Algorithmic Approach for the Application of Graphic Standards in the BIM Environment

Matteo Del Giudice, Emmanuele Iacono

Abstract

In the era of digital connection, the construction industry is crossing a transition that involves numerous aspects, related, among others, to the representation of the building artifact. Information and Communication Technologies (ICTs) in the construction process stimulate the adoption of innovative methods and tools aimed at communicating the design idea, shifting the focus from the digital drafting machine to the information model. The adoption of Building Information Modeling (BIM) is triggering a radical inversion of perspective, such that the development of a parametric 3D model allows the generation of a series of coordinated drawings, avoiding information redundancy and consequent inconsistencies. Traditionally, the production of design content takes advantage of standards and graphic conventions, inherited from information modeling tools. The contribution aims to develop a critical approach on the current capabilities of collaborative BIM models to produce such documents, as part of the construction process. This study is part of a broad field of research focused on optimizing the building process by improving the connection between tradition and innovation in the science of representation.

Keywords: Building Information Modeling, Visual Programming Language, graphic standards, connected BIM, algorithms.

Introduction

The digitization of the construction industry has seen a significant acceleration in recent years, largely due to the influence of the development of the so-called Information and Communication Technologies. It is an innovation process that does not only affect the construction industry, but involves the whole of contemporary society, which is therefore moving towards more and more articulated and complex systems of connection and optimization of data management, with a view to proceed towards the development of cities, and therefore of increasingly intelligent societies. All this is a consequence of the fourth industrial revolution, which necessarily implies a radical change in production processes, through sensor networks, smart manufacturing, cloud manufacturing, and a general paradigm shift in design and production methods [Qi, Tao 2018, p. 3585].

Among the numerous examples that could be proposed, one of the most eloquent can certainly be the introduction of sensors inside buildings, which allows the development of innovative building models that are not only able to replicate the properties and appearance of their constructive components, but also their behavior over time, in a dynamic way. However, these models require the presence of special graphic interfaces that make it possible to view data and information in order to satisfy the needs of the users concerned.

For these reasons, the architectural representation of design intentions is increasingly orienting towards the

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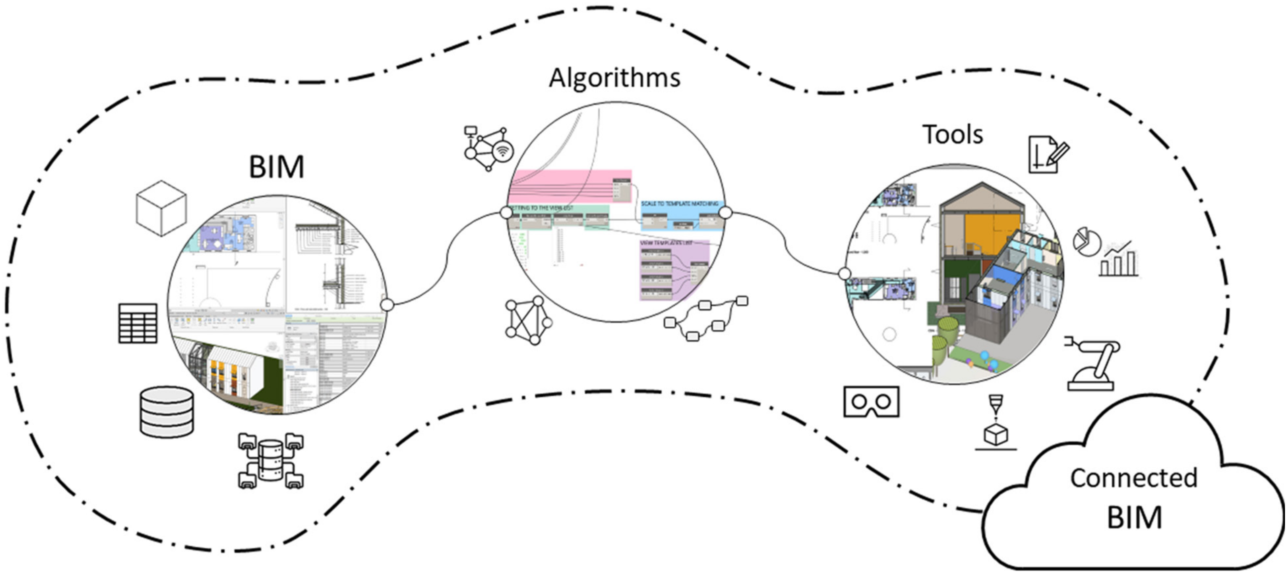


Fig. 1. Conceptualization underlying the Connected BIM hypothesis (image of the authors).

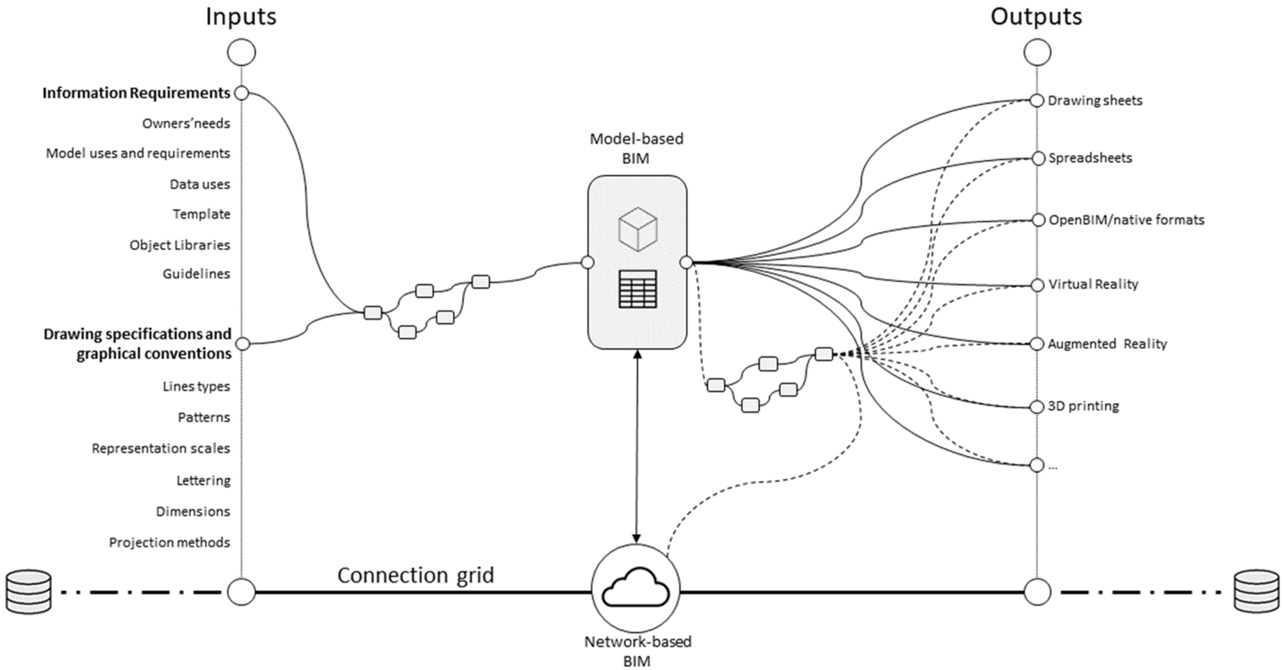
so-called BIM (Building Information Modeling) methodology. This is based on the creation of a three-dimensional parametric model, whose constituent elements host properties, data, and numerical and graphical information, in order to be able to optimize the information management of the building process [Osello 2012, pp. 29-33].
Therefore, the organization of the information models mentioned above must be aimed at representation not only through regulatory standards and graphic conventions, but also through new viewing methods, for example with virtual reality and augmented reality (VAR) technologies. From this it follows that it is possible to greatly optimize the potential of representation through the development of information models representing buildings and their behavior detected through connected sensors, consequently generating what is identified as a "digital twin" [Maatev 2020].
Given these premises, it is possible to say that the current times could be considered as what is called the "era of connection" [Autodesk 2020, pp. 6-12], in which the development of BIM models must be based on some fundamental concepts, such as data sets, algorithms and smart interfaces. The first ones can describe the characteristics and behavior of the building, both statically and dynamically. The second ones are capable of receiving, processing and producing large quantities of information and data, so as to be able to formulate considerations on the current state of buildings and predict their future behavior, optimizing their management. The last ones are able to ensure easy man-machine interaction (fig. 1). All the above should be made possible through constant sharing between users [Ratti, Claudel 2017; Garzino 2011, pp. 135-176].
At the moment, a similar conception of a connected information model is often associated with the development of a Common Data Environment (CDE), i.e. a shared data platform, which, however, does not automatically involve the preparation of algorithms capable of optimizing the graphical representation based on the planning requirements outlined by the design regulations. It follows that the adoption of a CDE is not sufficient to achieve a level of BIM maturity such as to allow an adequate Integrated Project Delivery (IPD) [Succar 2009, pp. 6-8, 31-34].

At best, the connection methods described above make it possible to use systems equipped with cloud-based platforms which, however, allow only viewing. On the other hand, it would instead be desirable that these systems can be further developed in such a way to allow directly interested users not only to view, but also to interact directly with the model by modifying, creating, deleting, integrating, updating the elements and data on them. This would ensure the possibility of an agile advancement and evolution of the model that goes hand in hand with the evolution of its building process.
The modeling and management process through BIM allows to generate significantly better project documents through the integration of models, analytical tools, collaborative platforms, and Big Data in general. Despite this, at the moment the gap between the production of these methods of visualization, and the graphic representations referring instead to conventions and standards codified within the discipline of drawing and graphic representation, is still significant.
This article presents a possible analytical approach based on the creation of algorithms, with the aim of testing their effectiveness in terms of optimizing the graphic representation in a BIM environment. This approach involves the application in an automated manner as much as possible of the coded representation rules, applied to specific views created by the information model on the basis of the graphic scale adopted, in an attempt to bring the contents provided by the BIM platforms closer to those regulated by the design standards. This analysis starts from the studies carried on as part of the drawing course held at the Polytechnic of Turin, by Professor Giuseppa Novello.

Methodology

In the realization of a BIM model the main logical steps basically are: 1) definition of the inputs; 2) creation of three-dimensional parametric models; 3) production of the outputs required by each specific phase. In addition, the bases for the development of an information model remain in any case requirements and specifications of the design and graphic conventions, which constitute the set of modeling inputs. After that, in order to improve the communication of the project, it is a usual procedure to manipulate the specificities of the model to obtain the appropriate graphical and alphanumerical outputs.

Currently, the processing of information content is often based on *ad-hoc* algorithms to carry out specific conversion operations, according to the characteristics and specificity of the project outputs and related requirements. Through this type of operations, the project representations are therefore conformed to the regulatory standards adopted without the need for further manipulations, with consequent benefits on the graphic level.
The further step in order to obtain a connected BIM model (fig. 2) currently involves its upload to a platform set up on the network to allow the sharing of its content and data. Such a connection, between the model uploaded on the network and the file-based model, it would be desirable to be adjustable through specific algorithms.
With the aim of unifying the different ways of representing and displaying projects, it is first of all necessary to consider both those relating to the construction process and those more related to the BIM methodology (fig. 3). With regard to the former, the Public Procurement Code (Legislative Decree 18 April 2016, No. 50) indicates a series of macro-phases of the building process, also specifically stating those relating more specifically to the design phases. In addition to these, the preceding and subsequent phases are also included, in order to consider the process in its entirety. On the other hand, as regards the BIM methodology, the so-called Levels of Development (LOD) must be taken into consideration. In the Italian regulatory framework they are divided into seven ranges. Each one is identified by a letter, with increasing graphic and information contents starting from LOD A up to LOD G [De Gregorio 2018, pp. 20-21; Novello, Lo Turco 2014, p. 3]. At the international level, ISO 19650 updates the concept of LOD by introducing the Levels of Information Need (LOIN) including criteria of quantity, quality and granularity of the information requested [UNI EN ISO 19650-1 2019, p. 27]. In addition to what is stated for the Italian legislation, it was considered appropriate to try and take into consideration also the concept of Graphic Detail (GraDe) proposed, in the British context, by the AEC (UK) *BIM Protocol V2.0*. However, it is worth observing that this concept actually takes into account only the graphic content of the models, thus not expressing an evaluation on the information content [Caffi et al. 2017, p. 70]. However, by proceeding to identify correspondences between the three different expressions of the evolution of the building process, through a transversal



LOD	Project phases								GRADE
	Survey	Feasibility study	Preliminary project	Definitive project	Executive project	Accounting	Technical testing	Life-cycle	
A		1: ≥ 500	1: ≥ 500	1:500	1:500				0
B	1: ≥ 200		1:200						1
C				1:100					2
D					1:50				
E					1:20	1:20			3
F					1:5	1:5	1:5		
G					1:1	1:1	1:1	1:1	

Fig. 2. Schematic of the transition between File-based and Network-based BIM methodology (image of the authors).

Fig. 3. Hypothetical matrix of correlation between project phases, LOD and GraDe through the representation scales (image of the authors).

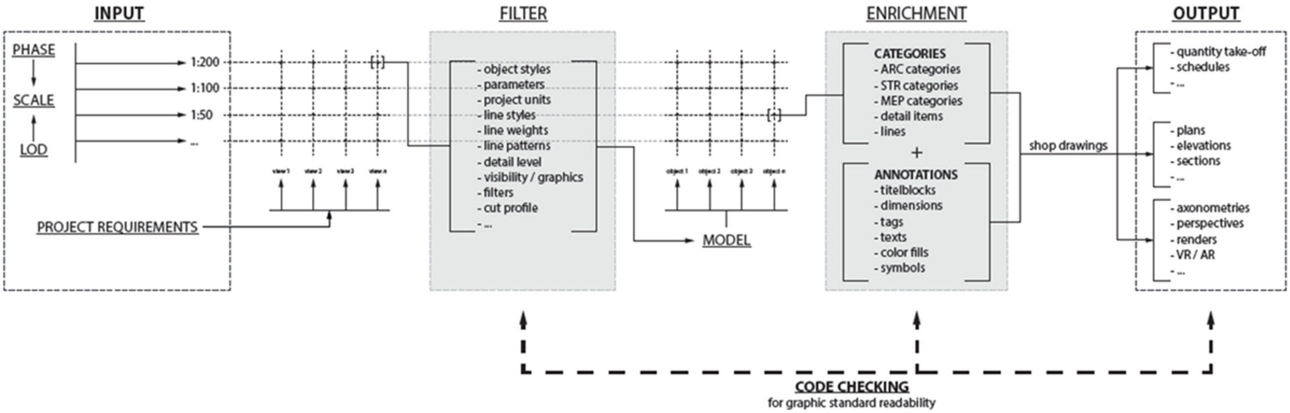


Fig. 4. Workflow diagram of the ideal automatic process for the improvement of representation outputs (image of the authors).

element such as the representation scales, it is possible to trace a logical path that leads to the setting, in an automatic way, of the necessary representations and the correct contents of a given current phase of the process, starting from the requirements and design needs.
The workflow illustrated in this document starts from the elaboration of an algorithm (fig. 4) consisting of a series of matrices capable of setting and regulating the representation of the project views starting from the definition of phase, design requirements, LOD and graphic scale. Hypothetically, the procedure is as follows: depending on the project phase in which the user is, the corresponding phase of the building process is identified, be it the project phase of technical and economic feasibility, the final design phase or finally the executive. These correspondences constitute a first input in the illustrated logical scheme. A further input consists of the LOD, in turn based on the level of detail that must be guaranteed in the design documents required by the phase, and on the respective information content. Once these first two inputs have been defined, the intersection between them, i.e. the intersection between the project phase and the corresponding LOD, especially as regards the graphic component, consequently identifies the most correct representation scales (1:500, 1:200, 1:100 etc.) to fulfill the starting requirements. Subsequently, the correlation between the appropriate graphic scale and the related graphic products to be processed, in order to correctly communicate the design idea, constitutes the third and final input of the algorithm. A first matrix of the documents necessary for the completion of the current project phase is generated by the intersection of the required representations, into which the project is divided, and the scales defined by the first two inputs. In particular, each element of this matrix must pass through an element, in the scheme called Filter, which is identified for each type of view (whether they are, for example, 1:200 plans, 1:100 sections, 1:50 executive drawings, 1:20 details etc.). This filter is a series of predefined system requirements, to which one or more specific functions or settings provided within the software used by the user can be associated (thicknesses and types of lines, fills, hatches, profiles, etc.). This operation has obviously the aim of improving the display of the different views of the model on the basis of the graphic design regulations and standards. The next step concerns the Enrichment section, which is a specific implementation of views and contents of the information model. Here, each element would be subjected to an analysis through operations that possibly add specific elements through categories and detail lines, as well as through further operations that act on the views by entering elements of annotation categories (e.g. dimensions, symbols, tags, texts or title blocks). Once the Enrichment phase has been completed, the production of the drawings will effec-

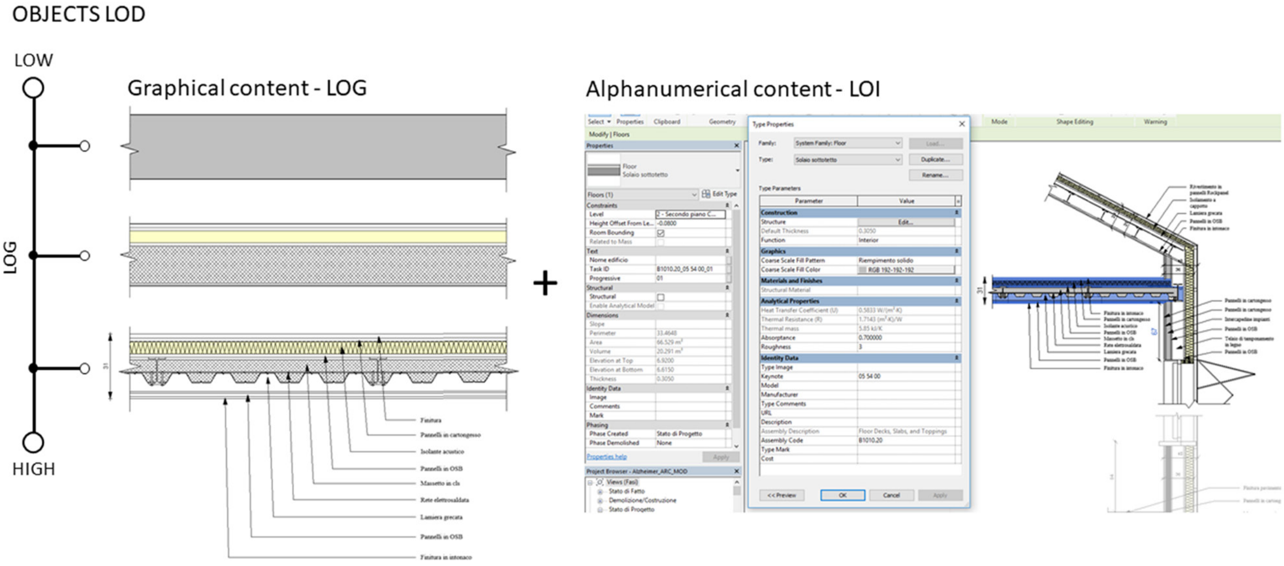


Fig. 5. Example of graphic and alphanumerical contents of the LOD (image of the authors).

tively be able to meet the regulatory requirements, whether they are two-dimensional (plans, elevations, sections, abacuses, etc.) or three-dimensional representations (axonometries, perspectives, renderings, VR/AR etc.). The set of these exported drawings forms the final output of the logical process, on which it is finally possible to start a validation operation, which consequently provides a response on the correctness of the filters set within the software.
This articulated series of operations would make it possible to obtain, as a product, the improvement of the so-called Level of Geometry (LOG) as well as the addition of various elements of detail that would help to understand the more advanced project phases, as well as the improvement of the Level of Information (LOI) [Pavan, Mirarchi, Giani 2017] (fig. 5). Depending on the BIM authoring application used to perform these operations, different subsets of representation settings may be required, whether they are based either on certain graphic filters, or on the addition of components and annotations, or on automatic or manual compilation of various properties of the elements. The study carried out in this document was based on the choice of Autodesk Revit software as BIM authoring platform to evaluate the strengths and weaknesses of the information model and the method applied to it. The degree of automation in the process is a crucial point, since depending on its incidence, it can become more or less burdensome.
The flow chart (fig. 6) proposes a hypothetical sequence of actions performed by the algorithm responsible for the validation. For each view in the model, the representation scale is assigned as the initial input and immediately associated with its view. Element by element, the compliance with the design regulations is checked. If this correspondence is correct, the algorithm proceeds with the next element; otherwise, the verification and enrichment process is initiated. This process evaluates, for each element, its specific requests and regulatory requirements. For each of them, in cases when these do not comply with the standards, the next step is the implementation of the object with the missing necessary elements. Once this is done, the algorithm continues with the following requirement, until compliance with each of them has been verified. Upon completion of the procedure, the element is considered compliant with the standard, and the program proceeds cascading to the subsequent objects.
The logical diagram hypothesized here, depicting the sequence of steps that the machine must follow, has been

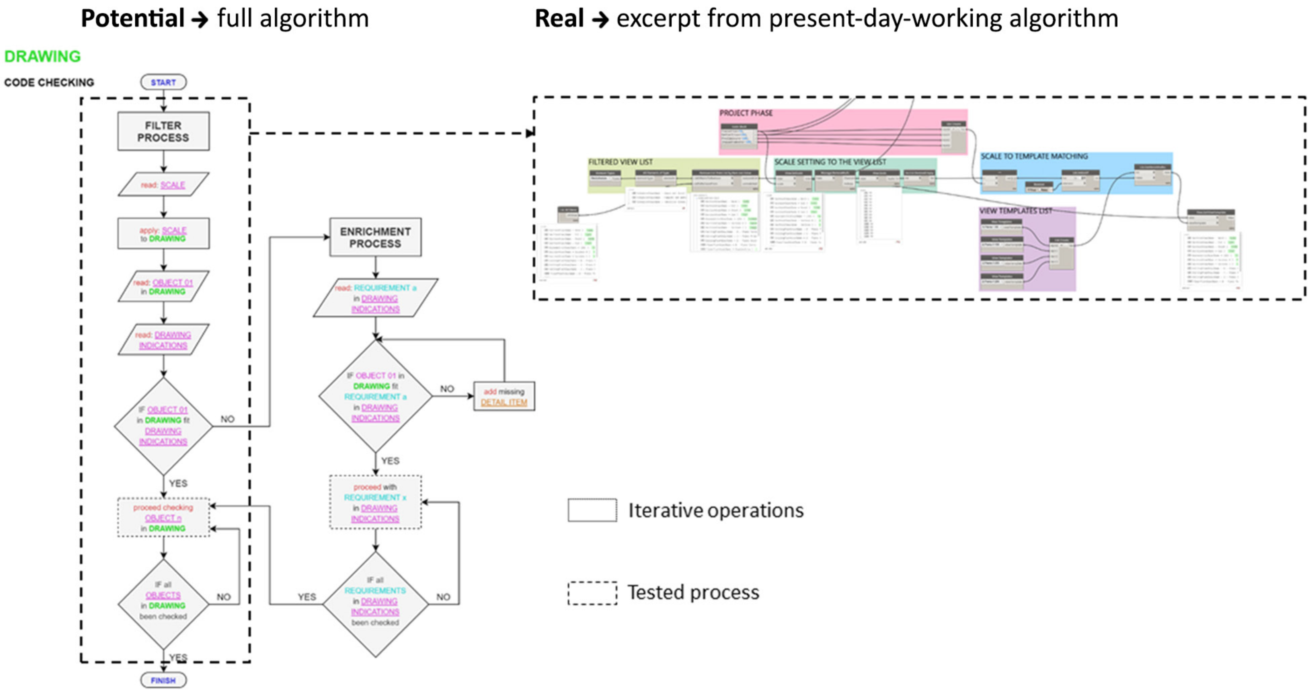


Fig. 6. On the left, logical flowchart of the proposed algorithm; on the right, a part of the tested script (image of the authors).

translated as Visual Programming Language (VPL) executable by the BIM authoring tool used (fig. 6), through the interface of the Dynamo graphic programming. The resulting script, visible on the right of the image, is the prototype of one of the tested sections of the complete algorithm, which is still under development and would must necessarily be made fully functional.
It should be noted that the currently working script has been developed starting from the assumption of first testing its ability to interact with the Views, thus using a preliminary simplification on the side of the inputs, which here have therefore been reduced to a simple reading of the set representation scale by the user. Furthermore, since some functions used in Dynamo do not provide for the possibility of an auto-refresh when the input is changed except by manually restarting the algorithm, a group of nodes capable of timing the automatic updating of data has been implemented inside of the script. Thus, the algorithm created (fig. 7) is structured in such a way as to update itself automatically, according to either a predetermined timing if keeping Dynamo running, or starting it whenever necessary through the Revit Dynamo Player.

Results

At the moment, the creation of connected information models that are able to correctly represent the design information is a process that can still be improved (fig. 8) and can be optimized, in the perspective of obtaining more efficient procedures, both as regards the visualization of information and data and for an integrated process. In particular, it is still necessary to evaluate as input to the process both the information requirements and the graphic settings, in order to proceed with the develop-

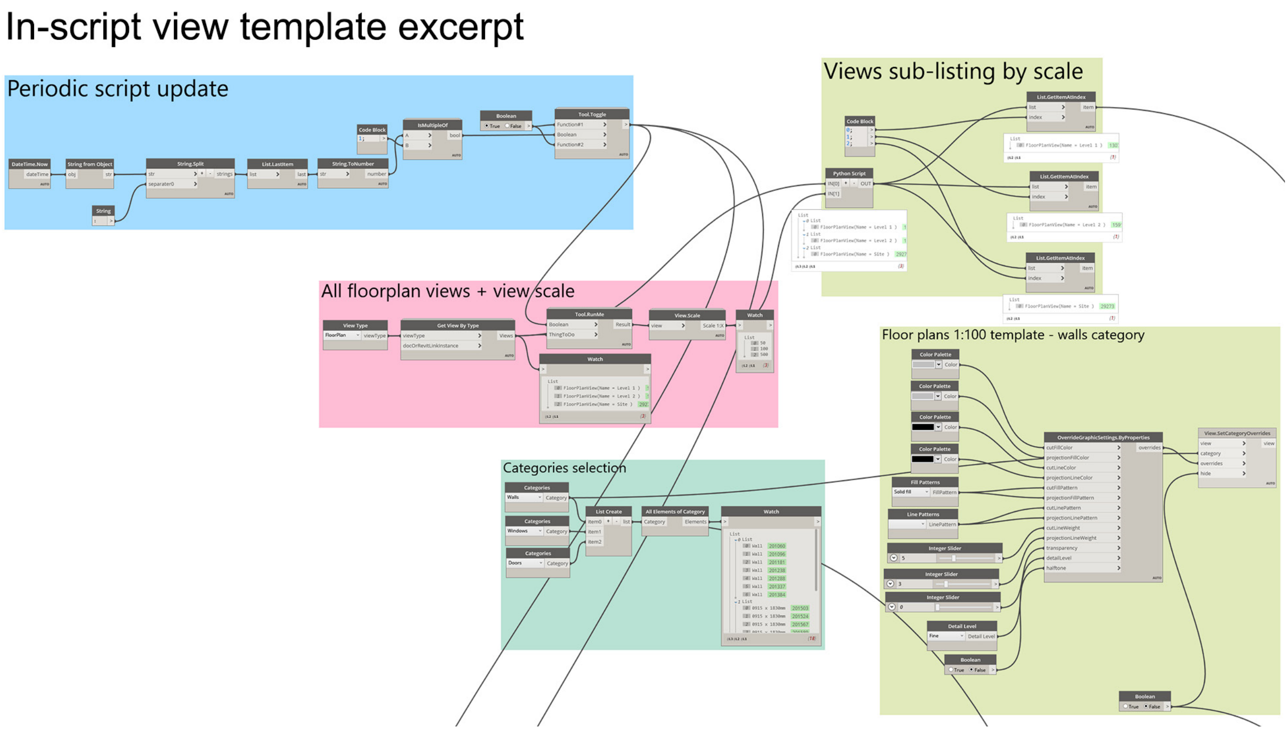


Fig. 7. Excerpt of the developed algorithm, as a focus on the management of in-script templates (image of the authors).

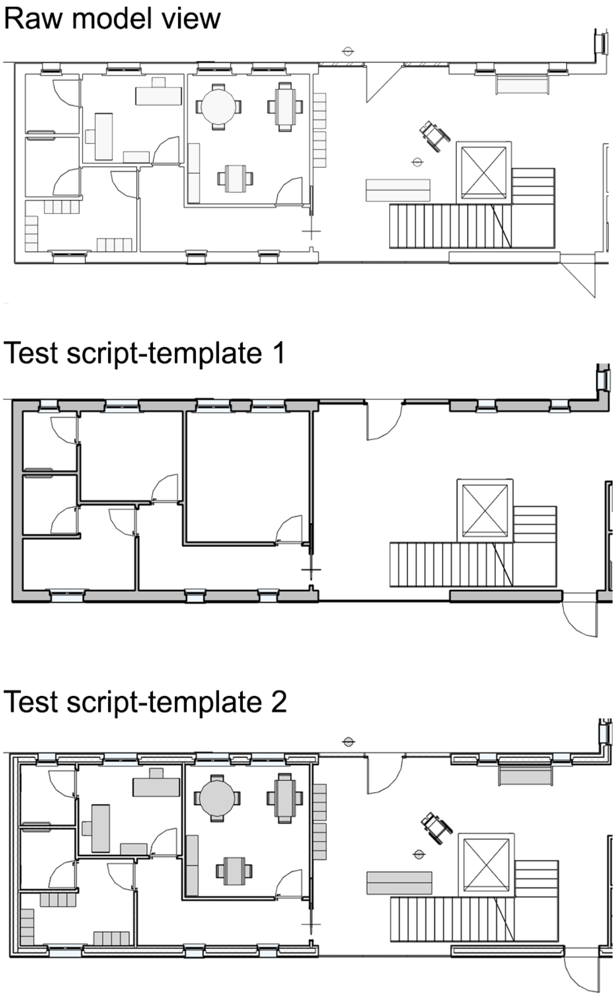


Fig. 8. Test examples of simple pre-set script executions starting from an untreated model view (image of the authors).

ment of a potential digital archive that is optimized to be able to collect and put together graphic and alphanumeric information.
This contribution underlines the validity of the introduction of automated steps within the building process, in order to facilitate the production of design documents, through a connection between the project inputs and the outputs required by the process itself through the use of graphic standards. Therefore, the level of automation necessary for the production of correctly set graphical drawings was evaluated through a schematic representation of the effort required for it (fig. 9), systematizing the correspondences between graphic standards and software-side settings. For example, the setting called Detail Level allows you to adjust the visibility of the different elements of the model in a simpler way than a setting like the one called Cut profile, which requires a greater work effort, as it requires to be individually applied for each desired view.
Therefore, the automatic procedure described above still presents certain criticalities, which are to be identified both in the objective current technological limits, and in the peculiarities and uniqueness, for technical and constructive choices, of each individual project.
Concretely, it is possible to operate on the filtering process, through a series of settings, which can be incorporated into the project templates, modifiable through scripts (e.g. with the use of plugins such as Dynamo), on the basis of the representation set on certain views. However, it is still entirely possible to refine the enrichment phase with the possibility of making it further automatable, since many elements present in this phase still need to be entered individually. In fact, the production of graphic drawings starting from BIM models also implies the need, sometimes, to insert additional objects, such as the so-called Detail Items or certain Annotations, which can determine a clearer and more understandable communication of the project.
Furthermore, as regards the integration between project templates and scripts, through the experimentation tested here it was possible to manage the large amount of graphic settings aimed at project documentation through scripting operations via Dynamo.
Moreover, the previously described ability of the algorithm to constantly self-update itself based on the simple adjustment of the scale of representation in the view, potentially makes it possible to set a series of predefined

Graphics Settings	UNI EN ISO 128-20	UNI EN ISO 128-21	UNI EN ISO 128-23	UNI EN ISO 5455	UNI EN ISO 3098-0	UNI 3972	UNI EN ISO 129-1	UNI EN ISO 5456-1	UNI EN ISO 5456 -2	UNI EN ISO 5456 -3	UNI EN ISO 5456-4	UNI EN ISO 7200	UNI 11337	UNI EN ISO 19650	Level of Automation
	Graphics Standards														
Object style	x		x		Text (Type property)	x	Dimension (Type property)	Views	2D Views	View cube	View cube	Titleblock			
Parameters													x	x	
Project Unit															
Lines styles	x		x												
Line Weights	x	x	x												
Line Patterns	x		x												
Detail Level				x											
Visibility/Graphics						x							x	x	
Filters						x							x	x	
Cut profile													x	x	

Fig. 9. Evaluation of the level of automation regarding the graphic settings and respective graphic standards (image of the authors).

pseudo-templates for different views within a single algorithm, maintained in action in the background.
The innovation proposed in this contribution favors the optimization of the production of graphic designs without which the time for adjusting most of the graphic settings within the application would be prolonged also with a view to transferring shared standards, with a simple exchange of a file of a few kiloBytes.
Surely, the article highlights the current differences between Project Views (specific to the BIM authoring platform) and the design drawings that are the real expected product of the current building process.
The illustrated study highlights how the effort required to complete the different tasks that are naturally part of the complex representation process is considerably different, and how this difference is essentially due to the specific functionality selected, activated or used in a given view or set of views.
This document has also investigated the relationship between the LOD scales with respect to the design phases, trying to establish a correspondence with the related representation scales. Therefore, the information level obtained in the project sheets must be considered to all intents and purposes one of the requirements for the definition of the so-called Levels of Information Need, defined within the ISO 19650 standard and the UNI EN 17412-1:2021 transposition.

To date, the choice of a scale of graphic representation is fundamental to achieve the project objectives in the context of the production of graphic drawings. Through the information modeling it is desirable that the graphic product be oriented to the contents of the BIM uses that integrate the requests for representation to the objectives and related uses of the information model.

Conclusions

The ability to communicate a design idea has always been a prerogative of the human being who, over time, has developed a series of skills to optimize communication between his peers. Within the construction industry, this ability has found an application on the production of graphic designs capable of facilitating the understanding of design intentions. This procedure has therefore always characterized the *modus operandi* of the engineer and the architect, who finalized their intentions in a variety of documents to describe the design idea. With the adoption of CAD, this ability has been refined, improving the quality and graphic precision of the documentary apparatus, which however continues to be uneven and uncoordinated, highlighting some limits on the consistency between the documents.
With the advent of BIM we are witnessing a reversal paradigm in which the uniqueness of the design idea is guaranteed by the development of a parametric 3D model from which various graphic representations are generated. This way the difficulties highlighted by the traditional methodology are overcome thanks to technology. In the era of digital connection, the purpose is to raise the level of BIM maturity by reaching a degree of collaboration and integration, orienting the construction industry towards implementation in processes, based on the development of a collaborative model. Certain activities, such as the development of project documents and the updating of data along the entire life cycle of the building, should be based on the creation of a model connected to heterogeneous databases, with a view to the development of smart cities.
This contribution analyzed the level of automation of the documentation production process aligned with regula-

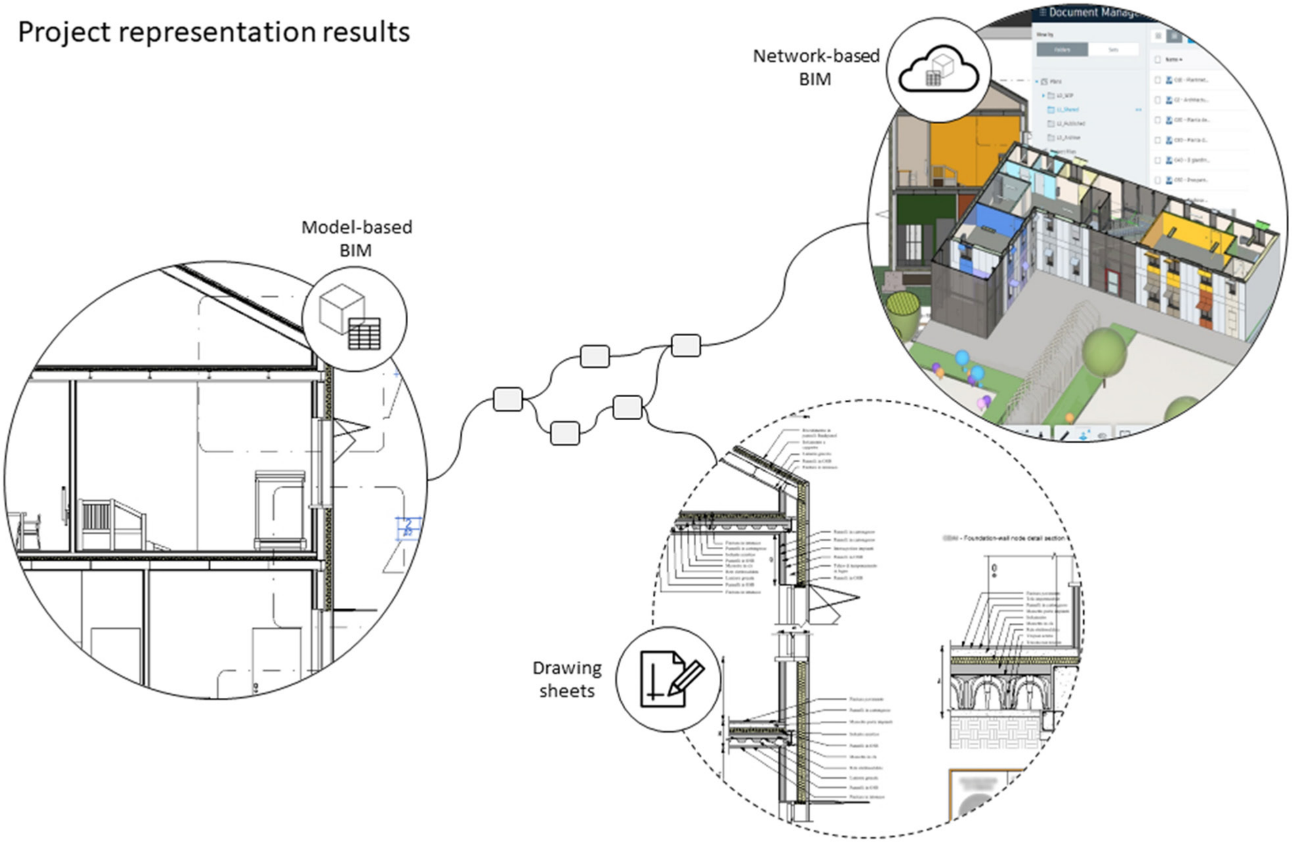


Fig. 10. Theoretical interaction between the connected BIM model and its representations (image of the authors).

tory requirements, taking up the BIM challenge of overcoming the current gap between simple visualization and correct representation (fig. 10). A further optimization could be the self-regulation of the proposed algorithms on the basis of certain entered data. It is hoped that in the near future the definition of the graphic and information requirements of the project documents will be further codified through the use of systems capable of correctly reprocessing the data set in the system within the various databases, and then transfer them to certain specific representations of reality.
Due to the complexity associated with the world of collaboration and interoperability between technologies on the construction market, it is desirable that current technological limits will be overcome in the near future. In conclusion, technological innovation will have the task of providing new methods and tools for the creation of connected information models, to be used with different interfaces for the multiple specificities of contemporary society.

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The authors agree on the contents, the methodological approach and on the final considerations presented in this research. In particular, Matteo Del Giudice introduced the contribution in the introduction paragraph. The methodology was addressed by both Matteo Del Giudice and Emmanuele Iacono. The latter focused on the obtained results, while the conclusions are meant to be a synthesis of the two authors.
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