

SI GraDi 2024

Biodigital Intelligent Systems

XXVIII International Conference of the Ibero-American
Society of Digital Graphics Proceedings

13-15 November 2024
iBAG-UIC Barcelona (Spain)

CumInCAD



INSTITUTE FOR BIODIGITAL
ARCHITECTURE & GENETICS



Universitat Internacional
de Catalunya

SI GraDi



XXVIII International Conference of the
Ibero-American Society of Digital Graphics

13-15 November 2024
iBAG-UIC Barcelona (Spain)

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Organization

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7
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Days remaining for Abstract Submission Deadline

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EXTENDED DEADLINE
for abstract submission
April 8th

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for abstract submission
April 8th

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For Abstract Submission
8th April

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Days remaining for Abstract Submission Deadline

2
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1
Day remaining for Abstract Submission Deadline

05 / 46
Countries

623
Abstracts Submitted
That is so awesome!

ABSTRACT REVIEW
IN PROGRESS

ABSTRACTS REVIEW
IN PROGRESS

ABSTRACTS REVIEW
IN PROGRESS

355
Abstracts Accepted

355
Abstracts Accepted

FULL PAPER
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REVIEW
IN PROGRESS
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248
Full Papers Accepted

248
Full Papers Accepted

248
Full Papers Accepted

CAMERA
READY
Deadline for Submission
October 14th

CAMERA
READY
Deadline for Submission
October 14th

CAMERA
READY
Deadline for Submission
October 14th

Welcome to SIGraDi 2024

The story goes like this... Members of SIGraDi (Ibero-american Society of Digital Graphics) noticed that for 25 years now, there has been someone in Barcelona (Spain) developing a unique systematic program of research, teaching, and professional practice in architecture and design, organized at iBAG-UIC Barcelona (Institute for Biodigital Architecture & Genetics, Universitat Internacional de Catalunya), working on the cutting edge of knowledge, around biodigital intelligent systems, from the Genetic Architectures Research Group & Office and the Biodigital Architecture Master's Program.

Then, realizing that the word "Ibero" also appears in SIGraDi's name, they decide to jump from America across the Atlantic to host, together with iBAG-UIC Barcelona, from November 13 to 15, their 28th annual conference, a high-impact forum on the avantgarde of contemporary architecture: in the city of Barcelona, "Gaudí's city," a pioneer of bio-learning in biological intelligent systems and their application to architecture, a pioneer of creating architecture with complex geometry, a pioneer of parametric architecture (without computers), opening the door to what a century later would consolidate as digital organicism. All that lies at the root of what interests us and what we develop in our lives and works.

On the other hand, ASCAAD (Arab Society for Computation in Architecture, Art, and Design), a sister association of SIGraDi, active in the south and east of the Mediterranean (North Africa and regions of the Arab world), after the unfortunate circumstance of seeing its own annual conference venue canceled just a few days earlier, looks a bit further north of that sea and asks to join, as a last resort, the same event at iBAG-UIC Barcelona.

Thus, something more than extraordinary, unique, is created, due to all the combined circumstances of geography, history, theme, and its people. Something that only exists because there is a great team behind it, united, diligent, and dedicated, to whom we owe all our gratitude.

Welcome, then, to SIGraDi 2024, at iBAG-UIC Barcelona! Biodigital Intelligent Systems... Surpassing the past: preparing the future. Surpassing the functional city: the city will be 50% biological and 50% digital, or it won't be. Surpassing the house as a machine for living: the house will be an active sustainability machine, or it won't be.

Alberto T. Estévez, SIGraDi 2024 Chair



Preface

Nature-based design has grown significantly in recent decades mainly driven by digital technologies. Consequently, this topic has been progressively integrated into SIGraDi conferences. At the SIGraDi 2020 Online Conference, the “Bioinspired design and ecosystems” track was created as the first approach to nature-based design. Since then, this track has been maintained during the SIGraDi 2021, SIGraDi 2022, and SIGraDi 2023 conferences. In 2024, iBAG at UIC is hosting the annual SIGraDi conference for the first time in Spain. The main theme, “Biodigital Intelligent Systems” highlights nature-based design, with a special meaning in Barcelona, the city where Antoni Gaudí was born.

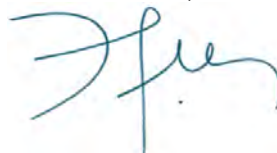
The SIGraDi 2024 conference was organized into nine thematic tracks: Digital architecture and design (theory, history, and society); Education in digital and hybrid contexts; Digital fabrication, robotics, and automation; Parametric design, generative design, and Building Information Modeling (BIM); Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR); Interaction design, interfaces, and devices; Biodigital architecture, biodigital design and ecosystems; Artistic practices and creative industries; Performance, simulation, and analytics.

The annual conference has significant achievements we need to celebrate: 623 abstracts were submitted from 46 countries and 5 continents (Asia, Africa, America, Europe and Oceania), 355 were accepted, 272 full papers were submitted for the second phase, 248 were accepted, and finally, 232 full papers from 46 countries and 5 continents (Asia, Africa, America, Europe and Oceania) were published. These achievements result from the synergistic work between the Local Organizing Committee (COL), the SIGraDi International Executive Committee (CEI), the Advisory Committee (CA), the International Scientific Committee, including 184 reviewers from 25 countries and 4 continents, graphic and web design team from Uruguay and the volunteers from the UIC, Barcelona. This project would not have been possible without this intense and generous collaboration. Thanks to everyone!

SIGraDi is not just a conference; it's a growing platform that connects researchers worldwide and expands knowledge and creative territories for architecture, design, and art. It's about integrating global digital technologies with local realities and this international community.

Goodbye Barcelona! Welcome Córdoba, Argentina 2025!

David A. Torreblanca-Díaz, SIGraDi 2024 Co-Chair



SIGraDi President's greeting

Dear SiGraDi Community: I am honored to present the Proceedings of the XXVIII Congress of the Ibero-American Society of Digital Graphics (SIGraDi), held in the city of Barcelona, Spain, from November 13 to 15, 2024. This time, researchers, academics, and professionals from various parts of the world have gathered to discuss the latest advances in the field of digital technologies applied to graphic design, architecture, the arts, and other related disciplines.

The current conference focuses on Biodigital Intelligent Systems, inviting reflection on the confluence of principles from biology, digital technology, and artificial intelligence to create intelligent systems inspired by living organisms through a systemic approach. This framework encompasses a wide spectrum of interdisciplinary areas, enabling the development of new technologies capable of optimizing current systems and projecting them toward a biodigital future.

This year, the SIGraDi community has expanded significantly, achieving the largest attendance in its history. The book gathers 232 papers, selected as the most outstanding contributions from the congress, all rigorously evaluated by the Scientific Committee, composed of international experts. This growth reflects the global interest in the topics addressed and solidifies SIGraDi as a key platform for the exchange of ideas and collaboration in cutting-edge digital technologies. The topics covered range from the application of new technologies in design education to the automation of creative processes, the impact of digital tools in architectural and urban fields, and the integration of new technologies across various disciplines—not only in representation and visualization but also in construction and creation.

The SIGraDi community shares a common goal with sister associations from different continents (eCAADe, ACADIA, CAADRIA, ASCAAD, and CAAD Futures), which is the dissemination of CAAD. We are committed to contributing to CuminCAD, the largest open-access database dedicated to research in computer-aided architectural design. SIGraDi is always willing to collaborate by interacting with sister societies on various levels, whether through workshops, round tables, or scientific meetings.

I would like to express my special gratitude to the authors who have shared their research, to the Editorial Committee and International Scientific Committee, to the Advisory Council, to the Scientific Committee for ensuring the academic quality of each presentation, and to the Local Organizing Committee, from the iBAG-UIC Barcelona (Universitat Internacional de Catalunya), who has worked tirelessly to make this congress a reality. Thanks to the collaboration of all, this book not only reflects current advances but also sets the course for future research in the field of digital graphics.

Finally, I extend my thanks to the leaders of the 13 special workshops held online and in person, from different countries, who generously share their knowledge and experience to propel our community forward. We trust that this book will be a valuable source of reference and inspiration for all those interested in digital technologies related to design and other applications. We invite you to explore the innovative ideas presented here and to continue the dialogue initiated at this congress.

Patricia Hernández, President



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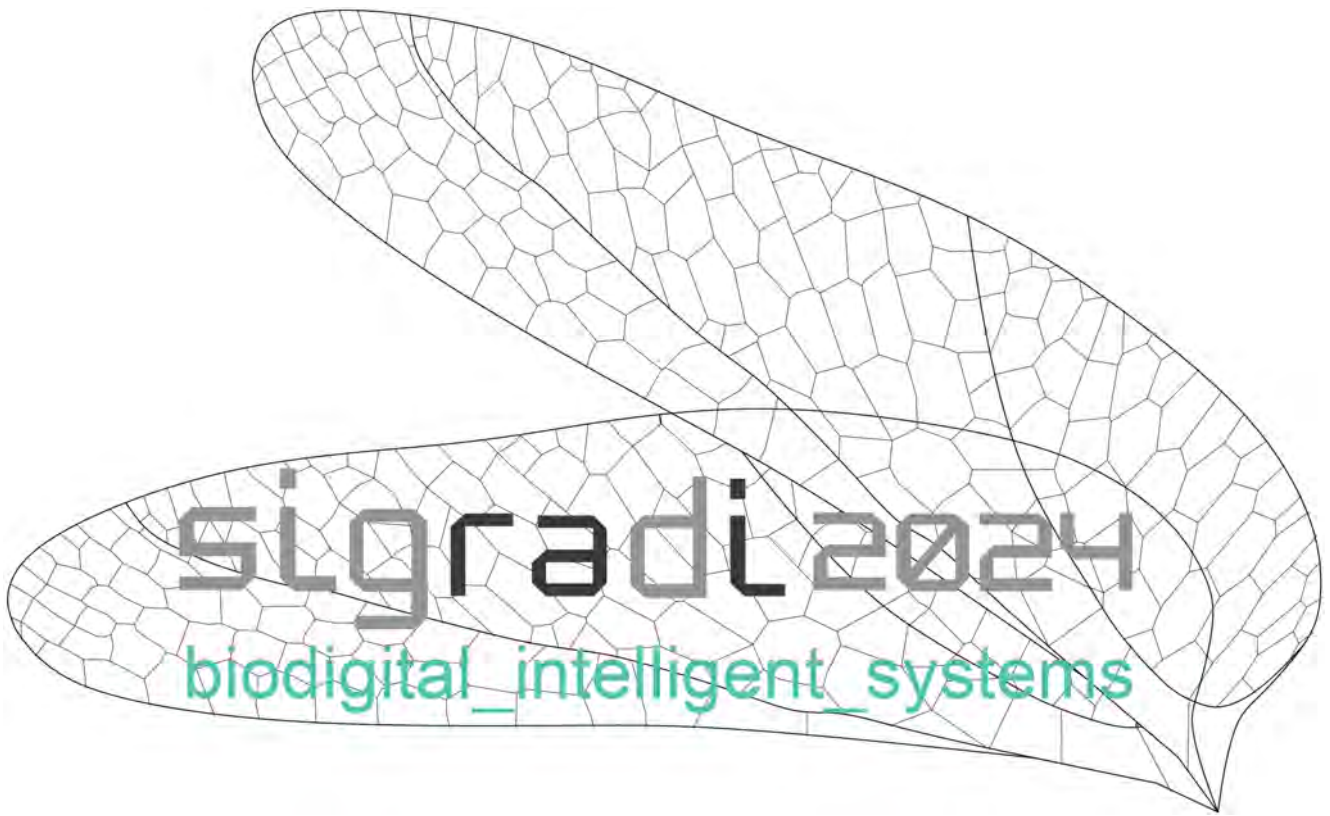
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Modeling Architectural Styles: decoding typological approach in Nineteenth-century Italian railway stations drawings using generative shape grammars

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Abstract. This study explores the integration of shape grammars and generative modeling to describe the architectural language of Nineteenth-century Italian railway stations. Shape grammars, known for their ability to generate and understand design rules, finds in generative modeling, primarily used in contemporary architecture, a innovative support that embeds design decisions into form-making algorithms. However, the combined use of these methods to illustrate architectural styles is underrepresented in design and architecture history. Analyzing historical drawings, the aim of this paper is to develop shape grammar algorithms able to decode the compositional design strategy in the case study of Railway Stations' heritage. The process involves synthesizing a corpus of well-documented examples and identifying design patterns. These patterns are then translated into Grasshopper environment, creating algorithms tested for reproducing and generating architectural instances. The results can lead to strategies for studying architectural styles and for analyzing the role of typological approach in design history.

Keywords: Shape grammars, Italian architecture, Parametric modeling, Parametric analysis, Typological approach

1 Introduction

Since its development (Stiny & Gips, 1971), shape grammars have demonstrated a pronounced capacity for generating and comprehending shapes and the process of creating compositions (Stiny, 1980; Tepavcevic &

Stojakovic, 2012) according to Chomsky's language theory (Chomsky, 1978). Furthermore, this methodology produced substantial prospects in describing and teaching historic architectural styles (Koning & Eizenberg, 1981; Li, 2011; Stiny & March, 1981), providing new and complementary approaches to exploring the language of designs defined by the grammar supported by digital transcription (Carpo, 2011). On the other hand, the generative modeling approach creates a revolution in the making of architecture (Oxman & Oxman, 2014), according to a new role of representation in enabling innovative strategies to manage the complexity of processes from data and information to knowledge in contemporary digital design, embedding parameters, relations, and rules in the form-making algorithms (Abdulmajeed et al., 2023; Dy & Stouffs, 2018; Stouffs, 2018), useful for understanding language (Duarte, 2005), innovating solutions (Bianconi et al., 2019; Bianconi & Filippucci, 2019; Bidgoli & Cardoso-Llach, 2015; Sass, 2006), and defining new style (Hensel & Menges, 2008; Schumacher, 2009)

Still, the combined use of shape grammar and generative algorithms to illustrate design strategies finds in architectural history a vast field of experimentations, starting from the theorization of Vitruvius' architecture in Roman times, rediscovered by Renaissance treatises: Leon Battista Alberti explains as "*Tota res ædificatoria lineamentis et structura constituta est*" ("Architecture is constituted by drawing and construction") (Alberti, 1485), and the word "lineamenta" is associated to a system of lines, a drawing, a model, parameters, relationships, and roles. All the historical treatises are a sort of algorithm, where grammar shapes are independent by parametrical input and generate families of solutions. In this interpretation, using generative design and grammar shapes approach, it is possible to understand historical architectural thinking (Bianconi et al., 2019; Figueiredo et al., 2013).

The rise of modern science is reflected in the design approach, the research of abstraction, and the construction of an ecosystem of categories, which are crucial not only in philosophy but also in all expressions of culture and architecture. The Illuminism and the Industrial Revolution emphasized new architectural concepts, advocating for the universality of architecture in response to the need for mass production (Benevolo, 2003; Tafuri, 1988). In this context of new polytechnical culture, various protagonists such as Quatremère de Quincy, J.N.L. Durand, Viollet-le-Duc, and Auguste Choisy played significant roles (Argan, 1965). This period also saw the architectural typological approach strengthened as a key research theme (Manganaro, 2013).

The case study selected is contextualized in this cultural debate, in a period marked by significant and rapid infrastructural development, where the railway became modernity's most prominent emblem (Aguar, 2008). The centrality of technic (Banham, 1960) is reflected in architecture, intended as a product, researching standardization of solutions, as demonstrated by sector-specific technical manuals (Chabat, 1862; Fadda, 1915). The typology approach is a strategy to create shapes based on architectonical rules, the relationship

between the structure and the part, measures and proportions, and form and details. The research of type is related to classification and abstraction, as well as to defining common features and universal and replicable solutions. In this historical context, railway stations represent tangible symbols of technical functionality animated by refined aesthetics, a perfect union of art and engineering (Garda et al., 2017, p. 324). Those assumed the character of temples of the Modern Age, whose cult wanted to be expanded into the Western world to affirm the new culture of progress.

Therefore, the present work aims to develop a shape grammar-based analysis that helps to structure a parametric model capable of describing the compositional language of Italian railway stations from the second half of the 19th century. The parametric model developed, informed by the analysis of case studies found in railway technical manuals, enables the generation of design solutions consistent with formalized design principles, offering a new perspective for the comprehensive and coherent reproduction of the architectural language of the era.

2 Methodology

Stiny & Mitchell (1978) is one of the first attempts to describe an existing architectural style by formalizing a shape grammar. The authors state that a style can be exemplified by a finite set of buildings where every individual creates a similar impression. In that sense, the problem of style is a problem of characterizing this likeness, clarifying the underlying common structure of appearance manifest in the corpus. This characterization should be able to provide the necessary conditions to evaluate whether a building belongs to the style and the mechanism to create new designs belonging to the style in question. Borrowing from the sources that inspired the shape of grammar theory itself, a style could be related to a coherent language.

The fundamental aim in the linguistic analysis of a language L is to separate the grammatical sequences which are the sentences of L from the ungrammatical sequences which are not sentences of L and to study the structure of the grammatical sequences. The grammar of L will thus be a device that generates all of the grammatical sequences of L and none of the ungrammatical ones. (Chomsky, 2002, p. 2)

In this sense, to understand the style (or compositional language) of the mid-19th-century Italian railway stations, a mechanism embedded with the characterization of the underlying common structure of appearance should be built. This mechanism should be able to produce several individuals who belong to the style and none who do not. The hypothesis of this paper is that it should

be possible to use a parametric model to act as this sort of mechanism and use the shape grammar procedures to identify and formalize this likeliness.

To do that, several key steps were followed. First, a coherent corpus of analysis was identified, recurring to archival research. Second, a graphic analytical procedure was conducted to extract constituent parts of the chosen examples and hypothesize possible production rules and steps. Third, some parameters were identified, and their values were tabulated to extract ranges, conditions, and proportions. Fourth, a parametric model was developed based on the data produced in the previous steps. Fifth, the parametric model was used to produce instances based on the formalized language.

3 Developing the grammar

3.1 Definition of the corpus of analysis

The first step, essential for the research's robustness, was to synthesize a coherent and well-documented corpus of analysis, providing a solid basis for future research and modeling. This corpus is not just a collection of examples but a critical selection of works that represent the characteristics of the period and style under analysis.

Given the importance of railway manuals in the period, the case studies were carefully selected from Italian railway manuals, which are comprehensive technical and stylistic knowledge repositories. During archival research, two historically valuable manuals were identified and are preserved by the "Fondazione FS Italiane": "Fabbricati delle stazioni e case cantoniere. Opere in muratura, Coperture e Pensiline 1906" and "Fabbricati delle stazioni e case cantoniere costruiti dal 1860 al 1885".

The first contains typical designs for train stations and their auxiliary buildings. The station designs are categorized into types A, B, C, D, and E, with type A being the smallest and type E the largest. This categorization will be used to classify the drawings found in the next manual. The second one compiles detailed designs of railway stations built during this period organized into plans, elevations, and sections. It presents 15 different designs, in which types A, B, and C can be identified.

For this study, the drawings classified as type B were chosen, including the stations of Maglie, Bozzolo, Spello, and Frattamaggiore-Grumo (Figure 1). These stations, with their striking constructive and stylistic characteristics, are emblematic examples of the constructive practices and stylistic trends of the time, ideal for exploring and formalizing the shape grammar needed to develop the parametric model.

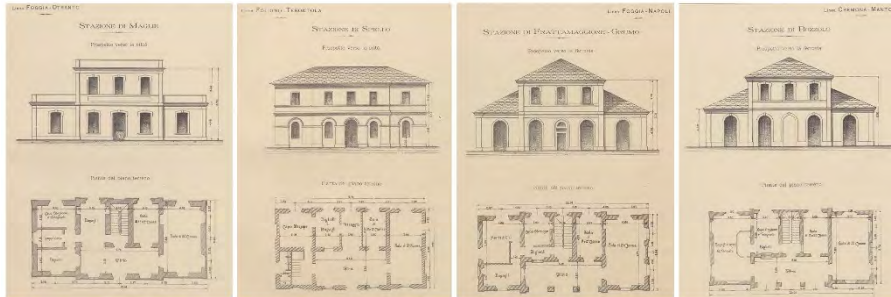


Figure 1. Corpus of analysis. Source: “Fabbricati delle stazioni e case cantonment costruiti dal 1860 al 1885”.

3.2 Analytical procedure

In this step, all four designs were vectorized to hypothesize a design strategy, design operations, and vocabulary. Starting from the plan, a series of structural axes can be drawn, identifying the position of walls and openings. The design hypothesis proposes a rectangular base as the initial form, which suffers a series of subdivisions, creating smaller rectangular areas that define the rooms of the building. The first subdivision is always symmetrical and splits the initial form into three bodies: the central one (bigger) and two symmetrical “wings”. The central one holds the main entrance and can be highlighted by an expansion of the boundary walls. It is, then, subdivided by a perpendicular line in two smaller rectangles: one defines the atrium, while the other is subdivided into three even smaller spaces, which could be the waiting room for 1st and 2nd classes, the luggage storage, the administration office, the stairs to access the second floor, and so on. As for the “wings”, one of them is often not subdivided and holds the waiting room of 3rd class. The other one can be split into two or three parts, having other functions such as lampisterie, ticket office, etc.

With the rooms defined, the main openings in every external wall can be drawn by a set of longitudinal and transversal axes. In the central body, for the type B stations, there are always 3 openings in each façade, centralized with transversal axis. The “wings” have one opening in each main façade, while in the side ones may have one, two or three (Figure 2).

3.3 Tabulation of measurements and identification of constituent parts and relations

Based on this examination, it is possible to identify constituent parts and transform them into descriptive parameters, each with its name, nickname, description, type, and formulation. This tabulation is a backbone for creating the parametric model (Table 1).

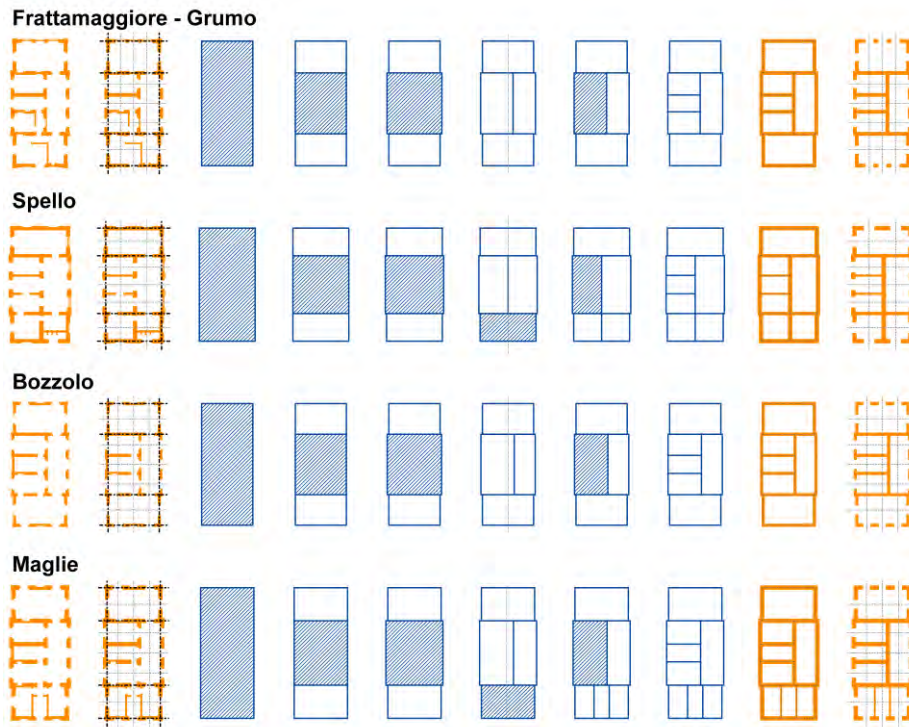


Figure 2. Graphic decomposition of the corpus of analysis. Source: produced by the authors.

Table 1. Identification, classification, and formulation of main parameters.

name	nick	type	formulation
originPoint	o_pt	numeric	{0, 0, 0}
generalLength	g_l	numeric	$\exists g_l (20 \leq g_l \leq 23)$
footprintProportion	f_p	numeric	$\exists f_p (0.45 \leq f_p \leq 0.52)$
generalWidth	g_w	numeric	$g_w = g_l * f_p$
generalHeight1	g_h1	numeric	$\exists g_h1 (6 \leq g_h1 \leq 3.5)$
generalHeight2	g_h2	numeric	$t_h - g_h01$
heightProportion	h_p	numeric	$\exists h_p (0.90 \leq h_p \leq 1)$
totalHeight	t_h	numeric	$t_h = h_p * g_w$
volumetricSubType	v_st	categorical	$\exists v_st (v_st = 1 \vee v_st = 2)$

coreLengthProportion	c_lp	numeric	$\exists c_lp (0.3 \leq c_lp \leq 0.5)$
coreLength	c_l	numeric	$(v_st = 1 \rightarrow c_l = g_l * c_lp) \wedge (v_st = 2 \rightarrow c_l = g_w + 2 c_e)$
coreExpansion	c_e	numeric	$\exists c_e (0.30 \leq c_e \leq 0.2)$
structuralWallWidth	sw_w	numeric	$\exists sw_w (0.40 \leq sw_w \leq 0.6)$

Source: produced by the authors

3.4 Development of the parametric model

Using the data collected, the shape grammar can be implemented in a computational environment. The software used was Grasshopper 3D, the Visual Programming Interface (VPI) inside Rhinoceros 3D. The choice was made since a VPI allows designers to quickly compose algorithms without previous knowledge of any specific programming syntax, using a diagrammatic representation more similar to graphical languages, commonly used by this type of professional.

The algorithm was structured to emulate the production rules step by step, incorporating the formulations for the parameters described in the previous section. A color code and a specific canvas distribution were used to evidence the basic parameters (possible manual inputs within certain ranges), the derived ones, the sequence of production rules, and an auto layout to make it easier to exhibit the whole process using the rhino viewport (Figure 3).

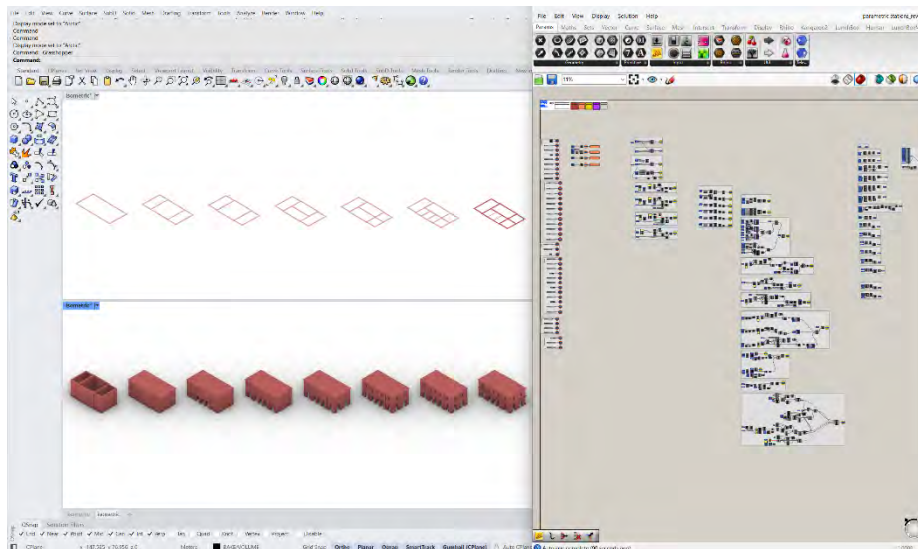


Figure 3. Screenshot of the functioning algorithm. Source: produced by the authors.

A total of 15 rules were created to allow not only the reproduction of the existing designs but also the recombination of elements and the exploration of the range of the parameters. The first step is to draw an initial shape, which is a rectangle described by its length (*generalLength* - within a range between 20 and 23 meters) and a proportion value (*footprintProportion* - within a range of 0.45 and 0.52) with which is possible to derive the width ($generalWidth = footprintProportion * generalLength$). Rules 01 to 06 are responsible for the subdivision of this initial shape, creating the walls' axis. Rule 07 creates the thickness of the walls by an offset of its axis, differentiating between structural and non-structural ones. Rule 08 creates the volume based on the footprint of the walls, allowing the possibility of a uniform height (with all the central body and the wings having two stories high) or a different arrangement in which the central body is two stories high and the wings have only one. Rule 09 allows two types of roofs, flat and sloped, with the possibility of varying the inclination angle for the second one. Rules 10 to 13 are responsible for adding the openings, allowing the choice between 3 types of profiles and control over the height and width of the openings of each sector (central body, wings – main façades, wings – lateral façades). Rule 14 allows adding “fake pillars” as decorative façade elements, with control over their depth. Finally, Rule 15 can add a base emboss, also a decorative element, with control over its depth and height. In order to better visualize this process, Figure 4 brings a partial decision tree for the production of Spello Railway Station design.

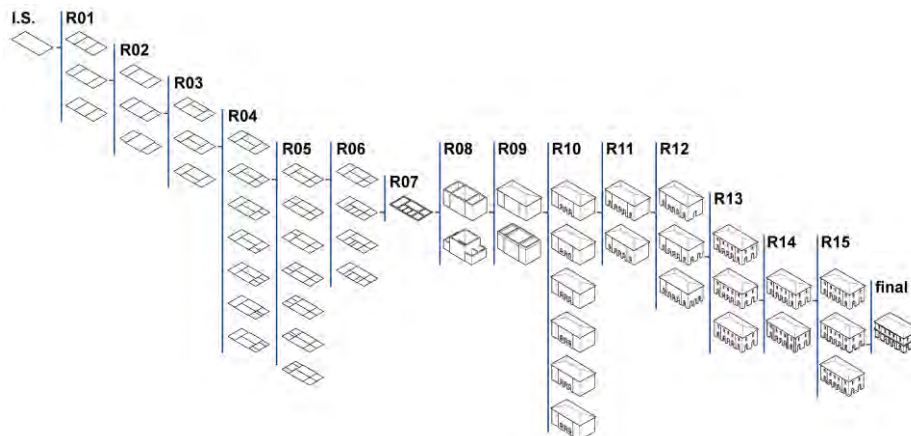


Figure 4. Decision tree for Spello Railway Station design. Source: produced by the authors.

3.5 Production of architectural instances

With the developed tool, it is possible to test the shape grammar implementation. To do that, the first task is the reproduction of the corpus of

analysis. This version of the algorithm can recreate a volumetric representation with a minor simplification of the decorative features. The results can be seen in Figure 5.

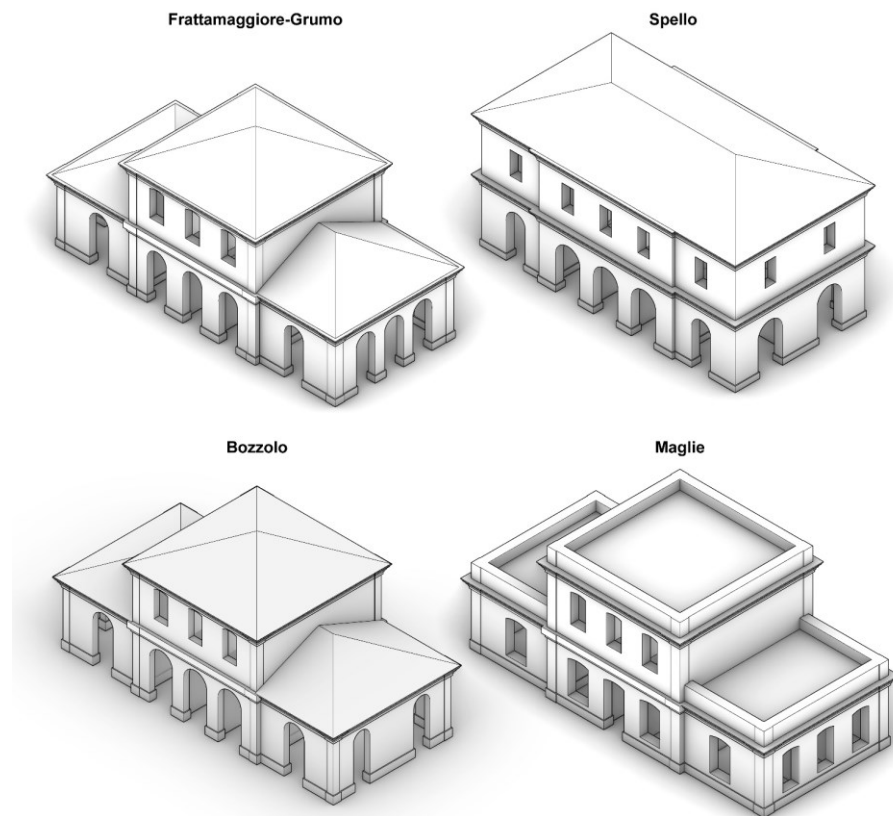


Figure 5. Reproduction of the corpus of analysis. Source: produced by the authors.

4 Discussion

As these are the first results of the research, the work presented here could benefit from some improvements. The first is the possibility of giving the algorithm the ability to produce other types of station designs (types A and C), which are present in the same manual. Despite being categorized as another “type”, these variations still maintain stylistic similarities between them that can place them as valid grammatical sequences of the language studied, since they are the same type of object and were built in the same historical period. To do this, it is necessary to study better the dimensional ranges that best describe the types and use these limits as conditionals for some formal operations.

The developed methodology and algorithm constitute a highly innovative contribution to the reading and comprehending of the architectural language of mid-19th century Italian railway stations. Using shape grammar, which requires the study and identification of formal patterns, spatial strategies, symmetries, and typological invariances of the architectures under analysis, this methodology sets a different approach compared to the traditional concept of cultural heritage conservation. This methodology allows the classic paradigm of historic preservation by digitization to be overturned, proposing an inverse approach: instead of faithfully replicating existing architectures, an algorithm is developed to encode the underlying "rules" of the architectural manuals of the period and then digitally replicate these models.

This digitalization process not only replicates the standardization of existing manuals and their digital reproduction but also enables the creation of architectural solutions that, while faithful to the original principles, are entirely new and previously unrealized.

Indeed, subsequently, a validation test will be carried out using the device to produce non-existent grammatical sequences, submitting the complete set of "sentences" produced to the scrutiny of experts so that they can try to identify which exist and which do not. In this way, it will be possible to get a better idea of whether, in fact, the algorithm is incapable of producing instances that are not part of the language, an important characteristic pointed out by Chomsky (2002).

This opens the way for a creative and contemporary reinterpretation of historical architectural heritage, ensuring consistency in the analysis of the typologies and stylistic elements of the past and understanding the approach to the project that has marked the history of modern design for decades.

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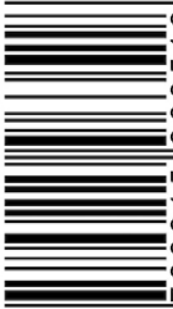
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