LOCAL VALUES in a NETWORKED DESIGN WORLD

ADDED VALUE OF COMPUTER AIDED ARCHITECTURAL DESIGN

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Autonomous mechanisms in architectural design systems

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Abstract

The development of architectural design systems that describe fully the form, structure and behaviour of a design relies heavily on the incorporation of intelligence in the representations, analyses, transformations and transactions used by the computer. Traditionally such intelligence takes either of two forms. The first is a methodical framework that guides actions supported by the design system (usually in a top-down fashion). The second is local, intelligence mechanisms that resolve discrete, relatively well-defined subproblems (often with limited if any user intervention). Local intelligent mechanisms offer the means for adaptability and transformability in architectural design systems, including the localization of global tendencies. This refers both to the digital design technologies and to the historical, cultural and contextual modifications of design styles and approaches.

Globalisation and architecture

Architecture has a long tradition in globalization. The most widely acknowledged product of architecture, style, generally travels well from country to country and from period to period. The remarkable history of Classical architecture and its migrations in place, time and symbolism are arguably the best examples of how a canon develops into a global standard, which nevertheless provides ample scope for local variation, adaptation and differentiation.[37; 39] Similarly, the emergence of Art Nouveau and the powerful domination the best part of 20th century architecture by Modernism provide many examples of decentralized development, convergence towards globalization of morphology and typology, and divergence into tendencies, schools, partial reactions and revisions.

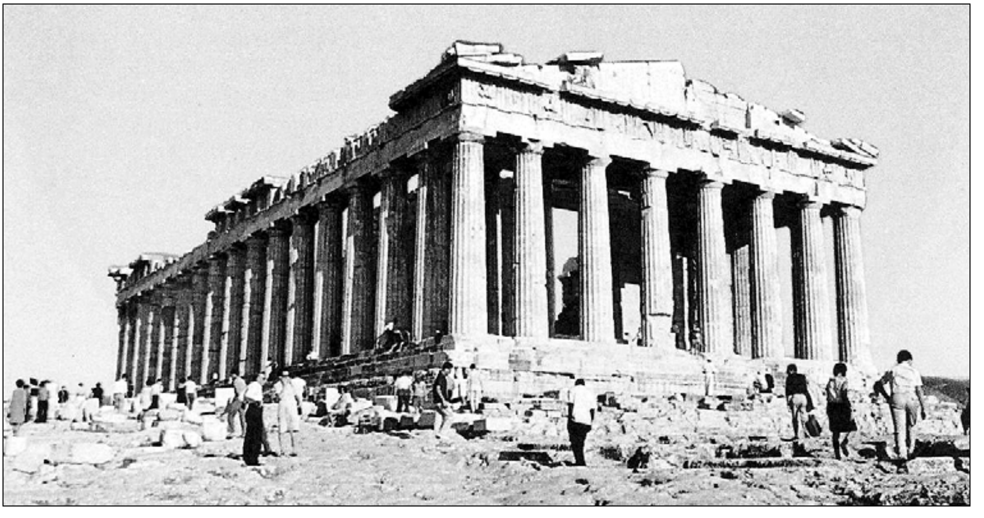

Figure 1: The Doric order: appropriate for a male deity or a bank

Construction is equally mobile and transferable, at the level of general principles (as in the Middle Eastern influences in Gothic architecture), at the level of construction types and materials (as in the applications of reinforced concrete and steel frames) or at the level of building systems (as in the impact of other industries on industrialised building). Globalization in building construction has had many positive influences on the quality and economy of the built environment, such as the widespread application of industrialised building systems in the reconstruction period following the Second World War. At the same time, many construction types and systems like the glass curtain wall have proved inflexible and inadaptable to site, climate or even internal activity.[28]

The culture of the 21st century is considered to be essentially global. The fabric of our lives is been adjusted to the already omnipresent but still evolving social and technological networks demonstrated by the Internet.[4] These networks are bounded by different constraints than their predecessors and provide new possibilities for supplying, processing and controlling information on a global scale. For example, the quality of information can be judged directly by the reliability and relevance of its source rather than the authority of the channel though which it is transmitted. [29] Time is also affected by the attenuation of the channel's significance, as periodicity is increasingly becoming a lesser issue in information dissemination.[19] In terms of supply of goods the significance of national and regional boundaries diminishes, as e-commerce not only allows for worldwide satisfaction of demand but also obliges local suppliers to offer a wider, up-to-date selection of goods that can be delivered almost immediately.

The effects of these changes on architecture cover a wide spectrum, from precedent use and aesthetics to economics and design technology.[26] The scope of the present paper is restricted to the last item and in particular to the digital design technologies used for representing architectural form, structure and behaviour. These are undergoing rapid changes that are accelerated further by the intensified globalization of architectural information. Not so long ago every country and practically every CAAD chair in the world was developing drawing and modelling systems that purportedly befitted the national or even regional building culture. While the CAD, modelling and visualisation markets were soon dominated by a few, internationally-oriented products and companies, there remained enough scope for add-ons and libraries that adapted the general-purpose products to the apparent requirements of an application area such as architecture or to the culture of a national building industry.

More recently the ability to disseminate software with more speed, the increasing globalisation of the economy and the clearly discernible but vaguely motivated dissatisfaction with general-purpose instruments and their partial adaptations have paved the way for products that are strongly linked to design approaches. These approaches generally relate to the increasing awareness of the importance of handling the complexity of design processes and design products with efficiency and accuracy. At the same time, research is once again paying attention to the representation of architectural form. This is motivated by a variety of reasons, from creativity and collaboration to the design and construction of complex or irregular forms.[7; 16; 14; 27] Common to all these developments is the attempt to lift the level of practical design technology by making this technology more intelligent and responsive to the intentions of the designer, as well as to the wider constraints of a project, e.g. client requirements or site constraints. In a sense, they negate the old, unproductive distinction between drawing and design that has been permeating CAAD for over two decades.

The hypothesis the present paper puts forward is that the addition of intelligence to computerised design systems and especially representations is a reliable basis for the flexible adaptation of global products. This combines

- the economic advantages of globally intended design systems for research and development,
- the possibilities for trans-national and multi-disciplinary design activities and collaboration on the basis of global standards and
- the ability to localise design decisions with respect to changing reference frameworks that reflect legal, economic, professional, situational and constructional constraints.

It is proposed that the desired integration of local constraints in global design systems can be achieved in a bottom-up fashion that employs autonomous mechanisms, which may operate in a semi-independent fashion. Such mechanisms are capable of evaluating design decisions with respect to external constraints by focusing on specific design entities. The evaluation can take place without user intervention (in the background of explicit user actions) and can result into automatic and transparent yet unobtrusive adaptations or warnings and proposals to the user.

Representation and intelligence

The computer is arguably the first technology to allow the full representation of architectural form with precision, accuracy and reliability.[9] This has had a significant contribution to the acceptance of computerized drawing and modelling in practice and has been a cornerstone of research into design computing. The potential of computer design representations is currently of particular relevance to two indirectly related but equally demanding developments in architecture:

- the increasing interest in complex and free forms, and
- the growing importance of design information management throughout the lifecycle of a building.[16; 17]

The first has stimulated the transfer of advanced computer graphics to architectural design systems, as well as connections with technologies that permit a closer link between design and construction, e.g. through rapid prototyping.[3; 2] The second has promoted more coherent and comprehensive treatment of digital information towards the integration of all design aspects and activities in virtual prototypes that describe fully not only the form and structure but also the behaviour and performance of a design.[18]

Both developments stress the importance of knowledgeable and responsive digital information. In particular drawings, models and other visual representations of architectural form are re-emerging as intelligent encapsulations of usable information rather than as passive recipients of extrinsic design actions.[23] Despite the unproductive insistence on distinguishing between design and drawing, CAAD has a long tradition in intelligent representations. This tradition generally relates to generative approaches. Generative systems rely frequently on representations that express the generative rules as constraints on entities. Such representations are central to techniques such as rectangular arrangements and shape grammars.[33; 35] For example, the Palladian grammar contains rules that link underlying patterns and the form of adjacent spaces with the shape of emergent spaces.[34] The resulting Palladian floor plan is not a mere collection of lines but an encapsulation of the rules and the processes that return a Palladian composition. The generative rules can be reversed in function and used to parse the floor plan in analyses of concepts relating to e.g. symmetry and proportion.[21]

The same approach of defining a complete methodical framework and imposing it onto design information underlies the majority of representations proposed in the general framework of design automation.[15] These representations structure information into coherent and comprehensive systems that cover the available aspects and abstraction levels. In addition to their structuring role, a methodical framework also supports the interpretation of information contained in representations, including the translation of one representation to another, the retrieval of information and the detection of interdependencies and conflicts. The coherence and consistency that are provided by such a methodical framework are counterbalanced by serious practical disadvantages relating to manageability.[11] Maintenance of a structured representation for a building of a realistic size, coverage of all aspects and design stages, and communication of new information and critical relationships to the parties involved are generally cumbersome, error-prone and time consuming. Use of such a representation requires an effort that is disproportionate to the expected efficiency improvement. Such problems are accentuated by the frequently top-down character of the methodical framework, which derives from a specific design approach that is primarily concerned with the higher levels of designing. Translating this approach to all aspects, levels and stages of the design process involves confronting a number of methodical and implementation problems. In most top-down approaches these problems are not resolved a priori but deferred to the user of the representation who is frequently obliged to improvise and spend time on refining the representation or the underlying approach instead of solving the design problems in hand.

The top-down imposition of a methodical framework is also questionable with respect to the subject of the present paper, the localization of globally intended design technology. The fundamental question concerns the existence of a framework that can encompass all others. Evidence from systematic research into such structures, as e.g. in shape grammars, suggests that this is highly implausible: there can be no shape grammar that is capable of generating all kinds of architecture, from Palladian to Wrightian.[36] Similarly, applications of a top-down methodical framework in different contexts than originally intended may cause inconsistencies and confusion that arise from lack of compatibility: design and building processes change with the context, as do materials and components. It is not only that a German window can be radically different in form or structure from an American one, the different ways they are ordered, produced and assembled in a building reflect fundamental incompatibilities that cannot be resolved by a relaxation of the methodical framework or the aggregation of various frameworks. Moreover, changes of cultural context also reflect on performance requirements, which may have widespread influences on all levels of a design and its representation.[25]

An alternative to adding intelligence on a representation by means of an extrinsic methodical framework is to concentrate on discrete, relative well-defined subproblems and parts and empower the representation with autonomous mechanisms for their local resolution. The definition of these mechanisms derives from an earlier formulation of multi-level architectural representation.[20] This formulation proposed that architectural representation cannot be reduced into building and spatial elements and bilateral relationships between elements, as in the simplest implementation of semantic networks and similar formalisms. A multi-level architectural representation has a form similar to that of the pyramidal structures used in image analysis and the modular hierarchical representations of computer vision.[30; 24] The proposed representation consists of three basic strata:

1. *Elements:* frequently the sine qua non of an architectural design,[37] widely identifiable entities with a variable integrity depending on scale / resolution

2. *Global coordinating devices:* schemata that describe general design principles or abstractions of a design, such as the 3 x 5 grid that underlies Palladian villas[40]
3. *Local coordinating devices:* collections of constraints into semi-independent structures that regulate the form and behaviour of elements, also on the basis of global coordinating devices

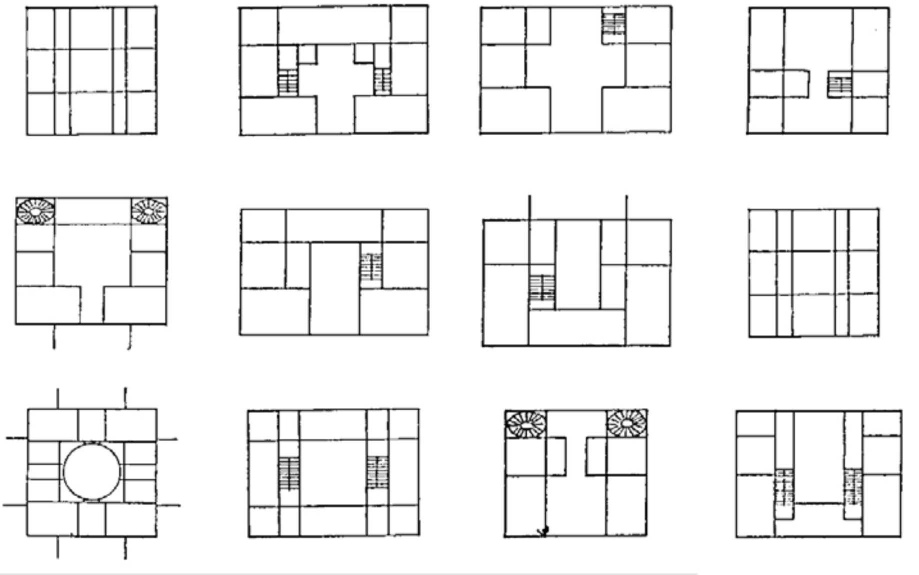

Figure 2. Global coordinating device: the 3 x 5 grid of Palladian villas[40]

(It is unfortunate that the terminology used in this formulation may initially confuse the reader. The terms ‘global’ and ‘local’ are used in the proposed representation to suggest mechanisms that refer respectively to the whole design and to a part or aspect of the design. At the same time the same terms are used to refer to cultural and technological globalisation and its opposite or reaction, localisation. What may make things worse is that local coordinating devives are proposed as a way of supporting localisation in design representations. I can only apologise to the readers for the unavoidable but hopefully short-lived confusion.)

The implementation of local coordinating devices as autonomous mechanisms is a clear reaction to the limitations of geometric parameterisation by means of constraint propagation, i.e. the addition of constraints to the elements and the correlation of elements through these constraints. The complexity of the resulting planar networks is too high to allow for efficient automation or for transparent management of the representation. Moreover, the constraints connect the general type of an element and its physical context. For example, the constraints that determine the positioning of a door reflect general functional requirements for entering or exiting a space in relation to the form and structure of adjacent elements such as other doors and walls. These constraints not only adjust the position of the opening and refine construction details but may also trigger a change in the door type used. In other words, a local coordinating device may focus on an element but does not belong to it – rather, the device refers to the type of its element from the particular viewpoint of the constraints that are integrated in it.

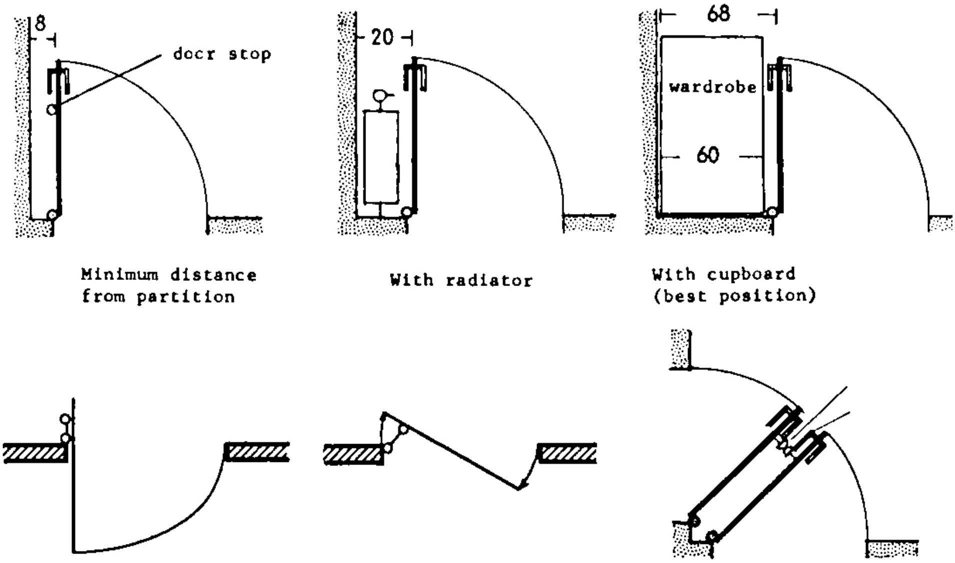

Figure 3. Constraints belonging to a local coordinating device

The autonomous character of local coordinating devices also relates to the increasing interest in agents and similar mechanisms in designing. [1; 5; 8; 12; 13; 22; 31] The attraction of such mechanisms appears to lie in the reduction of determinism and predictability they entail. Also the distribution of responsibilities and authority to self-sufficient devices with a known scope can be an effective way to tackle complex decision and achieve variation within the same design.[6; 32] Such capabilities agree with the requirements on local coordinating devices, which are expected to resolve the problems to which they refer with minimal if any user intervention, taking into account other devices in the representation (local or global), as well as external information from e.g. the design brief or applicable rules and regulations.

Detail and architecture

One of the phenomena linked to the globalization of culture and technology in architectural design is the current emphasis on conceptual design and design ideas as an epitome of the design product, as well as the design process. This abstraction level removes most information that links the design to its physical context and its content (activities and actors), while accentuating general morphological and typological aspects. Consequently, the application of globally intended systems remains unattached to the critical realities of functional analysis and constructional elaboration. The historical fixation of architecture on abstractions and central design ideas, as testified by the reverence for even the vaguest sketches, has created a highly tolerant climate for such attitudes.

However, equating creativity to high levels of abstraction and restricting its expression to the conceptual design stages only is uninformed and unproductive. The product of architectural design is a complete and reliable specification for interventions in the built environment. The long journey between the formulation of a design idea and this specification entails resolution of problems that were unaccounted for in the idea and its abstract form. Considering the consequences of the idea from different points of view and at various levels of abstraction does not equate to merely replacing defaults in the idea with precise values. It also involves revision of the idea in feedback loops initiated by local problems, extension of the underlying principles as a result of encountering problems not covered by the original design idea, and addition of new ideas that address design aspects not considered initially. For example, the structural solution of a design may be absent from the initial idea to the extent that the subsequent choice of a structure may change radically the spatial form of the design.

The final product of this process is a design specification that ideally works at all levels, from the abstract typological and morphological ideas that present the basic intentions behind the design and the general principles that determine the choice of subsystems and the distribution of activities in the building to the construction details, finishings, fixtures and furnishings that define the behaviour and performance of the built environment and in particular the interaction with its users. In architectural circles it is only too often forgotten that our daily interaction with the built environment may be conditioned more by details such as the properties of the surfaces we come into contact with and less by abstract design ideas, which may be invisible in the human scale.

Detailing also plays an important role in the localisation of global forms and patterns. A closer examination of even dogmatically global formal systems like the Modernist canon reveals great scope for local variation, depending on factors such as local materials, construction types and climatic adaptation.[10] Appropriate dimensioning, orientation, surface treatment and choice of materials can drastically alter the character and performance of a central feature. For example, an unprotected glass curtain wall in a hot, sunny climate is a poor choice with respect to energy consumption, as well as thermal and visual comfort. If the same essentially curtain wall is protected by external shading elements that limit the internal heat gain it may provide unobstructed views and a visually closer relationship between indoors and outdoors. Filtering direct sunlight by means of double reflection has proved a successful and reliable solution in this respect.[38]

Local coordinating devices offer the means for such adaptability and transformability in architectural design systems. Rather than having to develop national and regional variations of global design technologies we can delegate localization problems to such mechanisms, whose autonomous functioning allows for the direct yet unobtrusive correlation of design decisions at the level of elements and global coordinating devices with a plethora of constraints. These include the orientation of a building or element, local climatic conditions, the local building regulations, particular programmatic or functional requirements, specific activity patterns to be accommodated in the building, as well as aesthetic and constructional preferences of the designer or the client. Such constraints are frequently irrelevant to the central design idea of a building and generally neutral with respect to the basic design technologies used for representing the building.

Experiments with local coordinating devices have been quite encouraging. In these experiments the focal points for the devices have been components of the external envelope of a building (in particular windows, shades and louvers) and internal access openings. Such components represent critical parts of a building (as they may relate to several aspects) and are moreover characterised by limited flexibility (mainly due to the dominance of a specific function). The local coordinating devices for these components were implemented as frame-like constraint networks that incorporated specialised agents for providing input and output. One class of input agents consisted of infobots that searched for relevant information in off-line project files and online legal or professional documentation, including product catalogues. The infobots were activated by a second class of agents that recognised automatically the context of the components they focused upon. For example, if a door had to be translated in order not to overlap with a load-bearing vertical element, the new position was firstly analysed with respect to local circulation requirements and then, if proven satisfactory, its original dimensions were considered with respect to its new position. If the width did not fit, the agents passed on a request for a smaller door to the infobots. These recovered a number of appropriate candidates that were analysed further with respect to the particular requirements of the door (e.g. fire safety).

Output agents passed on the resulting properties and constraints to other components and their coordinating devices. For example, the relationship between a shading component and a window involved communication between a space, the window and the shade. Despite the complexity of the representation setup, the autonomy of the local coordinating devices operated efficiently. Most partial transformations of a design were resolved automatically. The only situations where the user had to be informed and asked for a decision arose when the window failed to provide the amount of daylighting required by the building regulations and when the decision involved multiple criteria, e. g. good view in a climatically unfavourable orientation.

Discussion

The use of intelligent autonomous mechanisms based on the concept of local coordinating devices is proposed as an efficient end effective way of handling problems relating to parts and aspects of a design. The resulting bottom-up integration of constraints allows for permanent design control with respect to internal decisions and external conditions in a generally transparent and unobtrusive bottom-up manner. Design decisions can be worked out without explicit involvement of the designer, unless conflicts emerge that are beyond the scope of the local coordinating devices.

A prerequisite to the use of such mechanisms is the availability of the constraints involved in digital documents (either offline or online). Setting up and training the mechanisms that search for and use this information is an extensive and cumbersome task. On the positive side, errors in the setup or training are not critical, as conflicts and inconsistencies are easily detected by the user and rectified by his decisions, which modify automatically the operational parameters of the autonomous mechanisms.

A primary advantage of the combination of local devices and autonomous mechanisms is that the designer can apply global solutions both in terms of design technology and at the level of types, precedents and cases. Globally intended instruments do not need to be modified with respect to their methodical framework and operational assumptions. Local coordinating devices can localise these by adding constraints derived from national or regional sources (e.g. building regulations, component catalogues, construction types and processes). The same applies to designs developed for other contexts. Autonomous mechanisms based on local coordinating devices are in principle capable of transforming automatically a precedent in accordance with the specifications of new brief, the constraints of a new physical location and the norms and rules of the new building regulations.

The main limitation of such autonomous mechanisms lies in the lack of compatibility control between different local coordinating devices. In many respects such control can be derived from global coordinating devices but the latter cannot possibly cover all design aspects. For instance, the choices of components made by different mechanisms can be coordinated in terms of constructional compatibility between adjacent and connected elements but consistency in the overall choice of materials and colours in the components that bound a space is left to the designer. In principle such tasks could be taken over by coordinating devices that focus on larger assemblies and spaces. However, this would increase explosively the complexity of the multi-level representation and reduce its transparency and sustainability.

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