A multilingual grammar for 'The International Style', and its hybrid grammar

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Abstract. This paper describes the proposal and results of a multilingual shape grammar to describe the designs of three architects, precursors of the 'International Style'. A shape grammar is a generative process that allows the recreation of designs that follow a language. Grammars are useful mechanisms to describe patterns and generative processes that can be used for analysis or design exploration. Most grammars represent one language. This study focuses on three independent languages within the same movement. The proposed grammar is parametric and allows the independent recreation of each independent design. Its difficult application can be linked to the difficult evaluation process. This research proposes a quantitative and a qualitative method of grammar evaluation, using respectively Principal Components Analysis (PCA) and user questionnaires. The results are then discussed and assessed using hybrids that fall in between languages and help delineate parametric spaces.

Keywords: Multilingual grammar, Shape grammar, Hybrid grammar

1 Introduction

The International Style dominated the beginning of the XXth century breaking with the mainstream architectural styles in use and proposing a more utilitarian, affordable, modular, industrial perspective to design (Frampton, 2020). Its popularity spread across the world but three main players can be accounted for its success, Mies van der Rohe (1886-69), Gropius (1883-69) and Le Corbusier (1888-65). This study proposes one singular grammar to describe all three languages with the hope to describe one movement "The International Style".
Mies, Gropius and Le Corbusier's design languages are idiosyncratic and distinct. Mies's style was rational, and minimal, with methodical respect for structural and regulating grids. Gropius's style was utilitarian and industrial, while Le Corbusier's language was plastic, volumetric and highly experimental:

'*These shapes are such that they are revealed in the light. The relationships between them have not necessarily had any reference to what is practical or descriptive. They are a mathematical creation of your mind. They are the language of architecture* (Le Corbusier, 2005).

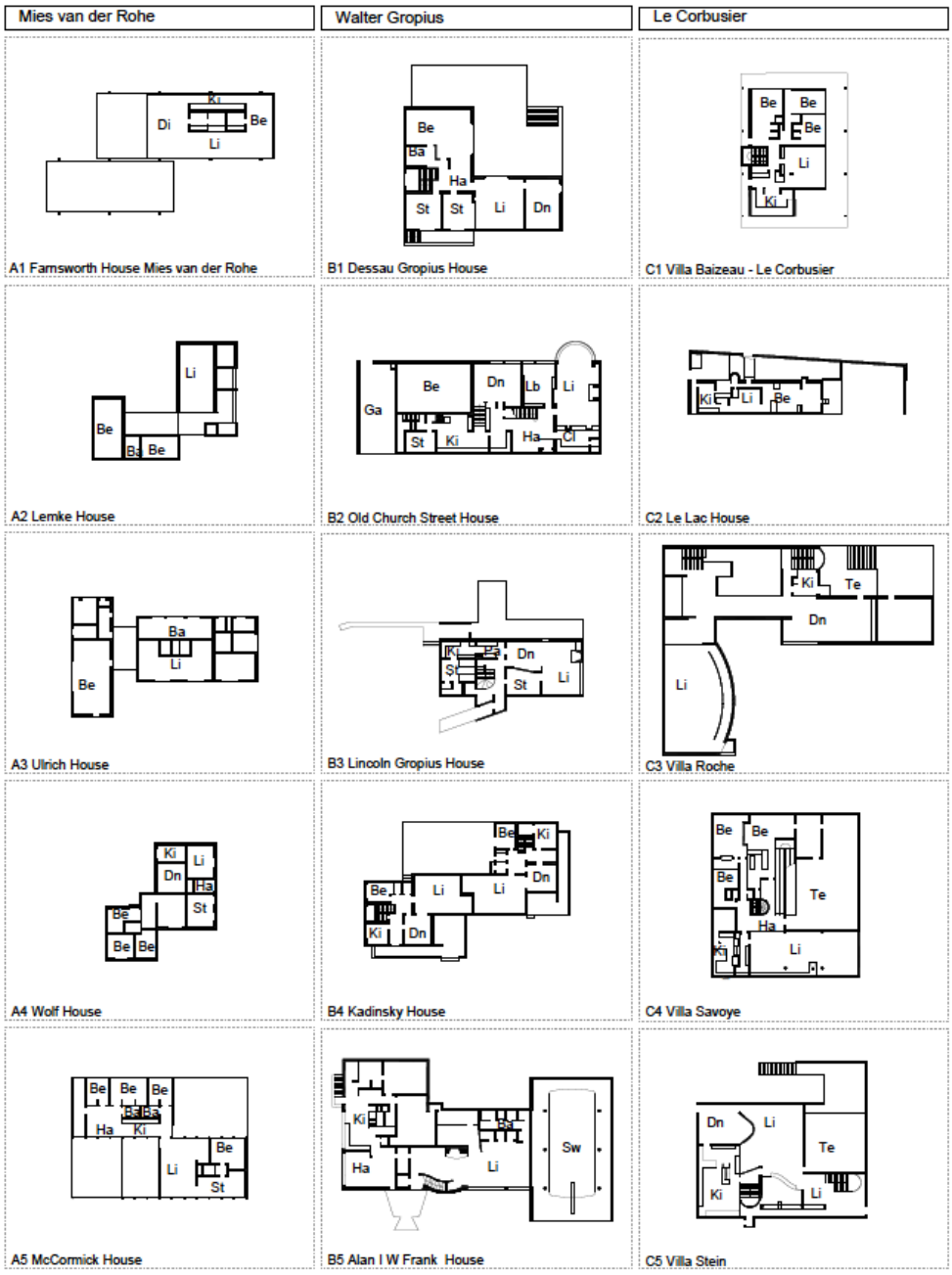

Figure 1. International Style case study of 15 houses from Mies van der Rohe, Walter Gropius and Le Corbusier. **Source**: D. Benros, 2022**.**

‘The International Style’ was a denomination coined by Philip Johnson and Henry-Russell Hitchcock while curating a modern movement exhibition in the newly opened New York’s MOMA in 1932 (Hitchcock & Johnson, 1932). All three architects shared a common ground. At the start of their career, they all worked at Peter Behrens’s office in Berlin (1908-10) where they were exposed to the benefits of industrialization, modularity and rationalization. (Janson et al., 2015). What they did with these principles was unique. Gropius left Dessau and the Bauhaus school to seek asylum first in London and then in Cambridge MA. Mies fled Germany to find exile in Illinois and Le Corbusier left his home country, Switzerland, to settle in France. Their careers developed in parallel in different countries and with little direct contact. All built prolifically in different typologies from commercial to offices, educational, public buildings, and housing. This paper will focus on their experiments in single-family housing and will propose a shape grammar to illustrate it.

A shape grammar is a generative procedure that allows the recreation of several existing design solutions that are part of the same family of designs or styles (Stiny, 1980). It uses a simple graphic formalism which describes rule by rule a set of geometric transformations from the start point to the result. By following these rules recursively the user attains a cohesive design that fits the design criteria described by the shape grammar (Stiny, 2006). The procedure is inspired by the idea of language grammar that uses a set of finite rules to describe numerous combinations of semantically correct sentences. The idea was introduced by George Stiny in the 1970s using a lexicon of shapes and a syntax of geometric operations. The first architectural grammar proposed the language of the Palladian villas illustrating the successful application of grammar using the extensive corpus of existing Palladian designs (Stiny & Mitchell, 1978). In the 80s a three-dimensional grammar is proposed to illustrate the work of Wright’s Prairie houses (Koning & Eizenberg, 1981), the methodology resembled Wright’s design procedure as described in his own words (Wright, 1974). This was followed by the first computer implementation of an architectural grammar by Duarte in the early 2000s using Siza’s Malagueira houses as inspiration and counting with the original architect as grammar ‘evaluator’ (Duarte, 2005, 2005).
The supra-cited grammars established univocal relationships with their corpus and were language exclusive. More recent studies have attempted to propose generic multilingual formalisms. Beirao proposed a generic grammar for urban design that attempted to bridge the gaps in urban planning by mapping generic rules (Beirão et al., 2012). Castro e Costa proposed a generic grammar to design tableware in the product design category. This explored a wide range of designs proposing a parametric grammar (Castro e Costa & Duarte, 2014). Benros also illustrated a generic grammar for housing. This parametric formulation used a case study of distinct languages and proposed a common procedure to design them. The novelty of this formalism was captured in the interval of values allowed for each language which conferred a sense of style.

(Benros, 2018). This study suggested two evaluation methods: a quantitative and a qualitative which allowed for an unbiased appraisal of the system.
The idea of hybrids was raised concerning generative systems and particularly with shape grammars. An unrestricted grammar, as described by Knight (Knight, 1999) will undoubtedly allow for the manipulation of rules and produce hybrid designs. Hybrids can be used for design exploration, design assessment or testing the boundaries of design. Hadighi looked into the presence of hybrids to assess the design evolution of Marcel Breuer-inspired designs to the definition of his signature style practiced on the Penn State campus by William Hajjar (Hadighi & Duarte, 2021). Al-Kazzaz (Al-Kazzaz, 2011) proposed a hybrid grammar for the minarets' designs of religious monuments. Hybrid design rules allowed the solutions to be recreated.
This work used hybrids as a benchmark and delineation of each language parametric space. A parametric space is an abstraction where all design solutions can be encountered within a language. Its boundary is highlighted by the space occupied by its corpus. The boundary line is empirically determined.

2 Methodology

This study is composed of five steps: 1) Definition of case study and rule inference 2) Multilingual grammar and rule system definition 3) Recreation of design examples using derivation 4) Evaluation using quantitative methods 5) Evaluation using qualitative methods:

1) Three precursors of the 'International style' were selected, including Mies, Gropius and Le Corbusier. All three men shared the ethos of a new minimal architecture reflecting the effects of industrialization but all with distinct, identifiable languages. Within the extensive corpus of preexisting housing solutions they designed, 15 houses were selected reflecting their independent styles including Mies, Gropius and Le Corbusier as illustrated in Figure 1.

Table 1. Houses by Mies, Gropius and Le Corbusier. **Source:** D. Benros, 2022

Mies van der Rohe		**Walter Gropius**		**Le Corbusier**	
House	**Ratio & Area**	**House**	**Ratio & Area**	**House**	**Ratio & Area**
Farnsworth-1951	1/2 (16x8m)	Dessau-1926	3/4 (20x16m)	Baizeau-1928	3/5 (10x16m)
Lemke-1933	4/5 (18x15m)	Old Church-1936	3/8 (31x12m)	Le Lac-1924	1/3 (28x8m)
Ulrich-1935	2/3 (24x15m)	Lincoln-1937	2/5 (18x7.5m)	Roche-1925	3/4 (27x35m)
Wolf-1926	1/1 (15x15m)	Kandinsky-1926	2/3 (25x16m)	Savoye-1931	1/2 (21x19m)
McCormick-1952	2/3 (22x15m)	Alan Frank-1940	3/5 (35x21m)	Stein-1928	5/8 (22x15m)

The case study then inspired several key features from each language from proportions to the area and overall ratios as Table 1 illustrates. Most houses from the corpus showed an orthogonal self-contained layout within an external boundary. Most designs inspired a linear subdivision of internal spaces. Several key internal proportions were captured with a predilection for 1/1, ½, 1/3, 2/3, and 3/5 ratios (in keeping with a more classical tradition). Some geometric complexity was added with processes of space merging of adjacent rooms (particularly evident in Le Corbusier's work).

2) A subdivision grammar was proposed to represent all three sub-languages within the 'International style'. This procedure allowed the levelling of the playing field between the three languages. A series of subdivision rules were included to allow for the complex internal compartmentation of each house.

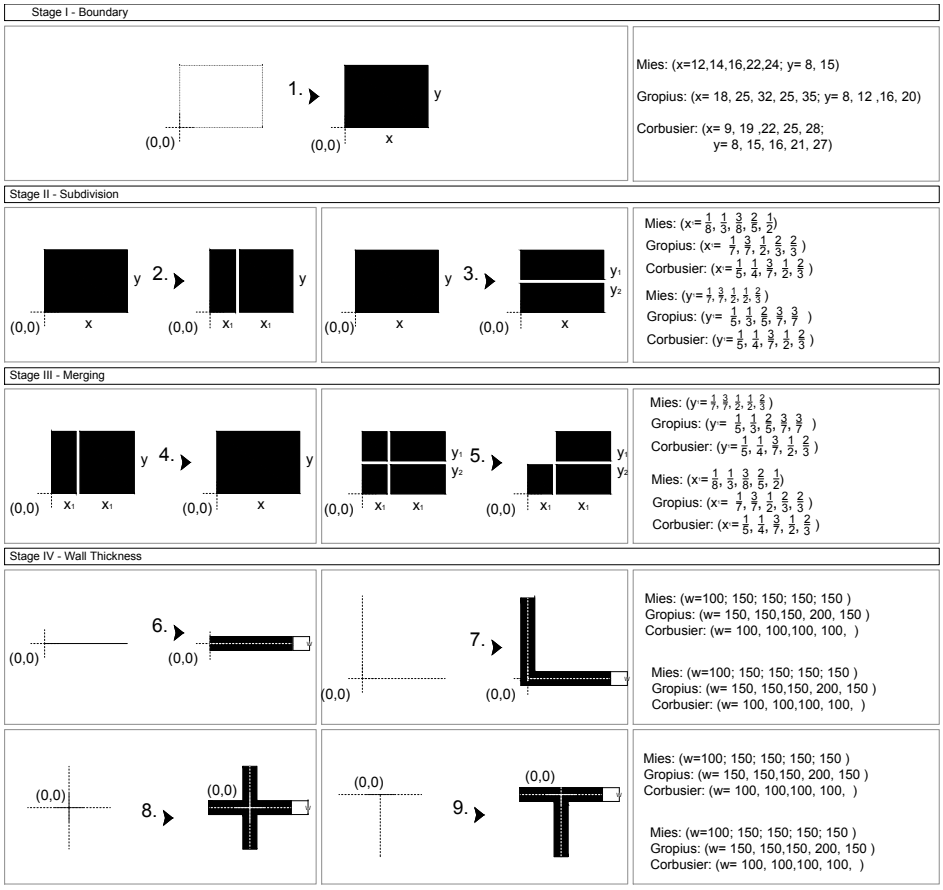

Figure 2. Shape grammar rules 1 to 9. **Source**: D. Benros, 2022**.**

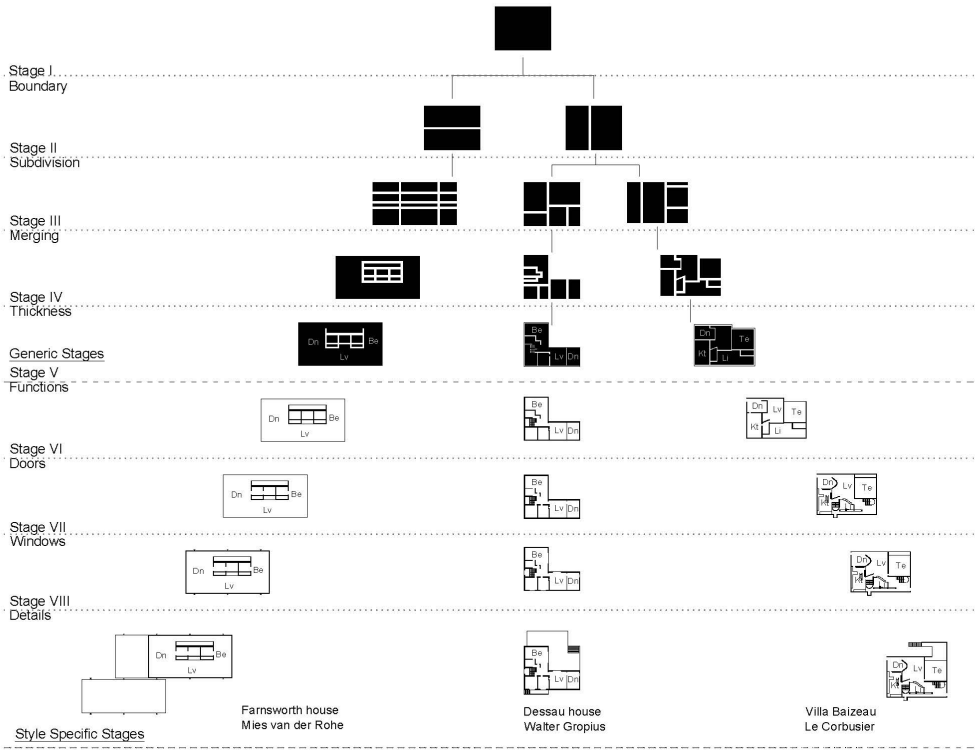

Figure 3. International Style shape grammar tree diagram. **Source**: D. Benros, 2022**.**

3) Within each language, specific parametrization is proposed responding to either Mies, Gropius or Le Corbusier's formulations. Figure 2 illustrates the generic rule system encompassing rules 1 to 9. The proposed rule system is split into generic stages and language-specific stages. The first stage is a typical additive stage and allows the inclusion of the external boundary, it contains one rule with polygonal addition. Stage II allows for subdivision with two rules proposed, a vertical and a horizontal subdivision. Both rules can be applied recursively until the minimal area is attained. Stage III allows spatial merging between adjacent spaces. Stage IV is the last generic stage and the last common branch stage allowing wall thickening. This is composed of four thickening rules that convey the right wall thickness by language and tectonic nature. From Stage IV on the grammar branches out into language-specific shape rules as the tree diagram from Figure 3 illustrates. These stages include Stage IV with functions, Stage V door inclusion, Stage VII with window openings, Stage VIII with the insertion of details (terraces, porches, external stairs, and access points) and the house conclusion. The diagram shows that any of the corpus houses can be recreated using an initial perimeter, their internal spaces recreated using recursive subdivision and further detailed using merging processes. The result is conducive to either the Farnsworth, Dessau House or Villa Baizeau while using the same grammar structure and the same

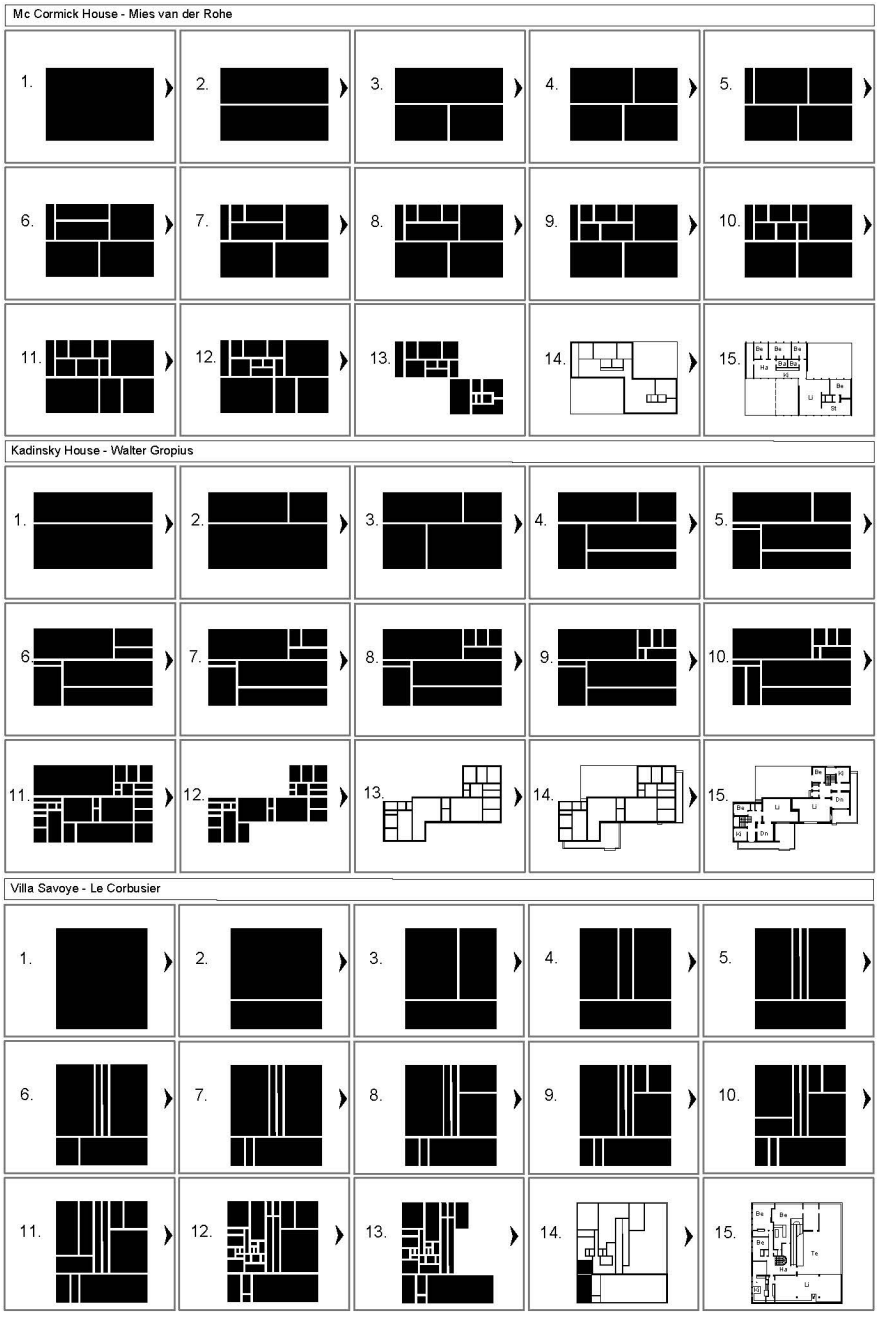

Figure 4-5-6. Derivation of McCormick house by Mies**,** Kandinsky house by Gropius Derivation of Villa Savoye by Le Corbusier. Source: D. Benros, 2022**.**

parametric shape rules. The multilingual parametric nature is also visible in this diagram which describes how different ratios can be generated from the same set of rules branching out from general.

4) In a typical shape grammar methodology, a form of evaluation is the recreation of the existing solutions in a structured and sequential way. This process is called derivation as it describes a graphic solution being derived from start to finish. In this study, all 15 houses' derivations were explored and this paper illustrates 3 examples including the Mc Cormick house designed by Mies and shown in Figure 4, the Kandinsky house designed by Gropius as shown in Figure 5 and Villa Savoye famously designed by Le Corbusier in Figure 6. All these examples represent the rule application system although they do not exhaust all the rules used to generate (for economy o space some subdivision steps and detailing rules were omitted).

5) Most grammars rely on empiric methods of evaluation such as derivation processes, and the recreation of new design solutions. This study proposed an objective form of evaluation. With all the parameters used to recreate the existing houses, the data was used to compare the existing examples. The data set was reduced using statistical methods such as Principal Components Analysis (PCA) and then illustrated in an orthogonal graph. This allowed each house to be represented using a cartesian point and mapped in the orthogonal space. A set of houses of each language would naturally cluster if successfully illustrated and delineate a boundary that contains all examples. That boundary describes what we call the ‘parametric space of a language’ where all existing and new grammar-generated houses would be mapped. This proved to be an unbiased and objective evaluation.

3 Results

The results of this study can be summarized and studied following two evaluation methods used: quantitative and qualitative methods: PCA resulted in a useful tool to illustrate the grammar results using an abstract graphic chart. This chart is illustrated in Figure 7 and maps out all 15 International style grammar-generated houses according to the parameters that originated them. A very strong clustering effect is observed for the Mies houses which naturally group on the top right of the chart. Le Corbusier’s parametric space also showcases clustering, however, a linear spread is visible. In the Gropius case study, the clustering effect is still observed but the spread is wider than in the previous language.
The cause of the wider spread in the former languages can be explained by the variety of the corpus in the original examples both in style, size, and proportion. At the bottom of the chart two houses are shown, Villa la Roche and Alan I W

Frank house. Both examples are paradigmatic and of large proportions. The first was designed for a wealthy Swiss businessman as his Paris home, the latter was designed as a large property for an affluent client which at the time was fitted with a large indoor swimming pool. Both houses might have swayed the range of the language and impacted its parametric space. Similarly, more compact, self-contained regular residences such as Corbusier's Villa Baizeau and Gropius Lincoln's house due to their geometries and compactness are more approximate to the Mies range and occupy a parametric space that overlaps all three styles.

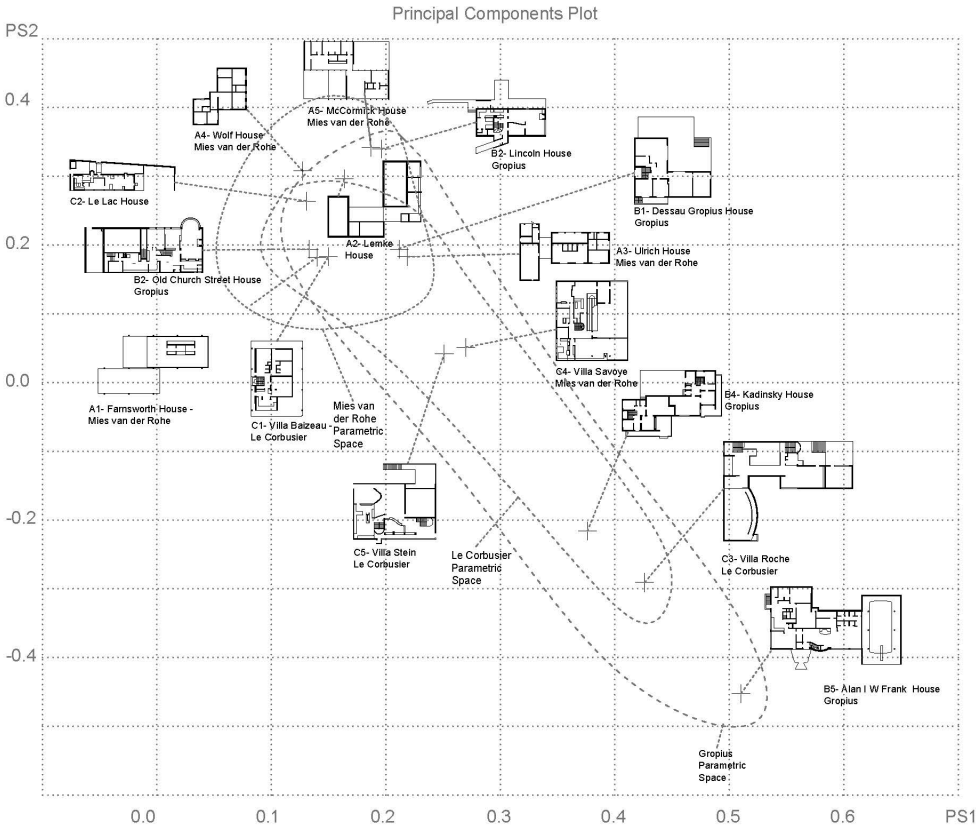

Figure 7. International Style designs from Mies (A), Gropius (B) and Le Corbusier (C) were generated by the multilingual shape grammar and their parametric spaces represented using Principal Components Analysis (PCA). Source: D. Benros, 2022.

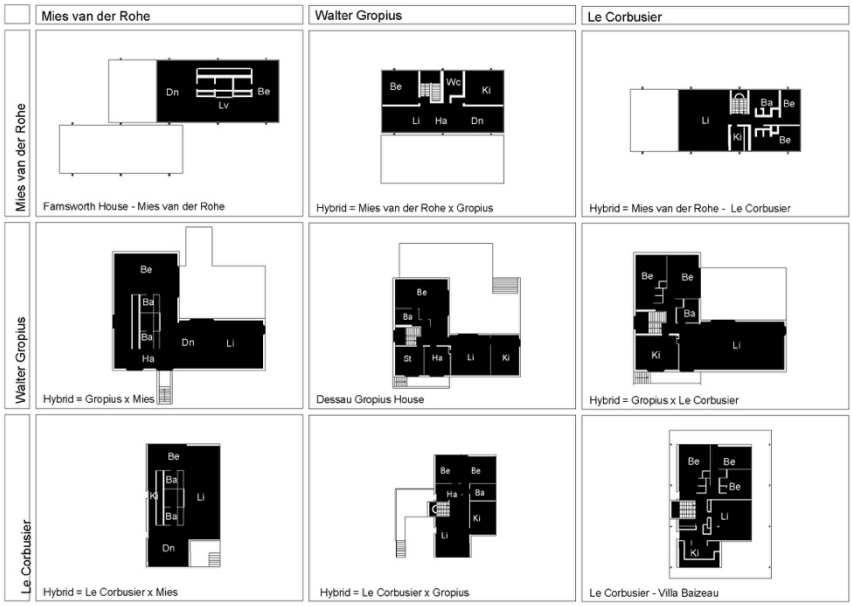

Figure 8. International Style hybrid designs. Source: D. Benros, 2022**.**

The proposal of a new corpus of designs is a good method of empirical evaluation if the new design fits the original features of style and follows the design criteria. Figure 8 shows a set of hybrid designs. These hybrid designs are not attained by morphing or creating new grammar rules as explored before (Al-Kazzaz, 2011), but by manipulating the allowed parametrization for each language. The image shows nine houses of which 6 are new hybrid solutions merged between Mies, Gropius, and Le Corbusier. All hybrids fall within the parametric spaces that are coincident to both parent languages which confirms the parametric space hypothesis.

The qualitative method of evaluation proposed was based on questionnaires posed to third parties both experts and laymen. The idea was that independent users could assess the similarities between a corpus of three houses, two examples from the original corpus and one hybrid. Most users did not distinguish (67% of the participants) the hybrid solutions as significantly different (from the original corpus. Most identified dissimilarities in the hybrid proposals (53% of the enquired). This seems to indicate that the new hybrid designs are identified as part of the ‘original corpus’ and do share perceived commonalities.

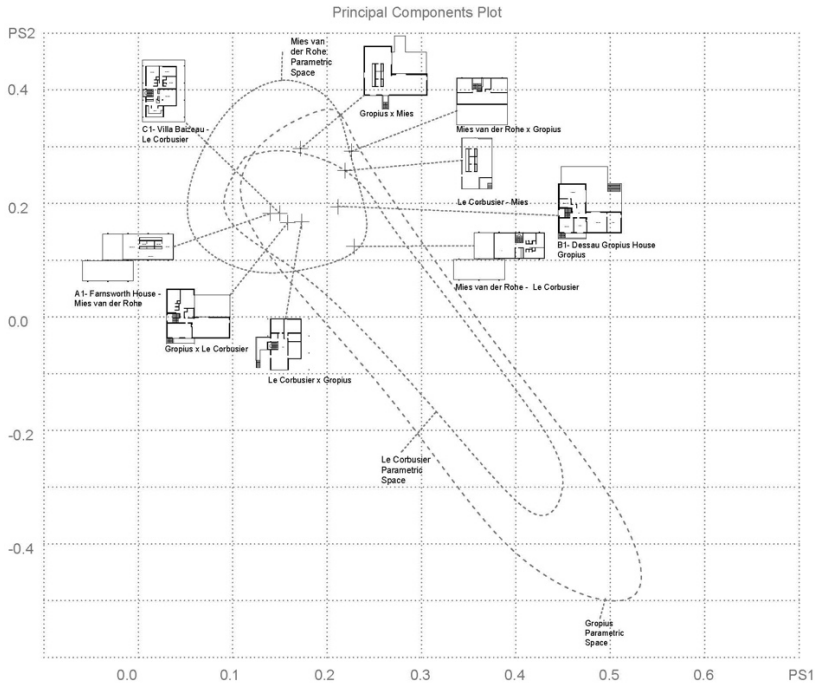

Figure 9. Hybrid designs from Mies van der Rohe, Gropius and Le Corbusier were generated by the multilingual shape grammar using (PCA). Source: D. Benros, 2022**.**

4 Conclusion

The paper exposed a multilingual grammar to reproduce 'The international style'. A subdivision grammar was presented, with the set of design rules. For each rule, a range of parameters was shown for each sub-language. Hybrid designs were also proposed. The novelty of the methodology used was the dual evaluation using both quantitative and qualitative methods, using PCA provided to map out and show graphically the range and parametric space of each sub-language. The introduction of questionnaires allowed testing the perception of the new corpus of designs using independent observers to highlight similarities and differences between the new designs and the existing families of designs. In most cases, the observers could not differentiate between the new hybrids and original designs. This provided the qualitative method. The introduction of the hybrid design allowed us to test the limits of each parametric space and assess the coincident parametric spaces. The methodology presented could pose a useful analytical tool for architecture historians, it also provides a good design exploration methodology and tool for design students. Future work would consist of a computer implementation tool with three-dimensionality.

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