

Computing Style

Presented as a poster at Nexus 2010: Relationships Between Architecture and Mathematics, Porto, 13-15 June 2010.

Abstract. Shape grammars are frequently used in analyzing style in architecture and other areas of design. But this is a more subtle task than is usually realized, and some grammatical approaches to design analysis are logically suspect. We examine the framework articulated by Stiny and Mitchell in 1978, fill in the operational gaps, and propose a more comprehensively considered approach to using grammars to compute style.

Introduction

One of the most perceptive contributions to shape grammar studies is, strictly speaking, not about shape grammar at all. Rather, it is about the more general problem of style, what it means to understand style, and how computation helps to achieve that understanding. In the conclusion of their Palladian grammar, Stiny and Mitchell [1978] described the problem of style analysis as follows (in what follows we paraphrase and generalize from buildings to designs).

We are given a finite set of designs that appear to be similar. This set, or *corpus*, is a subset of a set of all and only those designs that are also similar (i.e., a *target language* or *style*). Understanding this style means being able to do three things: first, create a new design in the same style; second, evaluate whether a previously unknown design is in the same style or not; and third, explain why the designs appear to be similar.

This is an inspired application of the scientific method to design analysis. It frames the question clearly as one of observation and operation: *understanding* means *being able to do*. This in turn explains, for example, why connoisseurship is ultimately unsatisfactory as a demonstration of understanding: the connoisseur is by definition a black box, unable or unwilling to explain how he does what he does.

All formal generative tools, such as programming languages and shape grammars, provide these three capabilities. But shape grammars have the additional advantage of being graphic, which makes them uniquely well-suited to studying style in design, which employs graphic, not symbolic, artifacts.

For the first task, we create a new design in the style by using the grammar to generate it. For the second, we use the grammar to try to generate the previously unknown design; if we can, it is in the style, and if not, not. And for the third task, that of explaining, the grammar embodies a generative algorithm: it is itself the explanation.¹

At the same time, however, Stiny and Mitchell are silent on the very real differences between design and natural phenomena. How, for example, are we to evaluate similarity? Using a grammar to generate a design is uncontroversial, but how do we know whether that design is in the style? You and I may not agree, and where would this leave us? This seems to be a hopelessly subjective question.

In fact, the question *is* subjective, but this detracts not at all from Stiny and Mitchell's elegant statement. If we examine this question more closely, we will gain a richer appreciation, not only of how computation can help us understand style, but also of how we humans are ultimately central to the very idea of style. The formal and the informal, the objective and the subjective all have a place, and we can come to terms with them by wrestling with the paradoxes.

Style analysis and science

The hypothesis proposed by a natural scientist makes predictions, and she evaluates those predictions by doing experiments. These experiments are essentially questions from the scientist, and are designed so as not to distort the answers from nature. To put it another way, the scientist and nature must be independent. We will emphasize this by referring to the natural scientist as the *investigator* and to nature as the *evaluator*.

In other sciences, such as the humanistic sciences, the evaluators may be humans. In linguistics, for example, a linguist studying a language proposes a grammar that generates new sentences (i.e., ones not in the corpus). A *native speaker* of that language evaluates whether those new sentences are *legal* (i.e., in the language). The linguist and the native speaker are independent: the linguist does not evaluate the sentences, and the native speaker does not create the grammar. In addition, we need to point out that the native speaker is *authoritative*: his judgement, like nature's, is accepted by the investigator and, she hopes, her audience.

Returning from science to style, it is now easy to imagine a setup with an independent and authoritative human evaluator analogous to the native speaker; we will call this evaluator a *native stylist*. The style investigator proposes a grammar (i.e., a hypothesis) that generates new designs, and the native stylist judges whether or not the designs are legal (i.e., in that style).

As an example, let us examine the case of José Pinto Duarte, who studied the houses designed and built in Malagueira, Portugal, by the architect Álvaro Siza [Duarte 2005]. Duarte proposed a grammar (without Siza's input), generated new designs, and presented them to Siza to evaluate. Siza is the perfect native stylist: he is independent of Duarte, and he is clearly authoritative with respect to his own work.

What did Siza think of Duarte's designs? He had four basic responses, varying in degree of legality.²

1. "No, it's not legal, but the difference is small."
2. "Yes, it's legal, but I wouldn't have done it for idiosyncratic reasons."
3. "Yes, it's legal, and I might have designed it."
4. "Yes, it's legal, and I designed it. ... What do you mean I didn't design it?"

Overall, the four responses suggest that Duarte's grammar was quite accurate. But they are worth a closer look. Siza's first response suggests that the boundary is clear to him, and yet also that illegality comes in shades of gray. His second response suggests that he recognizes two standards simultaneously. Here it may be well to realize that his approach in Malagueira was to develop a method that his assistants used to create house designs. Thus the first standard is for his staff; the second is for himself. The design in question is legal according to the first standard, but illegal according to the second. Taken together, these two responses suggest that the boundary is flexible, and that even the perfect native stylist may not be entirely consistent.

The case of Duarte and Siza may seem charming, but much of the charm is simple novelty in a world where native stylists are rarely available when we need them. We may want to study churches by Hawksmoor, but Hawksmoor is not at hand to evaluate our predictions.

Without independent and authoritative evaluation, we cannot know whether the designs predicted by our grammar are legal or not. The only designs that we know to be legal are those in the corpus. But this we knew before we proposed the grammar; we have learned nothing. Scientific experiments add to the known facts, but without an appropriate mechanism for evaluation, our grammatical setup does not. The number of known facts matters, according to a principle that scientists follow when selecting from competing hypotheses. This principle, known as Ockham's Razor, guides them to select the most parsimonious hypothesis that accords with the known facts. Thus, all else being equal, the more known facts that a hypothesis accounts for, the more powerful it is. And since grammars with unevaluated predictions do not add to the known facts, we lose one criterion for selecting among competing grammars.

With this in mind, we see that, because Duarte gets a reliable verdict on his predictions, he has established more known facts with which all grammars by subsequent investigators must be consistent. By contrast, consider the case of you, me, and Hawksmoor. Suppose that I propose one grammar and you propose another. How are we to choose between them? Without Hawksmoor's participation, my predictions and yours are simply speculative. All we know for sure is what we started with: the churches in the corpus. It's my word against yours.

At this point we would like to mention the role of embedding in the situation we have just described. In particular we would like to note that it echoes Stiny's [1980; 2006; 2011] consistent contentions that embedding is central to how we perceive the world and that shape grammars help us do that.

We have mentioned already that the corpus is a subset of the target language: it is *embedded* in the target language. At the same time, however, it is embedded in infinitely many other languages of designs. Our goal as investigators of style is to determine which of all these languages is the target language, even though, given only a corpus of designs, we cannot do this with any certainty. This condition evinces the inherent ambiguity of the inductive method.

Flawed approaches to grammatical style analysis

The framework that we have proposed has implications for how grammatical style analysis should be conducted. To begin, let us consider briefly some approaches seen in the literature. Some of these approaches are inconsistent with our framework; we believe that their results are therefore flawed.

In some cases, the investigator assumes that any design generated by her grammar is legal, because it was generated. She mistakes existence for legality. This is simply proof by assertion. To the extent that there is any evaluation at all, the investigator is acting as her own evaluator, which, as we have seen, is untenable.

In other cases, the investigator recruits lay people, such as students, exposes them to the corpus, and then uses them as evaluators. Having been trained by the investigator, they are not independent, and, being novices, they are not authoritative. As evaluators, they are not credible.

In still other cases, the investigator uses a connoisseur. A connoisseur is independent, but, like the native speaker and native stylist, is not always available. Unlike those

informants, the connoisseur possesses an authority that is not innate but acquired. As a result, the quality of his claim to authority significantly determines the persuasiveness of the investigator's results.

Sometimes the investigator removes a small number of designs from the corpus, puts them aside, and proposes a grammar based on the remaining designs. If the grammar generates the removed designs, then she considers those predictions to be confirmed. This has the advantage of making an evaluator unnecessary for those designs, but has disadvantages.

For one, it is difficult for the investigator to disregard the removed designs while composing the grammar. This could taint the independence of the predictions and their confirmation. For another, the grammar makes many other predictions, which remain unevaluated. In fact, since the "confirmed" designs come from the corpus, this setup does not actually add to the known facts. After all, if those designs are left in the corpus, the grammar still has to generate them. So the investigator has not accomplished anything more than she would have otherwise.

A "purer" version of this approach is to discover a new and credible instance of the style defined by the grammar. This is a chancy approach to evaluation, because the investigator can never be sure of finding a new and credible design when she needs it. But let us consider what this procedure might look like.

Suppose that our investigator proposes a grammar of Palladian villas. If she then discovers a previously unknown but authentic edition of the *Four books*, and it contains a villa that was predicted by the grammar but was not part of the original corpus, then she can consider that design legal; one of her grammar's predictions is confirmed. In effect, the newly discovered edition is the evaluating mechanism.

However, this begs the question: how do we know that this edition is authentic? We must examine the book itself and the circumstances of its writing and publication, and consider them in the light of what is already known about Palladio's work, life, and times. In other words, we have to evaluate, not the design itself, but the new evaluating mechanism. This suggests a workable approach to evaluation, which we now discuss.

Our approach to grammatical style analysis

Our approach is this. Once we have our predictions, we imagine what information we would need to evaluate them, we look for that information, and then we use it to evaluate them. As a hypothetical example, suppose that we generate a new Hawksmoor church. Does this design make sense structurally? We consider the technological practise of Hawksmoor, his time, and his place. And then we evaluate the design against that background. Does the design make sense functionally? We consider the religious practise that Hawksmoor was accommodating in that time and place, and consider the design in that light. We can consider any aspect, any area that we deem relevant.

The questions that matter are not grammatical ones. In the end, it all comes down to *us*, not as the evaluator of the design itself, but as the finder, evaluator, and applier of evaluating mechanisms. The evaluation is *indirect*. It requires imagination, as Barzun and Graff remind historians: "The researcher must again and again *imagine* the kind of source he would like to have before he can find it" [1992, 58–59, original emphasis].

This is exactly what Liang Sicheng, the pioneering historian of Chinese architecture, did when he began to study the hitherto indecipherable twelfth-century Chinese government building manual *Yingzao fashi* (*Building standards*). Wanting to study extant buildings, and imagining that some must exist in the countryside, he surveyed

historical documents and canvassed local people to identify buildings that might merit on-site investigation. This led to fieldwork and numerous important discoveries [Fairbank 1994]. We now turn to this book to illustrate more concretely just how much imagination and judgement are involved in grammatical style analysis.

An example

The *Yingzao fashi* [Liang 1983] was written by the court architect, Li Jie (d. 1110), and published in 1103 (Song dynasty, 960–1127).³ This book of standards was intended to enhance communication between the government (as a client) and builders it employed, and contains mostly written guidelines and some drawings. Among the drawings are eighteen sections of a building type known as a *ting* hall (figs. 1-4); these form our corpus.

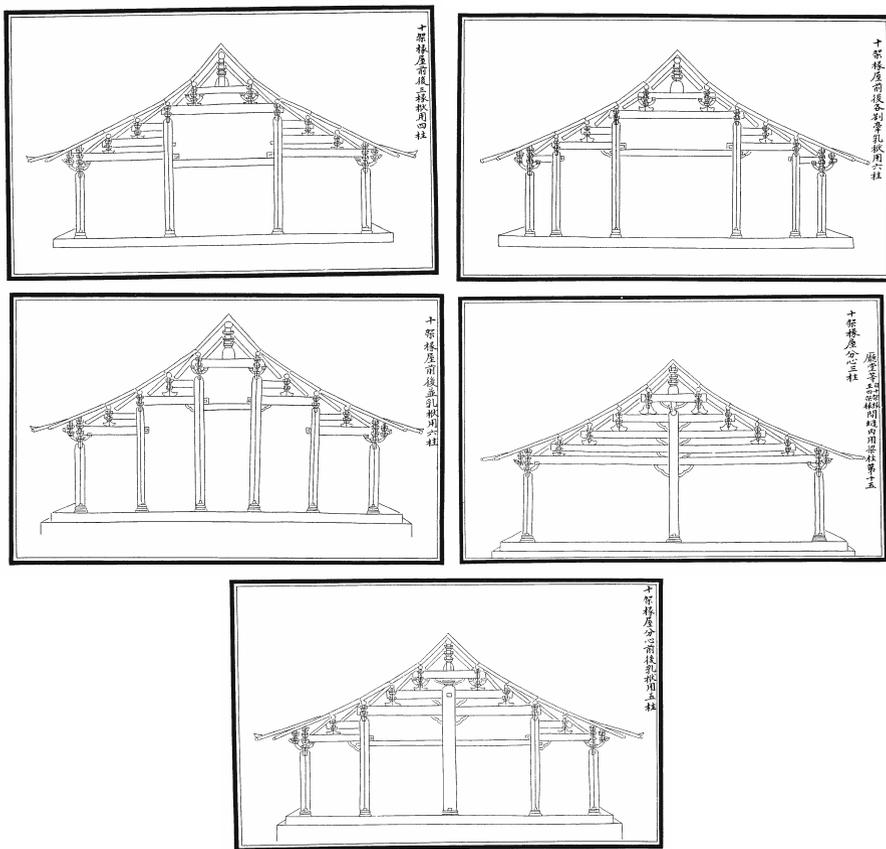


Fig. 1, a-e. Ten-rafter *ting* hall sections in the *Yingzao fashi* [Liang 1983: 313–15]

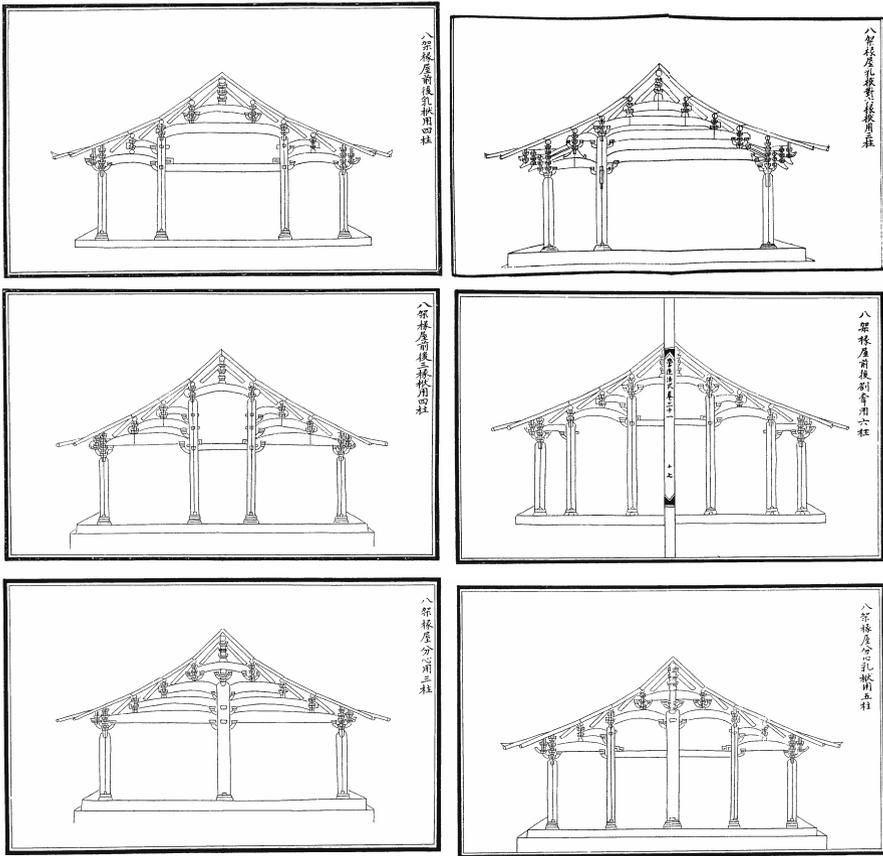


Fig. 2, a-f. Eight-rafter *ting* hall sections [Liang 1983: 316-318]

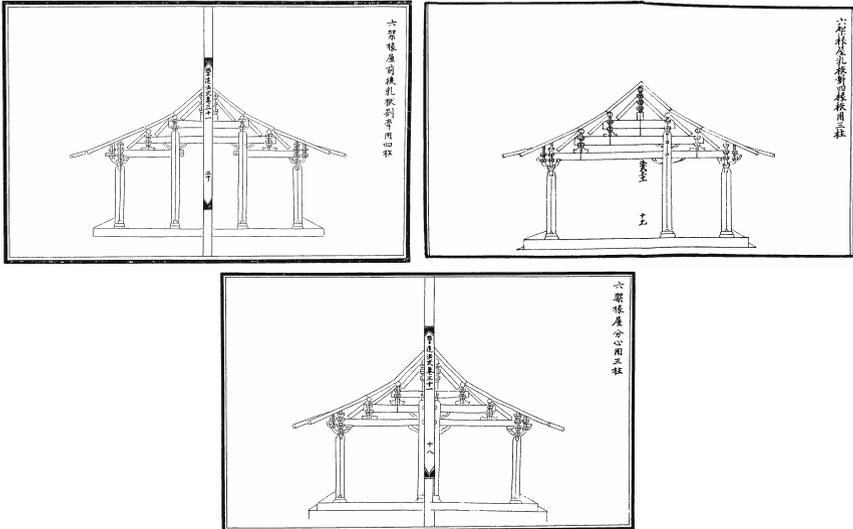


Fig. 3, a-c. Six-rafter *ting* hall sections [Liang 1983: 319-20]

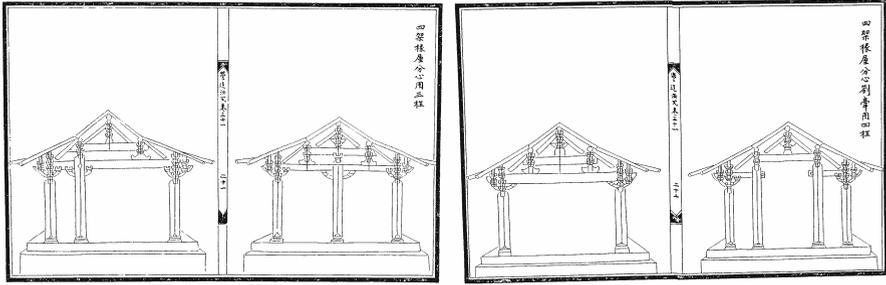


Fig. 4, a–b. Four-rafter *ting* hall sections (Liang 1983, 320–21).

Determining whether these drawings are reliable for our purpose is our first test of (extragrammatical) judgement. They appear at least 250 years more recent than the text, as the building components clearly reflect the style of the Ming and Qing dynasties (1368–1644, 1644–1911). It may be that Ming or Qing artists copied the drawings from an earlier edition (now lost), in the process substituting contemporary details. For our purpose, though, we can consider them simply diagrams, and judge that as such they probably preserve the information relevant to us: the depth of the building (measured by the number of segmented rafters in the roof structure) and the number and location of columns.

As we can see in the corpus, the building depth is 4, 6, 8, or 10 rafters; there is one column below the front eaves and another below the back eaves; and inside the building there may be additional columns below purlins (where adjacent rafters meet). It might seem obvious that we should infer the following guidelines for our grammar:

1. The number of rafters must be even.
2. The number of rafters must be not less than 4 and not more than 10.
3. Columns must be located below purlins (not between them).

However, we cannot be certain about any of these conclusions. For the number of rafters, a number such as 11 may be unlikely, but who is to say it is impossible? Perhaps an 11-rafter building once existed, but has since been lost. Perhaps it is a black swan, waiting to be discovered. In fact, if we consult extant buildings, we find that they overwhelmingly conform to the first two guidelines. We also see 2-rafter structures, which we might dismiss as being only gates and not buildings. In the Ming and Qing dynasties, we see buildings which appear to have an odd number of rafters, but we might consider the single curved rafter at the ridge as a fusion of two rafters. If so, we could dismiss these buildings as being irrelevant variants of even-numbered ones or simply anachronistic. Thus we might still keep the first two guidelines, but only after searching for and evaluating relevant evidence, and convincing ourselves.

The location of columns is trickier. Extant buildings with columns between purlins, not below them, actually do begin to appear about 150 years after the publication of the *Yingzao fashi*, in an area by then long lost from Song control (see fig. 5).⁴ The question now is whether we should consider such buildings as examples of Song standards.

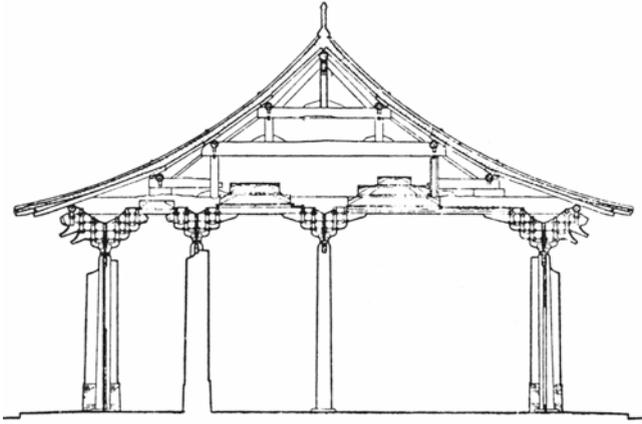


Fig. 5. The Sanqing dian of Yongle gong (1262), with columns located between purlins [Du 1963]

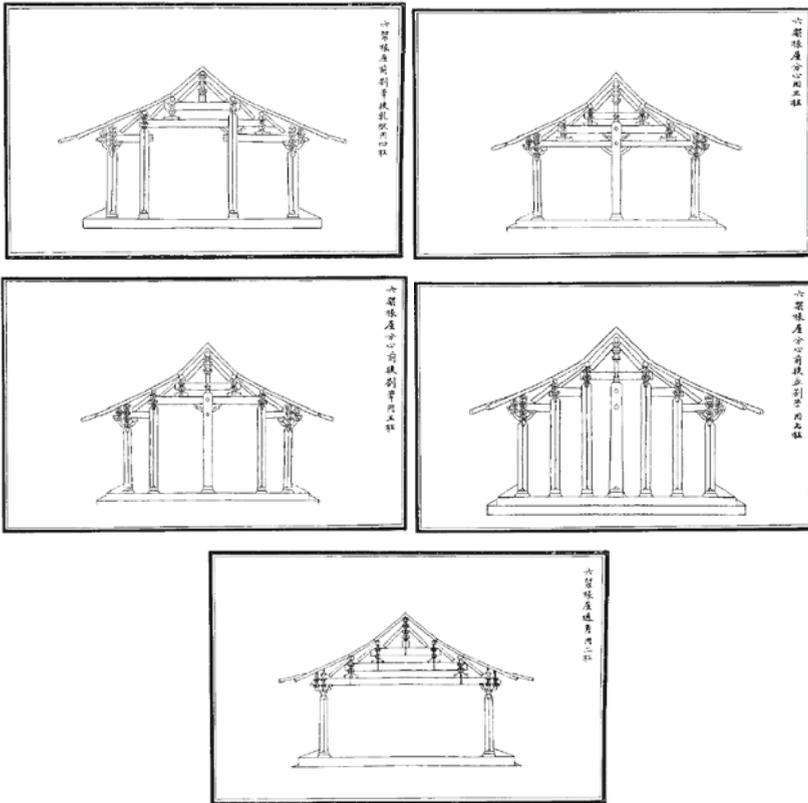


Fig. 6, a–e. New 6-rafter *ting* hall sections generated by our grammar (redrawn in the style of the *Yingzao fashi*)

We might survey extant buildings (and secondary evidence such as paintings and sculpture) and in that context conclude that columns between purlins represent a significant structural departure from previous practise. If so, we might argue that such buildings do not belong in the style defined by the *Yingzao fashi* and so should not be generated by our grammar. This would uphold the third guideline.

On the other hand, others might argue that the stylistic break at the end of the fourteenth century (between the Yuan and the Ming dynasties) is far greater (see [Liang 1984]), and that columns between purlins are simply variations within the style of the *Yingzao fashi*. They would then discard the third guideline. Again, it matters what evidence we examine and how we evaluate it; this requires historical judgement, not grammatical technique.

The guidelines we have discussed above are actually generic predictions that we evaluate *before* the grammar can generate them. Assuming that we have confirmed the three guidelines, we now have several predictions for 6-rafter sections, five of which we show in fig. 6.

Let us look at the fourth design, which has seven columns. How should we evaluate it? There is no such extant building, and we might invoke an architect's understanding of function to conclude that a building with no large spaces is unusable. Others might object that extant buildings are not government buildings, but temples, which require large spaces for gatherings. They would find the lack of built evidence irrelevant, and might instead search for a better understanding of how government buildings were used, perhaps in government documents. They would then head for the archives.

The fifth design has no interior columns; this arrangement has its own name: *tongyan*, or *clear span*. The lowermost beam, being undivided by interior columns, is 6 rafters long. In the corpus there is one clear span section, four rafters deep (fig. 4, 3rd section); there is no such section for depths of six, eight, or ten rafters. Should we take the 4-rafter clear span as representative and conclude that a 6-rafter clear span is legal? Or should we take the absence of 6-, 8-, and 10-rafter clear spans to be decisive? We might also note that a 6-rafter beam is seen in the corpus (fig. 2, 2nd section), which would suggest that 6-rafter-long beams were physically available and that 6-rafter clear span halls were structurally feasible. This might prompt us to study the absolute lengths of beams in extant buildings in various times and places to understand what materials were available, when, and where. (It is nice to notice that this is yet another example of embedding: the beam can be read as a subunit of the building or as a member with an absolute length, because it is both.)

This example shows the type of knowledge and judgement that go into the development of a mechanism to evaluate the predictions of a grammar. What is important here is that this knowledge and judgement have little to do with grammar and much to do with virtually anything else that we find relevant. By contrast, working out a grammar that produces designs that the mechanism finds legal is a relatively straightforward technical exercise. (Only relatively, of course: judgement is still called for in creating a grammar that explains the basis of the style clearly and persuasively.)

Conclusion

We have seen that, to evaluate design predictions credibly, we must exercise our judgement in matters that are unrelated to grammars. However, this is not cause for despair. On the contrary, the combination of grammars and Stiny and Mitchell's

framework is a powerful tool with which we can confront the paradox of hypotheses without direct evaluation. Grammars make explicit where designs come from, but they also can help us become aware of how those designs are evaluated. We should be mindful of the operational subtleties in constructing an evaluation mechanism: what knowledge we bring to bear, what criteria we develop, how we apply them. Then we can say what we are doing, and we can debate differing views. Thinking critically and imaginatively in this way is the essence of humanistic study.

Our approach to evaluation is consistent with the views of both Frege and Wittgenstein, which are sometimes thought to be contradictory. In Frege's view:

there must not be any object as regards which the definition leaves in doubt whether it falls under the concept; though for us human beings, with our defective knowledge, the question may not always be decidable. We may express this metaphorically as follows: the concept must have a sharp boundary [1977: 259].

A grammar defines a style with sharp boundaries, but the impossibility of equally sharp evaluation arises precisely because of our "defective knowledge." Wittgenstein [1958], on the other hand, insists on the possibility of vague boundaries. Each of our grammatical boundaries is sharp, but, because you and I may disagree or because, like Siza, you or I may even hold differing views simultaneously, they are also changeable and not mutually exclusive. Taken together, they are vague.

Style is not "out there," waiting to be discovered. Rather, it is constructed, both through the grammar and through the mechanism by which we evaluate our grammar's predictions. And it is the quality of this construction, more than the style itself, that should interest us. A definition of style is only as good as its evaluation mechanism. In this sense, to attend with care and self-awareness to both grammar and evaluation is to compute style.

Notes

1. This is not a new idea. As Dijkstra said: "I view a programming language primarily as a vehicle for the description of (potentially highly sophisticated) abstract mechanism" [1976: 9].
2. Paraphrased from an e-mail from Duarte dated 15 August 2003.
3. For an introduction in English, see [Glahn 1984]; see also [Li 2002].
4. This disposition is known as *yizhu* (shifted columns).

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