Architectural Design Methods with Commercial Computer Aided Design Systems

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Abstract. This paper seeks to contribute to the discussion about the changed expectations towards computers as design tools by presenting three case studies describing how a computer aided design (CAD) system is used in a design setting. The first case describes how the commercial CAD system is presented to students of architecture at a university. The second and third case studies show how designers in an architectural firm have evolved distinctly different ways of augmenting their creative thinking using the CAD system. The three cases demonstrate how designers adopt standard tools and adapt their individual design processes to utilize digital media creatively.

Keywords. CAD, digital design, architectural profession, innovative processes, creative processes

Introduction

The traditional idea of computer aided drafting and the tools needed to support it have saturated architectural offices. However, the idea of computers as mere production tools is no longer adequate. The critical question in the minds of architects now is how to use digital tools more effectively. They seek to gain value from computers not in the secondary role of drawing production, but in their core problem-solving activity, which is design.

This expectation that computers function as design tools and not merely as production tools has led architectural designers into an exciting new realm of digital investigation. Many thinkers in academic settings have sought to use computers as design tools for years and have introduced architectural students to innovative concepts (recent examples are Koralevic, 2001, Norman, 2001 and Fowler, 2002). CAD system usage in architectural practice, however, still seems limited to representing designs that were generated using other media. There is even dispute whether computers are actually usable as design tools (Johnson and Mueller, 2000). Considering the diversity and depth of exploration now occurring also outside of academia it becomes more important than ever to share and evaluate developing digital design methods. Therefore, we seek to contribute to this discourse by presenting three case studies describing how a CAD system is used as a design tool.

The first case study describes how the CAD system is presented to students of architecture at a university. In an age of massive technology training and retraining, this academic case study shows one way a CAD system can be effectively presented as a design tool. The second and third case studies show how designers in an architectural firm have evolved distinctly different ways of augmenting their creative thinking using a CAD system either in single-media or in multi-media design processes. The three cases together demonstrate how designers adopt standard tools and adapt their individual design processes to utilize digital media creatively.
Design Education Case Study at the University of Wisconsin

Like most practitioners, the faculty members at the University of Wisconsin – Milwaukee (UWM) School of Architecture prefer to use mainstream commercial drawing and modeling systems. Also like most practitioners, the school is slow to adopt new digital technologies. Modeling and visualization have only recently supplanted drawing production as the focus of computer instruction. This mirroring of professional practice provides an opportunity to study problems prevalent there, and to explore potential solutions without rejecting conventional practice outright.

In addition to the exclusive use of mainstream design systems, UWM uses a strategy for computer training commonplace in professional practice. Such training relies on generic instruction distributed in mass to participants with diverse backgrounds. And further, in order to control the cost of training (and retraining) firms commonly seek to maximize class size and minimize class duration. This economic strategy is also present at UWM, which requires only one computer course. Although the course does use hands-on, tutorial-based instruction, it is taught in an auditorium setting with an enrollment of 150 students.

This learning environment is not ideal, but it serves to simulate the impersonal nature of continuing education experienced by many practicing architects. The pedagogical challenge is to use UWM as a pseudo-professional laboratory to develop digital design instruction for mass distribution using mainstream digital tools, and to do so in a manner that cultivates the individual’s creative process.

Stated in broad terms, the solution pursued at UWM places technical procedures into a conceptual framework, generic enough for a wide audience and flexible enough to diverge in application. The mainstream tool, which does not clearly imply a creative process, is mapped to a specific set of creative techniques taught concurrently with the tool. In this way, the conceptual framework establishes a high-level correspondence between an a-methodological tool on one hand and the distinctive methods of an individual designer on the other. The remainder of this section of the paper describes the conceptual framework and how it is intended to operate.

A designer employs a collection of mental operations to manipulate form and space in the process of solving an architectural problem. He “folds,” “wraps,” “melts,” or “pierces” geometry. The possibilities are endless, but the specific choice of mental operation is a crucial means of directing the creative search. The choice to “fold” geometry, for example, leads to a different family of solutions than the choice to “melt” geometry. This proposition extends the concept of “mental frame” developed by Picon (1996) to explain the relationship between mental representations used and innovations discovered by scientists.

If such mental operations, implicitly or explicitly, drive a designer’s geometric manipulations, and if a CAD system offers a finite capacity to manipulate geometry, then we may ask how a designer’s mental operations map to a supported set of digital operations. The conceptual framework used at UWM results from our search for an overlap between these types of mental and digital action. Or more precisely, it results from identifying the mental operations supported by the mainstream design system used here (MicroStation TriForma by Bentley Systems, Inc.). There seem to be only five operations supported by the system, which are generally shared by other mainstream systems as well. They are “aggregating,” “carving,” “molding,” “extruding,” and “skinning.” These terms are used in their broadest sense, and there are many synonymous or near-synonymous operations subsumed within these categories. For example, “wrapping” is a variation of skinning;
“slicing” is a variation of carving; “sweeping” is a variation of extruding. Regardless of the semantic alternatives, there are five fundamentally different digital operations, each supported by a nearly distinct set of functions in the software.

These five mental/digital operations organize the content of the class. The first instructional module covers aggregating, which is the process of combining two or more simple geometries to create a more complex result. Students solve a design problem by aggregating simple objects while making a digital model by aggregating a corresponding set of digital objects. The second module focuses on carving, in which volume is selectively removed from a simple whole to produce a more complex result. Again, students solve a design problem specifically crafted to facilitate carving, while simultaneously carving a digital model of the solution. In each case, the student learns to align digital making with underlying thought process. One of the premises of the pedagogy is that when digital method harmonizes with mental method in this way, the computer often augments creativity.

The class proceeds through each module, organized around one of the five operations. This portion of the coursework satisfies the need for a mass curriculum, since the operations are shared by all. Then in the second stage of instruction the student begins using the operations selectively and in combination. This satisfies the need for flexibility. Later design problems require the student to select one of the five operations – emphasizing the need to maintain a mental/digital alignment regardless of the choice. And finally students are asked to think of the five operations like primary hues in a color system. The fact that all hues ultimately reduce to ratios of red, blue and yellow does not unduly limit the painter’s choice of color. In fact the world is full of sundry hues as a result of only three primaries. Likewise, the designer combines the five operations in various sequences and ratios to generate a wider range of possibilities. Just as violet, orange and green possess a distinct identity despite being secondary hues, when any two of the operations combine, such as when carving is combined with extruding, or when skinning is combined with molding, a new and distinct family of geometric solutions is revealed. It is our hope that the process of incrementally selecting from five basic alternatives in the context of a complex problem generates rich and diverse combinations that eventually contribute to an individual’s distinctive patterns of thinking and making.

**Design Case Studies at NBBJ**

The preceding case study describes a situation in which the combination of a specifically developed design problem with an appropriate selection of software tools creates opportunity for the use of these software tools as design tools. It is the privilege of an academic environment to establish such conditions. In contrast, in architectural practice there is no mitigation between encountered design problems and the design tools at hand, which include among others commercial CAD systems.

Rowe (1987) characterizes design thinking as an iterative process. Observation of an iterative process consequently may indicate that it is a design process. The following two case studies describe iterative processes involving use of CAD software. They strongly indicate utilization of software tools in support of creative design processes in architectural practice.

Four observations applicable to both cases are of special note: 1) the observed processes represent only a small part of the entire project design process; 2) the participants confirmed that they used the computer software to support their design thinking and not only to create digital representations of what they had designed in other
media; 3) the CAD software is not used according to the work flow for which it was designed but in a way that supports the design process of the designers; 4) the observed usage enabled design collaboration between two or more design participants preferring different media or modes.

The software in use at NBBJ is MicroStation TriforMa by Bentley Systems, Inc. The suggested work flow for this software is the creation of a three dimensional digital building model with subsequent extraction of two dimensional data for design documentation in traditional paper oriented formats. The software vendor’s proposed work flow is diagrammed in figure 1 together with the very different work flow variations observed in the two case studies.

Case Study 1

The first case study focuses on the design collaboration between two architects, the project’s design leader and one of the project’s technical architects. The design task was the development of façade systems for a large hospital project. Given the size and repetitiveness of the façade under investigation the participants decided to take for each façade system a portion of the virtual building model that had been creat-

Figure 1. Design work flow as suggested by software vendor; as observed in case study 1; and as observed in case study 2.

Figure 2. Digital model images of hospital showing major façade systems.
Two renderings of the digital building model illustrate two major areas of curtain wall systems in figure 2.

Both architects wanted to be able to examine the façade system in representations that revealed to them the information they required to make design decisions. The design leader wanted to be able to inspect the state of design in three dimensional representations while the technical architect preferred to look at the façade system in two dimensional representations. The design iterations occurred between façade sections with manipulation by the technical architect and extrusions of these sections into three dimensional objects with manipulation of either the sections or the three dimensional objects by the lead designer. The lead designer used frequent renderings of the three dimensional digital models for visual evaluation of the design progress. Numerous designs as illustrated in figure 3 were generated in iterations between those two modes until both architects agreed on the solutions to be presented to the client.

The material used for the client presentation was the same that was used in the design process and helped to address similar differences in media preferences within the client organization. The project is currently in the construction document phase.

Case Study 2

The second case study describes a more complex design collaboration. The project is a hospital addition. In this case the façades, landscaping, and interiors were designed in conjunction with each other.

The design participants gravitated to different design media or modes: the lead designer preferred two dimensional digitally drafted elevations, the landscape architect used two dimen-

Figure 3. Design iterations for façade systems in elevation, section, and rendered 3D objects.
sional digital plans, interior designers looked at three dimensional digital and physical models, and the client preferred to review the physical model. Based on the massing for the hospital building that resulted from site and programming conditions, the lead designer designed the façades digitally. Next to allowing evaluation of the proportion and rhythm of the façade these digital drawings drove a digitally controlled laser cutter which carved the façade designs from various materials. These physical façade pieces then were attached to a three dimensional model of the building’s structural frame as illustrated in figure 4. The physical model supported verification of the façade concept as it wraps around the building.

The client strongly preferred physical models as presentation media. The physical model also accommodated inserts for landscaping that were generated in a fashion similar to the façades. In some design iterations digital photographs were taken of the physical model and loaded into a graphics package to sketch over them for design investigation in a perspective view. Any changes then were interpreted in the two dimensional façade drawings which in turn were used to cut another set of model pieces for renewed inspection on the three dimensional physical model.

In this process it is interesting that iterations occurred across different digital and analog media, but in an iterative, repetitive sequence that afforded almost natural transitions between those media while utilizing different preferred perception and design skills.

Conclusion

The cases presented here demonstrate two trends in the use of commercial computer aided design systems. First, designers working with such tools face the conundrum of enacting idiosyncratic creative processes with generic tools. They reconcile process with tool both by modifying their creative habits and by pressing the tools to go beyond preconceived applications. Second, designers struggle to integrate innovative technology into the construct of an existing practice, rather than accept a paradigmatic change. Technological capabilities are hybridized with traditional media, pre-established habits, and desired team dynamics to achieve evolutionary progress, rather than an all-or-nothing adoption of the radically new. Both trends lead designers to a rich diversity of downstream technological and methodological innovations, which although often subtle, are gradually realizing the future envisioned by leading academic thinkers.
References


