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FACADE PANEL PARAMETRISATION IN THE MODERNIST HERITAGE OF NEW BELGRADE: A MULTIPLE-CASE STUDY

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ABSTRACT

Most of the modernist heritage buildings in New Belgrade are over half a century old. Additionally, there is a growing need for new residential and commercial spaces in the city of Belgrade, and New Belgrade with its incompleteness might integrate them. Digitalisation can play a key role in archiving, maintaining, and developing this part of a city, which underlines the necessity to convert its analogue form into a digital one as soon as possible. But how to efficiently perform that conversion? The parametric approach enables plenty of mutually similar elements to be generated for a short time, based on varying the values of parameters defined, which is especially useful when such elements are heavily repeated. Therefore, this research focuses on the geometric parametrisation of facade panels of various technological manufacturing processes and of diverse types of multifamily residential buildings located in the Central Zone of New Belgrade. It aims to identify key variable-wise characteristics of the facade panel morphology as well as to establish parameters relevant to describing these characteristics.

The methodology implies multiple-case studies, where the parameters to be included in the parametrisation-wise algorithm are determined in relation to varying the panel morphology from group to group of mutually identical panels. The goal of the research, on the one hand, is to further develop a methodology implemented so as to become applicable to the study of other similar architectural heritage objects, whereas, on the other hand, it is to discover opportunities for examining the facade panel design from different aspects. Also, the paper contributes to the development of more efficient digitisation based on digital automation as well as to the greater encouragement of the restoration and conservation processes of facade panels. The usage of proposed parameters imposes itself as an efficient way to flexibly describe the morphology of considered facade panels of various technological manufacturing processes, regardless of the building type those panels belong to.

KEYWORDS _ *algorithm, geometric parametrisation, morphological characteristic, modernist heritage, facade panel*

INTRODUCTION

According to the continuous progress in the built heritage digital reconstruction based on the actual survey techniques and instruments, nowadays the production of 3D models oriented to the already built structures could be considered an increasingly common procedure. The employment of both image-based and range-based surveying campaigns, even in an integrated manner, has attracted more and more attention to defining efficient modelling systems. On the other hand, one wants to encode knowledge of elements of architectural heritage (Dekeyser et al., 2003).

In recent decades, digital technologies have significantly enhanced working methods in the architectural heritage domain, emphasising the importance of transferring complex data into critically interpreted information to bestow meaning and value to the knowledge of the studied object (Santagati & Lo Turco, 2016). It became apparent that architectural shapes have to be recognised and segmented from the raw 3D data (regarding the geometric rules defined by historical treatises) to be, among other things, embedded in HBIM[1] (Chiabrando et al., 2017). Consequently, a fundamental task in geomatics implies feature extraction, i.e., derivation of geometric characteristics and semantic information. However, the subsequent conversion of acquired spatial data into parametric components is very time-consuming.

To speed up the entire pipeline of the image-based and range-based 3D restitution, the existing procedures require some improvements. The result should be the ability to produce truly 3D geometries with attributes and topologies (Remondino, 2011). The main problem regarding the aforementioned feature extraction involves determining the genesis of an element's shape necessitating the formalisation of architectural knowledge rules and the organisation of structured objects with a specific vocabulary within an architectural knowledge system (De Luca et al., 2006).

This study focuses on multifamily residential buildings of modernist heritage in New Belgrade, given that most of them turn over fifty years of existence. Additionally, there is a growing need for new residential and commercial spaces in the city of Belgrade, and New Belgrade as its consisting part and with its own incompleteness might integrate them (Blagojević, 2007). Accordingly, digitalisation as a process can play a key role in archiving, maintaining, and developing this part of a city. But how to efficiently perform the conversion from its analogue form into a digital one, bearing in mind the time-intensive processing of acquired 3D data? Does a parametric approach which enables plenty of mutually similar elements to be generated for a short time, based on varying the values of parameters defined, contribute to the noticed bottleneck's overcoming, especially when such elements (in this particular context, facade panels) are heavily repeated?

The parametric design of today is not fundamentally different from the way Moretti described it in the 1940s when he coined the term *Architettura Parametrica*. Namely, according to Frazer (2016), Schumacher describes Parametricism of today both as a style in the visual sense and as a process-driven architecture in terms of a method. The latter is more significant here. Accordingly, the conversion of acquired 3D data into parametric, semantic-aware components represents a very relevant issue to the purpose of this study. But, how to encode (in terms of varying) such a complex system of facade panel morphological characteristics?

The research subject implies examining the possibility of geometric parametrisation of facade panels differing in technological manufacturing processes and belonging to diverse types of multifamily residential buildings located in the Central Zone of New Belgrade. The research objective lies in both identifying key variable-wise characteristics of facade panel morphology (including exploitation-caused such ones) and establishing parameters relevant to describing these characteristics. The research goal is to further develop a methodology implemented so as to become applicable to other similar architectural heritage objects as well as to discover opportunities for examining the facade panel design from different aspects.

[1] HBIM, developed in the last decade is to become a new prototype-system of BIM, by modelling historic structures as parametric objects within a reverse engineering process (Chiabrando et al., 2017).

MATERIALS AND METHODS

When it comes to research methods employed, during the fieldwork, *in situ* research was performed in the form of observation, recording, photographing, and noting an as-is panel appearance. Analytical and synthetic methods were applied in parallel with *in situ* ones, particularly in technical documentation study and relevant literature review. To reconsider the as-is panel appearance in relation to the research question previously emphasised, the descriptive interpretation method (3D modelling) needed to be introduced. In the next research step, a multiple-case study method was implemented, which essentially supports both defining and subsequent verifying established parameters in terms of their applicability in the real environment (i.e., on considered representatives of the housing stock). The results obtained were processed through comparative, quantitative, and qualitative analysis in order to derive general conclusions about the parameters' applicability.

Considering the emphasised age of the modernist heritage buildings in New Belgrade, which exceeds five decades, and thus, the long-lasting exploitation of those buildings, the issue of their renovation, preservation, and maintenance is more acute than ever. Given that, the choice of New Belgrade for a study area is justified. The crucial criterion for further shrinking the study area refers to the fact whether some of the modernist heritage buildings simultaneously represent the cultural heritage or not. By using this criterion, the study area is significantly shrunk to the Central Zone of New Belgrade, given that its nine consisting blocks became cultural goods within a broader spatial cultural-historical entity in 2021. Blocks of this Zone abound in architectural solutions either in the form of single-tract or double-tract buildings when it comes to parts of the housing stock with pronounced horizontality as well as in solutions in the form of groups of towers when it comes to such parts concentrated at Zone's corners (Macut, 2022).

Given that the housing became the key content of New Belgrade in the phase of concept materialisation – unlike the initial plans which, according to Blagojević (2007), had reduced housing as a function in favour of state and party facilities – the residential buildings are chosen over others, exclusively. Three of nine consisting blocks of the Central Zone (24, 25, and 26) are excluded from, owing to the fact that the facade materialisation of their buildings is not of reinforced concrete, predominantly – contrary to the remaining six blocks (21, 22, 23, 28, 29, and 30) of whose buildings that is a common feature. The final selection of multiple-case study representatives shrank to only a few buildings of the housing stock of New Belgrade owing to the exact criteria previously defined (Macut, 2022).

It will turn out to be the multifamily residential buildings of Block 30. If the selection criteria of a different nature, defined by Macut (2022), are superimposed – Block 30 stands out unambiguously considering it abounds with the widest spectrum of different typologies of multifamily buildings, covered with facade panels of various technological manufacturing processes and of the most complex geometry among those considered, which all together greatly contribute to the desired parameters' establishing.

Accordingly, the applied methodology is based on analysing facade panels of multifamily residential buildings of diverse typologies, where the parameters to be included in the parametrisation-wise algorithm are determined in relation to varying the panel morphology from group to group of mutually identical panels. A somewhat smaller number of parameters shown below can be declared adequate from the research-objective point of view (the basis of an efficient digitisation pipeline's defining), despite the fact that the larger such number is, the more comprehensive algorithm will be.

One should think about what the data relevant to be captured is. The choice of the features to be digitised is crucial here since there are many aspects of an object (Pottman et al., 2007). Although the challenge in formalising the architectural elements' geometry lies in identifying their fundamental components, such a process cannot be led by analysing the elements' morphology and descriptive systems used for their design, exclusively – but also by consulting architectural treatises of the period the studied elements belong to (De Luca et al., 2007).

Therefore, let's return to 1948 when on the premise of a *tabula rasa* situation the construction of New Belgrade began with the idea of being the main management centre of the Federation. However, it has become one of the constitutive parts of Belgrade. During its execution in the 1960s, modernisation was introduced through industrialised construction. Nevertheless, an insufficiently developed construction industry limited architectural activity to partial research of spatial organisation and buildings' form varying (Blagojević, 2007). Since the construction of Block 24 in the early 1980s cancelled the idea of a promenade in the Central Zone, a theoretical critique of the entire concept of New Belgrade as a functional city has begun.

MULTIPLE-CASE STUDY

Although the initial concept of New Belgrade cancelled all those urbanisation strategies from the previous historical period, whose common denominator implied an idea that construction on the prepared land ought to represent the main direction of the already uncontrolled urban expansion of then Belgrade, a new turn is present where the unfinished New Belgrade as a field to be conquered – again is set.

Because of that, one should not get too ideologically carried away, but rather be aware of the fact that after the completion of the conceptual phase of New Belgrade planning, there was nothing more than the inert "filling" of empty space with residential blocks. In 1986, in their competition's work for the improvement of the New Belgrade urban structure, Lefebvre, Renaudie, and Guilbaud asked themselves what was the part of Belgrade realised on the left bank of the Sava River actually like. According to Blagojević (2007), the team mentioned above clearly states that the incompleteness of the urban fabric contributes to the impossibility of constituting the city as well as that one can be happy because New Belgrade is unfinished.

As Blagojević (2007) also summarises, open public space is disappearing under the onslaught of the commercial momentum of private capital, and a morphogenic process of the grey economy is taking place around poorly maintained blocks, which are inexorably ageing and decaying. She correctly sets the thesis that contemporary New Belgrade is a city at war with itself, with the Central Zone being the main battlefield. The elaboration of Block 30 previously chosen follows below (Figure 1).

Block 30 was realised in the mid-seventies according to the decision of an architect Prof. Uroš Martinović. The urban composition of the block was formed using three basic types of buildings. The first type of building consists of five high-rise towers. The design of the buildings is an example of facades with the most complex geometry among all considered blocks. By applying elements of complex geometry, the designer realised the presence of different plans on the facade planes (Macut, 2022).

The second type of residential buildings is represented by two single-tract buildings. With clearly divided units in a vertical sense, they are simply functionally solved. When it comes to design, these two buildings mutually differ in appearance, although they conceptually follow the same pattern as the previously explained building type. The central parts of buildings are covered by facade elements of complex geometry, thereby creating obvious dynamics further emphasised by regularly spaced bay windows along the facade planes (Macut, 2022).

The third type of building can be characterised as a meander that spreads out across the central area of the block. Although it may appear as one unit at first glance, the meander actually represents a set of interconnected buildings. The design of these buildings was carried out according to patterns similar to those that describe both of the previously explained building types, using various facade elements of complex geometry as well as bay windows. Despite being smaller in size than the other building types, the buildings that form a meander exhibit equally dynamic plans of facade planes (Macut, 2022).

Figure 1: Block 30 – Borders & Building Types Marked in the Urban Tissue of New Belgrade and Representatives of the First, Second, and Third Type of Residential Buildings (left-to-right, top-to-bottom). Source: Author, 2023

RESULTS

The results of the process of identifying variable-wise characteristics of the facade panel morphology are summarised in several parameters of various natures. Namely, dimension-, geometry-, and exploitation-wise parameters are introduced. Whereas the first two natures refer to immanent panel morphological characteristics, the remaining third nature testifies to spontaneous morphological changes in facade panels that result from user action. There are two parameters per each of the natures defined. The parameters established are listed in Table 1.

Table 1: Established Parameters Classified According to the Nature They Belong to. Source: Author, 2023

	Dimension-Wise	**Geometry-Wise**	**Exploitation-Wise**
Parameter 1	Panel Width	Panel Rib Spacing	Presence of Air Conditioning Conduit Hole
Parameter 2	Panel Length	Presence of Specific Details	Position of Air Conditioning Conduit Hole

Panel Width/Length imposes itself as a dimension-wise parameter, given that the dependence of the value of the measure observed on the facade panel position along the building perimeter/height, respectively – is identified as a variable-wise morphological characteristic to be described by.

On the other hand, *Panel Rib Spacing* is seen as a geometry-wise parameter, because it aims to describe such a panel morphological characteristic in terms of varying that relates to the identified dependence of the distance between its two neighbouring ribs on the shape of the panel manufacturing mould (formwork) applied. Nevertheless, *Presence of Specific Details* within the panel configuration observed (e.g., of certain mass cutouts), as another geometry-wise parameter, is not as causally explicable as the previous one was, but significant diversity of such details in terms of spatial articulations is still obvious.

Lastly, *Presence/Position of Air Conditioning Conduit Hole* within the observed configuration of the facade panel is declared an exploitation-wise parameter since it has been established to describe the panel's previously identified exploitation-caused morphological characteristic in terms of varying which lies in the fact that the hole occurrence/the location where the air conditioning conduit breaks through the panel mass – varies from panel to panel depending on the user needs/preferences, respectively.

Nevertheless, due to the limited number of pages, the parameters explained and tabularly listed above are graphically represented in the role of varying only on the example of the third building type as shown in Figure 2, although those parameters are established by considering all building types described in the previous Section. So, such a complex panel appearance is decomposed based on established parameters to be further studied in more detail by tracing the causal dependence of form on parameters' value changing, i.e., by fine-tuning ranges of those parameters.

DISCUSSION AND CONCLUSIONS

Panel Rib Spacing is a unique parameter among others established, given that varying its value is not so noticeable by considering only one building type or, more precisely, by considering only one manufacturing process of the facade panel in terms of the shape of the mould (formwork) applied. In contrast, the variation in the spacing value observed becomes more than obvious by considering multiple different cases related to such processes simultaneously and by comparing them to each other since the value of the spacing of panel ribs exactly depends on the shape of the panel manufacturing mould (formwork) applied. Additionally, it is important to examine the possibilities and limitations of the proposed approach, along with its contribution to the preservation and reinterpretation of architectural heritage.

One of the disadvantages of a set of parameters established is their non-comprehensiveness, i.e., that there is a certain approximation of the real panel appearance. Namely, phenomenon such as the structural and visual decay of the facade panel over time (caused by many factors) is not considered here, given that the progress of the said decays might be conformable with fractal rules. The targeted geometric parametrisation of the facade panel morphology here is considered from a non-fractal point of view, exclusively. Another disadvantage is certainly the fact that the variation in panel thickness as well as the variation in its layering within that thickness is not considered in the subject-related analysis, in order not to exceed the scope of defining the basis of an efficient digitisation pipeline.

The usage of proposed parameters imposes itself as an efficient way to flexibly describe the morphology of considered facade panels of various technological manufacturing processes, regardless of the building type those panels belong to. Although architectural design is not an algorithmic process, such pipeline defining is mostly included in. The fact that algorithmic procedures still cannot substitute it as a whole tells of scripting insufficiency to tackle anything beyond variational geometry. This confirms Frazer's (2016) state that the parameters selected by an architect to define the style and its aesthetics represent a very small subset of possible parameters whose values could be varied as well as that such selection is what gives that architectural style a particular appearance.

Even though the facades of the analysed buildings have undergone various changes in their surfaces and structures over the past decades, these buildings truly represent a resource that needs to be preserved. This research contributes to the development of more efficient digitisation based on digital automation as well as to the greater encouragement of the restoration and conservation processes of facade panels as representatives of the cultural heritage. Finally, it should be evident how the survey is not just a mere acquisition, but a knowledge tool that allows the complexity of architectural elements to be deconstructed into elementary units (Lo Turco et al., 2023).

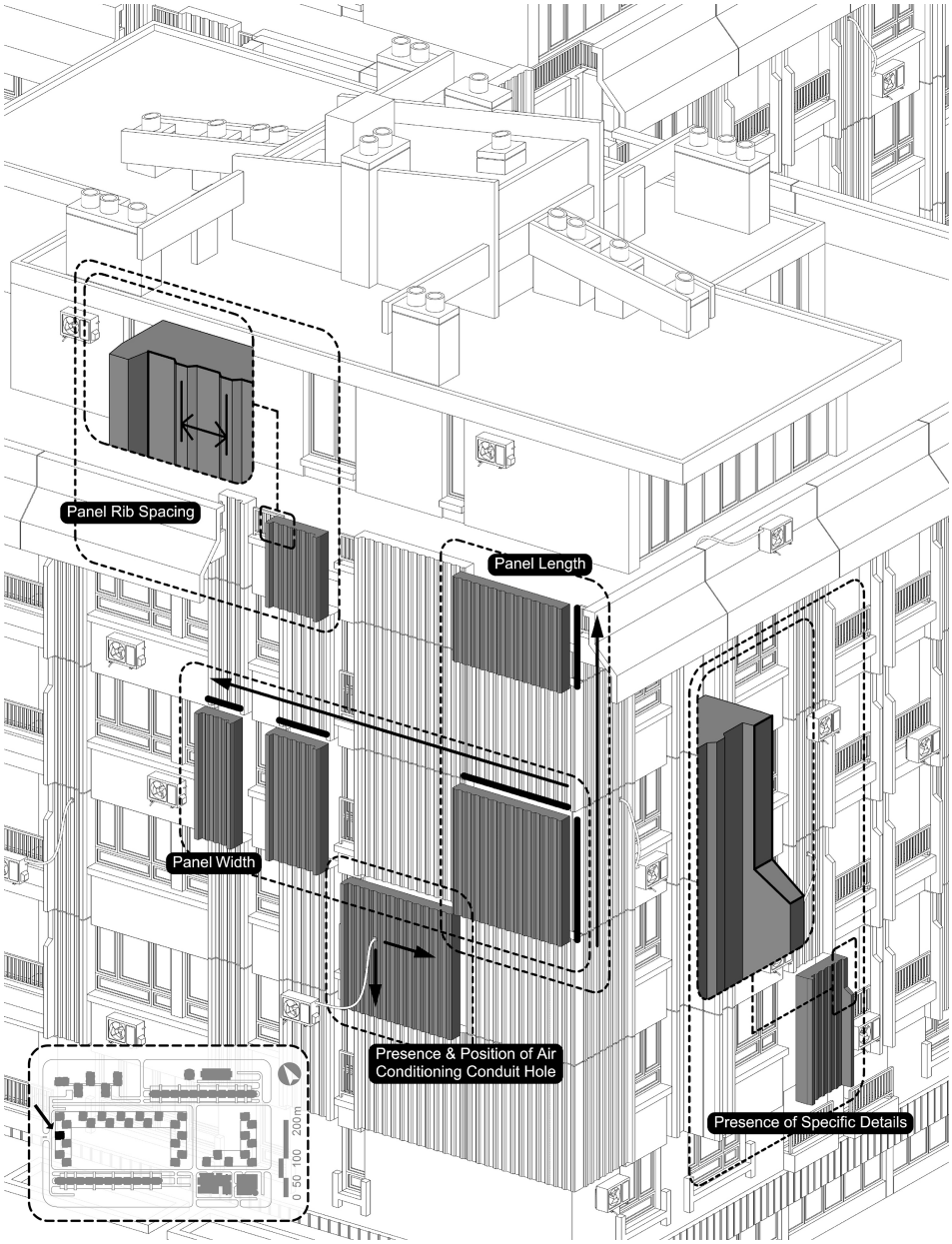

Figure 2: The Case-Related Spatial Articulation of Established Parameters. Source: Author, 2023

Future research will deal with developing as comprehensive algorithm as possible which could produce plenty of facade panel varieties based only on a couple of them analysed, i.e., to define a morphospace (a representation of possible morphologies) of the facade panel entity.

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