One of the most significant consequences of computerization in design practice is a spectacular increase in the amount and complexity of information produced for the specification, analysis and communication of design decisions and products. Computerization is intended to have a positive effect on such subjects but offers no built-in guarantees. The complexity, redundancy and amount of information that is generated on a variety of media has accentuated the problems of archiving, indexing and retrieving design documentation, either in the same project or in related ones. The shortcomings of visual information processing derive from a number of inherent problems: lack of integration in information carriers and kinds; organizational uncertainty, especially with respect to archiving and retrieval; superficial replication of analogue practices; limited understanding of information utility; chronic underestimates of automation potential coupled to overestimates of costs. A progressive improvement of design documentation should focus on: (1) the integration of information kinds and carriers in a single representation (in the direction of virtual prototyping); (2) correlation of information registration and processing with information utility; (3) structural rather than opportunistic or deterministic integration of utility requirements in design representations; (4) recognition of informatization and information management as a new specialization that complements existing roles in the design and management of the built environment.

**Keywords:** Computerization; management; visual representation; integration

**Computerization and documentation**

CAAD research and teaching is currently severely constrained by developments and tendencies in practice. Based on the general democratization of information and communication technologies, architectural computerization in practice has arguably surpassed the scope of academic CAAD and revised several of its premises (Koutamanis, 1993; Koutamanis, 2000). Similarly to other professions, architectural offices nowadays rely on the computer for the production of a wide range of documents for internal and external use. However, the extent of computerization does not necessarily mean improvement of effectiveness, reliability or even efficiency. This is most evident in the form of digital architectural documents such as drawings and renderings. It seems that, as the primary reason of these documents is to produce analogue versions, little attention is paid to issues such as structure, semantics, integration, correlation or overall utility. In other words, such documents rarely qualify as usable digital design representations (Koutamanis and Mitossi, 2000).

Architectural computerization in practice is often characterized by superficiality, segmentation of processes and products, a large number and high
redundancy of information carriers, rapidly increasing quantities of barely manageable information and an overall high complexity that combines the worst of the analogue and digital worlds. Efficiency improvement (the main promise of computerization) is at best only local. Nevertheless, efficiency should not be the primary and certainly not the initial target of computerization. More appropriate targets relate to the improvement of architectural information, its management and utility so as to provide a reliable and effective background to architectural performance (Mahdavi, Brahme, Lee and Mertz, 2001).

Some of the problems of architectural computerization are due to demographic reasons. Most applications in practice are decided, managed and implemented by older architects with insufficient grounding in architectural computerization and no incentive for proper on-the-job training. Other problems relate to the relative immaturity of digital media and devices. Both the ergonomics and the cognitive ergonomics of computer-based tools are frequently judged to be inferior to those of their analogue counterparts. Such shortcomings can be alleviated partly by technological evolution, e.g. larger screens and interface refinement and partly by human adaptation to the affordances of the computer. The latter is also related to the demographics of computer users.

However, the core of the problem remains architectural. The increase in the amount and complexity of information produced for the specification, analysis and communication of design decisions and products derives less from computerization and more from necessity to improve the depth (specificity) of architectural documentation (Nys, Provoost, Verbeke and Verleye, 2001). The tendency towards informatization in e.g. communication and manufacturing raises the level of explicitness, accuracy and precision in design information, as well as of coherence and completeness in the resulting information complex. Consequently, more and more detailed information is being produced to cover the width and depth of the required specification, even though it is generally acknowledged that quantity of information is not by itself the solution.

Computerization is designed to have a positive effect on both information production and coordination but offers no built-in guarantees. In terms of effectiveness and reliability it is constrained by the underlying methodical approach, while in terms of efficiency it adds to the tenacity and extent of design information processing. The complexity, redundancy and sheer amount of information that is generated on a variety modern media has accentuated the problems of archiving, indexing and retrieving design information, either for the same building project or for related projects (cases and precedents). Computerized archiving, indexing and retrieving design information has also made evident that the correlation of different items, aspects or abstraction levels is no trivial problem. The comprehensive representation of a design on the basis of correlated documents (i.e. partial descriptions) is becoming increasingly cumbersome, with negative effects on consistency and completeness.

The visual design document
Computerization has traditionally focused on alphanumeric information. Despite significant technical advances, visual documents remain relatively unexplored. Even advanced techniques like content-based indexing and retrieval may rely on human interpretation and segmentation. Disciplines such as architecture, which employ visual documents such as drawings and photographs, receive little technical support for the processing of such documents. Computerization appears to underestimate the potential of images as information carriers (Lopes, 1996). The treatment of visual documents as largely integral entities with an ad hoc structure and uncertain utility is symptomatic of the uncomfortable relationship between architectural attitudes and the mathematical and cognitive principles underlying architectural representations (Evans, 1995).
In practical terms, we are confronted with a variety of visual information carriers and kinds, which derive from different origins and different digitization channels. On the one hand, a large proportion of digital architectural documents are digitized analogue images (drawings, sketches, photographs). These are input in the computer usually by optical means such as scanners that transform them into arrays of pixels. Pixel images can be static (still photographs or technical drawings) or dynamic, i.e. sequences of static images (video). In addition to digitized analogue images, CAD and other computer programs are used to generate design documents such as two or three dimensional drawings and models. Computer-generated visual documents include pixel images (e.g. renderings) but are generally vector-based. Moreover, they are interactive: their appearance can be modified by the user by means of selective manipulation ranging from panning and zooming to turning layers on and off.

Production, transfer, storage and dissemination of digital images follow analogue practices. These are characterized by the integrity and self-sufficiency of each document. Cross-references to other documents are usually meant as a reference frame. This is due to the segmentation of information by projection (floor plan, section, elevation) and type / subject (detail, rendering, scale). Even though drawings can derive from the same representation, e.g. a three-dimensional model, CAD drawings generally reproduce analogue formats. For example, in a CAD-drawing it is quite usual to have floor plans drawn next to each other (instead of on top of the other) and sections and elevations around a floor plan (rather than on planes perpendicular to it).

This lack of correlation and connectivity extends to the relations between computer-generated and digitized images. While the former are emerging as the primary design documentation and specification, the latter are indispensable as carriers of additional visual information on the state of a building (photographs of damage), historical or cultural value (photographs of surfaces ornamentation) and behaviour / performance (light simulations). Such information can be registered in two manners: as alphanumeric annotations or as attached visual documents. Annotations are more useful in terms of classification but inevitably suffer from omissions (ellipsis) and subjective interpretation, i.e. inconsistency, especially where more than one persons are involved. Current CAD systems provide ample facilities for the integration of pixel images in vector models, as well as for linking external pixel documents to specific groups of vectors. Despite such facilities, CAD practices appear to be too firmly rooted in the tradition of analogue technical drawing to make intensive use of compound representations.

It is noteworthy that many of the missed opportunities relate to the lack of appropriate structure in CAD drawings. Overconstrained standardization schemes, overreliance on superficially structured component libraries (of inflexible symbols), the efficiency push and hypes such as the virtual workplace have conspired to reduce drawing structure to prescribed modularization (e.g. layers) and element description at the level of implementation mechanisms rather than that of the symbolized entities (Marr, 1982). In most CAD drawings elements are described by formally unrelated collections of graphic primitives. For example, a rectangular column in a floor plan may consist of four loose straight line segments, hopefully intersecting precisely at their endpoints. Even worse, a space bounded by building elements is only implicit in the drawing, as in its analogue counterpart. The lack of symbolic structure is a major obstacle for the integration and correlation of digital visual information (Koutamanis, 1995; Leusen and Mitossi, 1998; Mitossi and Koutamanis, 1998).

**Design information systems**

Despite the relative immaturity of visual design documents, the extensive application of digital design tools and the resulting huge production of digital visual documents have made practice sensitive to the management and utility of these documents. The solutions proposed to this end invariably involve
computerization, even if the documents are largely analogue. The envisaged design information systems profess to serve a variety of purposes at different levels of abstraction. In the case of a single design project they should constitute comprehensive dossiers for the registration and communication of design decisions. These dossiers should also be usable in other, related projects as sources of relevant cases and precedents. Moreover, with the proliferation of informatization in many aspects of the building industry, such dossiers also promote continuity of design information e.g. in the direction of construction and facilities management, as well as of stock and real estate management. A comprehensive archive of buildings and projects provides a stable, responsive and transparent background to strategic decision taking.

Attempts to meet such purposes can be classified in three basic categories. The first is the application of commercially available or purpose-built document management systems. These address the administrative side of designing by registering time, authorship, revision etc. In the best cases they also offer (interactive) indexing facilities and trigger automated background tasks, such as archiving and dissemination of documents. Even in complex, coordinated environments such as extranets and groupware for collaborative design, document management takes a prescriptive form by specifying the position, type and relations of an document and refers more to integral documents / carriers and less to the information they contain (Chiu and Yamaguchi, 2001; Morozumi, Homma, Shounai et al, 2001). This impedes the emergence of compound representations out of correlated collections of documents. Document management is an essential component of office automation that facilitates and supports human processes. However, it offers no solutions to domain problems like design control and guidance as feedback triggered by the identification of omissions or conflicts in the visual documentation of a design.

The second category derives usually from CAAD research and proposes to resolve coordination problems by means of holistic representation formalisms which integrate a wide range of design aspects in a single geometric description, usually heavily annotated or cross-referenced to external databases (Mahdavi, Brahme, Lee and Mertz, 2001; Mahdavi, Mathew et al, 1997; Ozel, 2000). In the framework of research such formalisms have generated useful insights and valuable refinements to representation approaches. However, practice generally views such holistic systems with skepticism. The level of automation they involved is considered to be too advanced and hence too expensive in terms of infrastructure, facilities and training.

Also the third category has academic origins but a much shorter tradition than representation formalisms. Its approach too is more radical, as it focuses on virtual information space and the use of advanced interfaces. These build on document management systems or general information technologies (usually on the Web) and place emphasis on communication and exploration (Schmitt, 1999; Stäger and Engeli, 2001). This category represents a possible new architectural application, provided that it moves beyond metaphorical (i.e. lay) use of space as an interface, so as to utilize architectural knowledge on human interaction with space.

Classification into these three categories reveals a fundamental shortcoming of current approaches to the coordination and management of visual design information: they are either subservient to existing operational patterns in practice or largely unrelated. This explains the frequent reluctance of practice to invest into applications of CAAD academic knowledge, as well as the largely technocratic approach to design automation, especially at the level of information management. Therefore, approaches to design information management are confronted with the following problems:

- Organizational uncertainty: The addition of computerization to architectural practice is seldom the result of a thorough plan of reorganization. This leads to several, usually alternative but frequently overlapping organizational structures
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which may confuse the user. This is most evident in the archiving and retrieval of documents: without personal knowledge of a project, identification of (all of) the desired information can be time-consuming and frustrating.

• Superficial replication of analogue practices in digital information processing: This is the joint product of organizational uncertainty and lack of knowledge of and experience in CAAD, especially with respect to the analysis and reconsideration of ends and the recognition of appropriate means.

• Limited understanding of information utility: One of the most frustrating aspects of computerization in practice is that digital information is rarely used outside its original purpose. Such rigorous segmentation makes practice unaware of possibilities for e.g. information exchange and hence reluctant to invest in coherent and comprehensive documentation.

• Chronic underestimates of automation potential coupled to overestimates of costs: This follows from all the above and forms a major obstacle to informatization. Approaches that require substantial initial investment and do not return immediate spectacular results compare unfavourably to the analogue equivalents, even if they are more economical and productive on the long run.

A bottom-up approach to visual documentation management in architecture

The analysis of the current situation in practice suggests that improvement of visual documentation processes and products can only be incremental, in a bottom-up manner, even when the target remains a comprehensive representation-driven solution or an advanced visual interface. The components of the proposed approach are:

1. Integration of different information kinds and carriers in a single representation: rather than introducing novel representation in a demanding, short-term environment such as architectural practice, we can integrate all drawings (floor plans, sections, elevations, details) of a design in a single document. This document also contains pixel images (photographs, video, sketches, scanned analogue drawings), either integrated or as cross-references (hyperlinks) to external documents. Provided that these partial drawings are structured in a consistent and relevant way, the emerging multilevel representation covers a variety of abstraction levels and can therefore be used throughout the design process (Koutamanis, 1997). Such a representation can evolve further in the direction of virtual prototyping and support continuity of information throughout the life cycle of a building. In the short term, integration of visual documents reduces drastically the size and complexity of a project dossier, thereby resolving most administrative problems and making the information carrier and storage less important than the transparent attribution of information. This is also beneficial to the correlation of individual actions and production to group frameworks and activities.

2. Correlation of information registration and processing with information utility: The current segmentation of design information derives from analogue practices. The transformability of digital information improves utility by facilitating information exchange between processes, continuity in the registration of design development and flexible, interactive treatment of designs. The comprehensive identification of situations where specific information forms the input or output of decision and communication procedures is a prerequisite to the evolution or replacement of existing practices.

3. Structural rather than opportunistic or deterministic integration: Identification of utility and matching to available information does not necessarily lead to structural improvements in design information and its management. As opportunistic or deterministic solutions seem more efficient in the short term, structural measures are
frequently put off to a later, more appropriate time, only to be forgotten with the next problem. Emphasis on the explicitness of utility requirements in well-defined representations of design products or processes is an effective and reliable approach to such problems.

4. Recognition of informatization and information management as a new specialization: Given the general acceptance of the demographic factor in the current state of design automation, a reasonable academic reaction is the development of a new specialization that complements existing roles in the design and management of the built environment. This specialization should become the carrier of new computational methods and techniques that utilize information and communication technologies in practice.

An educational perspective

The last component as well as the overall approach entail a strong educational dimension that has three main consequences for CAAD teaching:

1. The scope of adult education is increasing to a degree that makes it an obvious target for academic education. At the same time, adult education is hampered by the frequent inability of the existing workforce to go beyond analogue facsimiles and by the practical implausibility of on-the-job training.

2. The juxtaposition of existing commercial CAD courses and tutorials with academic CAAD education and training should make explicit the significance of design representations, and facilitate the transition from mere registration of a design’s form to design information processing and decision taking.

3. The production of the new specialists required for effective and efficient design information management is a combination of technical and organizational skills that should always remain coupled to domain knowledge.

References


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