From AI to H–BIM: New Interpretative Scenarios in Data Processing

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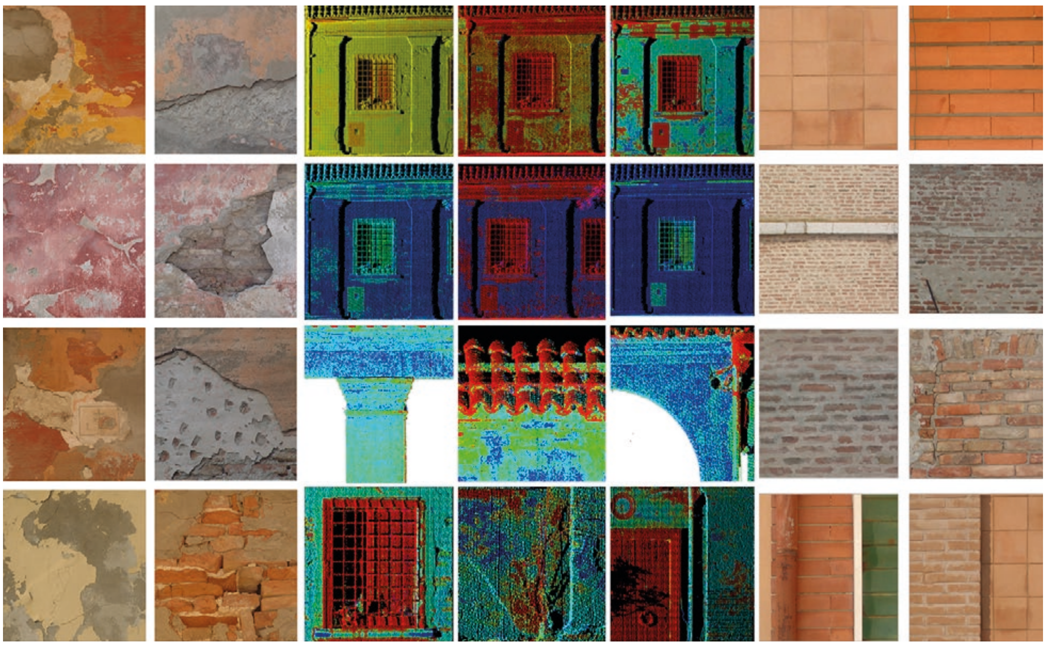
Abstract

The paper results from preliminary research experiences focused on the use of Artificial Intelligence as a tool for processing the large amount of data that can be obtained from digitisation processes applied to the Architectural Heritage. The new interpretative scenarios will be outlined starting, on one hand, from a series of consolidated experiences in the field of three–dimensional survey, modelling and semantic enrichment, and, on the other, from the use of Augmented Reality tools for the fruition of the Heritage itself.
The research aims to further investigate the great potential of processing point cloud models using Artificial Intelligence, to extrapolate, from the digitized data, information levels that go beyond shapes, offering better integration within the Building Information Modeling environment.

Keywords
cultural heritage, point cloud, artificial intelligence, H–BIM, data management.



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Research Scenario

Today's increasingly fast digital surveying tools boost the speed of scanning, but also the amount of data captured. This trend is leading to the development of research avenues in which Artificial Intelligence (AI) is aimed at the segmentation and discretization of data, mainly, but not only, for the recognition of shapes (object detection) and structures [Grilli, Menna, Remondino 2017]. This procedure is triggering a debate, still unresolved, that involves the interpretative aspects of the uniqueness that characterises Cultural Heritage, while the need to trace specific directions emerges more and more.
The research therefore aims to further investigate the great potential of processing point cloud models using AI towards data integration in Building Information Modeling (BIM) environment applied to Heritage.
The definition of a methodology able to automatically recognise specific characteristics from 3D point clouds can lead to the definition of new data sets, aimed at documentation, conservation and restoration, which can enrich BIM models, also thanks to a now necessary inclusion of advanced features in the Industry Foundation Classes (IFC) standard through new and shared Property Sets.
The integration of advanced surveying techniques, Machine Learning (ML) and Deep Learning (DL) in new standards for Heritage information modelling (H–BIM) can have a great impact on the process of documentation, representation, analysis and interpretation of Heritage [Bienvenido–Huertas et al. 2019], creating new representation levels and application scenarios in Heritage management, conservation and restoration.
This research scenario is strongly connected to an additional data management level, related to the application of Augmented Reality tools aimed at 'onsite' data exploitation. A series of experiments were carried out in order to create semantically enriched digital models in BIM environment within an open standard web platform [1]. Data access to the platform via Augmented Reality applications allows Heritage fruition, analysis, monitoring and assessment of Heritage buildings also for conservative purposes.
In this direction, the research includes the use of semi–automatically processed data, related to the state of conservation and technical assessment for asset management, maintenance and decision–making purposes by using mobile devices.

Digital Data Processing for Heritage Conservation

The need to document Cultural Heritage – characterized by uniqueness and complexity – has led to an increasingly widespread use of 3D surveying technologies. These technologies are able to produce very accurate models in a very short time. While, during the on–site survey, the advantages of speed and metric accuracy are evident, the processing of these data can be very time–consuming and complex. Today, the trend is to produce even faster and more robotic instruments (mobile devices) [Gallozzi, Senatore, Strollo 2019] that make it possible to scan (especially indoor environments) in a single shot. This produces an increase in scanning speed, but also a further increase in the amount of surveyed data. This course is leading to the development of a whole Artificial Intelligence line of research aimed at segmenting and discretizing data.
A further layer to be added to this framework is related to digital data representation and management. BIM is considered today the latest frontier of three–dimensional architectural representation, design and management of digital data, where interoperability [Osello et. al. 2015] is one of the central attributes. BIM software applications are growing rapidly and they are also becoming increasingly essential in conservation and restoration applications [Chiabrando, Lo Turco, Rinaudo 2017], thanks to their ability to integrate different information and features in relation to the model geometric shapes [Apollonio, Gaiani, Sun 2017]. However, the IFC, the interoperable standard for BIM, currently lacks in providing a solution for managing the preservation of the Architectural Heritage. Moreover, unlike geometric characteristics [Murtiyoso, Grussenmeyer 2019], an automatic process does not uniquely determine surface features. They become consistent and significant only if critically inter-

preted. Therefore, only if performed with a systematic and well–documented methodology, surface specification analysis can allow a completely non–invasive and strongly helpful support for condition assessment (fig. 1).
Currently, the interpretation of this data and its visual representation as a mapping of the state of conservation requires a manual or semi–automatic and rather lengthy process.

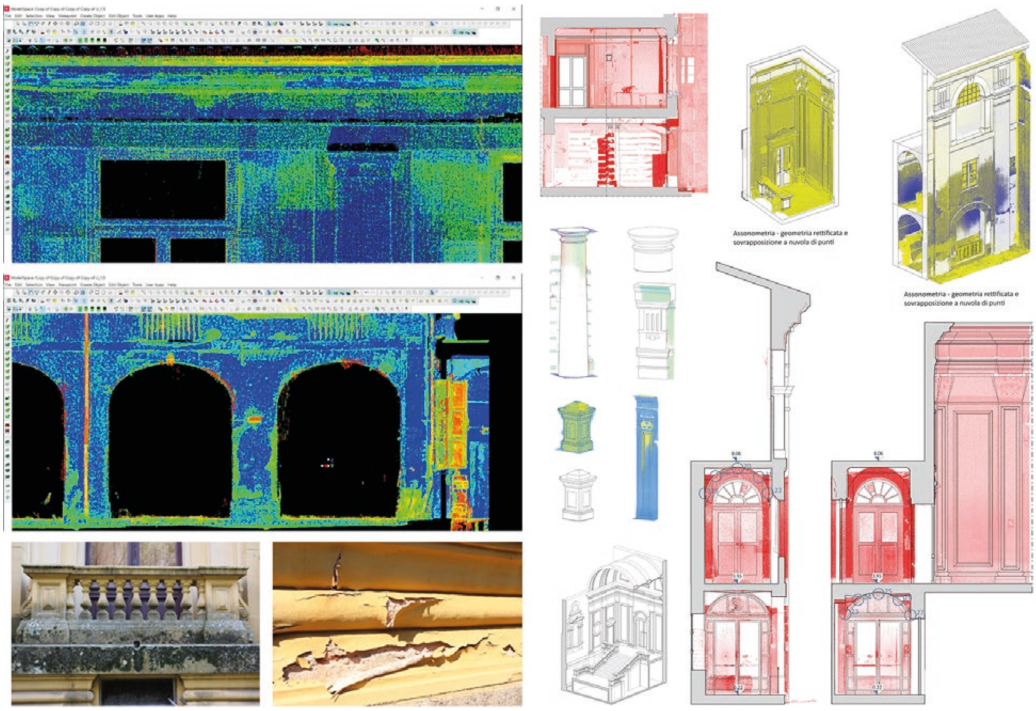

Fig. 1. Analysis of surface specifications by means of point cloud processing and data management in BIM environment.

Even if the concept of setting up automatic procedures and automatisms is very tricky in the field of cultural Heritage (where each building is unique and requires case by case assessments), AI technologies will be more and more necessary since the elaboration of huge amount of data is one of the most important tasks in the digital era [Janković 2020]. These processes can allow – starting from a massive set of data – to explore new forms of discretization and classification. From a single historical building or heritage site, it is possible to extract a huge amount of data that need AI, Machine Learning (ML) and Deep Learning (DL) processes to be analysed and compared. By using point clouds obtained by the 3D survey of a historic building, it is possible to process specific set of points (e.g. related to a certain surface) and to visualize specific surface features [Grilli, Özdemir, Remondino 2019]. AI, ML and DL can make this process faster and more effective [Malinverni et. al. 2019]. Of course, several parameters need to be assessed before the process starts. This procedure can be integrated by exploiting these additional layers of information derived from data capturing procedures for automatically populating the H–BIM model, a research field where there is large room for innovation [López et. al. 2018]. The definition of an extended data schema including information from the restoration discipline, reflecting a shared vision and approach.

From Artificial Intelligence to H–BIM

According to the research scenario about digital data processing for Heritage conservation previously outlined, the research aims to establish a new process of point cloud analysis by applying AI, ML and DL processes, generating interpretative algorithms allowing the segmentation and classification of large amounts of data, in order to outline and describe historical surface specifications. This leads to a methodological procedure as a connection between AI and the automatic recognition of surface specifications to the BIM model, allowing the creation of a new data schema for restoration, including in the IFC standard the detailed documentation of the state of conservation directly extracted from the 3D point cloud by the application of the interpretative algorithms. Such properties will be included into the IFC by the creation of a new set of 'labels' able to describe different data and information related to Heritage buildings within the BIM process. Specifically, the process (fig. 2) involves the selection of databases, the identification of features or properties to be processed through automatic recognition, data processing to identify the algorithm capable of recognizing specific properties, the extrapolation of datasets according to homogeneous features, implementation of new datasets in the BIM environment, and the definition of new IFC 'translators'. The careful selection of interpretation criteria and parameters will be an essential part of the workflow described above.

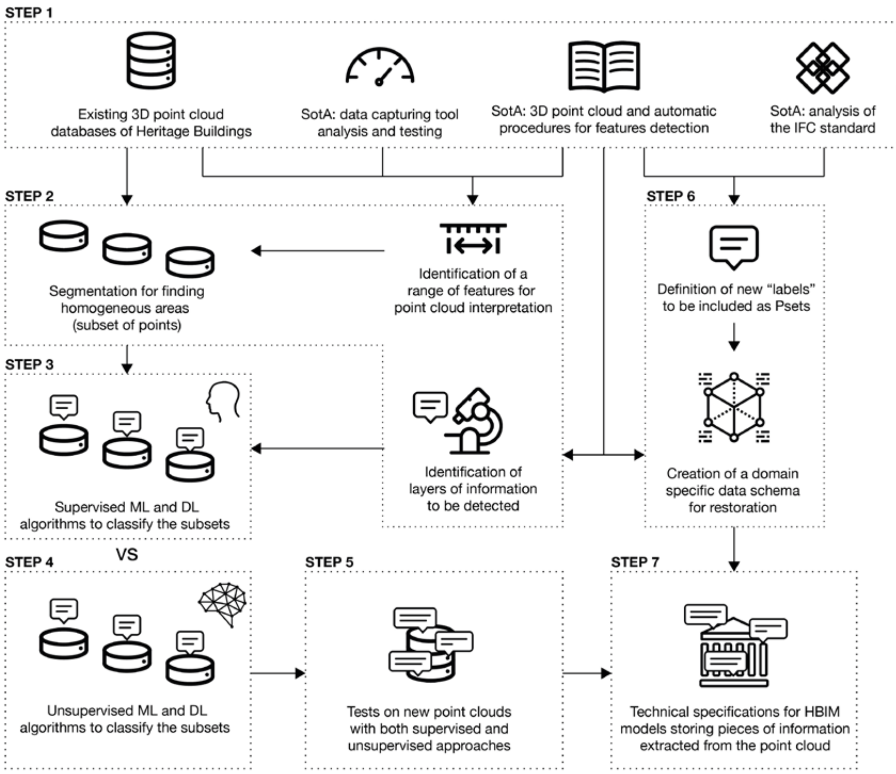

Fig. 2. Graphical schema summarizing the overall process.

This overall process is closely linked with the development of semantic models, beginning with the increasingly advanced identification of features to be incorporated into the BIM models, thanks to Artificial Intelligence. Via Virtual Reality applications, these models can be the foundation for advanced explorations, by leveraging a collection of features relevant to the state of conservation, materials, previous initiatives, technological documentation, directly on–site.

Conclusion

The outlined methodology is the first step in a starting research process, which requires consolidating the described procedures through a number of data sets. Anyway, the project results may have impacts by reaching interesting improvements in some challenging steps of Heritage digitization and data processing for conservation and restoration.
The state of the art outlined on the basis of national and international research related to the application of AI to Cultural Heritage shows indeed an articulated panorama composed of image classification algorithms, point cloud segmentation and representation models able to estimate levels of intervention on historical buildings. However, there is large room for experimentation and many unsolved issues that make the scenario still open and require that multiple levels of knowledge of the Heritage derived from digital languages and tools find a common ground.

At European level, several projects and initiatives are developing the use of BIM for regeneration, but there is still room for progress in the field of application to cultural Heritage. Through the described methodology, geometries and shapes can be integrated with different information regarding materials, state of conservation, historical documentation, previous restoration works, etc.
AI can lead to the development of new, increasingly targeted segmentation algorithms, also to trigger new uses and re–uses of digitised Heritage.
Future research scenarios foresee an integration of Computer Vision and Augmented Reality in the process, for 'onsite' applications, exploiting the data extrapolated through the described procedure, for the enhancement and management of Cultural Heritage, for monitoring or architectural restoration project.

Notes

[1] These experimentations have been developed under the Horizon 2020 project "INCEPTION – Inclusive Cultural Heritage through 3D semantic modeling", funded by the European Commission in 2015 and concluded in 2019 (GA 665220). The project, leaded by the Department of Architecture of the University of Ferrara, focused on semantic modelling of Cultural Heritage buildings using BIM to be managed through the INCEPTION web based platform for advanced deployment and valorisation of enriched 3D models, towards a better knowledge sharing and enhancement of European Heritage.

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