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From Building Information Modelling to Mixed Reality

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Editors

From Building Information Modelling to Mixed Reality

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AIM! Algorithmic Information Modeling: New Strategies for a Fully Integrated Approach in the Field of Cultural Heritage



Massimiliano Lo Turco, Michele Calvano, Elisabetta Caterina Giovannini, and Andrea Tomalini

Abstract Algorithmic Information Modelling (AIM) is an acronym that can be used to discuss and reason on the relationship between algorithms used in Visual Programming Language (VPL) platforms and the Information Modelling processes. In the Architecture, Engineering and Construction fields (AEC) the data management related to those processes are more usually managed through BIM tools able to handle heterogeneous data set characterized by different disciplines domains. The use of BIM processes applied to historic buildings (HBIM) moreover introduces new needs for the management of 3D information modelling. The research critically investigates some case studies concerning the relationship between the use of BIM processes applied to different architectural heritage fields, from the (virtual) reconstruction of existing buildings to the improvement of the efficiency of design activities for management applications. Most of the activities involved researchers of the Representation field, jointly with the Restoration, Geomatics, Building Physics, Architectural Technology researchers.

Keywords Heritage · BIM · VPL · Algorithmic Information Modelling

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1 Introduction

The topic of data interoperability is certainly central within the current operational strategies related to the AEC sector. The research faces the challenge to dynamically relate some of the most important software platforms that are used in the architectural field today focusing on their application in the field of cultural heritage.

Within an extremely generalized context, the experiences conducted by the research group here described, refers to the need to develop the most efficient approaches of graphic and alphanumeric modelling of BIM systems and applied them to historical buildings using the recent nodal programming tools, better known as Visual Programming Language (VPL). Within these processes, the parametric term becomes central assuming different meanings.

In BIM software applications parameters are key properties of the building elements and are central to the system to create dimensional links among various instances; in programming code, new parameters can be introduced as further variables of new phenomena, and this is a fertile ground for experimenting and studying totally new phenomena occurring to the building during its entire life cycle (Fig. 1).

New disciplines are characterized by different languages and processes that need a new set of data and information. To enrich and manage this kind of data into BIM environment became crucial the use of VPL suitable not only to manage parameters and attributes but also to generate specific geometries that need to be readable by BIM software augmenting the complexity of the workflow towards an interoperable and fully integrated approach. Algorithmic Information Modeling and its acronym,

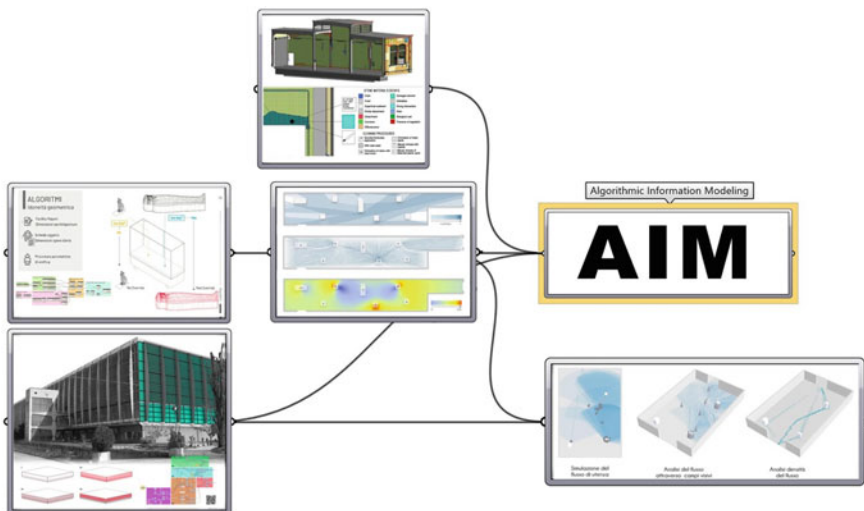


Fig. 1 When can we talk about AIM? With reference to the reported case studies, this methodology is introduced in cases where it is necessary to set up interoperable procedures between the BIM and VPL platforms

AIM can also be understood as the primary objective (the aim) to further develop interoperable processes that allow to unhinge some of the rigidities of the most widely used software platforms. Algorithmic procedures in Building Information Modeling are related with three main research topics: 3d modelling, information modelling and interoperability for the use and re-use of data.

The following case studies have the task of highlighting operational strategies and critical issues found in the resolution of different problems applied to extremely heterogeneous operational scenarios and application contexts.

2 BIM-Oriented Strategies for Cultural Heritage

In the architectural field, there is a wide diffusion of BIM applications, with particular reference to new building interventions. However, there are many criticalities if we consider the conservation field, for the enhancement and the management of the architectural heritage. Over the years it became necessary to critically reflect on the processes of instrumental information acquisition, standardization and data organisation, and their conversion into semantic models that must be interoperable and re-usable by different professionals in an interdisciplinary environment (Brusaporci 2017).

Starting from the definition by Murphy that describes Historic Building Information Modelling (HBIM) as a novel prototype library of parametric objects, based on historic architectural data, in addition to a mapping system for plotting the library objects onto laser scan survey data (Dore and Murphy 2012) the first investigate field in the past was to define best methodologies to obtain tridimensional models from a survey.

The metric acquisition phase of cultural heritage employing laser scanning and/or Structure from Motion photogrammetric techniques is concerned. This is the common starting point for the subsequent activities of reconstructive digital modelling oriented to the conservation of the historical-architectural heritage. Although data collection techniques are now very efficient and automated, the subsequent data processing still takes a long time to develop accurate models.

As far as the BIM methodology applied to Cultural Heritage is concerned, today there are still a limited number of research experiences aimed at understanding its potential in the specific field of historical buildings (Santagati and Lo Turco 2016). The theme is therefore still a frontier issue. The first difficulty concerns the lack of specific components/instruments for the modelling of historical architecture available within commercial platforms. In this respect, the reconstruction of complex and non-standardized forms still seems to be a particularly onerous activity (Bianchini et al. 2016).

In literature, some interesting works illustrate different approaches that adopt different applications to convert the point cloud into intelligent parametric objects, introducing the concept of the Level of Accuracy and Reliability (Bianchini and Nicastro 2018; Maiezza 2019). The most complex issue refers to the possibility

of preserving the metric accuracy captured by laser scanners and photogrammetric point clouds even in the infographic modelling environment. Some research make a comparison between the point cloud and the 3D model to quantitatively assess whether the deviation between the numerical model and the mathematical one is within acceptable values (Fai and Rafeiro 2014). Some approaches prefer to perform 3D modelling in other platforms (also using procedural modelling based on VPL—Visual Program Language) to better generate and manage NURBS surfaces (which better approximate the trend and irregularity of complex surfaces), and then adopt operational protocols to convert NURBS into parametric surfaces that can be shared with the most common BIM platforms. The most productive field of application in this context is currently the field of classical architecture that offers an already standardized parameterization of architectural elements (Quattrini et al. 2018; Giovannini 2017; Paris and Wahbeh 2016). Other studies can be traced back to a “rigorous BIM”, i.e. the adoption of the BIM methodology in the field of historical construction not only in terms of geometric precision, but also considering other variables typical of an information system (parametric objects, relations, attributes, the correct definition of graphic detail level, these are variables classified according to Italian laws in Level of Geometry—L.o.G.—, for what refers to graphic attributes and Level of Information—L.o. I.—for what refers to alphanumeric attributes). This work aims to reason on and explore the capabilities of historical building information modelling (H-BIM) for historical building restoration, to effectively combine with the geometric accuracy of the survey with the parametric flexibility and richness of information typical of the BIM processes, also investigating innovative interoperable processes with the algorithmic modelling platforms typical of VPL systems.

3 Between Heritage BIM and VPL

In recent years the research group has explored multiple approaches in an attempt to identify the best operational strategies to obtain geometrically reliable models that are prepared to accommodate and collect information equipment that can be used for different purposes, from documentation to monitoring, from restoration to functionalization. The proposed workflows investigate the use of BIM platform and VPL software to approach the restoration interventions management of historical buildings.

3.1 Palazzo Sarmatoris: Adaptive Models for a Degradation Map

Palazzo Sarmatoris, a seventeenth-century historical complex recognized in the engraving of the *Theatrum Sabaudiae*, located in Salmour, a settlement a few kilometres from Fossano (Piedmont). The ancient palace, currently owned by the “Casa di Riposo Villa Smeralda”, although it is protected by the ministerial bond, is abandoned and in complete disrepair. Because of its deep stratifications, and the lack of diachronic care, it is in a widespread state of dilapidation, with instability and degradation that could cause the complete collapse of the entire structure.

The work consisted in the definition of a workflow that could be shared between different disciplines (Geomatics, Representation, Restoration) that in the first phase was characterized by the acquisition of geometric data of the artefact, operating an integration between different surveying techniques: point clouds acquired through terrestrial and aerial photogrammetry were combined with the point clouds acquired with LiDAR systems.

This was followed by the realization of the parametric model conducted in different ways, operating critical approaches of segmentation and interpretation of the numeric resource. Considering the state of conservation of the structure, the last phase consisted in the construction of specific parametric components able to highlight the visible deterioration of the structure, facilitating the historicization of the data and the possibility to mark, describe and group together all the areas with similar problems (Fig. 2).

Moreover, the quantity take-off of the decays and the required actions were summarized in the form of schedules. This methodology makes the current practice more efficient: usually, it consists of a simple graphical representation of the degradation phenomena without any connection with the information apparatus that describes the nature and the related procedures of intervention. In this sense, the management in the BIM environment is undoubtedly a more efficient system to storage both graphic and alphanumeric data, interrelated and implementable: this is a critical support to the conservation process, from the “event” of the restoration project/construction site to the “duration” of the maintenance/conservation processes.

However, although the procedure provides for a better correlation between data of different nature, the process of interpretation and definition of the various degradation phenomena is not entirely easy: the expert draws point by point the perimeter that characterizes the pathology, making the procedure extremely time-consuming.

3.2 Bonavalle Castle: Algorithms for a More Automated Decay Representation

Bonavalle Castle is a case study similar to the previous one in terms of morphological complexity and conditions. The castle, a medieval building, is nowadays in a state of

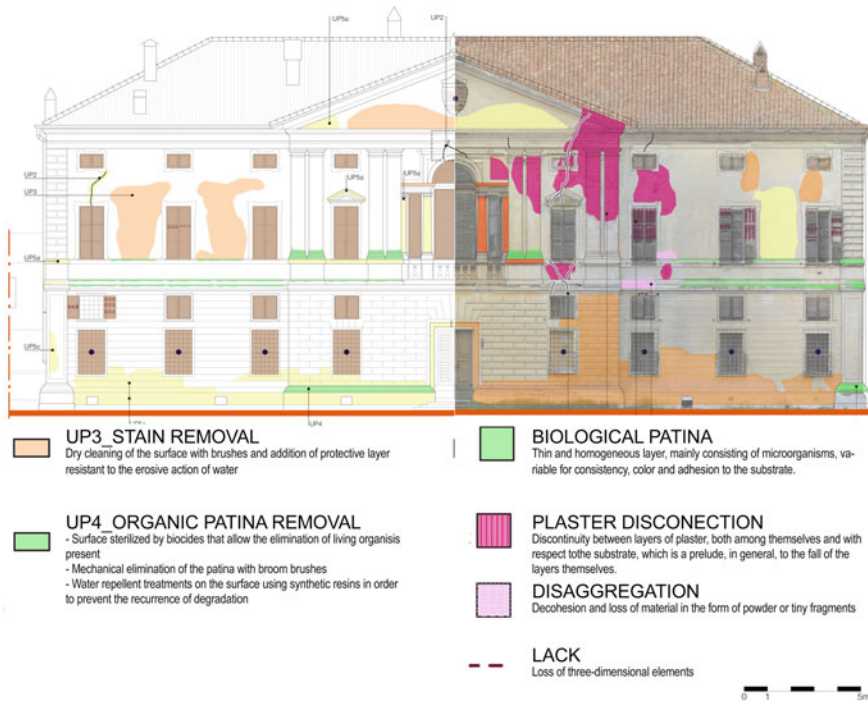


Fig. 2 Graphic and alphanumeric representation of the decays in H-BIM environment, through the use of parametric components. Palazzo Sarmatoris, Piedmont

disrepair. In the castle walls, it is possible to notice stratifications that can be traced back to different eras. The building is an example of what is called a “rural” castle, a settlement with an original defensive function, at the centre of a feud consisting of agricultural land, with a documented function of protecting people and products of the land. Over the years the castle loses its fortification functions, but it has maintained its characteristic function as an extra-urban “noble” residence, without definitively losing its original character, contrary to what happened in many other buildings that were transformed into villas from the seventeenth to the nineteenth century.

It is possible to identify two main phases related to the modelling of the castle and its decay. The first phase, related to the modelling phase of the castle was developed into a BIM platform, using existing tools, the second phase, for the creation of the decay map, involved also the use of VPL software to create algorithms that automated generate decay elements starting from orthophoto.

In order to digitally recreate the irregular sections that characterize the vertical components of the building, different conceptual masses have been modelled. The wall element that best approximated these sections was created using these masses as reference. To increase the level of metric accuracy of the digital model, once the virtual reconstruction of the principal elements was ultimate, a second phase was

to proceed on inserting other architectural elements, both functional and decorative, parametrically modelled to better approximate the dense point cloud. The work continued by modelling the state of conservation of the building through the mapping of the decay. As far as the representation of degradation and disruption is concerned, different approaches were tested in order to obtain better accuracy in the shortest possible time, through the use of VPL algorithms.

The experimentation has investigated the potential of VPL through the use of Grasshopper and Dynamo software, with the main objective to achieve a greater level of automation through the use of some digital products available, such as orthophotos or two-dimensional drawing processed in dwg format.

The use of Grasshopper to generate algorithms, it allowed, at first step, to generate new surfaces containing the decays starting from orthophotos.

After a colourimetric modification of the orthophoto was possible to distinguish different type of decay and generate their perimeters. Polylines generated by the algorithm were converted into surfaces and classified and generated in a semi-automatic way through the use of the Grevit plug-in (connecting Grasshopper and Revit). The creation of real components inside the BIM platform allowed to develop an interoperable process between the visual programming language and the parametric environment based on building objects.

One of the challenges was also to face the problem of accuracy of the tridimensional model compared with the irregularity of the point cloud by was generated the orthophotos. Trying to fill the gap generated by the partially overlapping of the two models, the proposed solution chose to project the surface of decay. The operation of projection was developed through the use of Dynamo, a second VPL-based software, and allows to identify the decay starting from the point-cloud orthophotos and then to project it on the building object surface. The same methodology can be applied using different starting data. For example from a degradation analysis processed in a CAD format, it is possible to transfer generated surfaces into a BIM platform, then the digital model of the decay can be enriched with different types of information. In conclusion, the proposed procedure is, therefore, a more structured way to implement automatic recognition processes of surfaces affected by degradation, working exclusively with the chromatic alterations present in the images in true form extracted from the point clouds. Other non-surface based pathologies such as gaps and disruptions will necessary follow different procedures that must be developed jointly with other professionals that provide a particular knowledge of the historic building and reading of involved phenomena (Fig. 3).

In conclusion, it is worth remembering that the use of BIM platforms makes possible to carry out multiple analyses, using a multi-criteria approach defined through qualitative and quantitative data. The database linked to the BIM model can be populated by much other information, including the corpus of historical iconographic sources available in specific archives, the retrieval and classification of recent and vintage images and data related to previous interventions that are necessary references for the planning and management of future interventions (Chiabrando et al. 2017).

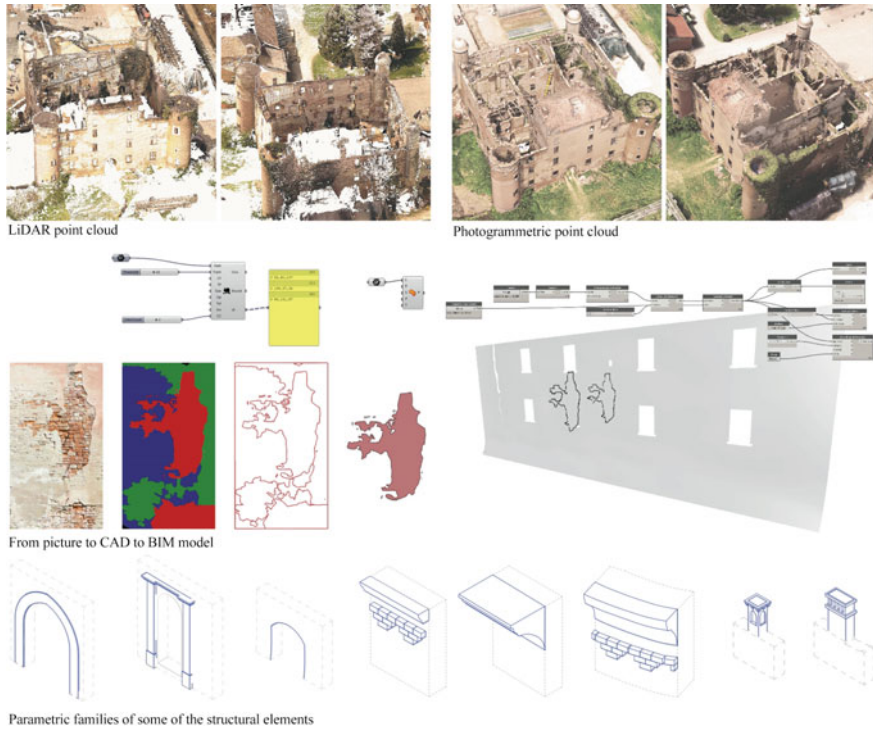


Fig. 3 Algorithmic procedure: from orthophoto to automated construction of closed profiles identifying the surface affected by the decays. Bonnavalle Castle, Piedmont

4 Management in Cultural Heritage Field

Even if the BIM environment was first developed to manage processes about new buildings, in recent years, it has also been used for the management of historical buildings, generating new fields of research, involving also Cultural Heritage (CH) domain where the contribution of the algorithmic approach can help to create new geometries to make the current digital reconstructive modelling processes more efficient and interoperable. The adoption of VPL system is crucial for the planning of a new intervention on historical architecture, because of a wider capability to be enriched by information and data by multiple actors. In the field of museums, VLP can be applied to manage museum building and their collections, creating a common language for data interoperability between the exhibition rooms (container) and the artefacts (content). The following case studies, describe some developed workflows in these fields (Fig. 4).

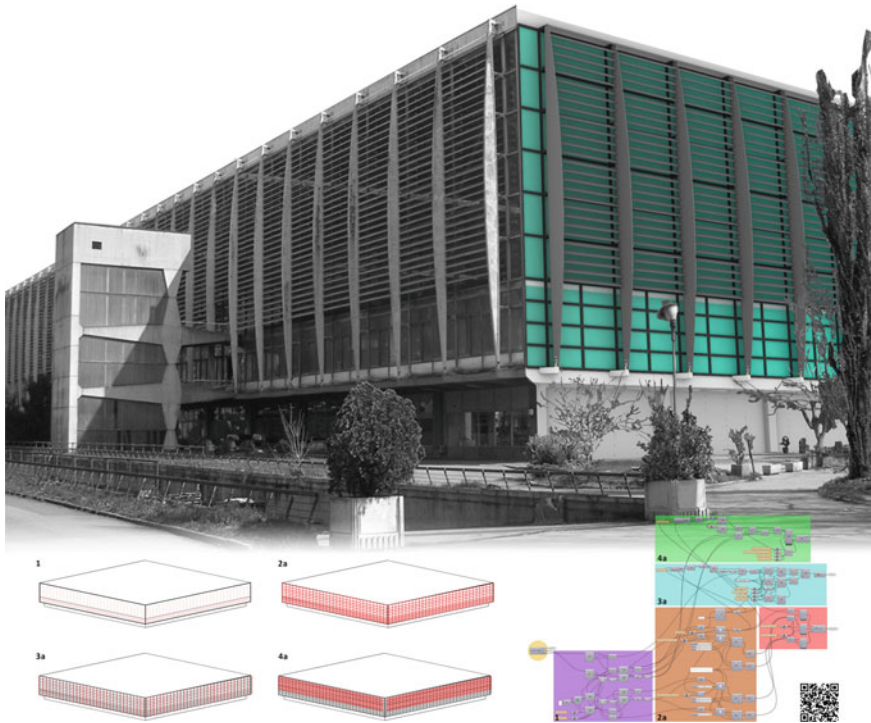


Fig. 4 Above, photo-insertion of the curtain wall modeled with VPL systems. Below, explanation of the sections that make up the parametric code. Palazzo del Lavoro of Pier L. Nervi

4.1 *Palazzo del Lavoro of Pier L. Nervi: Parametric Geometries for Automated Simulations*

The integration between these two parametric platforms has not only focused on the need to make the information heritage associated with the most recent integrated survey experiences richer and more controlled. The research group has developed new ways of sharing information useful to plan in greater detail the decision-making processes put in place in the subsequent phases of intervention on the historical building.

This is the case of the *Palazzo del Lavoro*, a work created to commemorate the Centenary of the Unification of Italy and designed by P.L. Nervi. Among the buildings made for the “Italia ‘61” celebrations is the one that, for its size and technological innovation, was the most published work by the main national and international magazines of the time (Pace et al. 2005). This masterpiece of modern architecture, through the 16 “umbrella” structural elements covering the 22,500 square meters of roof, the isostatic beamed ceiling of the perimeter balcony and the curtain wall

system that describes the vertical curtain wall, is certainly one of the best representations of the dialogue between structure, technological renewal and architecture. Unfortunately, once the event was over, the City of Turin was unable to make the most of it and today it is in a state of decay.

Also in this research, the global scale approach provided for the realization of the HBIM model of the entire building, while some building components of particular importance for the subsequent reuse of the asset were modelled in VPL environment: the large curtain walls that characterize the envelope, and the technological subsystem consisting of uprights, panels and shading slats were investigated in greater detail to make explicit the geometric relationship between the parts and the related control over the daylight factor that permeates inside the building (Tomalini and Lo Turco 2019).

The lighting engineering evaluations were therefore conducted in a VPL environment. Depending on the results of the simulation, different design scenarios can be hypothesized that can be reported on the BIM environment through interoperable processes between the two platforms.

4.2 SMART Museum Project: Toward an Integrated Collection Management System

The SMART Museum project is the result of the collaboration between the research group and the Fondazione Museo delle Antichità Egizie di Torino, a museum characterized by important collections set up in equally interesting environments. Although it has about 10,000 square meters of exhibition space, many exhibits are still stored in depots waiting to be exposed.

The aim (here intended as purpose) is the connection between the three parts of a museum: the building (the container), the collections (the content) and the visitors. Usually, the relationships between these three themes can be shown through the exhibition; the layout proposed by the curator to allocate the collections in the exhibition space and design the paths suggested to the visitors (Ippoliti and Albisinni 2016). As mentioned above, specialized software allows to create architectures combining architectural objects in which dimensional parameters and attributes are included. Therefore, architecture can be represented by 3D digital building components plus data. The same approach can be applied to the collections: this means that a sequence of procedures and tools can be identified for the digitization and the data enrichment of the artefacts contained in the museums, which can be identified by the acronym Collection Information Modeling (CIM).

After having mapped the information contained in the BIM and CIM models, and having identified comparable common parameters in a digital environment, the curator can match the setting up of the acquired objects, starting from very simplified Building Physics controls, such as temperature and humidity. The informed representation allows the connection of information between the container and the

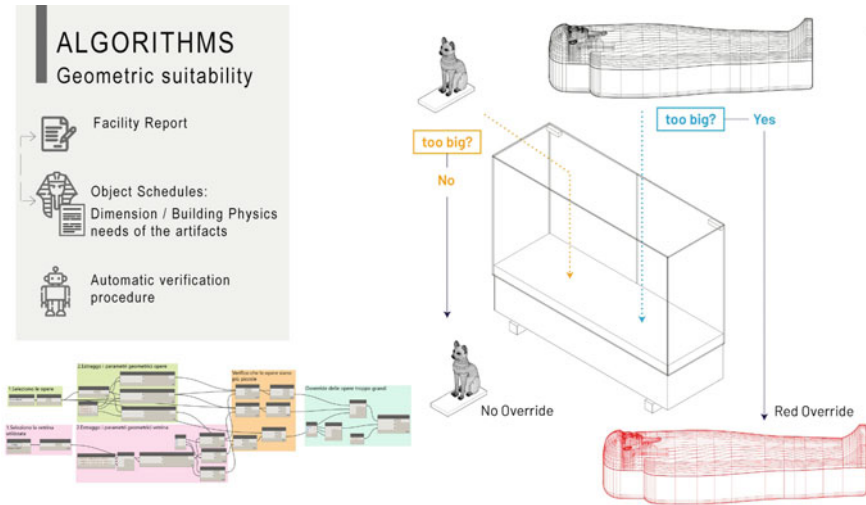


Fig. 5 The exploitation of the automated verification between the exhibition space, the dimensions of the artifact and the building physics features

content. The interaction between data can highlight a condition of the well-being of the artworks within an exhibition environment.

Therefore, once the conditions of well-being have been established, it is useful for a curator to think about the paths of the users within the exhibitions, highlighting the critical points where the flow of users can have some problems, such as bottlenecks and dead ends (Fig. 5).

So we can compare the artefacts as sort of attractor points used to evaluate the magnetic weight. For this reason, we must identify the parameters to understand the attractiveness of the object within the museum rooms. Some proposed fields are: the dimensions, the number of times that the object has been mentioned in web research, the number of people which saw the artefact in a previous exhibition, the historical and artistic significance just to mention the main ones. In order to better understand the research activities carried out, it is necessary to define some variables that have been useful to relate the physical environment and the collections.

In physics, a force field generated by a point entity describes the presence of a force applied to each point in a geometrical domain; the intensity of the charge is a parameter defined in relation to the characteristics of the associated metadata: in other words, points with high charge values generate a wider attractive force field. The association between charge and metadata of a point allows quantifying the “attractive weight of an object” within an environment, creating a hierarchy of contents. The decay represents the speed at which the effects of the charge decrease within the field. The visual acuity is the ability of the human eye to perceive as much detail as possible. The visual ray is similar to the sharpness of vision, therefore the ability to perceive distant objects. This parameter is set by the size of the length of the visual ray, and it allows you to define the amount of space perceived by the user (Fig. 6).

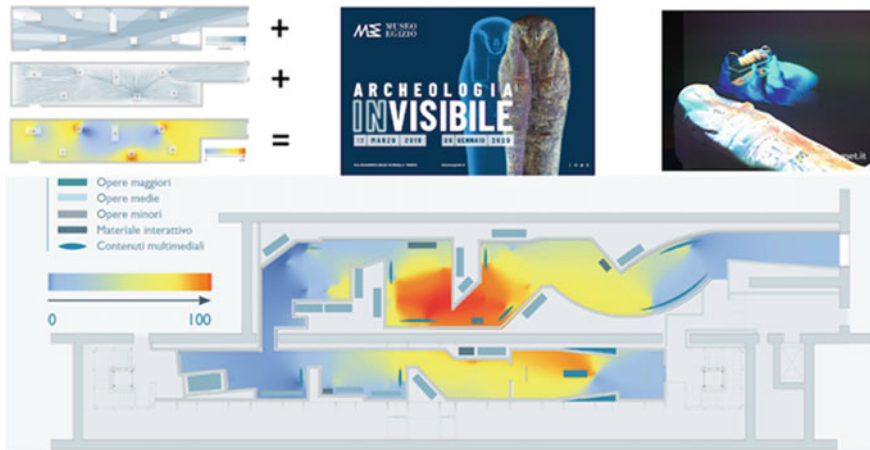


Fig. 6 Thematic maps that graphically describe the level of attractiveness and visibility of the collections

The prefigured behavior of the visitor derives from the adoption of the classification of the visiting styles elaborated in the ethnographic field by the scholars who grouped the different types of visitors into four categories, taking into account the amount of time dedicated to the visit, the movement in the museum exhibitions and the attention paid to the single works. This can be done by using known museum visiting styles to classify the visiting style of visitors as they start their visit (Zancanaro et al. 2007). They identify four different styles: the Ant, the Fish, the Butterfly and the Grasshopper (Veron and Levasseur 1983).

The on-going result is the creation of thematic maps that graphically describe the level of attractiveness and visibility of the collections. At the regard, the case study is the temporary exhibitions of the Museo Egizio named Invisible Archaeology is not so simple to be studied because it is characterized by a merging between artefacts and digital contents. The work is not intended to replace the experience of the professionals, but it aims to be useful support for the work of curators and registrars.

5 Conclusions

Thanks also to recent regulatory dictates, in recent years the professional practice has begun to adopt the BIM methodology mainly for large construction projects, in particular for new construction projects. Italian recent standards requests represents an acknowledgement of the widespread of BIM on a supranational level, especially due to its clear accordance with international standards and guidelines, regarding the

crucial theme of the relationship between information content (graphic and alphanumeric) and construction processes (Chiabrando et al. 2018). The adoption of these methodologies on historical buildings is undoubtedly more complex (Volk et al. 2014). Furthermore the new UNI 11337:2017 standard, defining the different LOD for restoration, has been recently published and states that the restoration activities on existent construction considered of cultural interest imply a continuity of information management, and thus are based on data content and representation detail as resulting from the scientific conclusions made by the previous intervention (LOD F) implemented in successive management activities (LOD G). Nevertheless, the high level of detail, both for digital representation and information, is an essential trait of information modelling applied to cultural heritage. The particularities eventually insignificant for the single technical activities, in fact, may acquire a crucial relevance for other design choices.

At the moment, the processes and methodologies illustrated require significant and demanding data acquisition and processing time, which unfortunately the professional world, at the moment, does not dispose. This is the reason why for the research environment is crucial to shall actively cooperate with the industrial sector for a systematization of automatic processes and for the semantic recognition of data to reinforce possible interoperable connections. The research activities proposed in the contribution go precisely in this direction, towards greater process efficiency pursued through new and possible collaborative scenarios. Even if they are heuristic approaches, it is easy to realize that, experience after experience, the proposed workflows allow to obtain new and interesting results in order to organize more and more interoperable workflows in favour of process transparency.

The examples demonstrate how VPL can generate new parametric approaches for the construction of digital models and their management in some specific fields such as the integrated survey for subsequent intervention operations, the foreshadowing of design scenarios involving different disciplines and knowledge concerning the building physics and its components, or the relationship between informed models of museum buildings and the collections they contain make it possible to interconnect usually independent information systems.

AIM processes finally generate new set of algorithms to challenge different issues creating a new catalogue of available procedures, through the connection between different platforms (i.e. grasshopper, dynamo for Revit) and eventually re-usable for several case studies.

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