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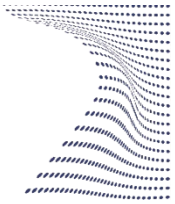

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Deep semantic segmentation for cultural built heritage point clouds

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Summary

This research falls within the broader debate on Digital Humanities, namely the field of study that results from the integration of computer science, computational procedures and multimedia systems in the humanities. This intersection aims to formalise the humanities, and it is mainly applied to textual analysis (documentary) and image processing in the fields of history, archaeology and historical-artistic disciplines with a particular focus on cultural heritage (CH). Experiencing and testing an approach that combines geomatics and its production of three-dimensional data of the built heritage with information technology is the core point of this dissertation.

In the digital CH domain, the ever-increasing availability of three-dimensional data, deriving from TLS (Terrestrial Laser Scanner), MMS (Mobile Mapping Systems), both LiDAR-based (Light Detection And Ranging) and image-based, or UAVs (Unmanned Aerial Vehicles), provides the opportunity to rapidly generate detailed 3D scenes to support the restoration, conservation, maintenance and safeguarding activities of built heritage. Concurrently, the recent research trends in geomatics are facing the issue of managing these multiple types of heritage data to enrich the geometrical representation of the asset, thus creating a complete informative data collector. In this framework, HBIM (Historic Building Information Modeling) constitutes a reference. Unlike the standard BIM process, it applies a reverse engineering approach and typically relies on point clouds to perform the *scan-to-BIM* activities. Nevertheless, these processes are still mostly manually carried out by domain experts or professionals, making the workflow very time-consuming, not fully exploiting the potential of point clouds and wasting an uncountable amount of data since parametric objects can be described through a few relevant points or contours. As literature demonstrates, there is still a broad use of manual operations to capture the geometries of built heritage from point clouds; thus, their semantic enrichment could help in this sense to automatize the whole pipeline. The use of Artificial Intelligence techniques for the automatic recognition of architectural elements from point clouds can thus provide valuable support through the semantic segmentation task. This task is a trending topic not only in the CH domain but also in other fields like autonomous navigation, medicine or retail. Precisely in these sectors, it has been mainly exploited and developed through machine learning (ML) algorithms and its deep learning (DL) subset, establishing solid literature in the last decade. However, applications of DL techniques on heritage point clouds are still scarce; therefore, a proposal to tackle this framework within the built heritage field is outlined in this work.

The proposed methodology allows increasing the Level of Detail in the semantic segmentation of built heritage point clouds compared to the current state-of-the-art. In this way, the recognition and following reconstruction of architectural elements in object-oriented software could be automated and speeded up. Thus some state-of-the-art Deep Neural Networks (DNNs) have been selected and tested on the newly created ArCH dataset. The latter has been specifically defined for this research, in collaboration with other Universities, and has been made available to the scientific community. Once the preliminary results were obtained and compared, one of the best-suited DNN for the ArCH dataset has been chosen among those available in the state-of-the-art: the Dynamic Graph Convolutional Neural Network (DGCNN). This network has then been modified and implemented to achieve better performances comparable with those of similar case studies, resulting from ML classifiers such as the Random Forest.

Along with a first approach to the AI explainability on point clouds, a new methodology is also proposed to integrate the prior knowledge into the architecture of the DGCNN. Starting from the recent research on ontologies and the development of taxonomies for CH assets, a study is carried out on the spatial relations between historic building's architectural elements and how they can guide the network in the learning phases.

The main outcomes of this research are: the first application of DL framework for CH point clouds; the creation of a unique and novel dataset available for the scientific community; the implementation of the DGCNN architecture and the improvement of its performances; the achievement of a new level of detail for semantic segmentation of built heritage point clouds, and the proposal of a new semantic neural network with the embedding of the prior knowledge.