Integration and classification of spatial data for 3D modelling and monitoring of built heritage

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Abstract

The role of 3D metric documentation in the cultural heritage framework is undoubtedly an essential aspect concerning the preservation and protection of historical built assets. The need for effective heritage monitoring techniques and tools is more actual than ever, underlining the critical importance of developing new efficient strategies to support experts working in the field of heritage conservation.

However, the complexity that intrinsically characterises heritage buildings introduces several critical issues that must be addressed, making it necessary to integrate heterogeneous data for proper and sustainable 3D metric documentation. This is true not only regarding well-established sensing techniques but also when extracting spatial information from data that traditionally are not used for metric purposes (in the case of the current dissertation, thermal images). These data fusion operations enable the production of enriched 3D models characterised by multi-layered informative contents, allowing the generation of value-added metric products potentially representing a powerful tool for heritage investigations. However, the data-fusion workflows for efficiently generating these enriched 3D models still need to be consolidated. Many bottlenecks have yet to be resolved. Here are a few examples of critical issues considered in the present dissertation: georeferencing issues, optimisation of the generated models, flexibility of the adopted strategies, usability of the enriched models, etc.

Another aspect that heavily affects the efficiency of managing spatial datasets is the low automatism that characterises many processes connected to heritage data. The processing of these datasets – often very time-consuming – requires a high cost in terms of the manual involvement of

the operator. In recent years, artificial intelligence has helped to increase automation, especially concerning repetitive and time-spending tasks. However, there are still a significant number of critical issues affecting the efficient use of this technique in the cultural heritage field, especially when complex tasks are concerned. For example, one of the more limiting bottlenecks concerning deep learning regards the significant amount of data needed as training datasets. Every element composing the dataset needs to be labelled appropriately, and this task is usually performed by onerous manual procedures. For this reason, the generation of these datasets represents a very demanding challenge.

Considering the aforementioned aspects, one of the main goals of this thesis is to explore the possibility of using – and optimising – 2D and 3D datasets by integrating heterogeneous geometric and radiometric data for the generation of multi-layered 3D models (derived from multi-source methods) in order to support studies and works of experts working in the heritage field. The explored strategy is represented by the possibility of exploiting the high spatial resolution of LiDAR or traditional SfM-based approaches to reference thermal information spatially, focusing on the opportunities offered by a data fusion-oriented strategy supporting historical analyses or the non-invasive monitoring of heritage buildings. Additionally, the optimisation possibilities investigated in this dissertation also focus on the onerous processes involving different data types. The possibility of implementing deep learning algorithms in other methods – e.g., improving photogrammetric pipelines – is explored. Specifically, image-based classification and multi-class semantic segmentation are considered. A strategy for the automatic generation of exclusion masks is proposed to save time and avoid repetitive and time-consuming tasks. In this case, the goal is to improve the operational workflows in the framework of processing heritage datasets, increasing the level of automatism. Additionally, a methodology to solve the problem of the training dataset generation – limiting the operator's manual contribution to the minimum – is proposed, exploiting the automatic generation of labelled and classified artificial images derived from 3D textured photogrammetric models, with the aim to produce synthetic training datasets.