film were used. The main disadvantage is the way in which the footage was shot. For this reason, processing and treating this data is a great challenge for photogrammetric research.

2 The proposed workflow

Considering these open issues, in this research a workflow (Figure 1) is presented to process historical images and to assess the metric quality of the reconstruction combining Deep Learning techniques with photogrammetry.

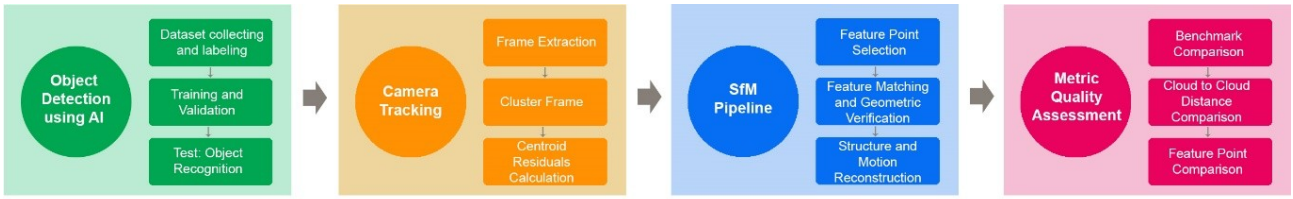


Figure 1: A sketch of the proposed workflow.

The first step of the workflow aims to make automatic the research of a specific architectural heritage identifying and tracking features from the video. This was performed using an object detection Neural Network trained to automatically recognise the monument in the film footage.

In the second stage of the workflow, the frames suitable to be processed with photogrammetry are selected from all the frames detected by the Neural Network. The selection is performed according to specific 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.

The third step concerned the photogrammetric reconstruction of the Heritage with open-source algorithms. During the process specific feature points are manually selected in order to guarantee their presence in the final point cloud. This step will be very useful during the fourth step of the metric quality assessment of the model.

The results of the 3D reconstruction of the Heritage were compared with a benchmark specifically created to evaluate the metric quality of the model according to the type of camera motion used. The

assessment was completed with the scale of the model through the feature points selected during the photogrammetric process and the comparison with existing material from which extract metric information: a point cloud, if present or historical drawings, for example. In both cases, the presence of specific feature points in both point cloud resulted from the process and the existing material is necessary for the metric comparison and scale.

3 Case studies and results

In order to test the workflow, two case-studies in Paris were chosen, the UNESCO Heritage of the Tour Saint Jacques and the pavilions of the Halles of Baltard. These case studies represent two different situations of the heritage because the tower was transformed over time but still exists (Figure 2 and 3) and the pavilions were destroyed in the 1971 (Figure 4 and 5). For this reason it is possible to compare the different results obtained from the implementation of the workflow to the two case studies. The Tour Saint Jacques is chosen for the tuning of the networks in the best situation of a heritage that still exists, and Les Halles to test the algorithms on a real case of an architecture which has been destroyed.

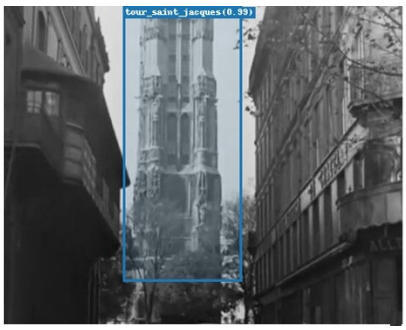
Figure 2: Tour Saint Jacques

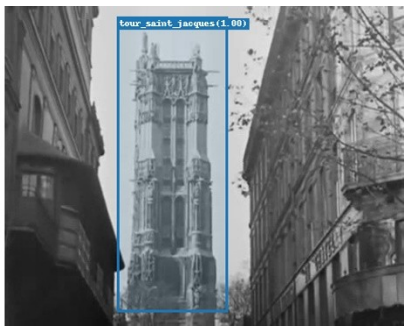
Figure 3: New state of the tower

Figure 4: Pavilions of the Halles

Figure 5: Demolition of the Halles

Figures 6 and 7 show that the method succeeded in the recognition of the correct frame for photogrammetric modelling, both in the case of the tower and the pavilions.





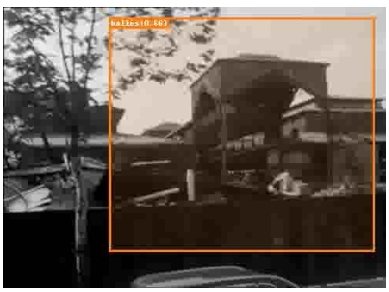


Figure 6: The first step of the workflow: the identification and tracking of feature from the video.

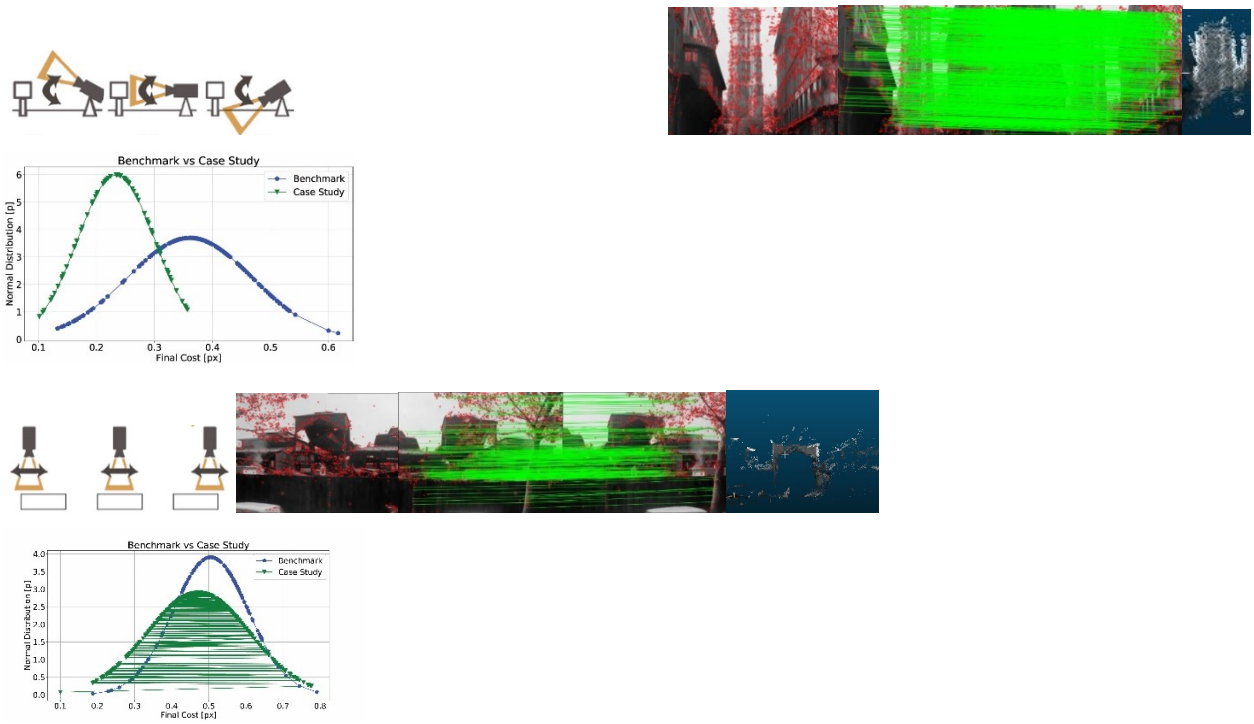


Figure 7: The second, third and fourth step of the workflow: the automatic extraction of the frame with the coordinates of the bounding boxes that contain the monument., the identification of the camera motions, the photogrammetric reconstruction and the metric quality assessment.

The experiments were conducted using the CINECA High-Performance Computing (HPC) clusters IBM Power9 with NVIDIA v100. Thanks to the use of this hardware, the results show that the reduction of the time required to process an image during the training stage is about 95% (0.3 s/image VS 9 s/image of a mid-range laptop).

4 Conclusions

The results show that combining different information from historical archives such as old surveys, projects and photographs of buildings, a three-dimensional reconstruction is possible, with acceptable range of precision. This research will prove useful in expanding the understanding of how the use of Machine Learning could really improve and boost well-known methods for the documentation of lost heritage. Nowadays, a large amount of multimedia content is produced. Therefore, the findings represent an important innovation in the documentation of destroyed monuments and open new ways to recover information about the past creating more efficient and accurate systems to manage and organize these materials that will become a memory for the future.

5 Publisher

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References - Author's scientific contributions

[1] F. Condorelli, F. Rinaudo, F. Salvadore, S. Tagliaventi, "A match-moving method combining AI and SfM algorithms in historical film footage", *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLIII-B2-2020, 813–820, https://doi.org/10.5194/isprs-archives-XLIII-B2-2020-813-2020, 2020.

[2] F. Condorelli, F. Rinaudo, F. Salvadore, S. Tagliaventi, "A Neural Networks Approach to Detecting Lost Heritage in Historical Video", *ISPRS Int. J. Geo-Inf.* 2020, 9(5), 297; https://doi.org/10.3390/ijgi9050297.

[3] F. Condorelli, R. Higuchi, S. Nasu, F. Rinaudo, H. Sugawara, "Improving performance of feature extraction in SfM algorithms for 3D sparse point cloud", *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W17, 101–106, https://doi.org/10.5194/isprs-archives-XLII-2-W17-101-2019, 2019.

[4] F. Condorelli, F. Rinaudo, "Processing historical film footage with Photogrammetry and Machine Learning for Cultural Heritage documentation", *MM '19: 2019 ACM Multimedia Conference Proceedings*, October 2019, Nice, France. ACM, NY, USA. 8 pages. https://doi.org/10.1145/3347317.3357248. p

[5] F. Condorelli, F. Rinaudo, F. Salvadore, S. Tagliaventi, "Architectural heritage recognition in historical film footage using Neural Networks", *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W15, 343–350, https://doi.org/10.5194/isprs-archives-XLII-2-W15-343-2019, 2019.

[6] F. Condorelli, F. Rinaudo, "Benchmark of metric quality assessment in photogrammetric reconstruction for historical film footage", *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W11, 443-448, https://doi.org/10.5194/isprs-archives-XLII-2-W11-443-2019, 2019.

[7] F. Condorelli, F. Rinaudo, "Cultural Heritage reconstruction from historical photographs and videos", *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2, 259-265, https://doi.org/10.5194/isprs-archives-XLII-2-259-2018, 2018.