Teaching Design By Analysis of Precedents

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Abstract

Designers, using their intuitive understanding of the decomposition of particular design objects, whether in terms of structural, functional, or some other analytical framework, should be able to interact with computational environments such that the understanding they achieve in turn invokes changes or transformations to the spatial properties of design proposals. Decompositions and transformations of design precedents can be a very useful method of enabling design students to develop analytical strategies. The benefit of an analytical approach is that it can lead to a structured understanding of design precedents. This in turn allows students to develop their own insights and ideas which are central to the activity of designing.

The creation of a 3-D library of user-defined models of precedents in a computational environment permits an under-exploited method of undertaking analysis, since by modelling design precedents through the construction of 3-D Computer-Aided Architectural Design (CAAD) models, and then analytically decomposing them in terms of relevant features, significant insights into the nature of designs can be achieved. Using CAAD systems in this way, therefore, runs counter to the more common approach of detailed modelling, rendering and animation; which produces realistic pictures that do not reflect the design thinking that went into their production. The significance of the analytical approach to design teaching is that it encourages students to represent *design ideas,* but not necessarily the final form of design objects. The analytical approach therefore, allows students to depict features and execute tasks that are meaningful with respect to design students' own knowledge of particular domains. Such computational interaction can also be useful in helping students explore the consequences of proposed actions in actual design contexts.

1. Motivation and Strategy

Recognition of the failure of CAD systems within design education has gradually reached a point where radical strategies for modifications of the approach to the use of computers within architecture and design schools is called for.

Firstly, the distinction between the environment of the design studio and the architectural office (for which the majority of systems are designed) is a critical one. Although the acronym CAD purports to represent *computer aided* ***design***, in fact *coniputer aided* ***drafting*** would be a more appropriate title, since to date this has been the main application of the more successful systems. System design has been largely a case of the recognition of one or more overt forms of architectural process which can be adequately supported by a computational environment. In the case of drafting processes this has proved relatively profitable (in more than one sense), with the result that *dumb* drawing systems are widespread permitting the manipulation of basic elements in a manner which attempts no recognition on behalf of the system of the *global* meaning of the collection of elements. Those *functionally oriented* systems which have sought to incorporate some degree of *intelligence* by way of so called *analytical* facilities (such as heat loss calculations, quantification, and use of predetermined constructional methods) have sought to recognise and clearly define certain processes within architectural production which are then represented and supported by systems. The *prescriptiveness* of such systems, the inflexibility of these recognised processes to the changing demands of the designer, has resulted in rapid redundancy with little use.

In the context of the British studio based format of design education, these systems retain little relevance to the teaching of design understanding. Although drafting systems and *function-oriented systems* may offer some assistance in the presentation and assessment of design proposals (albeit according to limited criteria) in a didactic sense they retain little significance.

Interaction with CAD systems *in an educational context* should, instead, allow design students to establish insights into the complexities of established design sources* as well as using them as enhancing tools for exploring their own developing design ideas. In architectural practice, the products of CAD systems are objects that have to be evaluated by designers, and therefore need to be in forms that are meaningful to them. The widespread use of computers should not inhibit the evolution of design knowledge. It is most often the case, however, that CAD is taught predominantly as a technical subject in which mastery of the use of the interfaces to particular systems is the be-all and end-all of this subject. Our view in this paper is that CAD teaching should be guided by design issues, rather than by new technological developments in the area of computing. Approaching CAD teaching in this way encourages more purposeful developments that may be genuinely useful in contributing towards the communication of design thinking. We need to provide computational environments therefore, that can be used by designers communicating with each other, in which they have full control over the descriptions held in the environment.

Before describing our own approach based upon the analysis of design precedents, we will first look at exactly what kind of models are implicit in the CAD systems currently available to design students, and assess how satisfactory these models are for the representation of design concepts. We will also take into consideration the significance of the physical scalar model in both studio and practice, and attempt to determine its essence as an architectonic tool.

We will begin with a review of the concepts embodied within existing CAD systems. Using critical considerations of architectonic models, we will examine new

* Existing systems have attempted to recognise specific aspects of design which due to their overt nature can be considered as a *process.* This, by its very nature assumed that elements of the holistic entirety of design are definable and can be systematised. Collective understanding of their metier by designers consistently denies this assumption, instead, reinforcing the converse appreciation of design as a complexity of internalised (and often hidden) and generally personally specific procedures. In totality, its vagueness, and lack of definition reinforces the need for an extended *apprenticeship* necessary to acquire the skills which help to constitute the *act* of design.

potential educational possibilities which have begun to emerge partly as a result of a second year CAD exercise set recently at the University of Sheffield. In it, we sought to examine the efficacy of 3-dimensional CAD modelling facilities for the study of specific design precedents. Supported by a review of established analytical design methodologies, the implications for CAD usage will be assessed.

Lastly, this short document will present a series of specific concluding points which will generate a coherent strategy for change. No attempt will be made to create a working system, but instead a set of ideas that could be used as the basis for a specification.

2. Computer Aided Design Models

CAD applications can be classified broadly into three categories [Bijl, 1989], roughly in descending order of ambition:

- *integrated data-oriented systems* targeted at whole design domains, supporting a range of tasks
- *function-oriented systems* developed to perform specific tasks where function corresponds to a user's perception of a task in some application domain.
- *dumb systems* which store and manipulate words and drawings without anticipating what the words signify or the drawings depict.

Integrated design systems employ a *single* model to accommodate all information describing a design object. This model attempts to correspond to knowledge supplied by different people throughout the design process. The system has to be capable of supporting a range of operations on the same model and to support peoples' different interests during the course of designing an object. The general model of design implied by integrated systems is based on the assumption that a design is a single coherent description of a design object, and can supply information for many varied design tasks. User experience of such systems, however, frequently illustrates how implementations of these kinds of general models do not correspond adequately to the variety of temporal models that exist within the building profession, such as those of structural engineers, quantity surveyors, and architects. There is always a greater or lesser but very significant degree of mismatch which was not anticipated in the computer implementation, and which leads to unforeseen problems of use. In addition, when considered in the sphere of design development, such integrated systems, by virtue of their design, necessitate *explicit* descriptions of design intentions/proposals, which are generally inappropriate to the level of resolution of proposals in the early, highly formative period of design. The necessity to accommodate precise dimensional and numerical qualities of highly resolved designs renders integrated design systems *unwieldy,* if utilised for rapid transformations of descriptions.

Function-oriented systems are systems in which an anticipation of some specific task in a user's world forms the primary motivation for developing the computer system. An example might be the calculations required for environmental appraisals to evaluate the performance of proposed designs for buildings. The anticipation of *task is* paramount in providing a specification for required system operations, and the organisation of *data* is regarded as subservient to the task. Typically, these tasks each require separate input and provide output which users have to translate into their own perceptions of design. The critical assumption implied by the function-oriented approach is that design products are a loose summation of the results of tasks applied to parts of design objects. In this view, designs are regarded as solutions to problems and designing seen as a kind of problem-solving process involving analysis, synthesis, and appraisal. Analysis in this context refers to the decomposition of problems into parts which are known to be overtly tractable and therefore computable. Synthesis refers to a fusion of parts into a whole which is more than the product of composition. Appraisal refers to the evaluations of parts which are defined by measurable goals and which are computable. This process is assumed to be cyclic, such that results from computer appraisals prompt modifications to the designer's synthesis.

The function-oriented approach requires *discreteness* of decomposed parts of a design in order that these parts can be quantified with computable functions. Problems arise from the boundedness of discrete parts and the consequent notions of classification and typing within a user's domain, which imply particular perceptions of design. Newer computing technologies such as expert systems, and shape grammars (examined in more detail in §3), whilst having the potential to be used in ways which are much more useroriented, have often been embodied with the same kinds of assumptions that have bedevilled function-oriented systems.

Again, just as with integrated systems, function-oriented systems seek to represent specific quantitative aspects of design proposals. The knowledge gained as a result of analyses such as heat-loss calculations, for example, is often of little formative assistance in the early development of design proposals. The criticism of functionalism which has occurred in the past two decades [Rossi, 1982], has indicated that conceptions of design which overemphasise the satisfaction of particular quantitative factors in a brief, inevitably lead to inadequate design solutions. Such quantitative assessments can be seen to be of diminished significance in design education. Complementary to this criticism is the recognition that systems should more adequately support qualitative considerations of design proposals, and more specifically, the *expression* of these qualitative aspects.

Dumb systems usually take the form of drawing systems in which operations invoked are not conditioned by any need to preserve an intended model a user might have in mind. Notions of correctness are matters for the interpretations of users. The advantage of treating drawings in this way is that they can be stored, recalled, subjected to edits and transformations, and reused. The generality and therefore the potential for widespread application of dumb drawing systems is dependent upon such systems not anticipating what it is that drawings depict. This then avoids conflict with the various states of knowledge within different users. The act of drawing requires an environment in which people can depict their own thoughts and evoke corresponding thoughts in other people. The use of computerised drawing systems differs from ordinary drawing practice, however. Users have to think of drawing as a deliberate act that is separate from thinking about depicted things, and drawing procedures have to be executed in a logically structured environment. Problems arise when the ways in which users expect certain kinds of drawing operations to work differ from their experience of using the system. We need to extend and develop such systems to make them more acceptable to designers. A way forward may be to place more emphasis on the *user--definition of drawing operations and transformations* of objects.

3, Shape Grammars

We have so far only provided a very broad classification of CAD systems. There are of course systems which have additional properties, as well as systems which contain features from more than just one of the above categories. One such model we will focus on here is that of *shape grammars.* The model of design embodied in shape grammar systems is one consisting of rules operating upon explicitly defined and highly specialised shapes. The shape representations of design objects are typically expressed as relationships between parts of shapes made up of lines. Shape grammars are implemented as sets of replacement rules. Lines that are composed into shapes exist without reference to other things in a design domain that these lines may represent. In this sense, therefore, shape grammars have a similarity with dumb drawing systems. Labels may be attached to shapes to differentiate between rules applied to similar shapes. Although there may be a sense in which these labels invoke semantic information in users, they are only of *syntactic significance* within the shape grammar system itself.

Shape grammars are based on the view that significant properties of design objects can be abstracted from existing instances of designs, and that these can be understood in terms of a syntactic structure. Formal grammars have been devised which correspond to perceived abstract structures of designs. These grammars can then be used to generate properties of designs which preserve properties of existing designs [Knight, 1980; Koning and Eizenburg, 1981]. The *prescriptive* nature of shape grammar rules, however, reduces users of such systems to passive roles in the design process. In shape grammar systems,

> *"...the mode of operation is to identify by pattern matching opportunities to which the user reacts;"* [Wojtowicz and Fawcett, 1985],

meaning that the user can say yes or no to the system instantiation of design changes. It is this characteristic of shape grammars in use that makes them more akin to expert systems than to CAD systems.

It is important to ask where the relationships that determine shapes come from. This question is crucial since it is the declared intention of shape grammarians that grammars should perform a generative role and should be capable of generating new instances of designs. The practice has been to study exemplars of good design by referring to the past works of individual designers. Any one system, however, only represents a particular type of design, and gives no insight into how this might relate to other designs. The method has been to infer from their drawings the abstract relationships between lines which they are believed to have employed (implicitly or explicitly). These relationships are then interpreted as particular grammars and implemented as rule systems. Thus we have examples of newly designed Palladio villas [Stiny and Mitchell, 1978], Frank Lloyd Wright houses [Koning and Eizenburg, op. cit.], generated by their grammars long after these designers have died.

This line of argument is presented as a general and practical justification for the intellectual effort invested in studies of shape grammar. A test of this argument, however, is to ask whether Frank Lloyd Wright, if he were alive and practising today, would still be designing in his style of the first quarter of this century? If he would, then perhaps these buildings may no longer be acknowledged as being good designs. Essentially, the shape grammar argument doesn't address the following two important issues:

- How design styles evolve in response to a changing world.
- How fashions and trends themselves affect the rules by which designs are judged to be good.

Shape grammars appear to rest upon an absolutist view of design which does not take into consideration the context of *design evolution.* But it is just *this* quality that is crucial to the teaching of design principles, in which it is essential to demonstrate to students how certain *general* principles recur in different design contexts (e.g. [Clark & Pause, 1985]).

If shape grammars can detach themselves from *particular* instances of design such as Palladian villas, then we can envisage how they might be made more generally useful. A *design grammar system* should hold representations of a variety of design precedents. Each design precedent should be decomposable within the system into known features and forms. These features and forms can then be viewed more generally as objects with certain properties. These properties in turn characterise instances of designs through certain rules of combination. Design grammar systems based upon rules could be used in a teaching context by allowing students to modify existing rules and add new ones, and observing the effect of these changes upon new instances of design precedents. Design students should be able to formulate their own grammars and add their own rules. Students can observe directly, therefore, how designs evolve through changing relationships between graphical parts and properties.

Although shape grammars provide convincing descriptive and generative rule systems, they still only provide a very low level of analysis in terms of conveying architectural knowledge in an educational environment. The operators used, and the geometrical way in which shape grammars are set out, are difficult to relate to the architectonic three-dimensional understanding of designs. It is interesting to note that W. J. Mitchell [Mitchell, 1990] refers to Durand's *"Precis"* [Durand, 1802], as an early example of a grammar system. But the same criticism of Durand's methods (in a generative sense) also apply to Mitchell's/Stiny's Palladian grammar which generates *plan formats* (i.e. 2-D graphics) only. The criticism which Oechslin [Oechslin, 1986] makes of Durand's axial and grid schemata as a geometrical *mechanism* apparently devoid of any poetic intentionality, reliant simply upon *economy* alone, when in fact the existence of such poetic intentionally is undeniable, can also be directed at Mitchell's work on *Palladian* grammar. Such a grammar can of course be set out as a derived shape system, which can, like Durand's axial and grid schemata, supposedly operate in isolation from the totality of holistic understanding which constitutes architectonic design. However, its significance without the background understanding and appreciation of three-dimensional form, space, and proportion, is highly limited.

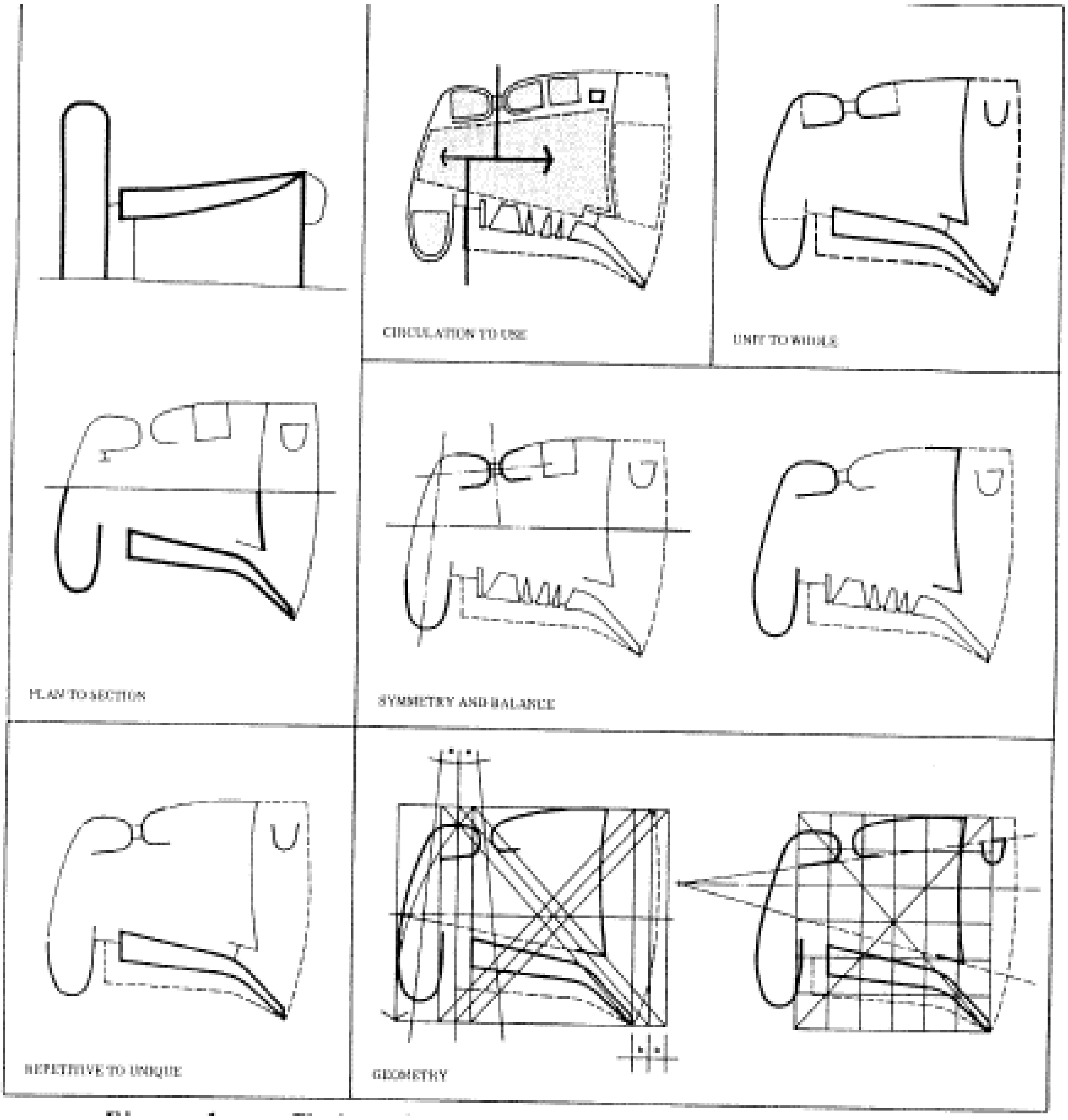


Figure 1: Clark and Pause use a structured graphical format illustrating a series of analytical criteria that can be applied to many design precedents.

· <u>Assumptions of CAD</u>

Conventional CAD systems, therefore, make very strong assumptions about the nature of design, and these assumptions are often taken for granted by their users. A primary assumption of *hierarchical decomposition* presumes that designers break down problems into several smaller sub-problems, and then proceed to work on these separate components. Associated with this assumption of hierarchical decomposition is the related assumption of *discreteness,* which presumes that once a design problem has been decomposed, it then becomes possible to generate designs for relatively discrete parts. A shape common with, and would be useless for generating tenement blocks. Integrated CAD systems then subject each of these discrete parts to separate tests. The completed component designs are then assembled together and further tests of performance applied to the assembly as it is built up.

The hierarchical decomposition assumption is applied not only to spatial objects, but also to the organisation of different architectural systems e.g. structural, heating, ventilation.

Hierarchical decomposition is not necessarily a *bad* assumption to make. However, it does tend to be used to the exclusion of other approaches of a more holistic nature. One could argue that good designers, whilst focusing on a decomposed part of a design, somehow still manage to relate this to an overall view which then has an effect on the more detailed design.

A further yet important consequence of adopting the hierarchical decomposition assumption within CAD systems is that it brings with it the associated problems of how to support the access and manipulation of nested composite objects. There are many alternative ways of implementing relationships between an object and its sub-objects and between an object and its parent. Different object/parent relationships lead to the implementation of different inheritance mechanisms. Most conventional CAD systems, for example, only support the access of sub-objects through their parents. This often leads to an overemphasis on discreteness since it becomes necessary to create new kinds of parent objects to work with.

Hierarchies also require the mechanism of composition, or compositional semantics, to derive the description or meaning of a structured object. We should note here that there are alternative strategies for extracting meaning such as *differential* [Pettit, 1975], or *analogical* semantics [Sloman, 1975].

1. Revised Considerations of Design

Design requires human abilities which cannot be externalised or made objective outside people. Formal techniques within computers on the other hand, condition forms of expressions as well as transformations. We need to look at how these techniques relate to other forms of expression used by designers, and at what kind of interaction is desirable between designers and machines. It is our view that computational environments should support any instances of forms of expressions and transformations, without attempting to know what these expressions mean to designers. Computational operations should be limited to *domain independent functionalities* that are well understood by designers, and that can be used on expressions that serve communicative intent between designers. From a domain specific point of view, we envisage designers as responsible users of machines.

"analysis: an-al'is-is,n.a resolving or separating of a thing into its elements or component parts: ascertainment of those parts: a table or statement of the results of this: the tracing of things to their source, and so discovering the general principles underlying individual phenomena." [Chambers, 1972].

"analysis and design are two parallel experiences, albeit different, which share a common cognitive end...

There exists no break between the moment of analysis and the moment of design, since the object of analysis is - in a strict sense - the object of design itself."
[Grassi, 1982].

Having formulated those criticisms of existing CAD models set out above we will now focus on a particular area of educational study which substantially reinforces the conclusions derived. This area of study is the formal analysis of design precedents, which utilises either a pre-existent formal model of the precedent held in a *library,* or alternatively a model constructed by the designer carrying out the analysis.

Unlike the quantitative *analytical* facilities offered by most *integrated* or *function-oriented* systems, the formal analysis of these types of design precedents would be undertaken in an intuitive and qualitative fashion which would place emphasis on the designer developing, and adequately expressing, his understanding of specific aspects of those designs. Focus of concern lies therefore, not with the establishment of ever greater levels of sophistication of mechanised analytical capacities retained by computational systems, but instead on the ease of facilitation with which the designer can utilise expressive and transformational capabilities offered by the machine to investigate in a didactic manner the formal qualities of the model.

Accepting for the present the criticisms of CAD models in relation to this specific didactic objective, two predominant issues emerge which we will now address. Firstly, what is the essential nature of the architectonic model, and how does this inform the desired qualities of the formal analytical model supported by the computational environment? Secondly, what are the primary considerations governing any purely formal analysis of design precedents and to what degree can these be adequately supported by existent computational capabilities and techniques?

1. The Architectonic Model

A dictionary definition of a *model* gives:
" Representation in three dimensions of existing person or thing or of proposed structure, esp. on smaller scale ...; simplified description of system for calculations etc."
[Chambers, 1972]

The apparent ambivalence towards the nature of the model outlined by these two generalised criteria provided by the definition is perhaps best illustrated by the dichotomy between the computational models being developed predominantly for practice usage, and the physical models which are prevalent in the architectural schools. This prompts the question, is the model simply an attempt to *represent* desired reality in the most exhaustive way (as most often utilised in the office), or alternatively should the model be recognised as a *presentation* of the essential ideas of the design? Commercial solid modelling systems are accelerating towards ever greater levels of accuracy in representing ultimate reality, the benefits of which are indisputable in certain applications, with facilities for modelling forms (curves, extrusions etc.) and sophisticated rendering capabilities. If we compare such sophisticated presentation formats with corresponding studio design work the contrast amplifies the differences between the two conceptions of the model. The importance of this degree of sophistication in an educational environment is questionable, whilst conversely the importance of the *presentation* of design intentions in an expressive manner is valid.

What becomes apparent is that the architectonic model, as an expressive and exploratory tool in design, relates more closely to the definition of a *simplified descriptive system,* but one which is utilised not for quantitative calculations, but instead for qualitative and intuitive *analysis* of specific criteria of the design proposal. Exact correspondence between the model and intended form (or existent form in the case of a design precedent) is not an essential maxim. In this respect, like a theatrical set, the essential and significant qualities are retained whilst inessential ones can be safely omitted without lack of clarity. As Hubert stated [Hubert, 1980]:

"perhaps the model concretizes the ontic condition of the project."

Although traditionally, therefore, the architectural model has been considered as a scalar representation of the intended final form, the analytical model is significant because it deliberately omits specific features to highlight others, and in fact many different formats for the analytical model exist, all significant for their essential aspects, often realised as schematic or diagrammatic representations of a design.

1. Formal Analysis of Design Precedents

Formal analysis of architectural design precedents is a long established educational technique, but with a wide variation in methodologies and intentions. A series of recurrent concerns and procedures can be seen to emerge from these methodologies, and it is informative to elucidate the more important ones in order that any proposed intuitive analysis of CAD models according to formal criteria can be carried out against this existing theoretical background.

Primarily, in any domain which is restricted to the specificity of form we should ask, what are the generative factors having a governing influence upon the derivation of form? Baker [Baker, 1989] proposes that form can be considered as a response to three specific forces: site conditions, culture, and functional requirements. His elaboration of these influences on form can be further summarised as follows:

GENIUS LOCI	: the specificity of place
POETICS	: semantic and analogical intentions
CULTURAL and SOCIO-ECONOMIC ENVIRONMENT	
TOPOGRAPHICAL CONTEXT	: immediate physical environment
PROGRAMME	: totality of functional considerations
MOVEMENT & CIRCULATION	: incorporating orientation and view
STRUCTURE & GEOMETRY	: incorporating composition

Although it is not the intention of this paper to focus in depth on each of these formal concerns, we will instead select those recurrent significant issues which need to be addressed, and which are relevant to the formal analysis of design precedents held as computational models.

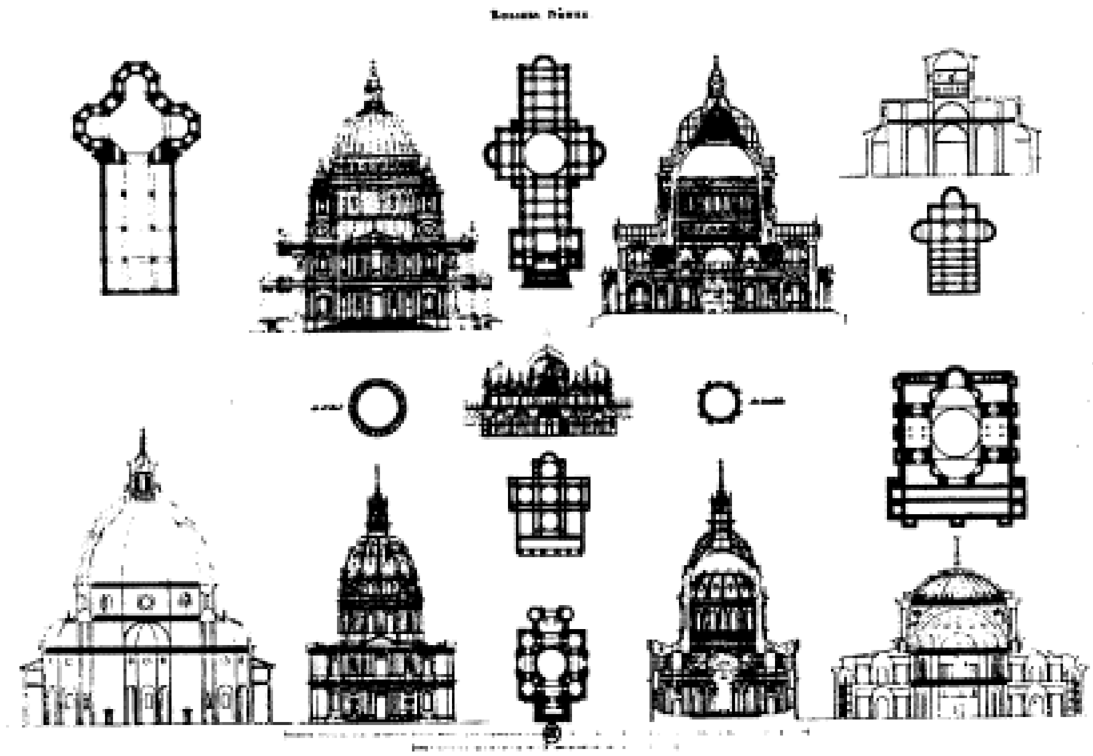


Figure 2: J.N.L. Durand. Systematisation of graphical presentation was deliberately used to allow comparative consideration and suppression of the related concern of socio-economic or cultural contexts.

Firstly, by definition, any *formal* analytical system must fix the consideration of the first three criteria as secondary, related concerns. However their significance on the determination of form cannot be denied or undervalued, and this apparent conflict is a recurrent theme in formal analytical procedures. One of the earliest examples of a structured approach to the analysis of historical precedents which addresses this difficulty, is the work of J.N.L. Durand. One of Durand's two primary works the *"Recueil et Parallele des edifices de tout genre..."* represents one of the first examples of a structured comparative review of ancient and contemporary architectural precedents.

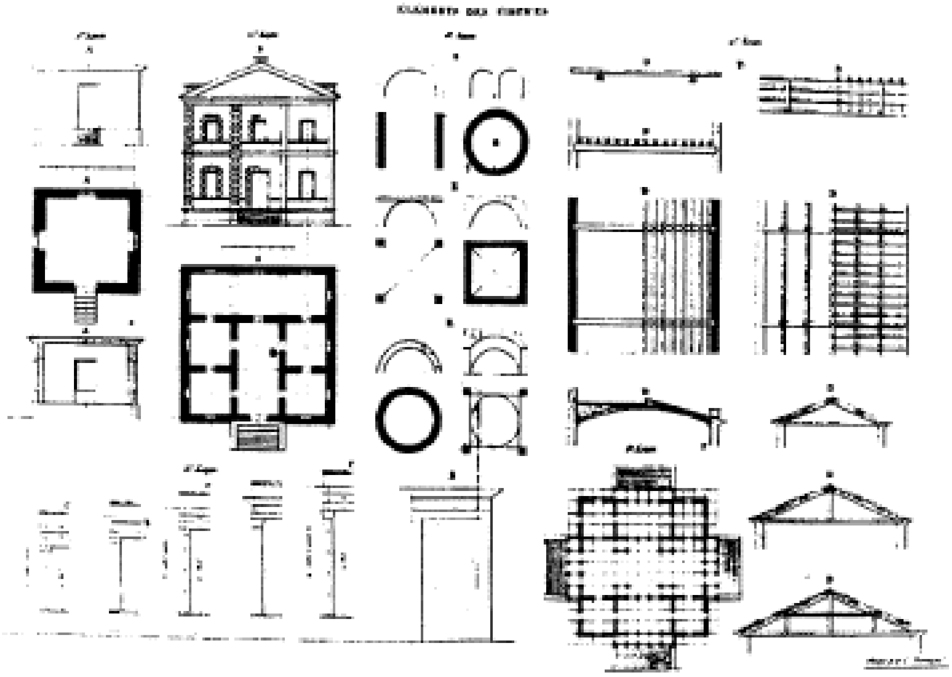


***Figure* 3:** J.N.L. Durand, Elements of Buildings, from *Partie graphique des cours d'architecture* (Paris, 1821). The *elements* could be selected from a source catalogue and systematically combined to produce building *parts.*

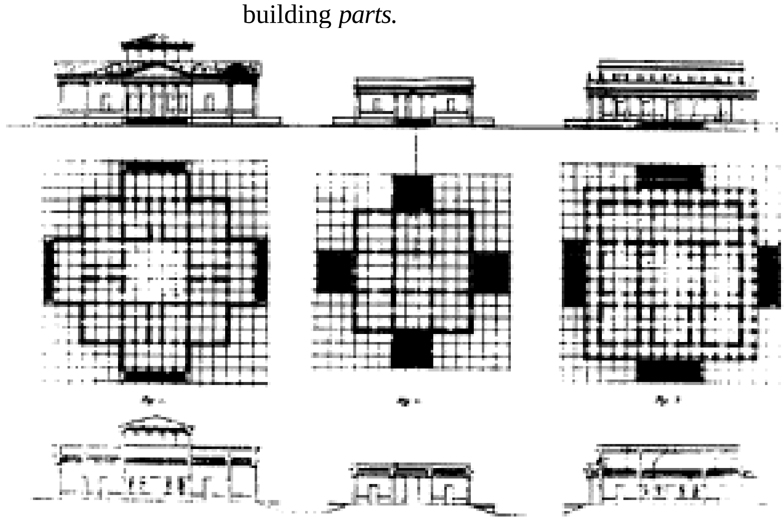
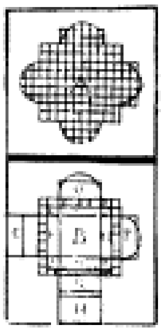
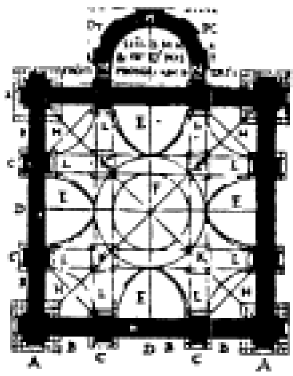


Figure 4: J.N.L. Durand, Horizontal Combinations, from *Precis.* Relationship between combinations of *elements* to form *parts* using grid and axial schemata.



Grid pattern (Cesariano 1521).



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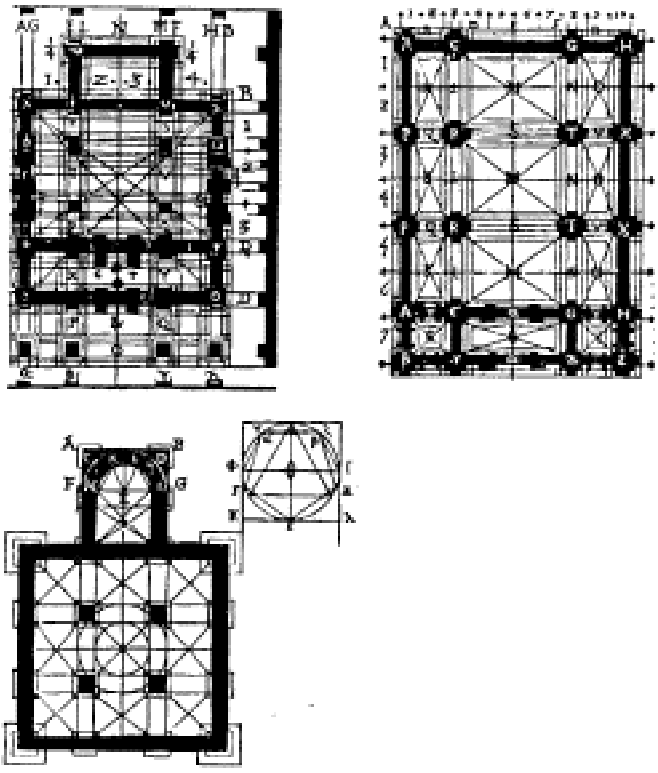

Figure 5: Classical Taxis schemata used for the combination of genera into parts of compositions.

Concurrent with the contemporary concerns of comparative anthropology, Durand extended the comparative study of similar building types which had earlier been carried out by Palladio and Serlio, to include examples of recognised important architectural works from all ages and locations. But in order to supposedly render the influence of cultural location and climate on the appreciation of these examples to a minimum, a rigorous format of graphical presentation was adopted, utilising only the most essential *architectonic details,* with a consistent scale and format. Thus it was intended that through this graphical format, the influence of these associated concerns could be diminished to a degree sufficient to permit a like-for-like comparative review. A parallel strategy has been adopted more recently by Clarke and Pause *(figure 1)* who similarly adopt a consistent graphical format for their presentation of design precedents from a wide variety of historical, cultural and topographical sources.

In a recent analysis of the formal characteristics of the compositional strategies of classical architecture, Tzonis and Lefaivre consider it necessary also to stress the essential link between the formal *structure* of classical architecture, which is the object of their analysis, and the social structure of the classical period which supported it. Their work, however, stresses the validity of a strictly morphological analysis of designs as a primary concern, but based upon the recognition of the existent relationship between form and the social-economic and cultural environment in which it is derived.

This limitation of analysis to architectonic form without the necessity of a parallel analysis of the associated relationships, is a primary strategy which is necessary before similar formal analytical techniques can be applied to computational precedent models.

To summarise this initial discussion on the link between form and the complexities of its *environment*, it is important to briefly refer to the long-standing debate between the existence of *a priori* nonnative principles which can be considered to be inherent in formal precedents, and the alternative understanding of such precedents as a product of a particular period in history, its culture, context and intentions. The former understanding, perhaps best illustrated by the Neo-Classical belief in the primacy of Natural Principles was, as Colquhoun has shown, epitomised by the belief that:

"Architecture, no less than painting, was an imitation of Nature through the intuition of her underlying laws." [Colquhoun, 1967].

Such a belief in constancy of principles was contrasted in the Nineteenth Century by Romanticism and its belief in cultural and contextual relativism, which to a large degree supported the historical eclecticism which predominated.

In summary, whilst the primacy of a strictly morphological analytical approach retains validity either in a traditional or computational environment, recognition of the essential relationship between form and the complexities of *environmental* context must be made.

Secondly, a consistently recurring technique applied to morphological analysis is the investigation of structure and geometry, traditionally categorised as *composition.* Returning to Durand, his second primary work *"Precis des Lecons d'architecture..." is* again, one of the first examples of a structured approach to composition, set out as a governing strategy for the analysis of the precedents given in the *"Recueil".* Having set out the source catalogue in the *"Recueil",* in the Precis des Lecons, Durand set out the analytical method necessary *"to comprehend the complexity), of the general laws governing the totality of the discipline" , outlined* in the form of:

- architectural elements
- composition in general
- analysis of genres

Of most significance to this current review is the general outline of composition, which Durand formulated as two specific interrelated levels. Firstly, the combination of basic *elements,* columns, walls, roofs etc., are organised to form *parts.* This combination of parts can be executed with the assistance of horizontal and vertical graphical formulas, in both plan, section and elevation. Specifically, Durand advocates the use of grid schemata and axial hierarchies, which he believes could adequately govern this primary operation (see ***figures* 3** and **4**). Secondly, these *parts* are composed to form the *whole,* but interestingly this latter process cannot be similarly governed, but must instead be subject to a normative logic which governs this combinatorial order. Strong similarities can be recognised if one compares Durand's compositional strategy with that of Tzonis and Lefaivre, who examines the conception of composition which governed the structure of all poetic works of the classical periods. This is based upon the *techne* of composition set out by Aristotle in his Poetics which consists of three levels of formal devices: *Taxis,* which divides architectural works into parts; *Genera,* the individual elements that populate the parts as divided by taxis; and *symmetry,* the relations between individual elements. An apparent similarity with the structure proposed by Durand can be recognised, although in this case the generative principles set out in their description of the taxis is a synopsis of classical manners, unlike the graphical *formulas* proposed by Durand. However similarities do exist, with each conception being based upon a tripartite categorisation of composition, namely:

- the graphical two dimensional schema adopted for the basic ordering of
- architectonic elements
- those higher level relational systems utilised to govern and control the former two.

A significant differentiation exists between the manners in which these two conceptions of composition are applied to precedents. Whilst Durand attempts to directly relate this method to a broad range of source works isolated from the history of architecture, Tzonis and Lefaivre instead set out their method as a derivation from the theoretical works of the humanist periods and then provide at the end of their book a catalogue of classical works, encouraging the reader to intuitively analyse the works according to the previously set out formal theories. Such a contrast between an analysis which is diagrammatically illustrated beforehand and a one which relies upon guided intuitive understanding for its didactic result, is an important one.

A further recent concern which has emerged in relation to the structured analysis of composition is the assistance and guidance which structural linguistics as a methodology can provide. In fact Villari [Villari, 1990], in his description of Durand's key works, draws attention to the similarities of approach which his three tiered compositional strategy has when compared with the methodology of linguistic structuralism. Structuralism, based on the idea of language as a mechanism for the production of meaning according to syntagmatic and paradigmatic constraints, also relies on the understanding that the meaning of the whole (for example narrative text) is based upon the combination of parts and elements on two levels.

A recent example of the utilisation of linguistic analogies to provide guidance in the structured analysis of a design precedent is Eisenman's penetrating analysis of Terragni's Casa Giuliani Frigerio. Peter Eisenman attempts to schematically and graphically illustrate the relationship between the so called deep level conceptual structure and surface level perceptual structure of the design, based upon the work of Chomsky on syntactic grammar. Although essentially concerned with the formal articulation of the facades, Eisenman illustrates a complex *architectonic* understanding of the transformational devices utilised by Terragni, whether subconsciously or not, to mediate between deep and surface level syntax. His graphical method of using axonometrics is vital also in illustrating the different transformational devices used in this design in contrast to another famous work of Terragni which Eisenman graphically illustrates predominantly by the use of elevations.

When comparing this analysis to a similar shape grammar analysis by Flemming on the same design, the efficacy of the latter in illustrating the architectonic devices inherent is quite limited, although apparently objectively correct.

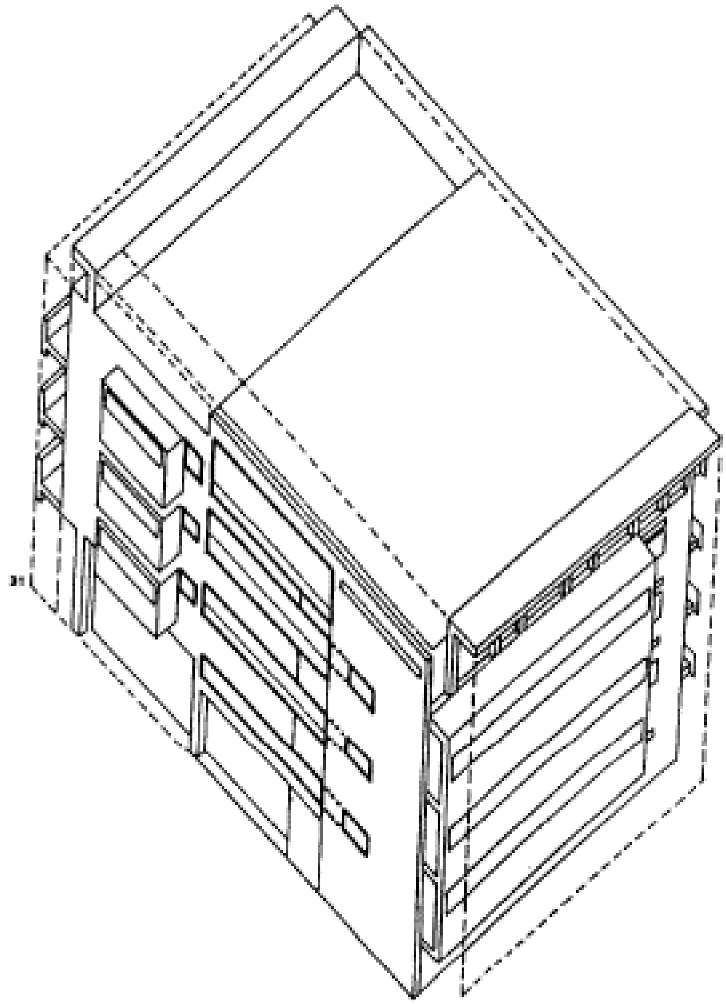

Figure 6:
Eisenman's graphical illustration of his analysis seeks to convey the transformational devices used by Terragni to mediate between his deep level and surface level design structure.

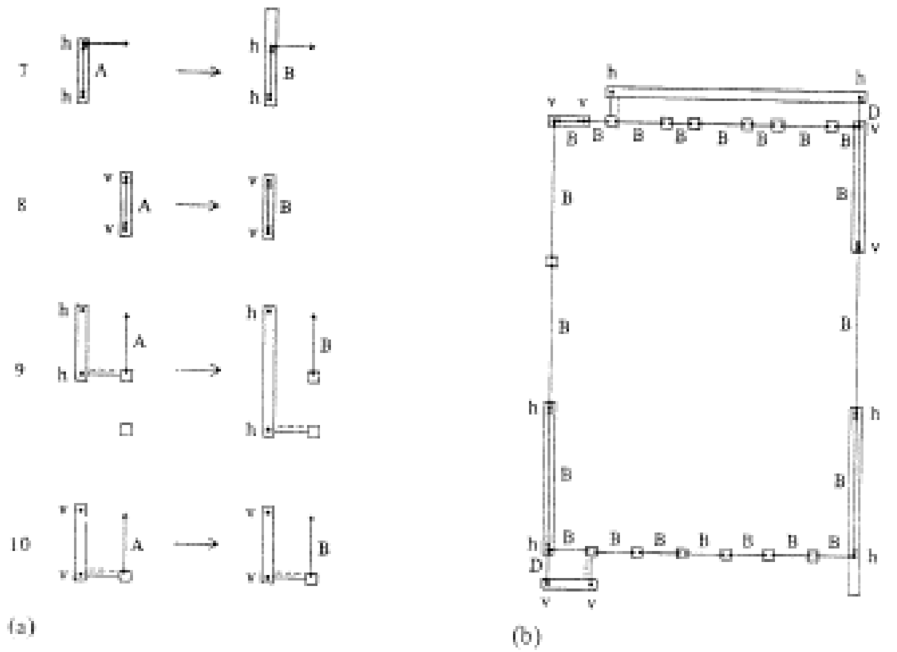

Figure 7: Flemming's analysis of G. Terragni's Casa Giuliani Frigerio uses clearly defined graphical operators which sequentially generate the plan form of the facades.

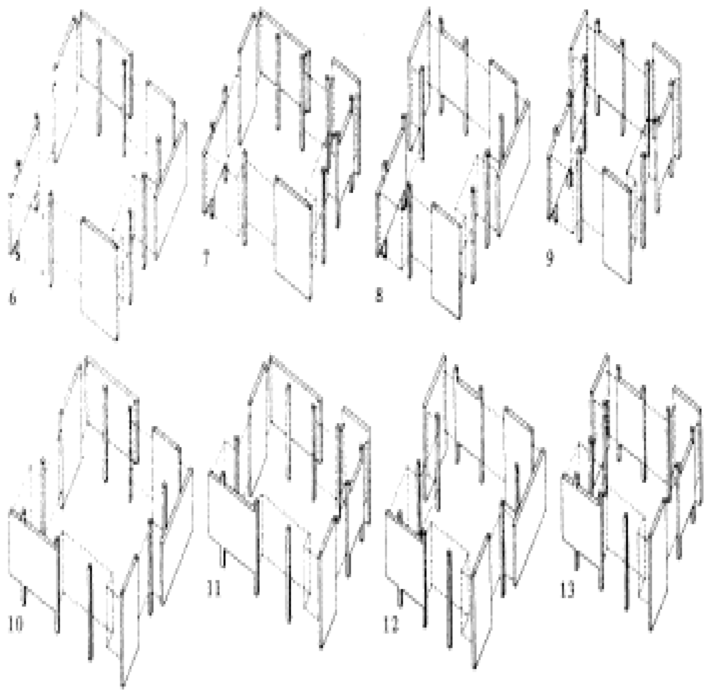

Figure 8: Flemming's shape grammar analysis generates multiple possibilities.

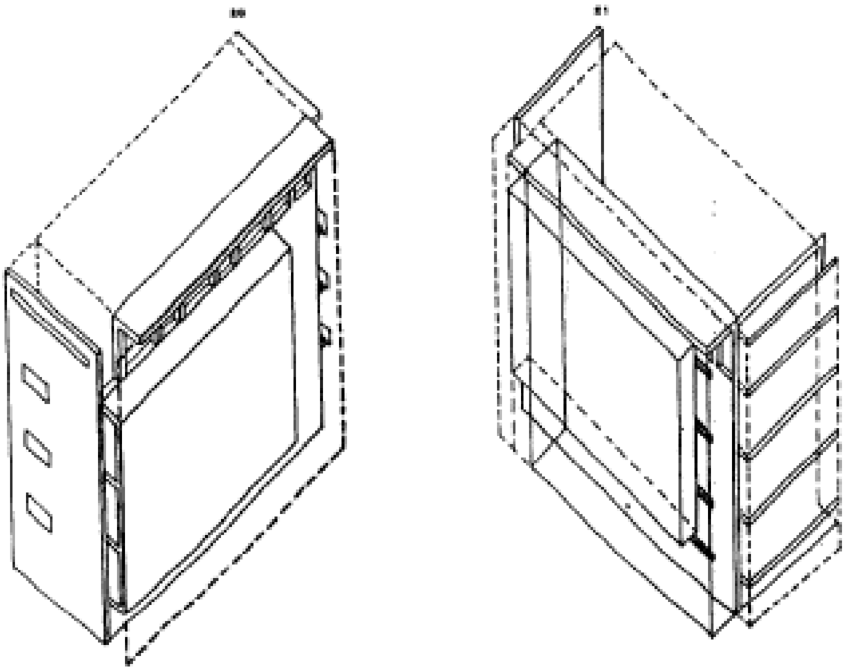

***Figure* 9:** Eisenman's decompositions illustrating Terragni's transformational devices on particular facades.

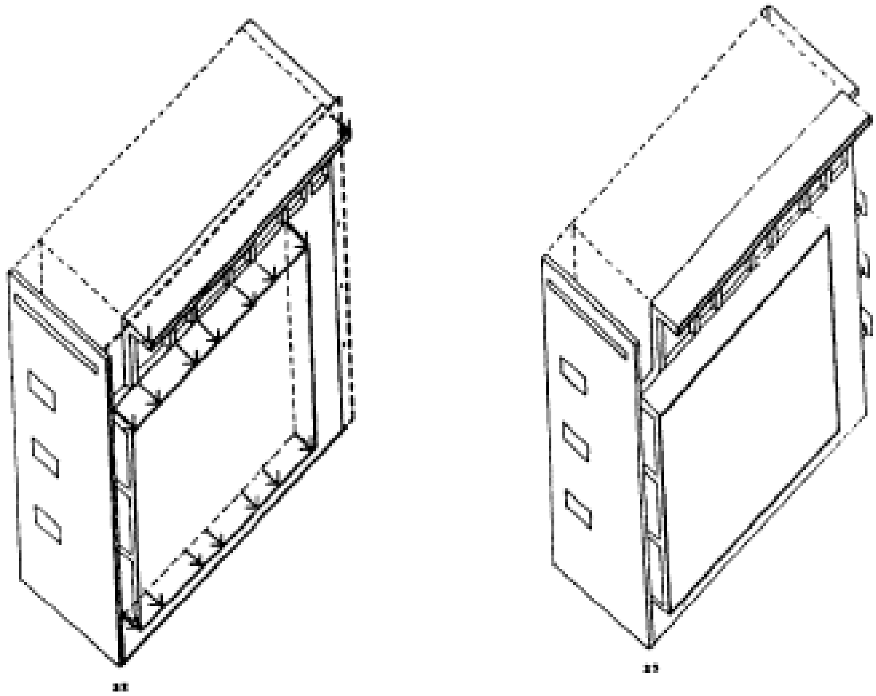

Figure 10: Eisenman's decompositions

Returning again to the governing criteria of form determined by Baker, the importance of movement and circulation on the derivation of architectonic form has traditionally been recognised as a significant component of any analysis. Joedicke [Joedicke, 1985] in his formulation of principles of space and form in architecture, makes clear the significance of the dynamic rather than static perception of architecture with his distinction between *measurable* space, being the constant relationship between fixed objects, and *perceptible* space being the constantly changing relationship between the observer and the former set of fixed relationships of elements. In both the work of Baker and Clarke and Pause, these considerations of dynamic perception are loosely incorporated within considerations of movement, circulation and resultant views. However computational systems now offer enhanced potential for the appreciation of these *perceptible* relationships in a truly dynamic manner in contrast to the static diagrammatic descriptions traditionally given.

Finally, to conclude this current discussion of formal analysis, we must highlight one strategy common to many of the methodologies considered, namely that of *comparative* analysis, which relies upon the appreciation of similarity and difference to highlight characteristics which would not otherwise be so apparent. Colin Rowe in his seminal essay *"The Mathematics of the Ideal Villa"* eloquently illustrates the efficacy of this method, comparing in this case the surprising similarities, as well as the important differences, between Andreo Palladio's Villa Foscari (Malcontenta) and LeCorbusier's Villa Stein at Garches. Of further interest is the manner in which this comparison was carried out, utilising in the main a linguistic technique with relatively little diagrammatic support.

Similar comparative analysis, but in a predominantly graphical manner is again that of Clarke and Pause. Their analysis of design precedents has the specific intention of highlighting by such comparative methods consistent formal devices utilised in architecture of widely varying periods and scales. An inherent facility for comparative analysis can be therefore be considered an indispensable tool for the effective consideration of formal qualities in any analytical system.

Conclusion

Having undertaken this review of analytical methodologies with the intention of informing a computational system for the formal analysis of design precedents, what can be considered the common concerns and intentions which emerge, and importantly, to what degree should each of these be supported in a computational environment?

i. Firstly, the difficulty of adequately representing the particular network of complexities of social, economic and cultural influences on a design represented in a three dimensional format, is apparent in each case. Although consistency of presentation can assist to some degree, it is valid for these complex issues to be accepted but suppressed in a computational environment, but in a manner which is intentionally structured.

ii. Compositional analysis of form is a highly beneficial technique for the understanding of design, although a structured framework to guide this process is critical. Common themes of a tri-partite understanding of composition can be of assistance in guiding this framework. Of crucial importance are the transformational operators in the computational system, together with their relationship to 2-D and 3-D representational models. Such analysis of composition also inherently contains concerns for geometry and structure. Whilst Durand's compositional structure, and also that of the classical one reviewed by Tzonis and Lefaivre are inherently hierarchical, we do not intend that this implies an imposed system specification. It is important to recognise the generalised manner in which they summarise traditional architectonic compositional tendencies, and use this to assist in the structured use of a system to intuitively analyse existent designs and to recognise that systems should permit many compositional tendencies within such loose compositional frameworks.

iii. Structural linguistics offers significant potential for informing new analytical techniques for compositional analyses of design precedents.

iv. Schematic or diagrammatic graphical representation, whether in two dimensional format or in a three dimensional format is essential. Straightforward presentation of the visible form of the design precedent has little value. The ability to intuitively either superimpose onto this, or extract from this a schematic model of some specific aspect of the design is of greater importance. Whilst the first model of the form can be understood in a *primary model* sense (this could be pre-existent library or catalogue), in fact the *secondary,* essentially schematic model intuitively derived by the analyser is of greater value. Format for the *primary model* and creative/transformational possibilities of the *secondary model* are two parallel concerns.

v. Dynamic perception of the formal qualities of design precedents is difficult to achieve through the traditional medium of photographs and text. Aspects of form such as routes, progression of spaces, circulation and views all relate closely to the perception of architecture through movement. Manipulation of three dimensional formal computational models in a *real-time* sense represents the potential for greater appreciation of this dynamic perception of form.

vi. Comparative analysis is a consistently recurring technique, and the facility for comparison within any analytical system is of importance. The added facility to undertake comparisons according to common criteria, by the manipulation of scale, by the superimposition of two or more formal models in the same three dimensional space, and other transformational possibilities, offer computational enhancements of the traditional graphical methodologies.

So having reviewed the nature of CAD as it exists today in relation to the field of design education, we have hopefully highlighted some of the more urgent areas which call for change. Through the explanation of some educational techniques we have also attempted to illustrate that initiation of such change should be generated from concerns within the discipline of design; not, as is too often the case, from the intemalised concerns of software or hardware development. Whilst this paper cannot expect to be all-encompassing in its coverage of a wide and complex field, it is hoped that at least to a small degree we have isolated the nature of significant problems which exist in the application of CAD systems to design education.

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