Square Peg in a Round Hole or Horseless Carriage?
Reflections on the Use of Computing in Architecture

Thomas Chastain, Yehuda E. Kalay,[1] Christopher Peri
Department of Architecture College of Environmental Design University of California, Berkeley

Key words: Design tools, design practice, affordence, design paradigms, tool making.

Abstract: We start with two paradigms that have been used to describe the relationship of computation methods and tools to the production of architecture. The first is that of *forcing a square peg into a round hole* — implying that the use of a tool is misdirected, or at least poorly fits the processes that have traditionally been part of an architectural design practice. In doing so, the design practice suffers from the use of new technology. The other paradigm describes a state of transformation in relationship to new technology as a *horseless carriage* in which the process is described in obsolete and 'backward' terms. The implication is that there is a lack of appreciation for the emerging potentials of technology to change our relationship with the task. The paper demonstrates these two paradigms through the invention of drawings in the 14th century, which helped to define the profession of Architecture. It then goes on to argue that modern computational tools follow the same paradigms, and like drawings, stand to bring profound changes to the profession of architecture as we know it.

1. TECHNIQUES, TOOLS, AND PRACTICES

> "Man is the problematic animal; and it is not to be expected that so essential a part of his existence as his technology should not also be problematic, whatever immense advantages come with it."
>
> William Barrett, *The Illusion of Technique*

[1] Corresponding author.

Technologies are not planned, but rather they emerge from our culture as it learns and builds. Perhaps because of this, their effect on our practices is rarely guided by reflection. More often, as our tools are transformed by technology, it is the practices that adapt to the changing context. The affect of these adaptations eventually becomes known, but by then the practices are irreversibly changed—with unintended consequences. In this process, the purposes and values of those practices can become displaced by the qualities and capabilities of the new techniques. In this regard, design technology is no different. And now, three decades after the introduction of computers into architecture, we find it necessary to re-examine the premises and purposes of our tools so that we may assess what has been displaced and adapted as well as realign our tools with the goals of the practice. We assume that we have shaped our tools, but the question is to what extent have our tools shaped us?

We would hope that our design technology helps us to work more intelligently, more responsibly, more efficiently, more effectively, and more carefully. Our representational methods, which comprise part of this technology, are employed to assist in the reasoning and communication acts required in designing. For instance, a study model allows for a quick comparison of the spatial qualities of design alternatives while maintaining a consistent building vocabulary—even if that vocabulary is largely diagrammatic. But design technology can also limit our perception and make the architects less aware of the consequences of design actions. For example, designs derived from working primarily in a plan view can result in an architecture less three-dimensional [Halasz 1979]. A designer's assessment of a building based on a 'massing' model made of clay may minimize the understanding of the actual experience of the building's space.

Design representations allow us to reason about the world—its events, places, and materials either real or imagined—without them being present. A representation is a symbolic expression of some reality or an idea. It is a process which transforms, by way of abstraction and encoding, realities and ideas into a communicable and presentable parsimonious formats. Abstraction serves not only to condense reality and ideas into a representational form, but also helps focus attention on the critical aspects of the represented phenomena. We can reason with a representation because we embody it with qualities or rules that connect it to the actual experience. Scaled drawings connect lines to actual dimensions and a study model constructed with small strips of wood arranged to indicate the structure, connects form-making considerations early in the design to the actual structure.

1.1 Affordance

Decoding the represented information requires an effort by the receiver, and is often accompanied by loss of information or misinterpretation. Representation is not reality, but rather some designation of it. It is thus a symbol that corresponds to some reality, to which it is attributed through some shared human convention or understanding. This abstraction results in a purposeful omission of certain details, or their aggregation into one 'chunk.' As an abstraction that reduces reality, it argues for a particular significance of one problem over others—allowing designers to "see the forest in spite of the trees." This 'argument' is critical in assisting the designer to reason about the problem in that it helps to sort out the complexity present in an architectural problem into manageable 'chunks.' What details are preserved in the representation, and what details are omitted or aggregated, frames this argument. We refer to the argument offered by a particular representation—its degree of abstraction, the embodied qualities, the implied rules and actions—as its *affordance.* The term, coined by psychologist James Gibson, describes a potential for action, the perceived capacity of an object to enable the assertive will of the actor [Gibson 1977].

The affordance of representation influences, channels, and even directs the reasoning that goes on in the design. Representation is a process where information is transformed from one form into another, more abstract than the first. This abstraction requires the party who receives the information to interpret it, in order to recover most, if not all, the conveyed meaning. What exactly is conveyed (i.e., what information passes the representational filter), what symbolic means are used to encode it, and what actions must be performed by the receiver of the information to decode it, determine the usefulness or value of a particular representation's affordance. Therefore, the affordance offered by the representation must be seen in relation to the task at hand. A crude diagrammatic model offers the affordance of being open to interpretation, which is valuable early in design thinking, whereas the drawing conventions of contract documents offer the affordance of having little ambiguity which is crucial in communicating the design to others.

The introduction of computer technology has provided representations with new affordances and has begun displacing previous design technologies. The efficiency, control, and intelligence made possible by these tools are increasingly essential to architectural practices. For instance, one clear motivation for the introduction of CAD tools in the practice of architecture has been in making the production of contract documents more efficient and co-ordinated. In a similar fashion computer modelling has reduced the production cost associated with physical models while increasing the options for their end use. But while it is clear that these needs have dominated the development and adoption of CAAD in the profession, it is less obvious how, increasingly, this technology is influencing practice beyond production. In many cases, the influence is misunderstood or not observed at all.

2. TWO TOOL-MAKING PARADIGMS

In the relationship between a technology, its affordance, and a practice, two paradigms emerge as ways of characterizing tool making. In the first, which we call *'a square peg in a round hole*,' tool making is a problem of adapting a new technology to current practice. As a new technology is introduced into a practice, a dysfunctional relationship can develop between the tools and a task. This can occur either because the task is poorly understood or because the process of displacing a traditional technology is largely one of the substitution of tools—ones with the wrong affordances. This inappropriate use of the design technology results in a poorer practice. An example of this can be seen in the use of rendering tools early in the design process, where what is needed is ambiguity and, instead, what is given is a photo-realistic image. This can lead the viewer of the information to a misconception about the precision of the design. An approach to this dysfunction is to 'round off' the square peg—by more clearly *identifying* the different actions in designing and *clarifying* how computational tools can assist these actions.

The second tool-making paradigm, which we refer to as *'a horseless carriage*,' is characterized as the shifting perception of a practice as it transforms in relationship to a new technology. In using the term a 'horseless carriage' the task of transportation is described through the lens of a previous technology—even though the practice of travel had changed. Understanding this paradigm requires asking a different question—how do the affordances provided by computers *change* a design practice? Do we understand how having more precision early in the process affects the reasoning of options? Do we understand how communication via digital files and video screens fundamentally changes the culture of a practice? How does knowledge once invested only in the designer but now ingrained in the tools, effect practice? In this paradigm it is assumed that the fundamental task does not change, i.e. the task of designing of a building. What is asserted is that the practice, constructed to design that building, does change and is influenced through new technologies.

In both paradigms, tool-making is connected to an *image of practice* [Boulding 1956]. This image of practice is a description of methods, habits, organization, knowledge, and culture of design in relationship to a task. And for architects, this image is often held but not always explicit. Designers may know *how* something is done, but can be less aware of the *values* implicit in a particular way of working. Toolmakers also hold an image of practice. This image is articulated in the assumptions made about the kinds of affordances needed within a practice. But toolmakers have the further responsibility (according to the second paradigm), to participate in the shaping of the emerging practice. Both paradigms require an *explicit* understanding of a tool's affordance in relationship to the design actions as well as the *implicit* embodiment of the values associated with a practice.

2.1 Affordances and actions

Mapping a range of attributes afforded by a method of representation results in the set of paired qualities organized as opposite poles of a continuum (Table 1). These qualities, when connected to design actions, can be assessed in terms of their appropriateness—at least in the 'square peg' sense.

Table 1. Affordance and Action

Abstract	to	precise
Implicit	to	explicit
Semantically poor (open)	to	semantically clear (closed)
Conceptual	to	concrete
Ideation (exploration)	to	descriptive

A view of this can be seen in the range of affordances offered in drawing. A design sketch is abstract, typically conceptual; it is more concerned with exploration than with describing a solution and implies more than it defines. The sketch as a visual representation contains configurational knowledge that structures exploration of variations and moves within the design—as opposed to a definitive description of the plan [Hillier 1996]. This affordance of the sketch is due in part to the embodiment of particular behaviors and structures to the drawing on the part of the designer. As Arnheim describes, the drawing reduces "a theme visually to a skeleton of essential dynamic features." The semantic openness and abstraction inherent in a design sketch serves to aid in the analogous reasoning used early in design task [Goldschmidt 1995].

As more is known about the design, drawings need to reflect and communicate with more precision to limit possible misinterpretation. The ability to collaborate and direct the action of others in the construction process requires concreteness, explicitness and agreement about what is represented in the drawings. These requirements are met through the affordances provided by the shared conventions of contract drawings. But design tools are not always so simple or linear in their relationship to these polar qualities. It is possible to map some representational methods as having high degrees of explicitness while still being abstract and explorative. This is certainly true of computational tools. Nevertheless, this range of attributes is useful in evaluating tools in relationship to design tasks. More importantly as a method of mapping, it describes the compression, overlap, and restructuring provided by new computational tools. A discussion of drawing—its practice, affordances, and the emergence of new forms of representation—reveals this transformation.

2.2 Drawing as a design technology

Drawings, which have come to be known as the traditional means of architectural representation, are in fact, relatively new inventions. Their origins can be traced back to the Renaissance. In the Middle Ages, buildings were often constructed from a simple schema or by use of the 'secret'—the Master Builder's trick of deducing the elevation from the plan by the application of a simple system of proportions, based on a triangle or a square. The 'discovery' of the texts of Vitruvius during the Renaissance, with its emphasis on proportions, symmetry and harmony, and its use of the classical orders, made it necessary to draw up a whole set of blueprints before construction could commence. Drawings have become exact scale representations, with dimensions marked. Specific types of drawings were invented, such as the section—to elucidated the vertical stacking of the spaces and the structure of the building; the orthogonal elevation—to show the true proportions of the building; and the perspective view—to show how the building would look from an eye-level point of view.

These inventions were used as a means for planning, or 'designing' the building, and allowed for analysis of its form and structure while planning its interior spaces. They also formed a means of communication which had major consequence: the architect ceased to be a technician who operated at the construction site, and became a designer, who spent his time at his 'studio' as a draftsman, rather than the Master Builder.

The new importance of drawings and theory relegated practical experience in construction to a secondary position, to the point where people not formerly associated with any form of construction practice became architects. One of the first, and most famous of them, was Alberti, a Florentine nobleman. His lack of practical experience, combined with distance from the building site, forced him to rely on professionals for the actual building. Working by delegation caused problems, despite Alberti's great talent, and may explain the relative two-dimensionality of his works (e.g., his famous Tempio Malatestiano in Rimini).

Thus, architecture, was transformed, in part, through the introduction of new design technology, gradually moving away from direct construction towards the theoretical, and in the process gained status and respect. Among the symbols of status was the new name of the professional—Architect, rather than Master Mason. But the separation of theory, or 'design,' from practice placed ever-growing emphasis on drawings, as the means of communication to others doing the actual building. One of the first to recognise the communicative role of drawings was Raphael, who in a letter he wrote in 1519 to Pop Leo X explained the need for drawings to include both plans and sections drawn to the same scale, placed one above the other, to minimize errors related to the measurements and placement of building components.

The removal of the architect from the actual construction of the building introduced a discontinuity in the design-build process. This discontinuity had many benefits, such as the ability to consider the whole building before its construction has begun, allowing for more complex and more sophisticated designs. It also introduced problems. On one hand, the potential for miscommunication and misinterpretation of the information, and on the other, the increasingly abstractness on the part of the architects' experience, while delegating some design decisions to the builder (the contractor). The reliance on means of communication such as drawings, and to a lesser extent, scale models, in bridging this discontinuity transformed the practice of architecture. It produced an image of practice tied to drawing and raised new issues of competence in the use of design tools; in particular issues concerning the degree of explicitness of the representation, and the designer's control over it.

2.3 Explicitness, control, and drawing

By being explicit about some aspects of the conveyed information, a representation is also in-explicit about other aspects. Drawings, for example, are explicit about the form and relationships of the components of a building, but not about its materiality. Materials are typically specified in accompanying texts, which lack form and relational information.

Drawings provide a parsimonious notational means of conveying both referential and frame-of-reference information, in the form of floorplans, sections, elevations, and details. However, much of the information that is conveyed by drawings is implicit, and relies heavily on interpretation. As described above this quality can be instrumental in the use of the drawing. But even where the affordance is one of precision, the understanding of the drawings is still rooted in a notational implicitness, which pertains to both the references and the frames-of-reference. For instance, the interpretation of any symbol as a 'door' or a 'wall' is vested in the reader, who must rely on his own knowledge of reading blueprints, a knowledge acquired independently from the particular drawing being read. Likewise, the relationship between the walls and the space they enclose is a matter of interpretation, as is the disciplinary frame-of-reference that determines whether the drawing is read as an architectural plan or as a structural plan. Additional symbols, annotations, and specifications help narrow the range of interpretability, but they cannot completely eliminate it.

This heavy reliance on interpretation, and the need to augment the explicit information with implicit assumptions, hinders the effective use of drawings as a means to engender shared understanding. The frame-of-reference information that is conveyed by drawings is limited to the immediate physical context of the project and does not include the cultural, economic, and other types of contextual information. Hence, drawings lack the ability to accommodate changing frames of reference or the ability to identify and propagate such changes: they are completely passive instruments. The effectiveness of this representation relies on information embodied in them through a practice. Towards this problem, much of the education of the architect is spent towards learning to draw. This education includes learning to reason with lines and understanding the drawing as a shared conventional practice. Students are typically asked to compare, through drawings, places and design precedents. Ultimately a student's judgement depends on the ability to interpret the drawings of projects they find on their desks and on exhibit in design reviews.

The introduction of computer-aided design has accentuated the divide between explicit and implicit information. In manual drawings, it is often hard, if not impossible, to tell whether a line designates the 'solid' part of the building, or its 'void' (the space). This is intentional, for in fact walls are intended to both bound space and provide structure. In CAAD, the lines and shapes clearly designate 'solid' objects—Yessios' early work is an exception [Yessios 1987]. The decision to focus the representation on 'solids' in CAAD has been made by the tool-developers: the vendors who design these tools. It shows an understanding of the explicit attributes of the traditional tool—lines representing elements, but lacks the sensibility implicitly embodied in the use of drawings as a practice.

3. OTHER APPROACHES TO COMPUTATIONAL DESIGN TOOLS

Computation has provided the means for other forms of representation, such as in databases and knowledge-bases, with new arrays of affordances. These tools are not simply an extension of drawing, but instead work to express the knowledge contained in the practice of drawing – with the encoding of that information being made by the toolmaker.

3.1 Product Databases

In an effort to provide more complete information than merely the form and relationships between the objects of the design, or separate materiality information, researchers have been developing product databases. This approach assumes that by providing a single representation there will be less need for individual disciplinary interpretations. Interpretation will also be enhanced if the semantic relationships between the various objects and their attributes are represented explicitly. Such approaches include PDES, the Interoperability Alliance's 'foundation classes,' EDM and BDA [Brauner 1986, Eastman & Siabiris 1995, Papamichael et al 1998].

While product databases are informationally more comprehensive and complete than other types of representation, they can provide only part of the general information needed to understand the project: they typically do not include contextual information, which may change the meaning of the objects that are being considered. [Kalay 1999] Moreover, product databases require making choices, on the part of the encoder, of what information to include, what can be omitted, and what relationships to represent. As such, although they are more complete than other representations, they too are subject to the choices of their makers.

3.2 Rule-based expert systems

Attempts to explicate and share the interpretive knowledge itself have mostly taken the form of Experts Systems, a conceptual framework borrowed from Artificial Intelligence (AI) research. These methods rely on packaging accepted disciplinary knowledge in the form of small modules, known as 'rules,' which represent the smallest units of experts' knowledge. Their modularity allows developers to focus on the content of the knowledge base, one chunk at a time, and to build it up incrementally.

In the context of architectural design, rules typically capture and make operational "special-case reasoning characteristic of highly experienced professionals" [Hayes-Roth 1985]. What constitutes such 'special case reasoning,' how is its applicability determined, and how are conflicts resolved, is highly variable: it depends on broad disciplinary know-how, 'good' practices, and personal judgement of the system developer. What may appear to be a 'rule' to one professional may not be so for another professional within the same discipline, and is likely to be completely incomprehensible for someone from another discipline.

Thus, while rule-based expert systems may appear attractive for capturing design knowledge due to their modularity, they are, in fact, highly personalized, arbitrary expressions of knowledge and operational practices. Although some rule-based systems are successful at what they were intended to do, they must often be accepted as 'black boxes,' which are difficult if not impossible to evolve, modify, and adapt by anyone other than their authors. Even more serious is such systems' sensitivity to changing contexts, which they are ill-equipped to handle, and the rigidity of the rules in the face of changing circumstances.

4. IMAGES OF PRACTICE

Computing has had only a few decades of experience with practice of architecture as opposed to drawing's long history. Therefore it is not surprising that the fit between the affordances offered by computing technology and design practice is more problematic than those faced by drawings. The question for us as toolmakers is how to understand that affordances and evaluate it's impact of our tools.

Our first paradigm offers one approach—which is working to smooth off the square peg. This begins by observing what designers do. As Gero argues, studying human designers leads to richer theories of designing, which in turn lead to making more appropriate tools [Gero 1997]. This is an *empirical* approach, which implies an emphasis on the cognitive aspects of designing, rather than an *analytical* approach to the design process, which is more 'convenient' and less 'messy' from a computational point of view. The empirical approach is supported by efforts using protocol analysis to 'capture' reasoning associated with design actions. These studies have provided insight into issues of emergence, analogy, visual reasoning, and use of representations in design. The connection of these insights to new tools ought to help the fit between the affordances and design actions—between the peg and the hole.

The second paradigm, though, is more fundamental and critical to the understanding of where we are heading. In approaching computational tools as a 'horseless carriage,' the observation shifts to include the practice as well as the designer. The promise afforded by these tools includes the ability to represent in the 'drawing' what was formerly held in the practice. As such, these tools will contain the toolmaker's understanding of the explicit aspect of the representation, but will also, more than ever, include an implicit understanding of the values held in the practice. And as before with drawing, the organization of the work changes, and the identity of the designer shifts and transforms the image of practice.

4.1 Tales from the kitchen designer

The design of a kitchen, while not a complex problem, turns out to be a good example of how a tool represents and transforms a practice. The practice of dwelling design (whose practitioners would include builders, designers, and architects) has by necessity included a competence in the design of kitchens. Rules of thumb concerning allowable distances between major work areas; knowledge of work surface dimensions and activity requirements; knowledge of cabinetry and its assemblage; principles about the organizing access and work areas, and finally familiarity with materials and their cost—all comprise a fundamental competence in kitchen design. As reflected in the number of televised home remodeling shows and magazines aimed solely at kitchen and bath design, the demand for design services has increased. This demand has given impetus to new kitchen design tools and practices. While most kitchens are still designed by practitioners using 'traditional' techniques, increasingly their knowledge is represented in design tools used by homeowners or sales people in building supply stores.

Figure 1 is a simple drawing of a kitchen layout constructed in a typical CAAD program. The drawing is supported by the geometry of the drawing program, but the designer is free to construct any shape desired. The elements of the drawing can be arranged and shifted around, but the representation holds no knowledge about their existence as objects, rather the designer does. While the drawing is diagrammatic it is sufficient to reason about initial organizational concerns. It might even be helpful in its limitation in that it allows for alternative schemes to be generated and assessed only in terms of how the activities are arranged—without the burden of resolving other issues such as materials and costs.

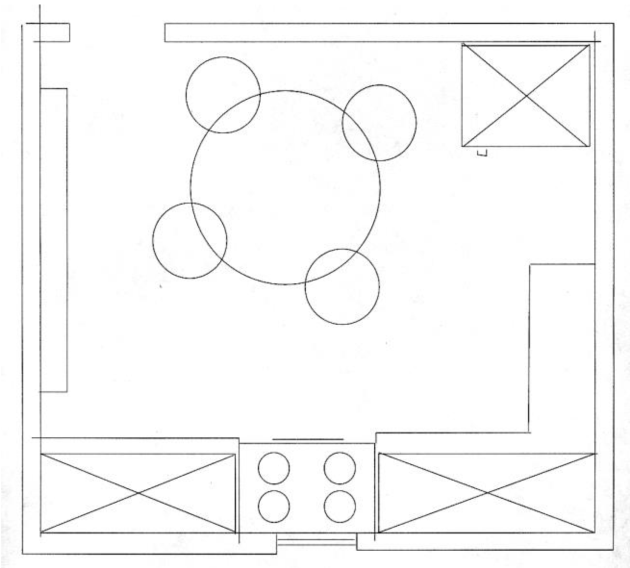


Figure 1. Typical CAAD drawings of a kitchen

Figure 2 is from a design tool named 3D Kitchen®, developed to help homeowners design their own kitchens. With this tool the design is constructed from defined objects, such as cabinets, appliances, walls, and doors, rather than lines. Thus, the designer—who is intended to be a novice kitchen designer—manipulates well-defined objects. Furthermore, the objects are connected to a data structure that allows them to be associated with specific materials and a cost, which can be examined by clicking on the object (Figure 3). The tool can, therefore, keep track of the running cost of the construction, and alert the designer when his stated budget has been exceeded. At no point in the process does the tool allow for ambiguity: each design 'move' is completely defined in terms of its expected results. Thus, if the designer changes his mind and wishes to replace one type of cabinet with another cabinet, he must delete the first one and insert the new one. Simply changing the label associated with the cabinet, as is possible in CAAD, is not enough. Since the program uses well defined objects, the plan can be easily translated into a three-dimensional view of the kitchen Overall this representation contains knowledge held within a kitchen design practice (like inferring objects from the lines in the drawing, standard cabinet dimensions, or relative price options.) But this tool is still not very 'intelligent': it does not know what a cabinet really is, hence it allows stretching it to be 20' long, and 2" wide. It also will allow pushing a cabinet into the wall, or use it to block the doorway.

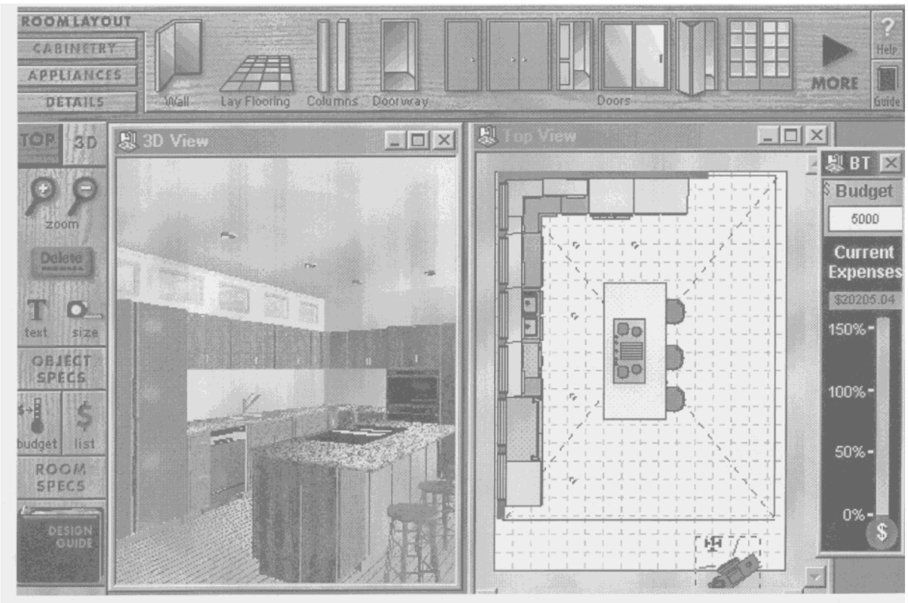
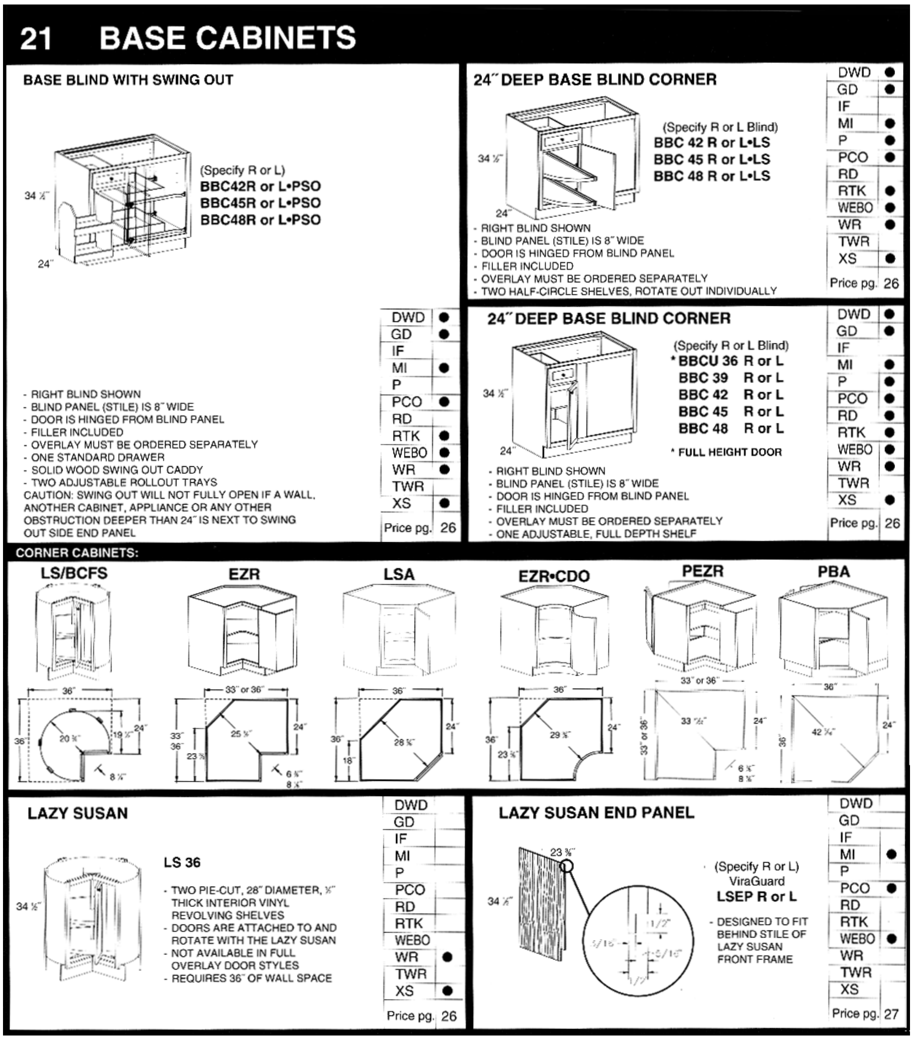


Figure 2. Kitchen layout using 3D Kitchen by Books That Work, Palo Alto, CA

Figure 3. Object database

Figure 4 shows some cabinets from the catalog of KraftMaid®, a commercial cabinet manufacturer. These cabinets can be ordered through building supply stores. The kitchen designer in the store uses a computer program, provided by the manufacturer, to help customers select and order the cabinets for a complete kitchen. Like 3D Kitchens, this program too works with defined objects, not lines. But it is even more 'knowledgeable' than 3D Kitchens: it knows not only about cost and form, but also about availability, delivery dates, and will not allow re-sizing the cabinets, since they represent actual manufactured products. This tool introduces even more precision at the beginning of the design process in determining costs and material orders. In both cases, the effect is to introduce early in the design process more affordances for concreteness, precision, and description than found in the CAAD drawing.



21 BASE CABINETS

BASE BLIND WITH SWING OUT

(Specify R or L)
BBC42R or L•PSO
BBC45R or L•PSO
BBC48R or L•PSO

- RIGHT BLIND SHOWN
- BLIND PANEL (STILE) IS 8" WIDE
- DOOR IS HINGED FROM BLIND PANEL
- FILLER INCLUDED
- OVERLAY MUST BE ORDERED SEPARATELY
- ONE STANDARD DRAWER
- SOLID WOOD SWING OUT CADDY
- TWO ADJUSTABLE ROLLOUT TRAYS

CAUTION: SWING OUT WILL NOT FULLY OPEN IF A WALL, ANOTHER CABINET, APPLIANCE OR ANY OTHER OBSTRUCTION DEEPER THAN 24" IS NEXT TO SWING OUT SIDE END PANEL

DWD ● GD ● IF MI ● P PCO ● RD RTK ● WEBO ● WR ● TWR XS ● Price pg. 26

24" DEEP BASE BLIND CORNER

(Specify R or L Blind)
BBC 42 R or L•LS
BBC 45 R or L•LS
BBC 48 R or L•LS

- RIGHT BLIND SHOWN
- BLIND PANEL (STILE) IS 8" WIDE
- DOOR IS HINGED FROM BLIND PANEL
- FILLER INCLUDED
- OVERLAY MUST BE ORDERED SEPARATELY
- TWO HALF-CIRCLE SHELVES, ROTATE OUT INDIVIDUALLY

DWD ● GD ● IF MI ● P ● PCO ● RD RTK ● WEBO ● WR ● TWR XS ● Price pg. 26

24" DEEP BASE BLIND CORNER

(Specify R or L Blind)
*BBCU 36 R or L
BBC 39 R or L
BBC 42 R or L
BBC 45 R or L
BBC 48 R or L

* FULL HEIGHT DOOR

- RIGHT BLIND SHOWN
- BLIND PANEL (STILE) IS 8" WIDE
- DOOR IS HINGED FROM BLIND PANEL
- FILLER INCLUDED
- OVERLAY MUST BE ORDERED SEPARATELY
- ONE ADJUSTABLE, FULL DEPTH SHELF

DWD ● GD ● IF MI ● P ● PCO ● RD ● RTK ● WEBO ● WR ● TWR XS ● Price pg. 26

CORNER CABINETS:

LS/BCFS EZR LSA EZR•CDO PEZR PBA

LAZY SUSAN

LS 36

- TWO PIE-CUT, 28" DIAMETER, ½" THICK INTERIOR VINYL REVOLVING SHELVES
- DOORS ARE ATTACHED TO AND ROTATE WITH THE LAZY SUSAN
- NOT AVAILABLE IN FULL OVERLAY DOOR STYLES
- REQUIRES 36" OF WALL SPACE

DWD GD IF MI P PCO RD RTK WEBO WR ● TWR XS ● Price pg. 26

LAZY SUSAN END PANEL

(Specify R or L)
ViraGuard
LSEP R or L

- DESIGNED TO FIT BEHIND STILE OF LAZY SUSAN FRONT FRAME

DWD GD IF MI ● P PCO ● RD RTK WEBO ● WR TWR XS Price pg. 27

Figure 4. Page from KraftMaid Cabinetry catalog, Middlefield, Ohio

There are drawbacks to the approach taken by such a tool. The lack of ambiguity may obscure possible choices early in the process through the interpretation of the constraints offered in the representation. In the case of the cabinet suppliers' design tool, the choices are limited to what is available in the catalog. Choices about other geometries, dimensions, or storage options are inherent in the design process, but the 'completeness' of the tool has the tendency to close the process around conventions in the representation. To return to the chart on affordances in Table 1, this concern can be seen as the distance from semantically poor, but 'open,' CAAD drawing to the semantically clear, but 'closed,' kitchen design tool.

For the competent designer, this distance is overcome through experience. A kitchen designer knows that the lines on the paper represent cabinets that contain dimensional constraints and, with enough experience, he ought to be able to estimate the costs even from a schematic drawing. For the experienced practitioner, the ambiguity afforded by the schematic drawing can be helpful, if not instrumental, in promoting creative ways of approaching the design. A traditional kitchen designer knows the practice and we would expect him to use the appropriate tool throughout a design process. He might begin with a series of quick sketches to generate different layouts and then move to the more explicit representation to test them out, and might even return to sketching to reason further about organizational options. In effect 'squaring off the round hole for the peg.'

But the critical implication of the kitchen design tool is not in its support for the designer, but in its transformation of the practice. The second and third tools are aimed at people who would typically not be considered traditional designers—homeowners and sales people. These new tools contain a knowledge that heretofore was the province of trained designers. Along with the object oriented representation, the kitchen design tool also holds lessons about 'rules of thumb' and design concepts for the naive designer. In essence, it represents and formalizes a kitchen design practice. With this design tool, anybody, trained or not, can make reasonable decisions about cabinet layout, use patterns, and costs. The fact that more kitchens are designed through the use of these tools is testament to their power: a label on the shrink-wrapped box of 3D Kitchen says "over 2 million sold."

The affect of the tool is to shift the design practice from traditional designers to others, much like the arrival of construction drawings allowed architects to move away from the role of craftsman. This displacement is more understandable within the horseless carriage paradigm of tool making, where the affordances of the new technology work to transform the practice. In this case, the affordance of precision, semantic clarity, and concreteness allow the knowledge of the practitioner to be held in the representation, which can now be manipulated by the novice.

Aside from the relative merits of this transformed design practice, two observations can made. First, that the practice has been changed by the technology. And two, that change has been brought about by the tool's ability to represent the practice.

4.2 Informing tool-making

The implications for design-toolmakers are clear. In the square peg/round hole paradigm, observing the cognition and behavior of the designer is critical. If we are to make better (more effective) design tools we need to examine the way designers reason and work. By matching affordances with design actions we can support, in a more inclusive manner, design reasoning and promote wisdom in the use of tools. But we need to make the distinction between the designer and the design practice. While we would not expect the cognitive workings of a designer to change radically, due to the use of CAAD tools, the setting engaged by that reasoning, the design practice, will. The horseless carriage paradigm tells us that through technology our current practices will be displaced—the questions are by what and how much. The kitchen design tool transformed kitchen design by representing an *image* of that practice, but we cannot assume that it is complete, sufficient, or even a benign image.

Along with knowledge about the problem, a practice also contains values which are often communicated only in the design. In designing a kitchen we need to know about the constraints inherent in the cabinetry, but we also hold certain values about efficiency and size as they relate to the activities in the kitchen. These values, which are not absolute, but rather shape the design through decisions both subtle and fundamental. Does the image of practice represented by the horseless carriage tool contain these values? It does, reflecting the values of the toolmaker. As the design practice shifts to others, will the embedded values behind the design decisions become as explicit as the knowledge of what we know about cabinetry? While we can assess the effectiveness of a tool by understanding its use by a designer, we must also understand the values it promotes within a practice. While it is not possible to anticipate all changes to our design practices, nonetheless as toolmakers we participate in their transformation. This requires us to examine the practice as well as the designer and to argue for the values in our *image of practice* that directs our efforts. Whose knowledge comprises that image and what values are displaced?

5. CONCLUSION

In this paper we have tried to illustrate, through the concept of affordance, how technology can be perceived both as ‘square peg in a round hole,’ when it changes older technologies used for the same purpose, and as a ‘horseless carriege,’ when it transforms the practices using the technology. Both paradigms are the result of our work as tool builders. It is us who have the power to develop round pegs in round holes, that will enhance the practice of architecture, or to re-package and transform the practice itself. Thus, these tools, and others like them, have created a new ‘designer’: the lay person who wishes to remodel his kitchen, or the building supply store employee who sells cabinets to this customer. While we may argue about the quality of these ‘designs,’ the fact remains: they have transformed the practice itself, creating a new ‘horseless carriage.’

“The best computational tools don't simply offer the same content in new clothing; rather, they aim to recast areas of knowledge, suggesting fundamentally new ways of thinking about the domain, allowing learners to explore concepts that were previously inaccessible.”

REFERENCES

Boulding, K. (1956). *The Image*. The University of Michigan Press, Ann Arbor.

Gero, J. (1997). “What are we learning from designers and its role in future CAAD tools.” *CAAD futures 1997* (R. Junge, ed.), pp. 61-70, Kluwer Academic Publishers, the Netherlands.

Gibson, J.J. (1977). “The theory of affordances.” Perceiving, Acting and Knowing (R. Shaw & J. Bransford, eds.), Erlbaum, Hillsdale, NJ.

Goldschmidt, G. (1995). “Visual displays for design: Imagery, analogy and databases of visual images.” *Visual Databases in Architecture* (A. Koutaminis, H. Timmermans and I. Vermeulen, eds.), pp. 53-74, Avebury, Aldershot, Netherlands.

Halasz, I. (1979). “Introduction.” *Processes in Architecture: A Documentation of Six Examples*, Plan 10, pp. 6-7, MIT School of Architecture and Planning, Cambridge, MA.

Hayes-Roth F. (1985). "Rule-based expert systems." *Communications of the ACM* 28(9):921-932.

Hillier, B. (1996). *Space is the Machine*. Cambridge University Press, Cambridge, UK.

Kalay Y.E. (1999). "Enhancing multi-disciplinary collaboration through sematically-rich representation." *4th Design Methods Research Conference* (W. Porter & G. Goldschmidt, eds.), Cambridge, MA.

Yessios C.I. (1987). "The computability of void architectural modelling." *Computability of Design* (Y.E. Kalay, ed.), pp. 141-172, John Wiley & Sons, New York.

Resnick, M. (1995). “New paradigms for computing, new paradims for thinking.” *Computer & Exploratory Learning* (A. DiSessa, C. Hoyles, R. Noss, pp31 to 34, Springer-Verlag, Berlin, GER., eds.)