AI: Inferring Unseen Pieces to Solve the Heritage Puzzle

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Intro

The relationship between architectures and models has always been of a dialectic duality: architects have been creating models of the geometries to be built and built geometries have been represented by means of models. Often implicit rules applied as to what made a model "resemble" or correctly capture an architecture. Frequently, the most relevant corresponding aspects were the geometrical and mathematical relationships and proportions. In some cases – as for some Gaudì creations based on reverse catenaries – models have been used to even "calculate" the geometrical structure of the prospected architecture based on physics.

A series of converging technologies now promises to make the relationship between model and architecture even more biunivocal and dynamic. In particular, a "Digital Twin" of an existing architecture or urban spaces allows for a simulation running in parallel to reality, and can be used in forecasting and detecting abnormalities, hence potential issues. The backbone of such a technology is the Building Information Modelling (BIM), a semantic-based and Object-Oriented modelling system where every "element" of reality is an "object", classified within object families and classes. It opens up the opportunity to both hard-code and to infer the relationships among objects and their behaviours, both statically (as building elements and interfaces), and dynamically, also as regards changing datasets stemming from new research findings. Hidden, hence unseen, objects – similarly to dark matter in physics – also seem to play an important role in the overall model fitness.

Aim and methodology

Can we imagine a new paradigm in purposefully using artificial intelligence (AI) in Heritage modelling, whereby all available data contribute to create new knowledge by inferring "unseen" aspects of reality? A critical review of use cases of AI for "seeing" hidden data, and keeping the model reality-twin, is carried forward in view of being applied to two promising areas: hidden physical structures and historical layers.

Prospected advances

To start with, it is worth recalling the state-of-the-art of HBIM knowledge-base system. For instance, "The INCEPTION project has defined the approach and the methodology for semantic organization and data management toward H-BIM modelling, and the preliminary nomenclature for semantic enrichment of heritage 3D models. The organization of consolidated knowledge is performed following a specific workflow in order to get them suitable for their reuse into H-BIM semantic model, accordingly to digital documentation and capturing protocols that have been developed" (Maietti et al., 2019).

Until now, all the above has been carried forward somewhat "by hand", through the work of researchers and practitioners. Artificial Intelligence (AI) promises to help maintaining the model and the underlying available knowledge-base datasets aligned over time, also along new knowledge accrual. Trained AI algorithms can draw on huge multidimensional and growing knowledge-bases to "foresee" what – based on the usual correlations within the dataset – would seem as the most probable interrelations among architectural elements. Moreover, by comparing them with the data of reality, the model could self-adjust to fit them. Could then the model help formulating grounded hypotheses as to non-observable – hence unseen – aspects of the heritage architecture at stake? They are in fact the missing piece of a puzzle where every observable aspect is linked, physically and historically, to other observable and non-observable ones.

AI and unseen (hidden) physical structures

New pieces of research have shown the potential of AI in reconstructing physical shape of not directly observable geometries. The question is whether and how such technology may help creating a HBIM model with less human intervention and less degree of uncertainty. In fact, while HBIM models can't be limited solely to the representation of the observable parts of an architecture – the Object Oriented logic requires every element to be a complete closed geometry with attributes – usually HBIM models must rely on the mere skills and experience of the modeller in order to hypothesize (smart guess) those hidden parts and phenomena which need to be included in the model. New approaches have been now successfully tested. For instance, "a Multimodel-based approach has been developed in which stone facades of existing buildings are digitized as IFC-model by using proxy entities and linked with web ontologies for semantic enrichment. Additionally, detected anomalies in the stone structure are implemented and linked with geometrical representations. By utilizing additional rules and inference mechanisms, the anomalies can be classified, and a knowledge-based damage assessment is processed" (Seeaed and Hamdan, 2019). The logic of such projects could be stretched to help enriching the knowledge-base of a HBIM model, based on which AI can help formulating and checking the correlation between the available (observable) data and the model, based on what is usually found in analogous situations. Moreover, once modelled, a reversed use of AI, specifically of Generative Adversarial Networks (GANs), can be used to maintain the model/twin aligned with the changing available data.

AI and unseen historical layers

There is a more futuristic field in which it seems AI can play a major role for the creation of a model encompassing unseen features. It is the case of historical layers. In fact, provided that such layers have left traces within the used knowledge-base, and that usually "similar" formal architectural phenomena tend to be repeatedly expressed within a certain time and space, it is possible to imagine

Fig. 1. A series of images created by Ethan Hein using AI GANs technology (https://www.flickr.com/photos/ethan-hein/with/26983399703/)

how AI could help drawing grounded hypotheses as to the past historical conformation of the architectures at stake. A semantically and historically well-organized knowledge-base is of course a prerequisite, but such an approach – especially when multiple data sets and models stemming from sound research are put together – could even help modelling the present as the result of a dynamic succession of different phases.

It is worth here quoting a ground-breaking piece of research whereby AI helps "translating" spatial relationships into different architectural "styles": "…studying the driving forces of the composition is maybe where AI can offer us some meaningful answers […] At a more fundamental level, we can think of styles as being the by-product of architectural history. If there is within each style a deeper set of functional rules, then studying architectural history could potentially be about understanding the evolution over time of these implicit rules. Being able to encapsulate each style could allow us to go beyond the study of precedents, and complement it by unpacking the behavior of GAN-models such as the ones trained here. Their ability to emulate some of the unspoken rules of architecture could allow us to address the 'quality with no name' embedded in buildings that Christopher Alexander defines in his book The Timeless Way of Building. AI is simply a new way to study it" (Chaillou, 2019). Then, somehow reversing such dialectic between knowledge-base and model, a new framework is proposed by which GANs-based AI techniques, instead of generating architectures in a certain historical "style", are used for devising plausible historical layers based on what survives of each "style" in the heritage building at stake.

Discussion

For the shown "reverse" use of AI (GANs) in seeing hidden Heritage layers to really bring disruptive capabilities to the field of HBIM modelling and digital twin, more experimentation seems needed for widening the current state-of-the-art use cases. In particular, wide and solid knowledge-bases – whereby it is possible to draw on shared and semantically "normalized" research contributions from various teams over time – appear as being the fundamental prerequisite for all this to happen, and probably will constitute the real challenge.

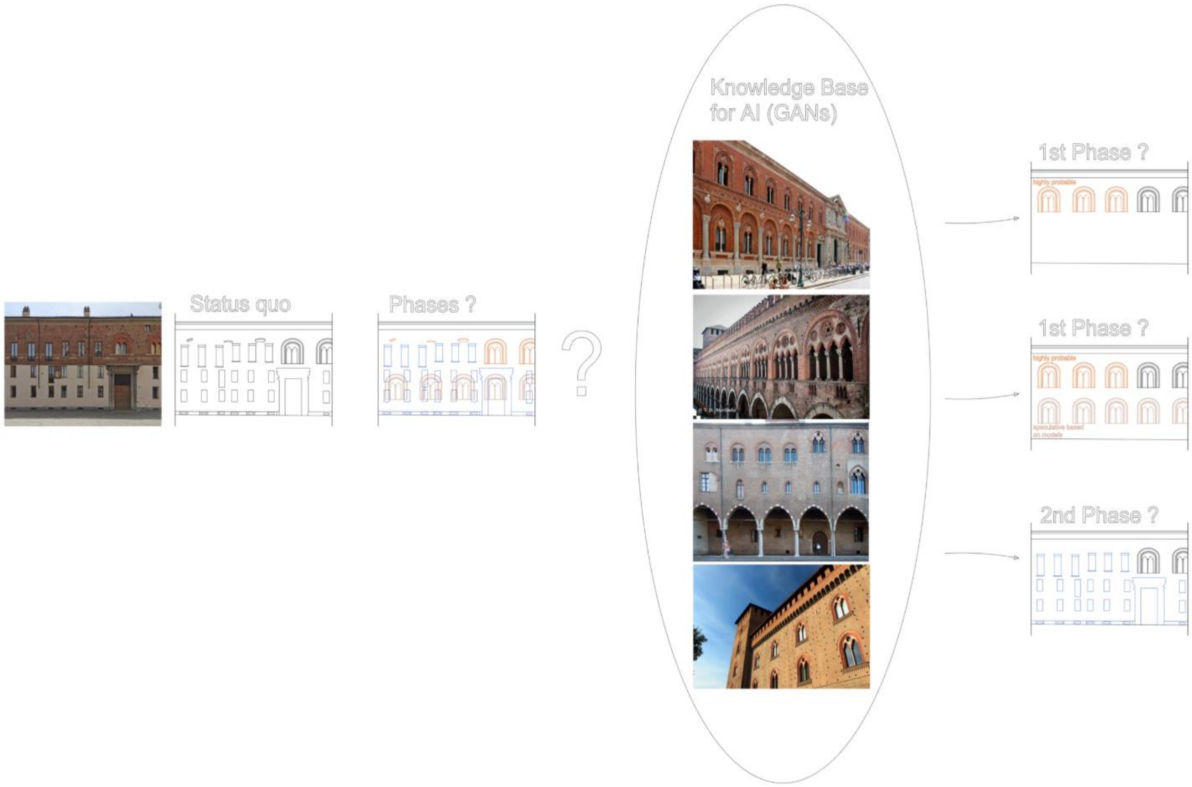

Fig. 2. “Seeing” the historic layers in the Palazzo Arcivescovile in Milan through a proposed reverse GANs generation process. (Image [1] and graphics by the Author. Images 2,3,4,5 respectively by: [1] Sailko; [2] Vittorio Destro;[3] Massimo Telò; [4] Matteo Ruaro)

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