25 VISUALISATION AND ARCHITECTURE

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25.1 RÔLES FOR VISUALISATION

Visualisation of real and imaginary space is a traditional strong point of architectural education and practice. Even when architectural design is removed from the influence of visual arts, the architect makes extensive and intensive use of visual methods and techniques in the development of a composition, the specification of a design product, the communication of more abstract concepts, and the analysis of design ideas. As a result, knowledge of the world's architecture stems more from published images than personal experience.[a]

Emphasis on visual matters in architecture is not accidental. Human inter-action with natural and built environments is predominantly visual. A wide spectrum of human activities, from aesthetic appreciation to planning of actions, relies heavily on visual information and makes use of visual means to analyse and formulate states and conclusions. Visualisation was a significant aid to understand and control complex processes. Widespread employment of pictorial instructions for e.g. assembling a piece of furniture, putting on a life jacket or tying a tie in a Windsor knot demonstrates the extendibility of relatively simple visual representations.[b]

Recent technological and cultural changes form a new context for a re-evaluation of the significance of visualisation for architecture. Pictures are re-emerging as vehicles for storage, manipulation and communication of information, especially in relation to the visual environment.[c] Such changes are a useful antidote to the aesthetisation of pictorial representation — of which design disciplines are often found guilty. Moreover, they agree with the primary dual purpose of visual representations in designing:

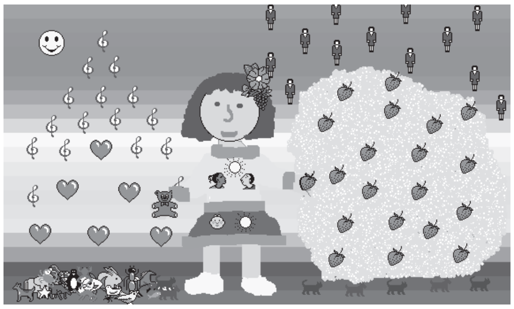
- registering input and output to cognitive processes: internal mental representations are refreshed and reinforced by creating external versions and subsequently internalising them again through perception.
- communicating design ideas: from visual / geometric specification of forms to be built to analysis of functional patterns.

25.5 THE DEMOCRATISATION OF COMPUTER TECHNOLOGIES

The re-emergence of pictures as information carriers relates to computerisation. Current developments suggest that we are entering an initial phase of the computer era. The most striking feature of this phase is democratisation of information technology. After two decades of relatively slow development, restricted to the initiated, the computer is becoming a ubiquitous appliance linked to a new information infrastructure. Computerisation of the workplace was followed by an increasing presence of computers in entertainment and at home.

While the computer's value in increasing efficiency has been amply proven, as in production and management of building documents, its applications have yet to lead to higher quality and performance in designing the built environment or in the built environment itself. The availability of computational power is not matched by methodical utilisation of computing for improvement of current practices. Most computing applications in architecture and planning are sporadic *ad hoc* transfers of technology that may resolve isolated problems, but do little to relate the solutions they provide to their wider context. The transition from analogue to digital media was restricted initially to two-dimensional representations (line drawings) matching limitations of available technology and priorities of architectural practice. Subsequent addition of the third dimension to two-dimensional drawings and production of photo-realistic renderings on the basis of three-dimensional models was also geared to efficiency and productivity rather to than new forms of expression.[d]

a Evans, R. (1989) *Architectural projection*.
b Gombrich, E. (1990) *Pictorial instructions*.
c Lopes, D. (1996) *Understanding pictures*.
d Mitchell, W.J. (1992) *The reconfigured eye;* Mitchell, W.J. and M. McCullough (1995) *Digital design media*.



241 Drawing by an eight-year-old (1996, KidPix on a Macintosh Powerbook 165c)

Still, the new technologies are already having a profound influence on architectural visualisation in three significant ways. The first is that, by making computational power available, affordable and relevant, they provide more efficient and economical implementations of pre-existing analogue techniques, as well as new, complementary tools. Younger generations are particularly proficient in digital visualisation. Figure 241 is a casual drawing by an eight-year-old with the program KidPix on a Macintosh Powerbook 165c. Despite the added difficulty of having to master the trackball of the particular computer model, the drawing comes very close to the child's drawings on paper. Even the use of standardised elements in the computer programme echoes her application of self-adhesive and stencilled figures.

The early familiarity of today's children with computer visualisation, their natural acceptance of cognitive and manual ergonomics, as well as their high exposure to related media, like video and arcade games, suggest that digital tools will soon cease to be an alien technology in architectural education and practice. Even thorny issues like digital sketching (cf. figure 241) will be resolved simply by the future users' proficiency in both the digital and analogue versions.

A second potential contribution of modern visualisation technologies is provision of sharper, more reliable and hopefully more intuitive geometric tools. The practical and conceptual necessity of describing three-dimensional objects with coherence, accuracy and precision created a strong but strained relationship between architecture and geometry. A frequent complaint is that orthographic projections may fail to register salient features of their subject. Consequent rebellion against the "tyranny of the box" oscillates between giving up geometry altogether and adopting other, more complex geometries —choices with an outcome never fully explored.[a]

The third influence of democratisation of computer technologies on architectural visualisation lies in that it opens a wide and exciting new market for visualisation in information systems. Graphical interfaces are frequently developed for spatial forms, as for example the Internet with VRML. The architects' experience in representing spatial patterns visually has led to the assumption that design of these interfaces and of inter-action in information space adds to the scope of architects who are arguably better suited to such subjects than other design specialists today.

25.3 REPRESENTATION: A DEFINITION

A suitable working definition of what a representation is and what it does can be derived from Marr.[b] According to this, a representation is a formal system for making explicit certain entities in a transparent manner, i.e. together with an explanation of how the explicitness is achieved. The product of a representation as applied to a specific entity is a *description*. Familiar examples of representations include Roman and Arabic numerals (decimal or binary). Figure 242 contains alternative descriptions of the number 17 produced by different representations.

XVII = 17 = 10001 = 𝍸 𝍸 𝍸 ||

242 Alternative representations

In each of them a number is described on the basis of a finite set of symbols and a rule systems for composing a description from the symbols. Arabic decimal numerals use the following set:

$$S_A = \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9\}$$

These symbols are correlated to a number in the following manner of positional notation:

$$n_n * 10^n + n_{n-1} * 10^{n-1} + \ldots + n_1 * 10^1 + n_0 * 10^0 \Rightarrow n_n n_{n-1} \ldots n_1 n_0$$

For example:

$$1 * 10^1 + 7 * 10^0 \Rightarrow 17$$

a Evans, R. (1995) *The projective cast, architecture and its three geometries*.
b Marr, D. (1982) *Computer vision*.

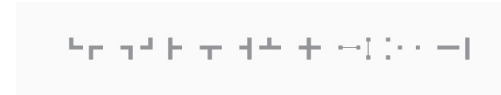
Arabic binary numerals make use of a smaller set of symbols and corresponding decomposition rules: $_B = \{0, 1\}$

$$n_n * 2^n + n_{n-1} * 2^{n-1} + \ldots + n_1 * 2^1 + n_0 * 2^0 \Rightarrow n_n n_{n-1} \ldots n_1 n_0$$

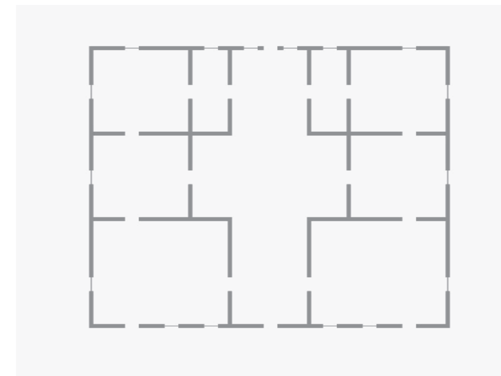
For example:

$$1 * 2^4 + 0 * 2^3 + 0 * 2^2 + 0 * 2^1 + 1 * 2^0 = 10001$$

Architectural representations are essentially similar in structure. They consist of symbols for spaces and/or building elements, relations between the symbols and correspondence rules for mapping the symbols and their relationships to the subject of representation. Figure 243 depicts the symbols of a basic set of building elements. The set is sufficient for describing orthogonal floor plans, like the one in figure 244, as two-dimensional arrays comprising generic building elements.[a]



243 A basic set of symbols for floor plans.



244 Floor plan created with the symbols of figure 243.

25.4 IMPLEMENTATION MECHANISMS

The significance of spaces and building elements in architecture has not been realised in practical design computing and visualisation. Drafting and modelling programs generally employ lower level geometric primitives, like points, lines and simple surfaces for the outlines of building components. Moreover, these geometric symbols are seldom grouped together into a coherent description of a component and have few, if any, explicit relations to other elements.

A useful distinction, also from Marr[b], is the one between representation and implementation. For every representation there are several alternative implementations, usually depending on the context of the application. For example, binary numbers can be represented with Arabic numerals (1 or 0) or with states of switches (ON or OFF). Both refer to the same representation: the implementation mechanisms change; not the actual symbols used in the representation.

The elevation of implementation mechanisms like lines and surfaces to primitives of architectural design is symptomatic of two general conditions in computerisation of architecture. The first: most digital techniques are direct transfers of analogue practice. This almost always includes unquestioning acceptance of the implementation mechanisms of an analogue representation as the basis of its digital equivalent. The second: an underlying mystification tendency, confuses implementation mechanisms and visualisation techniques with spatial form and perception. The use of spaces and building elements as primitives of architectural design representation is too prosaic to allow far-fetched associations and loose metaphors, which can be easily accommodated in neutral geometric justifications.

25.5 ELEMENTS AND RELATIONSHIPS

Research into the structure of symbolic representation focuses on two issues:

- which primitives should be employed and at what level,[c] and
- the possibility of units (chunks, partitions, clusters more structured than simple nodes and links or predicates and propositions.[d]

The primitives issue can be resolved by the analysis of existing representations of the built environment. These traditionally assume a direct, atomistic form. A conventional representation like a map or floor plan comprises atomic elements like individual buildings or building components. These elements appear at an abstraction level appropriate to the scope of the representation. Depending on the scale and purpose of a map, buildings are depicted individually or concatenated into city blocks. Similarly, a floor plan at the scale of 1:50 depicts building components and elements that are ignored or abstracted at 1:500. Most other aspects of built form remain implicit, with the exception of those indicated as annotations by means of colouring and textual or symbolic labels conveying information like grouping per sub-system, material properties or accurate size. Relations between elements, like the align-

a Koutamanis, A. (1995) *Recognition and retrieval in visual architectural databases*.
b Marr, D. (1982) *Computer vision*.
c Brachman, R.J. and H.J. Levesque (1985) *Introduction*.
d Brachman, R.J. (1985) *On the epistemological status of semantic networks*.

ment of city blocks or the way two walls join in a corner are normally not indicated —unless, of course, they are the subject of the representation, as in detail drawings.

Using formalisms like semantic networks, frames, scripts and objects, elements are brought together in associative symbolic representations that share the following features:

- representation consists of objects and relations between objects;
- objects are described by their type, intrinsic properties and extrinsic relations to other objects;
- properties are described by constraints on parameters;
- relations are described by networks of constraints linking objects to each other.

A comparison of such representations with conventional architectural drawings reveals that architecture is handicapped by omission of explicit relationships between elements. The reasons for this omission have to do with representational complexity and range from the user's unwillingness to input multiplicity of relevant connections, to the computer's inability to handle them efficiently and effectively. Consequently, architectural associative symbolic representations has restricted greatly focused generative systems where structure and intention can be controlled.

More ambitious representations have attempted to integrate all relevant aspects and entities. Their main intention: resolving real design problems as encountered in practice. However, large or holistic representations have a size and complexity that often make representations unmanageable both for computers and humans. Problematic maintenance and lack of predictability in the behaviour of such representations, especially following modification and augmentation, limit severely their applicability.[a]

25.6 ELEMENTS

Architectural composition is often equated to arranging items chosen from a finite set of 'solid' building elements and/or 'void' space forms. Building elements traditionally attract more attention than spaces. Especially within the confines of a single formal system we encounter relatively compact and well-ordered collections of building elements which form the *sine qua non* of the system. The best example of such collections is the orders of classical architecture, where canonisation of the system was achieved by standardisation of a small subset of building elements. The conspicuous presence of these elements in classical buildings led to the view that a building with classical proportions cannot be classical if it does not contain elements from the classical orders.[b]

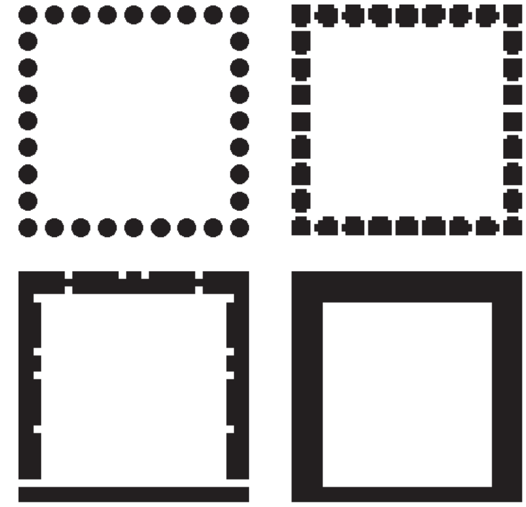
The attention paid to the arrangement and articulation of a specific subset of building elements has propagated a particular image of architectural design that is more akin to fine arts than to engineering. Even after the classical orders were dismissed by modernist architecture and replaced by abstract systems based on proportion and standardisation, this image remained an implicit yet powerful part of architectural methodology. Probably the best examples are the ideas on industrialisation in building developed and applied after WW II. These were dominated by standardisation of building elements in size and type and modular co-ordination for the arrangement of these elements. The resulting hierarchical system of building elements and positioning constraints bears similarities with the classical orders. The image of architectural design as arrangement and articulation of a finite set of building elements has been influential in computer-aided architectural design. It suggested a graphic system where the designer selects objects from a database and integrates them in a design by means of simple geometric transformations.

A significant issue relating to the elements of architectural representations is the duality of 'solid' building elements and 'void' spaces in the representation of the built environment. Spaces are less frequently chosen as the atomic elements of architectural composition than building elements. This is frequently attributed to the implicitness of spaces in conven-

a Gauchel, J., S. van Wijk et al. (1992) *Building modeling based on concepts of autonomy*.
b Summerson, J. (1980) *The classical language of architecture*.

tional analogue representations like floor plans. A possibly more significant reason is the equation of spatial arrangement to a fixed pattern locally elaborated, annotated and studded with building elements. Such an interpretation appears to underlie traditional design practices, as well as computational design studies including space allocation[a], shape grammars[b] and similar generative systems.[c]

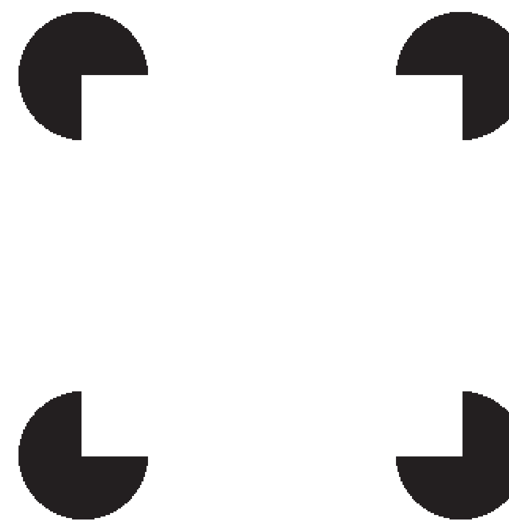
In cognitive studies the representation of objects by their parts and modules has been a common hypothesis for computational and cognitive studies of vision and visual recognition.[d] According to this hypothesis, a visual scene is parsed into components, normally corresponding with the canonical parts of the objects depicted in the scene. The representation derived from a scene has a multi-level structure, each level corresponding to a different abstraction level. At the highest level an object is represented as a single component analysed into smaller components at subsequent (lower) levels. For example, a human form starts as a single component, then sub-divided into components for head, torso, arms and legs. Each component is further sub-divided, e.g. an arm into upper arm, forearm and hand. Again the hand is analysed into components for palm and five fingers.[e]



245 Elements and abstraction

Elements are straightforward to define and recognise in a multi-level structure; but their applicability is limited to a small range of abstraction levels. In figure 245 the actual elements (top left) are thirty two bullets arranged along the sides of an imaginary square. Nevertheless, the image is normally described simply as a square. Rather than describing the atomic parts we group them in one pattern denoting the overall configuration. The same effect can be achieved by lowering resolution of the image, as in figure 245 (sequence: top right, bottom left, bottom right). By doing so, the individual parts progressively lose individuality and fuse into a solid square.

In other situations the actual elements are interpreted as something different than what they actually are. In figure 246 the four incomplete disks are interpreted as four complete black disks partially occluded by an illusory white square.[f] The instability and degradation of elements suggest that beyond certain levels of abstraction atomic elements are replaced by co-ordinating devices. These devices can be derived by purely visual processes (figure 245). This, however, does not preclude the existence of these co-ordinating devices as separate entities existing independently of the elements and which may appear in representations with or without elements.



246 Elements and illusory contours

Despite limitations in applicability of elements, it is assumed that, at a low level (before significant abstraction occurs), the representation of complex visual scenes can be based on a small set of basic components. Biederman proposed that this set can be reduced to 36 simple components, called *geons*.[g] Similar principles have been employed for recognition of line drawings of three dimensional scenes where the repertory of possible edge junctions was reduced to a small number of configurations labelled with respect to convexity/concavity.[h] In an austerely trihedral environment the number of possible junction configurations is just 18.[i] The same applies to representation of spaces in orthogonal floor plans (figure 243 and 244), where 8 types suffice.[j]

The arrangement of elements is normally represented in terms of an associative structure linking discrete components to each other with spatial/geometric relationships.[k] As with the number of elements, it is proposed that the number of basic relationships is quite low. Geons relate to each other by means of five edge properties.[l] In line drawings correlation of edge junctions takes place on basis of the labelling of each edge with respect to convexity / concavity in an iterative constraint propagation procedure.[m] In orthogonal floor plans each space corner is linked to two other corners, one in horizontal, one in vertical direction. For a given space corner type there are two possible types of corners it can be linked to in either direction.[n] This also suggests that certain relationships are implicit in the type of the elements: each element is characterised by specific expectations concerning type and position of elements to which it relates.

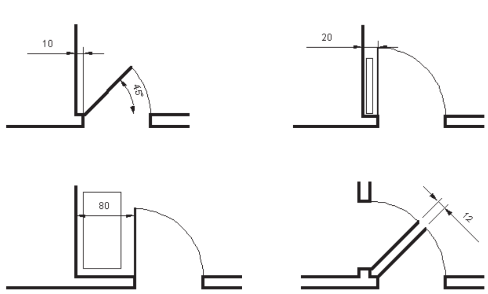
a Eastman, C.M. (1975) *Spatial synthesis in computer aided building design*.
b Stiny, G. and W.J. Mitchell (1978) *The Palladian grammar*.
c Hersey, G. and R. Freedman (1992) *Possible palladian villas*.
d Brooks, R.A. (1981) *Symbolic reasoning among 3-D models and 2-D images;* Marr, D. (1982) *Computer vision;* Tversky, B. and K. Hemenway (1984) *Objects, parts, and categories;* Biederman, I. (1987) *Recognition by components: a theory of human image understanding;* – (1995) *Visual object recognition*.
e Marr, D. (1982).
f Kanizsa, G. (1979) *Organisation in vision. Essays on Gestalt perception preager*.
g Biederman, I. (1987, 1995).
h Guzmán, A. (1966) *Computer resolution of three dimensional objects in a visual scene;* Clowes, M. (1971) *On seeing things;* Huffman, D. (1971) *Impossible objects as nonsense sentences;* Mackworth, A.K. (1973) *Interpreting pictures of polyhedral scenes;* Waltz, D. (1975) *Understanding line drawings of scenes with shadows*.
i Winston, P.H. (1992) *Artificial Intelligence*.
j Koutamanis, A. and V. Mitossi (1992) *Automated recognition of architectural drawings;* Koutamanis, A. (1995) *Recognition and retrieval in visual architectural databases*.
k Marr, D. (1982); Winston, P.H. (1992).
l Biederman, I. (1987, 1995).
m Waltz, D. (1975).
n Koutamanis, A. and V. Mitossi (1993) *Computer vision in architectural design;* Koutamanis, A. (1995).

25.7 LOCAL CO-ORDINATING DEVICES

While representation of elements in both analogue and digital design practice is explicitly supported by symbolic techniques, less importance has been attached to the way in which elements are integrated in a design. This is normally left to the designer who has to position and connect each new element in a building representation with little help from his instruments. For example, many drafting and modelling systems still fail to address the physical impossibility of two objects occupying the same space, let alone attempt to interpret the designer's intentions in overlapping objects. In analogue design media, this is a logical consequence of their implementation structure. An analogue representation is perceived, recognised and interpreted by the human viewer. Computerised representations, on the other hand, are not limited by human interpretation. On the basis of explicit relationships between objects the computer can provide meaningful feedback on the basis of qualitative and quantitative analyses complementing and supporting the designer's creativity.

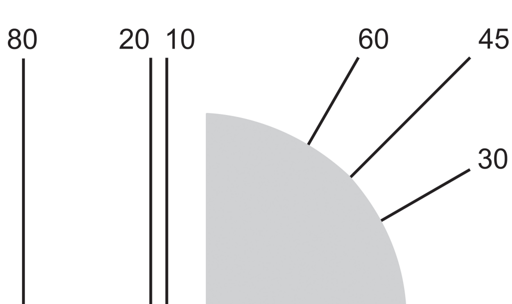
Frequent absence of meaningful explicit relationships between elements in architectural representations does not imply lack of knowledge on the subject. Architectural and building textbooks deal extensively with relationships between building elements and components. The positioning of one element relative to another derives from formal, functional and constructional decisions and has consequences for the articulation and performance of the building. Textbooks provide guidelines ranging from ergonomically sound distances between chairs and tables to correct detailing of joints in roof trusses. Frequent and faithful use of textbook examples has resulted in a corpus of architectural stereotypes. Even though stereotypes may lead the designer to repeating known solutions, they help reach levels of reasonable performance in designing and in the built environment. By obeying underlying rules and reproducing textbook stereotypes, the designer ensures conformity with norms of building regulations, professional codes and general empirical conclusions.

In textbooks, aspects of a recommended configuration are usually presented separately in a proscriptive manner, by means of sub-optimal and unacceptable examples. These are annotated with the relevant relationships and usually ordered from general to specific and from simple to complex. It is assumed that the reader of the textbook makes a selective mental aggregate on based on the aspects that apply to the problem at hand. Despite that, incompatibilities between different aspects and examples are seldom addressed in textbooks. Forming an aggregate representation is generally a straightforward hill-climbing process. For example, in designing a door, one starts with basic decisions relating to the door type on the basis of spatial constraints and performance criteria. Depending upon the precise type, the designer proceeds with constraints derived from adjacent elements and activities. In the case of a single inward opening left hinged door of standard width (figure 247), these constraints determine position and functional properties of the door, i.e. the distance from elements behind the door, and the swing angle, orientation and direction enabling the projected entrance and exit requirements. These can be adjusted by other factors unrelated to the initial decision. For example, the existence of a load-bearing element in the initial place of the door may necessitate translation of the door and hence a re-formulation of the initial design problem.



247 Textbook representation of local co-ordination constraints

Similarly to textbooks, templates offer useful insights into stereotypical interpretation of local co-ordination constraints. In templates, building elements usually appear as holes or slits. Each one is accompanied by annotations in the form of dents, notches and painted text. These facilitate geometrical positioning of a form, as well as geometric interpretation of spatial constraints. The configuration of forms and annotations typically represents a simplified fusion of parameters reduced to typical cases (figure 248). Even though superimposition of different patterns makes the template less legible than the more analytical textbooks, the template comes closer to the mental aggregate of the designer.



248 Template representation of local co-ordination constraints

The manner in which local constraints are centred on elements, the connections between elements and their stereotypical treatment in designing suggest that mechanisms like frames or objects would be appropriate for representation of local co-ordination devices. In a frame-based representation the relationships of e.g. a door with walls and other elements of the immediate context can be described as slots and facets linking the door frame with frames of walls, spaces and other elements. Such an implementation strategy has obvious advantages for the representation of local co-ordination devices, for example with respect to inter-changeability of elements by means of abstraction and inheritance. It is quite plausible that a single prototype would suffice for representation of all kinds of doors. This could facilitate manipulation of doors in computer-aided design, including automated substitution of one door type by another, if needed; due to spatial conflicts or a change in the designer's preference.

25.8 GLOBAL CO-ORDINATING DEVICES

Global co-ordinating devices generally appear in two forms. The first: sketches and diagrams explaining the general spatial articulation of a design. Such abstract representations —even if devised post factum— are commonly seen as embodiment of the driving forces in the development of the design. For our purposes they form a useful précis which can be placed at the top of a multi-level representation. The second form: the product of formal analysis. Usually applicable to more than one design, it is expressed in more abstract terms: grids, zoning schemes. Probably the most celebrated of such devices is the 5 x 3 grid proposed by Wittkower as the underlying grid of Palladian villas.[a]

This grid is universally accepted as the canonical formal expression of the intuitive perception of the Palladian villa's "triadic composition" of two symmetrical sequences of spaces laterally flanking the central series of spaces along the main axis.[b] As a result, the 5 x 3 grid forms the basis of most Palladian studies, including the Palladian shape grammar.[c] In it, the first stage invariably concludes with the definition of the 5 x 3 grid which serves further as a template for definition of spaces and positioning of building elements.

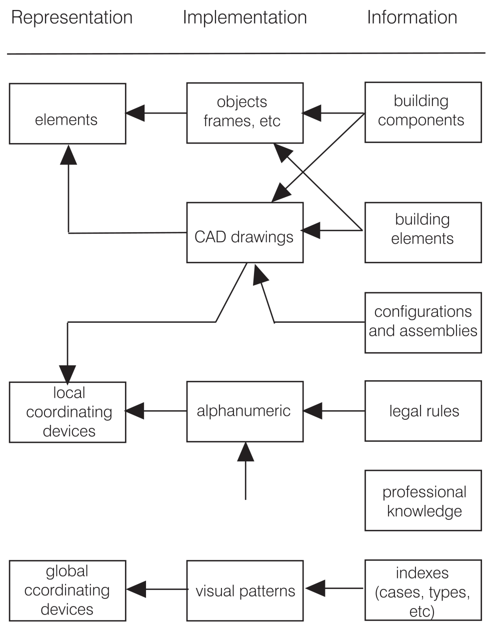
Global co-ordinating devices can be derived by visual abstraction eliminating the individual characteristics of elements and returning a skeleton, as in figure 245. This does not imply that these abstractions are accidental products of various, possibly unrelated design decisions. Another option is to treat devices like the Palladian 5 x 3 grid as prototypical patterns systematically repeated in variations. Such a view underlies most computational studies, even though there is no historical evidence that Palladio set out to exhaust the possibilities presented by a single pattern. The 5 x 3 grid appears to be an fusion of different preoccupations and influences, from notions of harmony to the traditional centralised arrangement of the local house type.[d]

25.9 MULTI-LEVEL DESIGN REPRESENTATIONS AND INFORMATION NETWORKS

Integration of all entities in holistic associative structures applies to design problems of limited size and complexity. As a problem expands to more elements, aspects and abstraction levels, atomistic associative representations grow beyond what is manageable for computation by computers and for direct comprehension by humans, even if compact implementation mechanisms like frames and objects are employed. In multi-level representations networks of architectural elements are complemented by local and global co-ordinating devices at different levels of abstraction. These devices integrate relationships in consistent and coherent local or global frameworks regulating positioning and properties of elements. Multi-level representations build on the natural abstraction of architectural representations; evident in the conventional sequence of drawings at different scales: 1:200, 1:100, 1:50, 1:10.

One main advantage of multi-level representations comprising elements, local and global co-ordinating devices is connectivity to external information sources. The increasing availability of design information on networks like the Internet makes connectivity a pre-requisite to integration of such networks in designing. The ability to instigate searches by means of intelligent, autonomous agents that collect appropriate information, to integrate this informa-

a Wittkower, R. (1952) *Architectural principles in the age of humanism*.
b Ackerman, J.S. (1977) *Palladio*.
c Stiny, G. and W.J. Mitchell (1978) *The Palladian grammar*.
d Ackerman, J.S. (1977).



249 Multi-level design representations and information retrieval

tion in design representations and to maintain a dynamic link with the original source of the information are already available on a limited or experimental basis.

Integration of hypermedia possibilities in drafting and modelling systems and addition of vector information in hypermedia interfaces to the Internet currently focus on dissemination of information on building elements and components. These are distributed as CAD documents to be downloaded from an Internet site and subsequently integrated in a design. Dynamic linking of a local document to the representation of a component or element on a remote system is also feasible.

With respect to integration of on-line information on elements a multi-level representation is similar to any analytical representation. The advantages of multiple co-ordinated levels on top of the networks of elements emerge when we consider integration of other kinds and forms of information. One such kind already being distributed through the Internet, but frequently escaping attention, are relationships and constraints that constitute local co-ordinating devices. This information is normally included in texts describing or analysing legal codes and regulations, as well as professional knowledge of the kind encountered in textbooks. Identification and extraction of relevant items from these documents is conceptually non-trivial but technically straightforward, given the hypermedia structure of current Internet interfaces.

These items can be linked to a design representation in the same way as elements, with the difference that elements are self-contained, while textual or mathematical information on rules and regulations constrains items and relationships between items. The explicit representation of local co-ordinating devices, either embedded in elements or as separate, superimposed entities, facilitates direct connection to external alpha-numeric values (figure 249). This permits precise control of input and constraint propagation in a design, for example for analysis and modification of specific aspects due to a change in the legal framework of the project. Co-ordinating devices are equally significant in guiding information retrieval. The constraints encapsulated in local co-ordinating devices often determine acceptability of an element to a particular situation.

As a result, network search routines can derive part of their parameters from the relevant local co-ordinating devices in the design, test the retrieved elements against the requirements in these devices and receive feedback on relevance of the search. Global co-ordinating devices can also be employed this way, especially for assemblies and sub-systems of elements. Such parts of a design are becoming increasingly available as examples of the application of principles, systems or elements.

The proliferation of ideas on case and precedent-based design could also increase the number of on-line configurations of elements. Their manipulation for retrieval and integration in new design can only be achieved by analytical means matching the complexity of the configurations. However, we may expect that most information on cases, prototypes and precedents will be at a high level of abstraction. This suggests that global co-ordinating devices can be used for indexing designs in a database and, hence, as query terms for retrieval of whole designs. The utility of current indexing schemes (usually on basis of a controlled vocabulary) demonstrates the advantages of such search intermediaries. Local, and especially global co-ordinating devices can enrich indexing with visual schemata which can be directly matched to the searcher's own graphic input.[a]

25.10 ANALYSIS AND REPRESENTATION

Well-defined design representations are a pre-requisite to analysis and evaluation of building behaviour and performance. With the increasing complexity of the built environment and rising requirements of environmental quality, analysis and evaluation of programmatic and functional aspects are becoming one of the highest priorities in architecture. Unfortunately, architectural analysis (and design) has been driven by normative models belonging to either of the following deontic approaches:

a Gross, M.D. (1995) *Indexing visual databases of design with diagrams*.

- *Proscriptive*: formal or functional rules that determine the acceptability of a design on the basis of non-violation of certain constraints. Formal architectural systems like classicism and modernism, as well as most building regulations are proscriptive systems.
- *Prescriptive*: systems that suggest that a pre-defined sequence of actions has to be followed in order to achieve acceptable results. Many computational design approaches are prescriptive in nature.

Dominance of a specific system or approach in a historical period has been instrumental for the evolution of architecture. It allowed in concentration of effort on concrete, usually partial problems within the framework of the system and hence supported innovation and improvement.

The eclectic spirit of recent and current architecture reduces the value of normative approaches, as it permits strange conjunctions, far-fetched associations and unconstrained transition from one system to another. In addition, the computer provides means for analyses and evaluations of a detailed and objective nature. These dispense with the necessity of abstraction and summarisation in rules and norms. This does not mean that abstraction is unwanted or unwarranted. On the contrary, abstraction is an obvious cognitive necessity, that emerges as soon as a system has reached a stable state. Consequently, one can expect emergence of new abstractions on the basis of the new detailed, accurate and precise analyses. It is quite probable that several older norms will be among the new abstractions.

The main characteristic of new forms of analysis is that they follow an approach we may call *descriptive*. They evaluate a design indirectly, by generating a description of a particular aspect comprising detailed measurable information on the projected behaviour and performance of the design. This description is normally closely correlated with formal representation of the design and therefore permits interactive manipulation, e.g. for trying different alternatives and variations. In short, the descriptive approach complements (rather than guides) human design creativity by means of feedback from which the designer can extract and fine-tune constraints.

In functional analyses it has become clear that most current norms and underlying principles have a very limited scope: control of minimal specifications by a lay authority. They are often obsolete as true performance measures and grossly insufficient as design guidance. The solution presented by the descriptive approach is substitution of obsolete abstractions by detailed information on functionality and performance, for example abandonment of Blondel's formula of stair sizes in favour of an ergonomic analysis of stair ascent and descent by means of simulation.[a] The analysis is performed in a multi-level system connecting normative levels to computational projections and to realistic simulations in a coherent structure, where assumptions of one level are subject of investigation at another level.[b]

25.11 AESTHETICS

The intuitive appreciation of aesthetic preference has been a hallmark of architectural design in practice. It has also been one main reason for conflict between architect and lay person, as the latter's appreciation of built form and space is less tempered by dominant architectural doctrines and more by the élite dictating good taste and 'vogue'. As vogue is often at odds with architectural history and criticism, architects have been reluctant to change what they consider to be part of their methodical background. The predominance of the intuitive approach agrees with many types of human inter-action with the built environment and its representations. This agreement adds an element of common sense to architectural analysis that may temper indifference to practical problems. However, common sense can be distorted or refuted by expert opinion and interpretation, especially if specific human experiences do not involve directly measurable performance criteria. Such distortions and refutations have contributed to the deep dichotomy between form and function in architecture and to the frequent

a Mitossi, V. and A. Koutamanis (1996) *Parametric design of stairs*.

b Koutamanis, A. (1995) *Multilevel analysis of fire escape routes in a virtual environment;* Koutamanis, A. (1996) *Elements and coordinating devices in architecture: An initial formulation*.

elevation of formal considerations to the highest priority in architectural design, either as a priori norms and canons or as direct and inescapable consequences of functional issues and problems.

In the descriptive approach the principles of architectural aesthetics are drawn from perceptual and cognitive sources; and these principles are connected to architectural issues, strictly in this order. In other words, rather than starting with ordering, the existing architectural aesthetic norms and then proceeding to a search for cognitive relevance and justification, we apply general computational models of perception and cognition to architecture. This leads to an analysis that does not derive from a normative architectural model or system. Therefore, it does not exhibit any bias towards specific approaches but potentially accommodates all possible architectural systems. Different systems correspond to variations in the analysis with respect to the configuration of analytical devices, as well as to (parametric) differences within each device. The common basis of the different systems and of the corresponding analyses is an objective representation of the architectural object, i.e. a description not relating to a specific architectural formal system.

The distinction between the derivation of a description, its interpretation and finally its evaluation, is common to computational studies of vision but also of aesthetics.[a] Its particular value lies in that it stresses affinity between figural goodness in perception and aesthetic appreciation of built form. Figural goodness has been linked to aesthetic response by means of the relation between perceptual arousal and complexity.[b]

25.12 AESTHETIC MEASURES

The first significant attempt to quantity aesthetics was by the American mathematician George D. Birkhoff who, following, among others, Leibniz and Pythagorans, proposed that the aesthetic experience relies on principles of harmony, symmetry and proportion. Three successive phases:[c]

- arousal and effort of attention;
- the feeling of value or aesthetic measure which rewards the effort of attention; and finally
- the realisation that the perceived object is characterised by a certain aesthetic order.

Birkhoff states that the effort of attention is proportional to the complexity (C) of the perceived object and links complexity, the aesthetic measure (M) and aesthetic order (O) in the basic aesthetic formula:

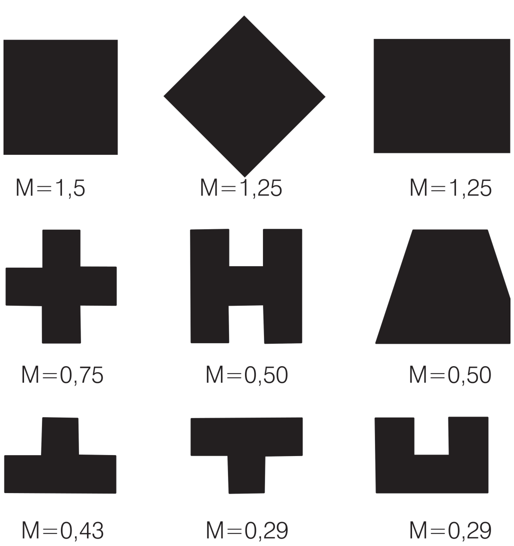
$$M = O / C$$

Complexity is generally measured by the number of elements in the perceived object. For example, in isolated polygonal forms complexity is measured by the number of distinct straight lines containing at least one side of the polygon, similarly to the gratings of rectangular dissections.[d] The measurement of order varies with the specific class of objects to be evaluated but generally takes the form of the sum of weighted contributing elements:

$$O = ul + vm + wn + \ldots$$

where l, m, n, … are the independent elements of order and u, v, w, … indices which may be positive, zero or negative, depending upon the effect of the corresponding element. Aesthetic order and consequently aesthetic measure are relative values which apply to specific classes of objects, so restricted that intuitive comparisons of the different objects becomes possible. There is no comparison between objects of different types.

Birkhoff suggests that order relates to associations with prior experience and acquired knowledge triggered by formal elements of order, that is: properties of the perceived object, like bilateral symmetry about a vertical axis or plane. Formal elements of order with a positive effect include repetition, similarity, contrast, equality, symmetry and balance. Ambiguity, undue repetition and unnecessary imperfection have a negative effect. For example, a rectangle



250 The aesthetic measure of isolated polygonal forms according to Birkhoff [e]

a Stiny, G. and J Gips (1978) *Algorithmic aesthetics. Computer models for criticism and design in the arts*.
b Berlyne, D.E. (1960) *Conflict, Arousal and Curiosity*; - (1971) *Aesthetics and psychobiology*.
c Birkhoff, G.D. (1933) *Aesthetic measure*.
d Steadman, J.P. (1983) *Architectural morphology*.
e Birkhoff, G.D. (1933).

not quite a square is unpleasantly ambiguous, according to Birkhoff. Also a square whose sides are aligned with the horizontal and vertical is superior to an unnecessarily imperfect square which has been rotated about its centre by 45 degrees "because it would be *so easy* to alter it (the rotated square) for the better" (p. 25).

In the example of isolated polygonal forms aesthetic order is measured by the formula

$$O = V + E + R + HV - F$$

where V stands for vertical symmetry, E for equilibrium, R for rotational symmetry, HV for the relation to a horizontal-vertical network (reference framework) and F for unsatisfactory form. "Unsatisfactory form" encompasses too small distances between vertices or parallel sides, angles too near to 0 or 180 degrees and other ambiguities, diversity of directions and lack of symmetry.

Ingrained aesthetic prejudices reduce applicability and reliability of Birkhoff's aesthetic measure. The highest values are achieved with symmetrical forms with the least number of parts. The square with sides aligned to the vertical and horizontal is the clear winner among polygonal forms, followed by the square rotated by 45 degrees and the rectangle with horizontal and vertical sides. Still, the aesthetic measure is important to our investigation for three basic reasons relating rather to the way the measure is calculated than the measure itself.

The first is that it equates beauty with order. While this does not hold for aesthetics in general, it is obviously relevant to prescriptive and proscriptive architectural formal systems where conformity to canons and rules, often explicitly and paradigmatically expressed, constitutes the usual measure of formal acceptability.

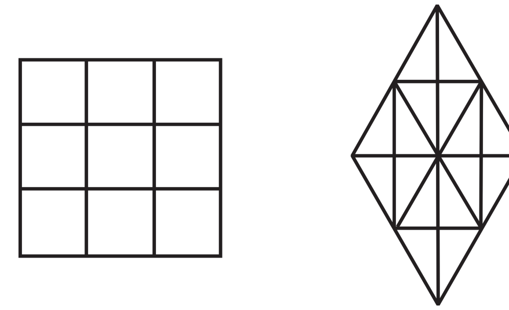
The second reason is factoring aesthetic order into discrete, independent formal elements each with a limited scope. The third reason is the rôles of order and complexity in the aesthetic measure and their affinity with information processing and the rôle of figural goodness in perception. This affinity was not lost on Birkhoff's epigones who linked aesthetic measures to information theory.[b] The applicability of Birkhoff's approach to architectural aesthetics is consequently restricted to:

- analysis of factors contributing to aesthetic appreciation and preference and
- evaluation of an object with respect to each of these factors.

25.13 CODING AND INFORMATION

Probably the greatest shortcoming of Birkhoff's approach is that it fails to take account of perception, that is, of processes by which an object elicits a pleasurable reaction. By linking aesthetics to perception we depart from the objectiveness of Birkhoff's measure and adopt an inter-subjective model of aesthetic appreciation stressing the cognitive similarities that exist between different persons and cultures.[c] Inter-subjectivity also allows to correlate different aesthetic approaches, i.e. different architectural formal systems.

Gestalt psychologists have formulated a number of principles (or 'laws'), like proximity, equality, closure and continuation, which underlie the derivation of a description from a percept by determining the grouping of its parts.[d] Probably the most important, certainly the most mysterious of the Gestalt principles of perceptual organisation is *Prägnanz* or *figural goodness* which refers to subjective feelings of simplicity, regularity, stability, balance, order, harmony and homogeneity arising when a figure is perceived. Figural goodness ultimately determines the best possible organisation of image parts under the prevailing conditions. As a result, it is normally equated to preference for the simplest structure. The view of perception as information processing has led to attempts to formulate figural goodness more precisely. Given capacity limitations of the perceptual system and the consequent necessity of minimisation, it has been assumed that the less information a figure contains (i.e. the more redun-



251 Examples of horizontal-vertical networks according to Birkhoff[a]

a Birkhoff, G.D. (1933) *Aesthetic measure*.
b Bense, M. (1954) *Aesthetica;* Moles, A. (1968) *Information theory and esthetic perception*.
c Scha, R. and R. Bod (1993) *Computationele esthetica*.
d Köhler, W. (1929) *Gestalt psychology;* Koffka, K. (1935) *Principles of Gestalt psychology;* Wertheimer, M. (1938) *Laws of organisation in perceptual forms*.

dant it is), the more efficiently it could be processed by the perceptual system and stored in memory.[a]

Arguably the most powerful model in this line of investigation was Leeuwenberg's coding or *structural information theory*.[b] According to Leeuwenberg a pattern is described in terms of an alphabet of atomic primitive types, like straight-line segments and angles at which the segments meet. This description (the *primitive code*) carries an amount of structural information (I) equal to the number of elements (i.e., instances of the primitives) it contains. The structural information of the primitive code is subsequently minimised by repeatedly and progressively transforming the primitive code on the basis of a limited number of coding operations:

- iteration, by which the patterns

a a a a a a b b b b b b	(I = 12)	become respectively	6 * [(*a*) (*b*)]	(I = 3)
a b a b a b a b a b a b	(I = 12)		6 * [(*a b*)]	(I = 3)

- reversal, denoted by *r* […]:

  a b c = r [*c b a*] (I= 3)   reversal allows the description of symmetrical patterns (Σ):

  a b c c b a = *a b c* r [*a b c*] = Σ [*a b c*] (I = 4)

  a b c b a = *a b c* r [*a b*] = Σ [*a b* (*c*)] (I = 4)

- distribution:

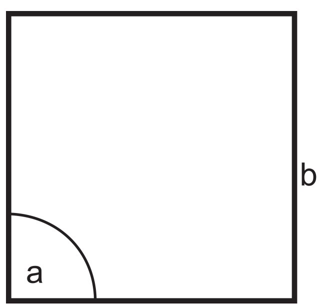
  a b a c = <(*a*)> <(*b*) (*c*)> (I = 3)

- continuation (⊂…⊃), which halts if another element or an already encoded element is encountered:

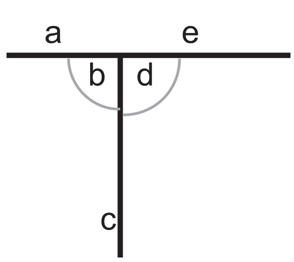
  a a a a a a a … a = ⊂*a*⊃ (I = 1)

The coding process returns the *end code*, a code whose structural information cannot be further reduced. The structural information (I) of a pattern is that of its end code.

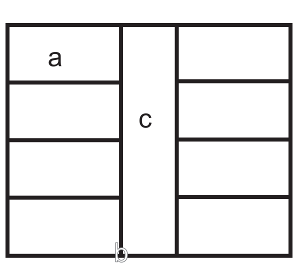
The structural information of a pattern is a powerful measure of its figural goodness. By equating a figure's goodness with the parametric complexity of the code required to generate it we can both derive the different descriptions an image affords and choose the one(s) that contain the least information.



252 Coding of square: abababab = ⊂a b⊃ (I = 2) (repeat a and b until reaching the starting point again, structural information is 2)



253 Coding of branching with bifurcation signs: a {b c} d e (after c return to end of a and proceed to following d)



254 Coding of a floor plan:
aaaabcbaaaa = 4 * [(a)] b c b 4 * [(a)]
= Σ [4 * [(a)] b (c)]
(I = 5)
(mirror 4 times a connected to c by b, structural information is 5)

25.14 ARCHITECTURAL PRIMITIVES

The main problem of theories of perceptual organisation, from Gestalt to structural information theory, is that they are developed and discussed within abstract domains of simple, mostly two-dimensional patterns and elementary primitives like dots and line segments. Such basic geometric forms should be treated with caution in evaluations of design aspects, as they refer to implementation mechanisms rather than to symbols of spatial representation. An extension to the three-dimensional forms of the built environment and to complex two-dimensional representations employed in architecture involves the problem of determining the primitives of these domains. Use of spaces and building elements as primitives demonstrates clearly the potential of structural information theory. In figure 254 coding of a floor plan on the basis of spaces yields a succinct and accurate description of spatial articulation.

The end code is a symmetric tripartite configuration of two space groups flanking a central space.

Attempts to discover or define the primitives of architectural perception are impeded by confusion between the real built environment, its architectural representations and conventions underlying these representations. For this reason, we should make a sharp distinction between analysis and manipulation of representations and perception of and inter-action with the built

a Attneave, F. (1954) *Some informational aspects of visual perception;* Hochberg, J.E. and E. McAlister (1954) *A quantitative approach to figural 'goodness'*.

b Leeuwenberg, E.L.J. (1967) *Structural information of visual patterns. An efficient coding system in perception.;* – (1971) *A perceptual coding language for visual and auditory patterns*.

environment. The former rely firmly on architectural conventions and should be accordingly considered from the viewpoint of architectural knowledge. The adoption of building elements and spaces as the primitives of such representations offers pragmatic advantages that should not be neglected. On the other hand, a preferable starting point for the perception of built form and space are general computational models of perception and recognition, possibly enriched with constraints of architectural representation. These models provide a better understanding of perceptual and cognitive devices that also underlie architectural design and analysis. In addition to their direct applicability to the analysis and recognition of realistic architectural scenes they could ultimately also lead to improvements in existing architectural representations.

Following low level processing, the first stage in recognition of a scene is invariably decomposition of its elements into simple parts, like the head, body, legs and tail of an animal. The manner of the decomposition into parts does not depend on completeness and familiarity. An unfamiliar, partly obscured animal or even a nonsensical shape are decomposed in a more or less the same way by all observers.[a] Detection of where parts begin and end is based on the *transversality principle* which states that whenever two shapes are combined their join is almost always marked by matched concavities.[b] Consequently segmentation of a form into parts usually occurs at regions of matched concavities, i.e. discontinuities at minima of negative curvature. The results of the segmentation are normally convex or singly concave forms.

At first sight one might expect that there is an unlimited number of part types. However, with his *recognition-by-components* theory Biedermann proposed that these forms constitute a small basic repertory of general applicability, characterised by invariance to viewpoint and high resistance to noise. He calls the forms geons and suggests that they are only 24 in number.[c] Geons can be represented by generalised cones, i.e. volumes swept out by a variable cross section moving along an axis.[d] A scene is described by structured explicit representations comprising geons, their attributes and relations derived from only five edge properties.

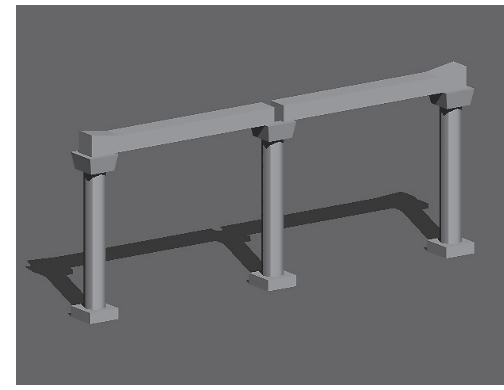
A combination of structural information theory and recognition-by-components provides a comprehensive basis for evaluation of figural goodness in architectural scenes. Coding geons according to structural information theory permits, moreover, grouping of a higher order than local binary relationships. This allows the development of multi-level representations which are less complex, better structured and ultimately more meaningful than atomistic relational representations.[e] In addition, the combination of the two theories makes it possible to establish general preference criteria for alternative descriptions on the basis of code compactness, which in turn relies on formal grouping principles.

The application of this combination to architectural scenes concentrates in first instance on definition of primitives and relationships. In that respect, the only deviation from the original theories concerns the relationship ignored in coding. In structural information theory this is horizontal alignment. In architectural scenes this changes to vertical alignment, in compliance with the general architectural bias for the vertical as canonical orientation. We presume that this bias refers both to a general reference frame reflecting the significance of the vertical in the real world (e.g. gravity) and to a specifically architectural reference frame which relates to the interpretation of general orientation preferences in architecture.

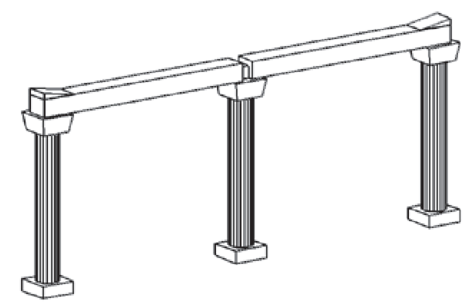
On this basis, the scene of figure 255, 256 and 258 can be coded as follows:

a b {c d e} f g {c d e} f g b {c d e} a (*I* = 17)
<({c d e})><(a b) (f g) (f g b) (a)> (*I* = 11)

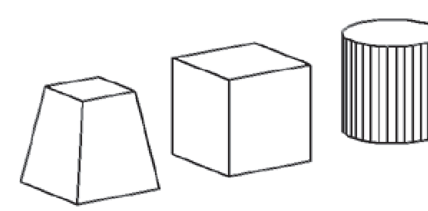
The use of distribution in the second version of the code makes the grouping of the elements comprising the column explicit, as well as the repetition of the group in the scene. This reflects the translational symmetry of the scene (colonnade). The bi-lateral symmetry that char-



255 An architectural scene

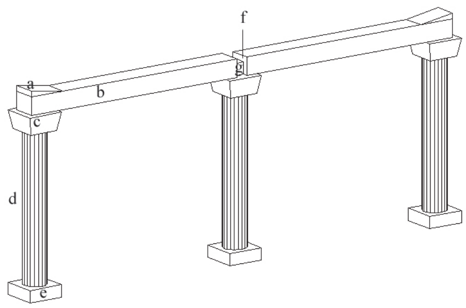


256 A decomposition of figure 254 into geons



257 The geons in figure 256

a Biederman, I. (1987) *Recognition by components: a theory of human image understanding*.
b Hoffman, D.D. and W. Richards (1985) *Parts of recognition*.
c Biederman, I. (1987); – (1995) *Visual object recognition*.
d Binford, T.O. (1971) *Visual perception by computer;* Brooks, R.A. (1981) *Symbolic reasoning among 3-D models and 2-D images*.
e Koutamanis, A. (1996) *Elements and coordinating devices in architecture: An initial formulation;* – (1997) *Multilevel representation of architectural designs*.



258 Coding of figure 256

acterises the total scene is largely lost because of the integrity of the elements and groups in the scene. Bi-lateral symmetry would be discovered in the code, if line segments were used as primitives. This would have meant encoding the outline of the elements rather than the elements themselves and would permit splitting of a column into two symmetrical halves with respect to the vertical axis. However, the advantage of discovering and describing explicitly this accidental bi-lateral symmetry in a repetitive configuration like a colonnade does not counter-balance the corresponding multiplication of structural information in the primitive code and the initial detachment from the reality of the perceived integral components / geons.

25.15 THE EVALUATION OF ARCHITECTURAL FORMAL GOODNESS

Recognition-by-components and structural information theory provide the basis for:

- recognising and representing the solid elements of an architectural scene;
- grouping the recognised elements in multiple alternative configurations;
- evaluating alternative configurations with respect to coding efficiency; and
- establishing preference for one or two dominant configurations which represent the intuitively acceptable or plausible interpretations of the scene.

These operations link the representation of the built environment to perception and figural goodness. The necessary deviations from established conventional architectural representations reflect the choice of general cognitive and perceptual theories as starting point of the investigation. It is proposed that architectural representations and in particular:

a) the use of outlines to denote solid entities and spaces and
b) the deterministic decomposition into known components

should be reconsidered with respect to the recognition-by-components theory and related vision research.

The addition of a memory component to structural information theory would facilitate transition from the basic level of the primitive and end codes to known configurations denoting familiar objects.

The representation of spaces remains a problem deserving particular attention and further research. The use of outlines, as in figure 254, is the obvious starting point, as it conforms to the way we read floor plans and other conventional representations; and to existing computational representations like rectangular arrangements and shape grammars. This would allow exploration of structural information theory and recognition-by-components in the application areas of these representations. From a cognitive point of view, however, the outline of a space in two or three dimensions might not be a relevant or meaningful representation. It has been proposed that surfaces could form a representation level that not only links higher with lower vision,[a] but also agrees with the Gibsonian perception of space in terms of surfaces which fill space.[b]

This view differs entirely from the mainstream Euclidean co-ordinated organisation of perceived space whereby the two dimensional retinal image is enriched with depth information derived primarily from binocular disparity. Perception of space in terms of surfaces stresses the biological and ecological relevance of these surfaces as containers of different actions and as subjects of their planning. One example of this relevance is locomotion for the ground surface and related generally horizontal surfaces.

Another issue requiring further study concerns the essentially bottom-up character of both recognition-by-components and structural information theory. The addition of a memory component to the system, i.e. a database of geon configurations corresponding to known, familiar entities, would facilitate processing of information at basic levels and permit rapid

a Nakayama, K., Z. He et al. (1995) *Visual surface representation: a critical link between lower-level and higher-level vision*.
b Gibson, J.J. (1966) *The senses considered as perceptual systems*.

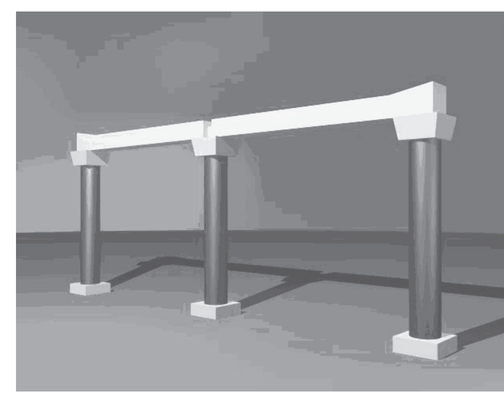
transition to higher levels of the representation. As these configurations would represent compact structures with respect to structural information, we assume that exposure to and recognition of similar or equivalent scenes leads to transformation of earlier experience into memories influencing our understanding and aesthetic evaluation.[a]

25.16 PROJECTING APPEARANCES

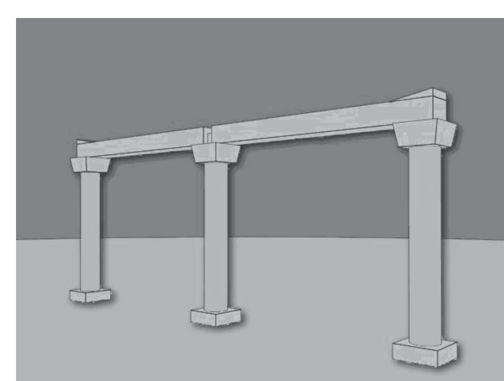
The difference between pictorial and other descriptions (e.g. textual) is commonly explained by resemblance. A picture represents a subject by the intended resemblance of its pictorial properties to the visual perception of its subject. Some interpretations of resemblance may lead to limited views, like assimilation of the experience of seeing a picture to the real life experience of seeing the picture's subject, which moreover are unrelated to the symbolic structure of a picture's content.[b] Nevertheless, resemblance remains an appropriate vehicle for investigating perceptual and cognitive issues in visual representation.

Architectural visualisation has been rather ambivalent with respect to the resemblance issue. On one hand, most basic design representations combine orthographic projection of canonical views with conventional symbolisation. On the other, axonometrics, isometrics, perspectives and especially the rendered ones consciously attempt to project or reconstruct a veridical visual experience. This ambivalence stresses correspondence of composition and projection in architecture to Euclidean and projective geometry. In both architecture and geometry a historical shift can be detected from measurement and accurate representation of a picture's subject to the picture itself.[c]

Proliferation of affordable computer tools for photo-realistic visualisation is placing even more emphasis on the architectural picture. The connectivity of these tools to the standard CAD documentation of design practice means that computer-rendered photo-realistic perspectives are often used instead of simpler images which would convey the same information, especially when the photo-realistic version includes too many assumptions concerning colour and material. It is ironic that some of the more interesting additions to computer visualisation include references to simpler rendering techniques from the past. For example, figure 260 has been rendered with the Illustrator 2 plug-in for 3D Studio MAX. In their attempt to reproduce the quality of colouring and backgrounds in comic books, such techniques are an alternative to the standard, almost photo-realistic renderings (figure 259). The abstraction of comic book imagery is arguably better suited to most stages of the design process, as well as to human recognition of built form.



259 Image produced with the standard (scanline) 3D Studio MAX renderer



260 Image rendered with the Illustrator 2 plug-in for 3D Studio MAX

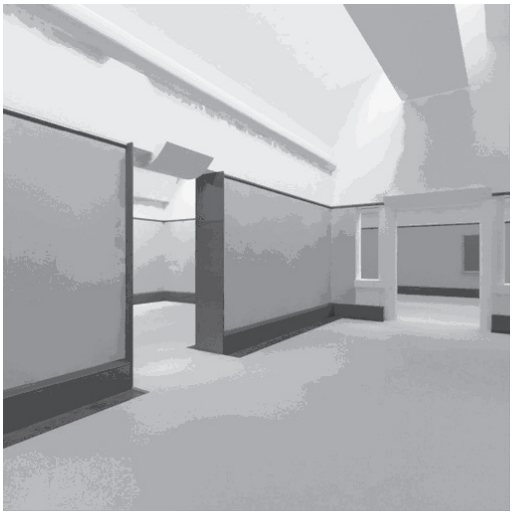
25.17 BEYOND INTUITION: SCIENTIFIC VISUALISATION

Design analysis was traditionally performed with normative rule-based systems geared to generative approaches. Numerous dissections of the design process have resulted in a multiplicity of models attempting to describe the steps a designer takes in the quest for a satisfactory solution. Most models also aspire to prescribe the optimal sequence of design actions. What they propagate is a form of *orthopraxy* (as opposed to the orthodoxy of formal systems such as Classicism and Modernism). Their underlying assumption is that if one follows the sequence of design stages prescribed in the model, one can arrive at a design *satisfying* the programmatic requirements.

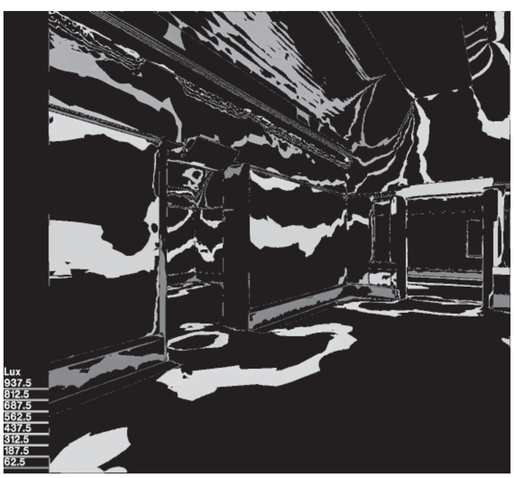
It is unfortunate that no such model to-date can match the intuitive performance and creativity of the human designer. Based on metaphors and similes, most models do little beyond explaining a few specific aspects of designing. Moreover, while they may improve the designer's awareness of actions and decisions, they seldom lead to the development of new, better tools for higher effectiveness and reliability in the face of today's complex design problems. Perhaps the main reason for the scarcity of such tools lies in a lack of interest in the analysis of design products.

Historically such an analysis was subservient to synthesis. Long before terms like functional and programmatic analysis were invented, buildings and design decisions were parsed

a Scha, R. and R. Bod (1993) *Computationele esthetica*.
b Goodman, N. (1976) *Languages of art: an approach to a theory of symbols;* Evans, G. and J. McDowell (1982) *The varieties of reference;* Lopes, D. (1996) *Understanding pictures*.
c Evans, R. (1995) *The projective cast, architecture and its three geometries*.



261 Photo-realistic light simulation (Radiance image by A.M.J. Post)



262 Light simulation: false colour intensity analysis in the space of figure 262 (by A.M.J. Post)

towards an identification of their causes and effects, and subsequently formalised into rules and stereotypical "good" solutions serving as the basis of most building regulations and design textbooks. Rules and stereotypes have a proscriptive function mostly. They attempt to offer design guidance by pointing out errors and inadequacies, i.e. what falls short of established norms.

Proscriptive approach also underlies computational studies focusing on the analysis of designs using the same or similar rules transformed into expert or knowledge-based systems. In these, a design is described piecemeal; which permits correlation of the relevant aspects or factors with the rules. The end product of the analysis is an acceptability test based on matching the constraints of the solution space. The added value of such systems lies in provision of feedback facilitating identification of possible failure causes.

Design analysis is moving towards a new paradigm, based rather on simulation than abstractions derived from legal or professional rules and norms. Recent developments in areas like scientific visualisation provide advanced computational tools for achieving rich detail and exactness, as well as feedback for design guidance. Close correlation of photo-realistic and analytical representations (figure 261 and 262) clarifies and demystifies the designer's insights and intuitions. Moreover, the combination of intuitive and quantitative evaluation offers a platform of effective and reliable communication with other engineers who contribute to the design of specific aspects, as well as comprehensible presentation of projected building behaviour and performance.

25.18 DYNAMIC VISUALISATION

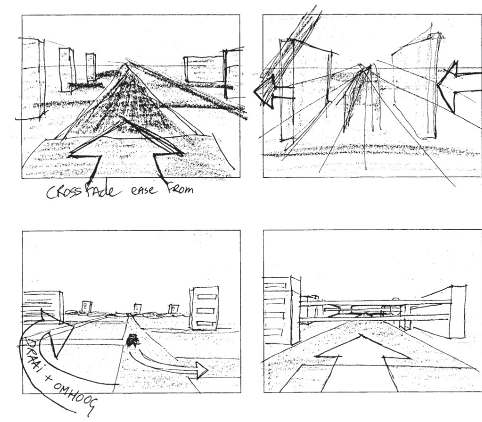
Dynamic visualisation is often presented as the pinnacle of architectural representation, the fullest form of visual realism. By including movement of one sort or another in a three dimensional representation the designer adds depth and time to the subject under controlled conditions, i.e. in the framework of a specific event or state. Since a dynamic description is a sequence of static, photo-realistic images, the results can be superior to other representations for visual inspection, analysis and communication.

As with photo-realism, a frequent argument for dynamic visualisation is the ease with which it can be produced out of three dimensional design representations. While this is true for simple, undemanding movements of the camera or in the scene, more complex subjects and presentation techniques require knowledge and skills beyond the scope of architecture. These are best found in filming. They range from camera positioning and movement to lighting and editing, mixing and visual effects. The technical aspects are largely integrated in the digital tools, but the architect must effectively step into the film director's chair so as to coordinate, guide and manage the process.

Directing a dynamic description is a rôle that in principle fits the architect as specifier and co-ordinator of design and construction of a project and who does not necessarily have physical involvement in actual building. However, the fulfilment of the rôle necessitates substantial transfer of filming knowledge complementing the technical possibilities of digital dynamic visualisation. Ironically most of this knowledge refers to techniques for reproducing on film environments and events without actually having the camera there and then. Even when shooting on location artificial lighting and sets are used to enhance resemblance to the scene envisaged in the script. In the studio everything is not only artificial, but also opportunistically fragmented so as to minimise cost without loss of effectiveness and efficiency. The techniques involved in making a coherent and believable sequence of images from short takes of such fragments and illusions forms the core of the knowledge that has to be integrated in architectural visualisation. Several techniques have already been adopted in architectural design. Matting, for example, is widely used nowadays in making composite images from rendered perspectives of new designs and photographs of their prospective sites.

The main problem with filming techniques is that they run contrary to the holistic undercurrent of architectural design and CAD. The use of partial models for different aspects and abstraction levels does not agree with the idea of a single, complete and integral three-dimensional representation for the whole design. On the other hand, a multi-level modular representation is capable of accommodating the practicalities of dynamic architectural visualisation without sacrificing coherence and consistency of the representation.

Most filming techniques are born out of necessity. However, they are not restricted to compensating for practical limitations. They also offer the means for constraining and controlling a process. One such device is the storyboard, a series of annotated drawings, essentially similar to a comic strip (figure 263). The drawings depict the découpage of the film, i.e. its structure in terms of takes, camera positions and movements. The application of storyboarding in architectural visualisation on the basis of a modular co-ordinated representation adds a vertical co-ordinating device responsible for specific aspects arranged in a sequential way.



263 Storyboard extract (by I.R. van 't Hof)