

Grammar Transformations: Using Composite Grammars to Understand Hybridity in Design

With an Example from Medieval Islamic Courtyard Buildings

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Abstract: Hybrid designs are those that develop from multiple sources. This paper presents the methodology of composite grammars, developed by merging multiple grammars, for the analysis of hybrid designs. The methodology is discussed with an example from Islamic architecture, which is known to have developed by borrowing from various sources. The methodology is seen to be useful for the analysis of the evolution of historic architecture, as well as for the development of new languages of designs.

1 THE NOTION OF ‘HYBRIDITY’

Webster’s dictionary defines ‘hybridity’ as “the blending of two diverse traditions (and transforming them) into something heterogeneous (...) in composition” (Neufeldt 1988). The essence of hybridity is in the interaction of different forces and their transformation into something new. The topology of hybrid systems is not one of a simple melting together of two traditions, but rather, of a ‘third’ independent system with its own parameters and logic (Kapur 2001).

Hybridity as a concept is used in the context of diversity and multicultural influences in arts and literature (Hybridity 2000). It has been related to the notion of ‘conflict’ and ‘synthesis’ in the design process and has been used to understand the continuous modifications in the process of design development.

The notion of hybridity has been used extensively in architectural theory to understand the confrontation and fusion of differing architectural traditions. It has been used in the context of urban design and city growth; in the transformation and evolution of architecture under the influence of various cultures, and particularly, in the development of architecture in Asian lands under the influence of foreign rule (Kapur 2001). It is hence often associated with Islamic architecture which has developed through similar confrontations of varied architectural cultures; a well known instance is that of the fusion of Persian Islamic and local Hindu forms in the traditions of Islamic art and architecture of south-east Asia (Grover 1996).

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The combinatorial potential of hybridity is seen to have significance in creating a meaningful cultural expression. Current studies of hybridity in design and architecture rely on traditional descriptive methods of historical analyses. We believe that the methodology of composite grammars as presented here offers an objective, computation based framework for the examination of hybridity in design.

2 SHAPE GRAMMARS FOR THE ANALYSIS OF ISLAMIC ARCHITECTURE

Shape grammars (Stiny and Gips 1972) have been in use for over three decades. Their utility in design generation and analysis has been well documented (Knight 2000). Grammars are both prescriptive and descriptive: the rules of a grammar generate designs but can also be considered as their morphological descriptions.

A promising application of shape grammars lies in their transformation of grammars. Knight (1994) proposed a model for the development of new design languages, based on the transformation of existing grammars. The transformation process begins with the analysis of a design language and the creation of a grammar to describe it. The rules of such a grammar are then transformed into a new grammar, which would create a new style of designs. Knight's model has been used to describe the historical evolution of known styles into succeeding ones, as demonstrated in the transformation of the Vantongerloo and Glarner grammars to reflect the development of De Stijl paintings.

Our previous work involved a study of ground plans of medieval Islamic courtyard buildings of central Asia using shape grammars (Ahmad 2004). Typical of Islamic architecture, the design of these buildings was based on formal organisational principles such as symmetry, balance, hierarchy, rhythm and axuality. Such compositional and visual correlates are believed to be effectively analysed using shape grammars (Knight 2000) and thus justified its use for the analysis of Islamic building types. The work involved the creation of a parametric shape grammar for the design generation of Roman and early Islamic fortifications, wherein lie the origins of a number of Islamic courtyard building types. The grammar was then transformed to develop three other grammars that generate the ground plans of Islamic courtyard type buildings: caravanserais, madrasas and mosques. A primary outcome of this research was the development of a methodology to merge a set of related grammars to create 'composite' grammars.

In this paper, we propose that such composite grammars could aid in the definition of 'hybrid architecture', such as the Islamic building types, that develop out of multiple sources. This is illustrated with an example of the medieval Iranian caravanserai, which is believed to have originated from the designs of fortifications and Parthian houses (Pope 1971; Hillenbrand 1994). We use the transformation techniques described by Knight (1994) for the creation of composite grammars, and as such this work can be seen as an application of Knight's work on the transformation of grammars.

This work could be of particular use for the analysis of Islamic architecture, which—due to its diversity and overlaps in forms, building styles and types—presents hurdles in traditional analytical methods. A unique characteristic of Islamic architecture was that it developed by borrowing from various sources and was notable primarily for the originality of the manner of combining diverse elements (Hillenbrand 1994). The composite grammar methodology, which combines grammars for the development of new design languages, could thus be considered consistent with the design methods of Islamic architecture, and could be used for the generation of new, contemporary designs of Islamic architecture.

3 COMPOSITE GRAMMARS

Composite grammars as described here are different from the notion of composite algebras as described by Knight (2003). Composite algebras are formed by the combination (sum or cross product) of different shape algebras. The shapes in composite algebras are compound shapes made up of different elements from different algebras.

On the other hand, the analogy of composite shape grammars is that of grammars of composite natural languages. Natural languages constantly transform when they come in contact with other languages, thus resulting in the development of different varieties of language. An example is that of Creole languages, hybrids of two or more languages. A Creole usually takes the structure of one language and the vocabulary of another. The terms ‘borrowing’ and ‘loan’ are used to refer to instances in which one language takes something from another language. Borrowing can affect all components of a language’s grammar, with vocabulary as the element most commonly borrowed. English, for example, has borrowed a large part of its vocabulary from French and Latin. Syntax also can be borrowed. For example, Amharic, a Semitic language of Ethiopia, has borrowed syntax from neighbouring non-Semitic languages (Comrie 2004).

Similarly, composite shape grammars are formed by a merger of two or more shape grammars. The word ‘composite’ as used here has been used to imply an entity ‘made up of various parts or elements’.

Rule sets of various grammars can be combined to create ‘hybrid’ grammars, which, for example, might have the structure of one design language and the vocabulary of another. The usefulness of such a grammar—created by the ‘fusion’ of two or more grammars—would be primarily to create and evolve new design languages. It could also be used to map relationships between different building styles, as demonstrated in Section 4.

In the following sections, we discuss some ways in which a composite grammar could be generated.

3.1 Creation of Composite Grammars

We refer to Knight's (1994) method of grammar transformation for modifying a grammar by addition, deletion or modification of grammar rules, either by shape replacement or by modification of spatial relations.

Figure 1 illustrates two parent grammars A and B, and three 'hybrids' created from them. Parent grammar A consists of a rule that takes a given rectangle and adds another one perpendicular to it. Grammar B consists of a rule that offsets a square, by half its width (Knight 1994, 65 fig. 3.25c). The examples here of composite grammars describe three different ways in which a composite can be created. Composite 1 has been created by merging the shapes of grammar A into grammar B. This is analogous to the idea of a hybrid natural language which merges the vocabulary of one language into the structure of another. A composite grammar created in this manner would have characteristics of both its parent grammars; its designs, however, would be exclusive to the designs generated by either grammar. Structure grammars (Carlson and Woodbury 1992), which generate designs as structures or sets of shapes, exhibit similar behaviour, in that the separation of 'structure' and 'motif' in these grammars facilitate the transformation of either independently.

	Shapes	Spatial Relation	Initial Shape	Rule	Designs
Grammar A					
Grammar B					
Composite 1					
Composite 2					
Composite 3					

Figure 1 Example of composite grammars

Composite 2 has been created by merging the rules of Grammar B into Grammar A. This has been done with the anticipated knowledge that the rules of grammar A generate emergent shapes which make possible the application of rules from Grammar B. It should also be noted that the language generated by Composite 2 is a superset

of the language of Grammar A. It generates all of the designs produced by grammar A in addition to 'new' designs.

In a manner similar to the previous example, Composite 3 has been created by merging rules. In this case, however, deliberate changes have been made to the structure of the host grammar to accommodate rules from the other grammar. In this case, this implies modification of shapes of the host grammar B. Elsewhere, the sequence of rule application may be altered to achieve the same result.

4 COMPOSITE GRAMMARS FOR THE ANALYSIS OF HYBRIDITY IN ISLAMIC ARCHITECTURE

The example chosen here is that of early medieval caravanserais of the Iranian world, dating from 11th to 12th centuries. Caravanserais were rest houses for caravans, built on trade routes between central Asian cities in the middle ages. The design of a typical caravanserai consisted of a fortified development with a central courtyard, and a cellular growth of rooms all around it. It was often square or rectangular in plan, with bastions marking the fortification wall and towers at the angles. The access was often through a single portal placed at a location on the orthogonal axis. The Iranian caravanserai was often developed on the traditional four *iwān* plan, with arcades surrounding the courtyard, and emphasis at the central bays (Pope 1971).

Although it is said that the architectural origins of the medieval caravanserai are difficult to identify with precision, most scholars link the origins of the caravanserai to Roman fortifications and Parthian houses. A Parthian house consisted of a courtyard surrounded by a range of rooms. Its exterior was articulated by fluting or serried engaged columns. A significant feature of these residences was the use of iwans in the planning and articulation of the building. A Roman castrum (camp) consisted of a fortification, square in plan, with regular bastions and a single fortified entrance (Hillenbrand 1994; Pope 1971).

The features of the aforementioned building types can be observed in the Iranian caravanserai and hence it can be considered a 'hybrid' of the same.

4.1 Characterisation of the Caravanserai 'Composite' Grammar

A corpus of designs of the discussed building types was identified from the work of Hillenbrand. Based on it, grammars were written to characterise the different building types. Grammar A generates a fortification plan with regular bastions and a single fortified entrance. Grammar B generates a Parthian house plan with a large open/covered central space surrounded by a set of cells and highlighted orthogonal bays. Designs from these languages are shown in Figure 2.

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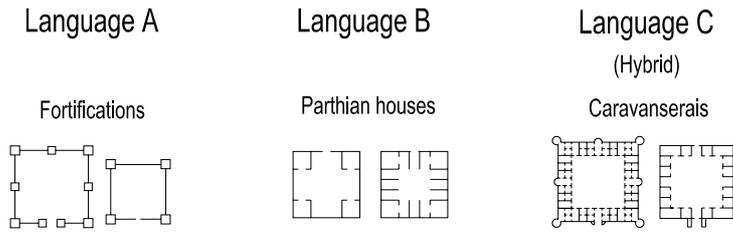


Figure 2 Designs from the three languages

The rules written for the two grammars were such that they shared a commonality in naming and state label conventions. Rules were classified into distinct rule sets in three phases of design development. Phase I contains rule sets for the interior development of the plan. Phase II contains rule sets for the exterior development, whereas Phase III has rule sets that define and articulate the exterior and aid in the termination of the design generation. The organisation of rules in such a manner gives the grammars the potential to be merged easily. It would also make easier the insertion of new rules and rule sets into the scheme of a given grammar. This also gives rules the potential to be modified, by ascribing new forms in the articulation rules. Table 1 illustrates the rule sets used for the creation of the composite caravanserai grammar, while Figure 3 illustrates a subset of the rules for the grammars. We show just a few rules to illustrate the contribution of rule sets from either Grammar A or Grammar B to the composite grammar.

Composite grammar C was developed by combining the Phase II (exterior development) and Phase III (articulation rule sets) of host grammar A, with the Phase I (interior development) rules of grammar B. The primary component of the transformation is the inclusion of new rules for cell generation, orthogonal bays and corner cell zones into grammar A. The initial shape of grammar A was modified to allow the application of rules from grammar B. Grammar C thus generates caravanserai plans with a fortification wall and a configuration of cells around a courtyard. In terms of the manner of its creation, Grammar C most closely resembles Composite 3 of the previous section.

For the purposes of this paper, we have not considered the difference in the scale of the building plans, with the fortification plan obviously much larger than the houses. We have also disregarded wall widths as well as slight variations or inconsistencies in designs. Parameterisation of element dimensions has not been detailed in this project. We believe this would not be difficult to incorporate, as building designs in Islamic architecture were based on modular systems.

Table 1 Grammar Rule sets

Rule Sets	Grammar A Fortifications	Grammar B Parthian Houses	Grammar C Caravanserais (Composite)
I. Interior			
Central space		•	
Orthogonal Cell		•	•
Corner cell		•	•
Cell division		•	•
II. Exterior			
Entrance	•	•	•
Bastion placement	•		•
III. Articulation			
Fluting		•	
Bastion definition	•		•
Tower definition	•		•
Entrance definition	•		•
Termination	•	•	•

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	Grammar A	Grammar B	Grammar C
Initial Shape			
Orthogonal Bay Development			
		$x = 1$	$x = 0$
Corner Tower Definitions			
	$x = 1$		$x = 5$

Figure 3 Subset of grammar rules

5 DISCUSSION AND FURTHER WORK

In this paper, we discussed the notion of hybridity in design and presented the concept of composite grammars as a framework to analyse it. We illustrated some ways in which composite grammars could be created, and used the methodology for the analysis of the medieval Iranian caravanserai. A pair of shape grammars, characterising the source styles of the caravanserai, was fused for the creation of the caravanserai grammar. Such a description of the evolution of building styles ensures a plausible encoding of historic design processes, which can be reused for the design of new buildings. We thus conclude that the concept of composite grammars could be used as a formal method for the analysis of the evolution of hybrid designs, as well as for the generation of new ones.

A significant factor in the combination or merger of two entities is the value of conflict between them. Here we have merged two 'related' grammars, bearing similarity in shapes, spatial relations and structure. However, in the history of art and architecture, dissimilar design styles have often been merged, such as the Islamic and Hindu styles in the Islamic architecture of India. Another worthy investigation would be the analysis of the blending of such complementary design languages.

The methodology used here has obvious correspondences with those of genetic modelling. We plan to investigate the models of SGGA (Loomis 2002) and evolutionary design (Schnier and Gero 1998).

Seen as a characteristic of postmodernism, hybridity is a growing characteristic of art and architecture today where the collision of cultures has become the norm rather than an exception. Contemporary visual phenomena increasingly reflect cross cultural pluralism. Architectural design, in particular, continually undergoes transformations under the influence of building traditions it comes across with.

Composite grammars offer a methodology that allows one to study such transformations in designs and analyse different 'moments of hybridity' over time. The methodology allows shape grammars to be merged, thus allowing the investigation of diverse results that cross breeding could produce, through a variety of inventions and conflicts. The benefit of such a framework is that it allows conscious merger and alteration of existing traditions and replaces them with novel solutions.

The composite grammar methodology is seen to be consistent with the design methods of Islamic designers of the past. Composite shape grammars also address the issue of the analysis of the great diversity of designs in Islamic architecture of the past, and could lead to the creation of a great number of contemporary Islamic designs. Finally, the composite grammar methodology offers a new and useful alternative approach for the study and analysis of historic architecture, with an emphasis not on chronology, building style or type, but on design complexity. Such a study offers a deeper understanding to the structural changes that may have appeared in the designs of historic buildings. This utilisation of composite grammars developed from the analysis of traditional historical styles and the merging of the resultant grammars has the potential to offer a unique computational method for the design of contemporary Islamic architecture.

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