Surface Symmetries: The Smith House Revisited
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Abstract

This work proposes the use of partial order lattices along with representational schemes to account for patterns of ambiguity and emergence in the description of designs. The complexity of such designs is viewed as an aggregation of spatial layers that can all be decomposed by the subgroup relations of the symmetry of the configuration. At the end, this methodology points to a combinatorial approach that generates visual prototypes for future use in design synthesis. Here, Meier’s work is just a case study that validates the group theoretical approach.
1. Introduction

A fascinating aspect of certain classes of architectural works is their ability to escape easy interpretations based upon existing formal tools. This is especially true for several architecture works of the modern movement that feature asymmetrical arrangements and diverse kinds of complexity. A new look at existing formal tools can perform the task, if applied, though differently. Currently formal analyses using group theoretical tools focus on repetitive designs that show immediately their recursive structure. It is suggested here that complex designs can still be described and analyzed in a group theoretical manner. Some first steps towards the extension of the tools of group theory to explain such designs have already been taken [1], [2]. [3]. This work builds upon these methodological approaches and proposes a model that investigates whether the combination of existing group theoretical formalisms with appropriate systems of representation can cast light in the analysis of such designs. More specifically the work proposes the use of partial order lattices along with representational schemes to account for patterns of ambiguity and emergence in the description of such designs.

The object of analysis has been polemically selected here to be the Richard Meier’s Smith House, a design that clearly exemplifies formal qualities of late modernism architecture such as abstraction, layering, complexity, depth, collage and so on, all aesthetic categories appearing impenetrable to a systematic and rigorous analysis using existing group theoretical formal methods.

The paper is divided into four sections: In section 1, the introduction and motivation of the work are given. In section 2, the formal model of notational representation and subsymmetry analysis is described in detail. In section 3, an application of this methodology is given for the Smith House including visual computations capturing sub-symmetry relations for all parts of the house and a complete catalogue of recombination of all symmetry parts of the house. In section 4, the discussion is given on the degree to which the symmetry decompositions can support visually the established discourse on the house and the possibility of using such formal tools in CAD applications.

2. Formal Model

The formal analysis model proposed in this work requires a system of representational conventions to codify the aspects of design that are of interest to the analysis and a group theoretic formalism to parse the design to identical parts. The system of representational conventions discussed below under the heading 2.1. Architectural notations, is built upon three features of architectural representation including abstraction, projection and weight. Other aspects of representation conventions are omitted. The group theoretic formalism discussed here under the heading 2.2. Order, relies on
subsymmetry analysis and uses partial order lattices as the primary mode of pictorial representation. A brief discussion of these two characteristics of the formal model follows below.

2.1. Architectural Notations

A three-dimensional model or a two-dimensional drawing typically provides an abstracted representation of an imaginary or a real architectural object. This visual representation does not depend solely on formal similarities. This representation is not a mapping of an object's complete form but a mapping of certain privileged or relevant aspects. Depending on the number of features being deleted from the original or alternatively being added or transformed in the mapping a level of abstraction is then arbitrarily defined. Here abstraction is used entirely in terms of essential and accidental properties [4]. An abstracted version in any mapping is the one that keeps certain characteristics of the original object while dropping others. All such different levels of representation allow the analysis to describe shapes at different generative stages and establish links which are not immediately available to the viewer. In this sense plans, sketches, and working drawings are all scaled analogs and highly abstract notational scores that condense visual and non-visual amounts of information into a codified language of symbols.

A second aspect of architectural representation is its ability to describe architectural space through the deployment of depthless drawings. Among the various techniques of projection including plans, sections and elevations and systems of lines linking them all one to another, a specific composite projection technique is quite unique in architecture and not in other engineering fields. This technique combines essentially orthographic and affine transformations and has the unique feature to represent abstract space both visually and metrically. This type of composite projection, also known as an axonometric paraline and oblique paraline projection has attracted the interest of twentieth century architects and theorists because seeing in oblique views is essential for depth perception [5]. It is significant that such composite axonometric projections foregrounded two functions initially thought as one: the axonometric as a representational device and/or as a conceptual device. The former is progressively enriched by the methods of multimedia presentations, the latter is able to support the communication of spatial qualities of an architectural object during the process of conceptualization. In all cases the exploitation of the fundamental ambiguity of the axonometric projection has been the discourse of much architectural theory in the twentieth century and it is suggested here that this should be the primary mode of representation to adequately describe and analyze the architecture works of that period.

The third aspect of architectural representation discussed here is its ability to represent materiality. A pen stroke has a width. Lines are of different thickness. Typically these widths and weights of the lines refer to what is represented and worked upon a set of conventions widely shared and understood. Different types of conventions and assumptions often give
the clues about what is represented and weights distinguish formal attributes from physical properties. Shapes made up of basic elements and weights answer to the Vitruvian categories: physical properties being included in firmness, functional properties in commodity, and spatial properties in delight. This particular understanding of weights as a characteristic of representation itself is taken here as a powerful construct for formal analysis. In this view, weights suggest a different kind of projection directly alluding to transparency, a key feature of the twentieth century architecture, whereas the three-dimensional qualities of the design are illustrated through the weighting of lines [6]. Varying degrees of transparency and opacity can be strategically deployed to hierarchically differentiate preselected conditions important to the development of the work.

These three aspects of representation, suggested here, a) shape; b) weight, and c) projection provide indeed a powerful notational armature to begin to describe architectural designs: Shape captures the geometrical characteristic of the architecture object described and is defined by sets of lines. Weight denotes the physical characteristics of the architectural object such as opacity, translucency, or transparency and their relation with the observer and is defined as sets of weighted lines in the representation; three types of notations of lines are used here: Solid, thin, and dotted. Projection denotes the specific orthographical or oblique mapping of the model of the architecture object upon the plane of depiction. Other aspects of architecture representation routinely used in architecture notation are omitted here.

Still, these three aspects of representation can be combined in various ways to create a large number of possible notational systems for architecture design. In principle, there can be a large number of such notational models that privilege diverse aspects of the design and capture some, but of course not all, conventions characterizing a design. Here, three levels of notational languages are suggested as a minimum for formal analysis.

The first level of notation, called here the architectonic level, is the level that approximates in some way the original notation used for the language of the actual design model into its closest geometric representation. The notation privileges functional elements such as walls, slabs, columns, and beams, walled furniture, handrails, and openings of various kinds such as windows, doors, stairwells, chimneys, and so forth. The second level of notation, called here the spatial level, privileges space divisions and corresponding openings in these boundaries, and discards all other information. This level essentially picks up planes that function as walls and slabs and so on and the connections between them and their interface-ventilation, light, sight and so forth. At this level, a spatial model that emerges is a spatial decomposition of the building with geometric shapes that bound the space. The third level of notation, called here the diagrammatic level, foregrounds underlying, emergent boundaries of space and discards all connections between them. This level of notation, closely related to the parti of a design, the geometrical diagram or pattern that emerges when all details
have been dropped out, is the most abstract version of the model and functions as a scaffolding of the design. An example of the architectural notation exemplifying the features of shape, weight, and projection along with the three levels of abstraction is given in Figure 1.

2.2. Order

The similarity relation permits overlap between elements of the set, whereas the equivalence relation separates the set into disjoint classes. Equivalence relations are represented by trees and similarity relations are represented by lattices [7]. Here the key operator that parses the representations is the partial order relation defined by the symmetry group that describes the maximum subsymmetries of the configuration. The fundamental significance of symmetry arises here from its capacity to reveal two opposing aspects of form: transformation (change) and conservation (invariance). That which is conserved during a change is an invariant; the set of transformations which keeps something invariant is its symmetry group. The set of elements and their structural relationships forming the complete system are conserved as a single whole and this order identifies all the nested parts in any configuration that have a group theoretical relationship to the overall group of the configuration.

The key idea is that spatial representations of complex objects can be understood as layered compositions of simpler parts and these parts can all be related through symmetry values from group theory. These values can be structured as a partial order lattice that pictorially presents the symmetry structure of any spatial configuration; the number and qualities of the symmetry subgroups found in any given configuration provide the maximum number of layers that can be found in a spatial configuration; for example, in any spatial arrangement that is based on the structure of the rectangle, the maximum number of layers and spatial constructs that can be build upon those is five because this is the number of symmetry subgroups of the rectangle. Typically, Hasse diagrams are used to represent such order and show the nested relations of the subgroups in graph [7].

An example of a graph of the symmetry group of the rectangle is given in Figure 2. The complete group of the rectangle with four symmetries is on top, three subgroups with two symmetries are in the middle row and the single group consisting of only the identity symmetry completes the graph in the lower row.
3. Applications

Several initial departure points can be conjured to test the model; the 1967 Exhibition New York Five is as good as any, and very productive too. The NY5 exhibition on the early work of five New York City architects, namely Peter Eisenman, Michael Graves, Charles Gwathmey, John Hejduk and Richard Meier, and the subsequent book Five Architects published in 1972, has indelibly stamped the course of the history of modern architecture of the late twentieth and early twenty-first century [8]. The explicit reference of NY5 to the work of Le Corbusier in the 1920s and 1930s and its ironic allegiance to a pure form of architectural modernism made the exhibition pivotal for the evolution of architecture thought and language in the subsequent years and produced a critical benchmark against which other architecture theories of postmodernism, deconstructivism, neomodernism and others have referred, critiqued or subverted [9]. Among this early work of NY5 the Meier's buildings were closer from all on the modernist aesthetic of the Corbusian form and in fact even the later buildings that Meier produced since then have all remained truest to this aesthetic. This work traces the history and logic of the evolution of Meier's early language and its direct relationships to spatial and formal investigations of early-twentieth-century modernism as well as its direct reciprocal relationships with the rest of the NY5 languages. The departure for this inquiry of such centrifugal relationships between rules and products, between notation and performance, for the purposes of this work is Richard Meier's Smith House, an early pivotal work, an acknowledged forerunner and embodiment of the full repertory of Meier formal strategies and language [10]. In the same way that Richard Meier's work constitutes a hyper-refinement of the modernist imagery that has been inspired not by machines but by other architecture that was inspired by machines and especially Le Corbusier [11], the group formalism that can describe Meier's architecture constitutes a hyper-refined construction that relies on specific representations and mappings that foreground internal complex relationships of the structure itself, i.e. the symmetry subgroups and supergroups of any given spatial configuration. A succinct account of the discourse developed about the house and its critical role in the formation of contemporary architecture discourse is given elsewhere [12].
3.1. White Geometries

The Smith House is in Darren, Connecticut, and it is situated on a 6000 m² site overlooking Long Island Sound from the Connecticut coast. The house was built during 1965–67 on a site literally adjacent to the water and it was designed for a family with two children. The entrance area and master bedroom are on the middle floor. The lower level is for dining, kitchen, laundry and domestic help. Both the living and dining areas open directly to outdoor terraces. The top floor contains children’s bedrooms, guest-room and library-play. The house is finally topped by an outdoor roof deck. An axonometric view of a three-dimensional digital model of the house is shown in Figure 3.

The house itself appears to be a hyphenation of two canonical structures: the Citrohan house and the Domino house [13]. The Citrohan zone is a series of closed cellular spaces and the Domino zone is leveled as three platforms within a single volume enclosed by a glass skin. Meier investigates a language of oppositions of a denied dialectic between the total transparency of the panoramic façade and the solid compartment of the entrance façade. The handling of the layer stratification of the building parallels the post-Cubist conception of spatial relationships. On this basis, we can conceive the spatial arrangement of the house as the development of combinations and assemblages of lines, planes and volumes, independent of what the given elements may represent.

3.2. Rewind

The analysis proposed here proceeds along visual computations that are all based upon representations that capture some, but of course not all, conventions characterizing a design. The key idea behind these computations is that they are designed to decompose the house in sets of basic elements that are then recomposed to redescribe the house or reflected upon to consider other possibilities and help interpret the basic assumptions about the system.
itself. All pictorial descriptions below use the features of shape, weight, and projection as well as the three levels of abstraction discussed in the previous section in the description of the formal model. The architectonic representation for all three floors is shown in Figure 4, the spatial representation is shown in Figure 5 and the diagrammatic representation in Figure 6.

The initial shape that starts the subsymmetry computation is the three-dimensional diagrammatic version of the model of the Smith house. The symmetry partition of the house occurs at this level because this is the simplest possible schema for the design; the spatial correspondences in the diagrammatic level are easy to identify and compute. The nice feature of the model is that the symmetry decomposition of the diagrammatic model is directly mapped to the equivalent decompositions in the spatial and the architectonic levels. In this sense spatial relations in these other two notational levels that would be very hard to pick up or even impossible, are now are extracted in a straightforward way. The key idea here behind these
mapping between notations (and the shape rules and their reversals that do such mappings) is that the decomposition and recomposition of the design helps to evaluate basic assumptions about the design and the system itself. All these visual computations and subsymmetry relations are nicely captured in partial order lattices that pictorially present the subsymmetry structure of the underlying spatial configuration of the rectangle. Two different ordered relations for the first and the second floor of the house are shown in Figure 7 and 8 respectively. The spatial notation is omitted for clarity of

Figure 7. Partial order lattice of the first floor. Upper: Diagrammatic; Lower: Architectonic
Figure 8. Partial order lattice of the second floor.
Upper: Diagrammatic;
Lower: Architectonic
representation. A complete presentation requires the lattices for all three floors and for all three levels. The details are left to the interested reader.

3.3. Pause

The partial order lattices foreground the wall as the major compositional element that structures the design. Meier himself has attested to his preference to spatial elements rather than construction elements and especially his predilection for the wall to be a homogeneous plane [14]. This basic unit of the composition of the Smith house, the wall, has been defined so far in a series of successive subtractions of features from a given representation that approximates the original pictorial language of the house. A close examination of the instances of the wall in the house and their spatial relations suggests compositional processes such as parameterization, dematerialization, deformation, defragmentation and alternatively the design of an overall framework for a critical description and interpretation of the house. This suggestion is based on a series of experiments upon the representational elements of the house and their consistent typological reduction in the planar unit of the wall. The subtractive process is paused here and the basic unit is approached constructively as a geometrical object that is subject to a given set of rules. The hypothesis is that the basic unit of the Smith house and all its variations comprise a subset of a specific set of topological transformations of rectangular prisms and correspondingly of the full vocabulary of the NYS architecture. The initial function of the wall is to enclose space, so openings appear as punched out holes or as cut-outs. Through voids, missing walls are virtual elements or space elements treated as solids. A vertical wall is a wall whose height is greater than the distance from floor to floor. A horizontal wall usually serves as interior partition. Wall and block together constitute a hybrid unit. Here, the frame-infill walls comprise all of the above types too: the window wall open frame, and the glazed curtain wall. There are three fundamental instances of geometric cuboids: a) massive block-space volume; b) opaque wall-opening; and c) surface-plane. All these bodies can be parameterized through density and permeability to create binary oppositions: opacity—transparency, solid–void, and in-between or hybrid entities. Oppositions emerge including block–space, wall–opening, surface–plane. Parametric procedures generate geometric elements in this particular design style. The parameterization of the block produces variations in dimensions, density and edge condition. Interesting cases emerge: A massive piece of wall or block can generate any of the most unlike elements: chimney, closet, recess, threshold, staircase, and so on by subtractive operations. A solid opaque wall can be subject to operations of filtration, permeability or translucence. A solid transparent wall may instantiate either a glazed curtain wall or a window wall. Finally, a virtual wall as an abstract plane is then defined by its edge condition. A line on the plan may mark the separation of inside—outside, but it can also signify the edge of the volume, a change in material or level, or the presence of
something above or beyond. A combination of a solid - opaque wall and a transparent glazed wall may yield a translucent wall. The combination of the solid wall with space volume yields to a hybrid wall.

The frontal wall of the house is a triplet of planar and volumetric elements imbued with materiality and permeability. The glazing element incorporates open frames of wood| steel with an infill of glass. The trabeated element plays the role of concentric shell which acts as another filter. In-between is found an appended volume of space. The lateral window facade is layered same as the frontal one. Hybrid units are layered in parallel. Here, all the enclosing walls are hybrid. In the middle, there is the medial wall to create a vertical layer for the promenade architecturale and to structure deep and shallow space.

The basic mechanism to abstract the elements of the house and foreground their relationships as they are translated from level to level has been put in place. What is interesting in this process is the re-working of the compositional machinery of the design and the exploration of the possibilities that this system allows. This section starts the whole project from scratch and explores the formal possibilities in the bridging of these languages that are constructed in-between these consecutive notational levels. For the purposes of this analysis, the formal representation of the wall is taken to be a geometric cuboid parametrically defined in terms of characteristics including height, length, thickness, and degrees of permeability, density and openness. This primitive is a mathematical object that is described in a finite rectangular Cartesian system. Variations of this single schema may give rise to a range of essential elements used in the vocabulary of Meier’s architecture and of course a great deal of other modern architecture works.

If the cuboid and its parametric variations provide the basic vocabulary of the diagrammatic representation of the house its gradual fragmentation provides the basic vocabulary for the spatial representation of the house. The types of the fragmentation have to clearly foreground the relationship of the part-to-whole and should clearly evoke the fact that the parts belong in larger entities that they have been detached from. The specific decomposition of the three-dimensional cuboid considered here is based on a decomposition of the two-dimensional square into specific gridiron systems. By de-fragmenting the modules of vertical planes to determine the classes of openings in a plane, we can easily extract from this set the subset Meier uses. Among all possible gridiron systems the $3 \times 3$ was chosen here as the most generous for architectural purposes. The basic cellular grid and its cycles of permutations under the symmetry group of the square are shown in figure 9.

The method of counting of non-equivalent configurations based on a given permutation group of vertices of a geometric shape has been given by
Polya in his theorem of counting [15]. Nice applications of this theorem in architectural design can be found in other sources [16], [17]. The core of the theorem is that any shape can be represented as a function of the cycles of permutations of vertices $f_r$ that are induced under the symmetry group of the shape. The sum of all the cycles of permutations and their products divided to the sum of permutations of the symmetry group of the figure provides the cycle index of the figure. This cycle index provides the blueprint for the enumeration of all the possible subsets. More specifically, for a figure inventory $x + y$ where $x$ and $y$ represent the quantities that will be enumerated, its expansion according to the theorem is given in Eqn (1).

$$f_r = x^r + y^r$$  \hspace{1cm} (1)

If we substitute the figure inventory into the cycle index by replacing a cycle $f_k$ with $x^k + y^k$, and expand the cycle index in powers of $x$ and $y$, the resulting coefficient of $x^r y^s$ is the number of distinct ways of configuring the $x$ cells and $y$ cells with respect to the permutation group. The equation can be solved in a straightforward way by taking advantage of the multinomial theorem shown in Eqn (2).

$$(x + y)^n = \sum_{r+s=n} \frac{n!}{r!s!} x^r y^s$$  \hspace{1cm} (2)

In the specific case here for the 9-cell grid, the computation of the equations (1) and (2) for a figure inventory $x + y$, whereas $x$ means white squares and $y$ black ones, provides a total of 102 distinct non-equivalent configurations. These configurations are symmetric regarding the quantities $x$ and $y$. The 102 n-cell configurations for $x + y \leq 9$ are shown in Figure 10.

The exciting part of this enumeration is that it provides the complete set of all possible configurations of all binary systems embedded upon a given grid and therefore it provides a systematic framework to explore all the possibilities implicit in the system. It is clear for example, that some of these configurations have been used in many different circumstances in the design of the Smith house; these configurations consist of arrangements of black and white cells that denote respectively open and closed spaces or some hybrid in-between spaces. The reworking of this material provides a rich palette to visit not only the composition of the house itself but to contemplate on the possible configurations that are not used in this specific case but are used in other cases either by Meier himself or any other of the NY architects. A sample of these rules and the ways they apply to the abstract configurations computed above is given in Figure 11.

3.4. Fast-Forward

The subsymmetry analysis parses the design in layered identical parts that foreground qualities that are hidden within the overall structure of the design. Here a somewhat different approach is taken and the focus switches
on the juxtaposition of all these correspondences, one with another, at the architectonic level. More specifically the goal here is to examine all partial group theoretic descriptions of the Smith house one by one and in doing so foreground specific relationships that a straightforward application of group theory wouldn’t do.

The lattice of the symmetry group of the rectangle consists of five symmetry subgroups. These subgroups can be combined one with another
to comprise a set of $2^5$ or thirty-two possible design worlds that are differentiated one another with respect to the number of elements that belong in each subset. The number of combinations of symmetry elements $r$ among a set of $s$ elements is given in Eqn(3).

$$\frac{s!}{r! (s-r)!}$$  \hspace{1cm} (3)

For example for a set $s$ comprised of five elements the number of subsets $r$ comprised of three elements is given in Eqn(4).

$$\frac{s!}{3! (s-3)!}$$  \hspace{1cm} (4)

The complete list for all subsets comprised of five elements including dihedral symmetries (D), vertical reflections (V), horizontal reflections (H), half-turn rotations (S) and identity transformations (C) is given in Table 1.
Table 1. Complete listing of recombination of subsets of symmetry group of the rectangle

<table>
<thead>
<tr>
<th>$n$-ary set</th>
<th>Recombination List</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Null</td>
<td>( \emptyset )</td>
<td>1</td>
</tr>
<tr>
<td>Unary</td>
<td>D, V, S, H, C</td>
<td>5</td>
</tr>
<tr>
<td>Binary</td>
<td>DV, DS, DH, DC, VS, VH, VC, SH, SC, HC</td>
<td>10</td>
</tr>
<tr>
<td>Ternary</td>
<td>DVS, DVH, DVC, DSH, DSC, DHC, VSH, VSC, VHC, SHC</td>
<td>10</td>
</tr>
<tr>
<td>Quaternary</td>
<td>DVSH, DVSC, DVHC, DSHC, VSHC</td>
<td>5</td>
</tr>
<tr>
<td>Quinary</td>
<td>DVSHC</td>
<td>1</td>
</tr>
</tbody>
</table>

Furthermore all these design worlds, a total of thirty-two sets, can be individually augmented with three representations each corresponding to the three floors of the house, making then a total of ninety-six drawings including of course the empty set. And still, all these drawings can be further given in three different versions corresponding to the architectonic, spatial and diagrammatic notation bringing the total number of representations to two hundred and eighty-eight. This recombinant vision exhausts all possible ways that the parts of the house can be combined and should therefore be able to capture all theoretical statements on symmetry that have been said or could be said about the house. The thirty-two sets of subsymmetries of the dihedral group are depicted in Figure 12.

Figure 12. A complete list of the diagrams of all combinations of symmetry parts

A nice outcome of this constructive combinatorial approach is its ability to capture and reflect on existing debates on formal analysis of the house. For example Frampton has suggested that the theme of simultaneous frontal and rotational development of composition pervades Meier work—and as a matter of fact the whole work of the NY5 architects that Meier was a part of—but it is not resolved in Meier’s work. Rosemarie Bletter critiques Frampton that his categories of frontality and rotation are in the end too broadly defined and too general to help precise analysis and that the applications of the two categories in the analysis of buildings are somewhat non-systematic [18]. She further claims that Frampton’s notion of
frontality is applied in different ways for each of the NYS architects: in Hejduk’s projects it is used to refer to overall massing, in Graves’ work it is used to refer to the entrance while in Eisenman’s and Meier’s work it is used to describe the interior gridding of the space. Such arguments and similar ones can be nicely captured and discussed using the group theoretic combinatorial approach suggested here. The ten possible ternary models of the house foregrounding characteristics such as rotary movement (S), collage elements (C) and so on, are all given in Figure 13.

Figure 13. The group theoretic ternary models of the Smith house. First to last row: DVS; DVH; DVC; DSH; DSC.
Figure 13(continued). The group theoretic ternary models of the Smith house. First to last row: f) DHC; VSH; VSC; VH; SHC

All these models are interpreted here using two distinct descriptive systems: facts and values, or forms and functions [7]. Functions are suggested by values such as reflection, rotation, identity and so on, and a relation $\lambda$ represents the mapping of one system to another with logical variables 0 and 1. The models juxtapose the qualities one against the other and examine how the presence of the one clarifies or obscures the significance and role of the other. For example the recombinant model DSC in Figure 13 foregrounds the individual values of parallel layering (D), rotary movement (S) and collage elements (C). Clearly, the house is partitioned in terms of frontal symmetries—in the original model the (H) symmetries. The corresponding partition to the

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side symmetries, in the model the (V) symmetries, shows clearly the part of the design that is subject to these transformations. The embedded relationship of the rotations to the two systems of reflection is a byproduct. Furthermore, the relatively dense partition of the design given the dihedral, rotational and identity transformations suggests that the house is conditioned in a great extent by both orthogonal axes and not just one.

The DSC model, and in fact several other subsets of the building can help investigate questions and criticisms like that. These properties are clearly foregrounded in the representation suggested here. Three issues are important here: a) the isolation and foregrounding of specific subsets of symmetries happens in the diagrammatic level and all lessons learned transfer then to the architectonic level; b) all partial and incomplete correspondences that may be observed in the Smith House are captured by the group theoretic decomposition of the parti of the house, that is the rectangle and therefore the five symmetry subgroups and the ninety-six subsets of the complete set of transformations of the rectangle; and c) the interpretation of a set of chosen recombinant parts suggests a constructive understanding of the design and provides a view on how these recombinants can be used toward synthesis as a visual prototype to start with.

4. Discussion

A major motivation of this work is that there is a correspondence between the evolution of architectural languages and the formalisms that can be used to describe, interpret and evaluate them. Classical modern buildings can be and have already successfully been described by group theoretical techniques. In the same way, Richard Meier’s work constitutes a hyper-refinement of the modernist imagery that has been inspired not by machines but by other architecture that was inspired by machines. The group formalism that can describe Meier’s architecture relies on precise representations and mappings that foreground internal complex relationships of the structure itself, i.e. the symmetry subgroups and supergroups of any configuration.

It is clear that the complexity suggested in the reading of the Smith house could be contextualized within a wider set of designs with similar properties and especially the corpus of the NY5 [19]. Other houses could have been selected to test the formal method suggested here. Still, it is argued here that among all such candidates, the Smith House stands out as the best candidate. The house has a long legacy: Frampton has nominated the Smith House as a classic and selected the young Meier as the one architect out of five who knows history the most and learns from it [20]. Rykwert has asserted that the house is a classic case of an architectural typology that uses a formal vocabulary whose elements are all abstracted from the repertory of early modernism and juxtaposed back as a collage [21]. Jencks has asserted that Meier uses a mixture of traditional forms of modernist architecture [22]. And still many other key discourses have been suggested to include the themes of compositional grid and patterned frames [11], the discipline of the Domino and Citrohan structures [23], and Mies’
aesthetic of rhythmic linear elements [10]. Clearly, Meier's language, iconography, and elemental categories force comparison and differentiation with the work of other architects and at the same time call attention for a precise analysis in itself.

At the end, this research points to a series of other extensions and domains. These extensions generally fall into two categories: a) on the improvement of the system itself; and b) on the interpretative capabilities it affords for the construction and evaluation of critical languages of design.

References