Chapter 1 Introduction

Chapter 1 provides the setting for this work, including the motivations, aspirations and contributions of the research. The section provides a brief overview of formal methods in design and positions this work within this wider milieu and particularly within other approaches that use group theoretical tools. The section concludes with an outline of the dissertation.

1.1. Prelude

Formal systems in design have been used for systematic studies in analysis and synthesis of form for a long time and with a great degree of success. There are several generous accounts of their history and logic - see, for example, (March and Stiny 1985), (Kalay 2004). Among these methods the group theoretical approach has been particularly successful (Weyl 1952). This could hardly be otherwise as long as group theory provides the mathematical language for symmetry and symmetry has been one of the cornerstones of formal composition in architectural design and in the arts in general (Shubnikov and Koptsik 1974). The recent emphasis of contemporary architecture discourse on issues of pattern making and parametric variation only reaffirms the traditional role of symmetry and structural repetition as a ubiquitous and indispensable principle of composition in architectural design. Still, even if contemporary emphasis on pattern making extends the research in new trajectories including space-packing techniques, layer stacking, periodicity and non-periodicity, and so on, some basic questions regarding the value and fitness of symmetry in formal composition remain unanswered. More specifically, it remains unclear whether an apparently complex plan can be described or interpreted in a group theoretical way or not. There is a great body of work on the description of the symmetry properties of architectural works of Palladio, Soane, Ledoux, Wright, Le Corbusier and others (see for example (March and Steadman 1971); all of these designs typically exemplify their apparent correspondences and the power of the method is immediately appreciated. Still, there is a great body of architecture work that the power of the method seems inadequate to explain. For example, a great number of designs and especially those of late modernity in the twentieth century cannot be easily explained with existing tools. Some first steps towards the extension of the tools of group theory to explain these designs have been taken by March (1998), Park (2000) and Economou (1999), (2001).

This work builds upon this methodological approach and proposes a model that investigates whether the combination of existing group theoretical formalisms with appropriate systems of representation can indeed cast light in the analysis of such works and therefore construct a rigorous body of foundational research in formal composition in architecture design. The broader question that is opened up here is whether a complex architecture object – or part depending on the interest of the researcher, can be interpreted as a layered object whose parts are all related symmetrically; in other words whether an asymmetric shape or configuration can be understood in terms of nested arrangements of some order of symmetry.

1.2. Method

A fascinating aspect of symmetry is that it can provide a measure regarding the formal structure of an object; it tells the number of the parts that the object consists of and the ways these parts combine. This quest for an aesthetic measure is closely related to the efforts of, say, George Birkoff (1933) to realize aesthetic formalisms or, for that matter, of all the ancient Greek mathematicians and their work on the theory of means (Heath 1932). This formal grounding of symmetry on mathematical grounds and in specific group theory has provided an approach that has generated several applications in analysis and synthesis of objects that are composed by identical parts. Classical accounts of applications in analysis and synthesis in formal composition in the visual arts have been given by March and Steadman (1971), Shubnikov and Koptsik (1974) and more recently by Park (2000) and Economou (2001). Still, this approach does not look as powerful in the analysis of designs that do not exhibit an apparent repetition in their structure. A classic example of such designs is the NY5 architecture, a set of designs that are all clearly exemplifying formal qualities of abstraction, layering, complexity, depth and so on. The key idea that is used here is that these representations of these complex objects can be understood as layered compositions of simpler parts and that these parts can all be related through symmetry values. The basic tool from group theory that is used here is the 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 square the maximum number of layers and spatial constructs that can be build upon those is ten because this is the number of symmetry subgroups of the square. Still, the symmetry subgroups can only provide the logical framework to compute an architectural composition; what is critical is the representation of the designs that are going to be analyzed within this framework.

This work suggests three aspects of representation to be computed within these subgroups: the first built on abstraction, the second on weighting, the last on projection. All representations rely on successive deletions of features of architectural representation. There are three levels that are suggested here: a) the first level, the architectonic level, retains all the conventions of projection and section of architectural drawings: walls, windows, doors, stairs, parapets, encased furniture, tiling, rails all represented as arrangements of lines. The next level of abstraction, the spatial level, records only topological relationships and aspects of connectivity: walls and openings of all kinds. The third and most abstract level of abstraction, the diagrammatic level, records only divisions of space. Finer distinctions of space and notations are all recorded in these drawings with a weighting of lines to show materiality, transparency, or simply other kinds of experiential relations of spatial elements next to each other. Three types of notations of lines are used here: Solid, thin, and dotted. It is suggested that this method of representation based on three types of levels of abstraction and three types of lines provide a rich repertory of devices to be computed in partial order lattices and show essential relationships in complex architectural arrangements.

1.3. Contribution

The formal techniques and methods that are developed here can be used in a variety of ways in the analysis and synthesis of form. The formal theory is applied mathematics, in particular group theory and combinatorics. The use of group generators in the generation of symmetry groups and subgroups, the use of lattices in the partial ordering of subsymmetries of a design, and the use of the cycle index of a permutation group of a given set are three key tools used extensively throughout this research.

The object of analysis has been polemically selected here to be the NY5 architecture, a set of designs that are all clearly exemplifying formal qualities of abstraction, layering, complexity, depth and so on. One specific case study has been selected in particular to fully illustrate the methodology of analysis, the Smith House by Richard Meier. All plans of the house are represented in three different levels of abstraction moving successively away from the architectural representation to a purely diagrammatic one that foregrounds divisions of space. All representations are fed into an analysis algorithm to pick up all symmetry relationships and the parts are constructed as instances of a binary composition of a family of rectangular grids. Finally the process is reversed to fully account for the construction of the space of the house as a three dimensional layered composition.

1.4. Outline

The dissertation is roughly divided in three parts; the first three chapters present the problem statement of the subsymmetry analysis and provide a literature review of the general class of methods that this problem belongs too as well a state-of-the-art account of the specific methods that have solved other aspects of this problem. The following chapter provides the hypothesis and methodology of the subsymmetry analysis attempted here and the following chapter provides one case study to test the methodology and its value. A discussion of future research directions and a summary of the work conclude this research. More specifically, the research work here is proposed in the following parts:

Chapter 1 presents the case for the research and contextualizes its position within the current state of architecture discourse on formal methods in design.

Chapter 2 provides a literature review of formal methods in design and focuses on the history of the applications of these methods in analysis and synthesis in architectural design with an emphasis on group theoretical applications.

Chapter 3 presents the logic of the system adopted here, the group theory. All basic formal constructs that are used in the research are presented here.

Chapter 4 provides the hypothesis and methodology of this work. Currently all formal analysis using group theoretical tools focus on repetitive designs that show immediately their recursive structure. It is suggested here that highly complex designs can still be described and analyzed with group theoretical manner. The key idea is that the complexity of these designs can be seen as an aggregation of spatial layers that can all be decomposed by the subgroup relations of the symmetry of the configuration.

Chapter 5 shows the application of this methodology in analysis using Richard Meier's Smith House as its major focus. All plans of the house are decomposed and abstracted in various ways and the computation of all symmetry parts takes place in entirely visual terms. The computation is entirely visual. A reassemble of the layered symmetries explains the structure of the symmetry of the house and provides an illustration of the basic thesis of this research on the foundation of a theory of emergence based on symmetry considerations.

Chapter 6 provides a summary of the work, an assessment of its strengths and limitations and suggests future work.

References

Birkhoff, G. (1933). Aesthetic Measure. Cambridge, Harvard University Press.

Economou, A. (1999). "The Symmetry Lessons from Froebel Building Gifts." Environment and Planning B: Planning and Design **26**(75-90).

Economou, A. (2001). "Four Algebraic Structures In Design."

Heath, T. L. s. (1932). Greek Astronomy. New York, E P Dutton & Co.

Kalay, Y. (2004). Architecture's New Media: principles, theories, and methods of Computer-Aided-Design. Cambridge, MIT Press.

March, L. (1998). Architectonics of Humanism: essay on number in architecture. Chichester, John Wiley & Sons.

March, L. and P. Steadman (1971). The Geometry of the Environment. Cambridge, Mass, MIT Press.

March, L. and G. Stiny (1985). "Spatial Systems in Architecture and Design." Environment and Planning B **12**: 31-53.

Park, J. H. (2000). "Sub-Symmetry Analysis of Architectural Designs: Some Examples." Environment and Planning B 27(1): 121-136.

Shubnikov, A. and V. Koptsik (1974). Symmetry in Science and Art.

Weyl, H. (1952). Symmetry. NJ, Princeton University Press.

Content