THE IMPACT OF INFORMATION TECHNOLOGY ON ARCHITECTURAL DESIGN IN THE 21ST CENTURY

YEHUDA E. KALAY
University of California, Berkeley, USA

ABSTRACT: Architecture uses technology to achieve certain functional, cultural, social, economic, and other goals. In turn, technology transforms the discipline. Information technologies promise to change design processes, practices, and products. The first uses of computing in the service of architecture have been rather timid, mimicking older practices. This is changing rapidly: new design and evaluation tools allow architects to imagine new building forms, more responsive (and environmentally more responsible) buildings, even radically new types of environments that blend physical with virtual space. Understanding and shaping this transformation are the basis of architectural design research and education in the 21st century.

KEYWORDS: Architectural design, built environment, computer aided design, design practice


MOTS-CLÉS : Conception architecturale, environnement construit, conception assistée par ordinateur, pratique du design
1. INTRODUCTION

Technological revolutions are dramatic changes that affect the production of goods or services, brought about relatively quickly by the introduction of some new invention. Through complex interactions with individuals, institutions, cultures, and the environment, technological revolutions are among the most important events that happen to humanity, ranking as high as grand political changes and natural disasters. Technological revolutions can affect the size of the world population, life expectancy, education levels, standards of living, the nature of work, communication, health care, war, and the natural environment. They affect society as a whole, as well as individual lives, through impacts on governance, entertainment, human relationships, our views on morality, cosmology, and human nature. 11,000 years ago, the agricultural revolution ended the hunter-gatherer. It led to improved food production, spurred population growth, and was followed by cultural and technological developments that included the invention of writing (a media revolution), new materials (bronze, iron, and later concrete, glass, and steel), and power sources (steam, electricity, gasoline, nuclear). Similarly, Johan Gutenberg’s invention of the movable type printing process in 1448 fueled the Renaissance, the Reformation, the Scientific Revolution, and gave rise to mass literacy. The invention of scale drawings in the 15th century, which allowed dilettantes like Leon Batista Alberti (1404-72), to enter a profession formerly practiced only by Master Builders, has transformed both the product (the buildings) and the profession as a whole.

The Information Technology revolution started in earnest after World War II. Like other technological revolutions, it is characterized by rapid diffusion and acceptance, wide-spread impact, and being part of a broader socio-economic change. It made the production, manipulation, and dissemination of information cheap and easy, and information itself more readily accessible, and eminently shareable. It also made it possible to re-define the traditional sequences of information production and consumption, re-assigning the responsibilities and the privileges of owning it. Consequently, it has revolutionized information-centric enterprises, and has been coercing other types of enterprises to adapt information-based practices so they too can benefit from the phenomenal growth potential associated with this technological revolution.

Architectural design is an information-centric enterprise: it uses information to analyze current states of habitation and devise plans for new states that are deemed preferable to the current ones. To do so, it gathers and processes information from many different sources, re-arranges the information, produces new information, simulates its expected impacts and evaluates its desirability. The information it produces is then used by traditional, heretofore information-poor practices, to construct and realize the outcomes of the design phase, which are later used by information-rich habitation practices.
Hence, a technological revolution that impacts information processing has the potential to affect the core processes and products of architecture, and have a 'revolutionary' effect on the profession and the discipline of architecture. It can do so by transforming the current strictly hierarchical design process into a network of design, manufacturing, marketing, and management organizations, where the responsibility for design operations is distributed across multiple professions, organizations, geographic locations, even time. By embedding inter-connected computational devices in both the building components themselves and the means of producing and assembling them, the process of construction and its products can become more 'intelligent,' able to respond to changing needs of the occupants without re-design, thereby affecting what can and needs to be designed in the first place. And, by creating Cyberspace—a new kind of space in which more and more activities 'take place' (learning, shopping, entertaining, transacting business, etc.), Information Technology can promote a new kind of 'architecture' that shares the most cherished sense of place-making with its physical counterpart, albeit dressed up in a different material cloth.

Some of these changes are already evident today, albeit in a rather primitive, tentative, even bungled form. Most applications of computational technologies in architecture are still in their 'horseless carriage' phase—emulating older techniques and methods, like drafting and modelling. Yet, in spite of its early, humble manifestations, Information Technology promises to become a revolutionary, rather than evolutionary development in the history of architecture. Like other revolutions, it will take time to explore, develop, and accept the new possibilities. Their effects will likely be felt by all the professionals who have traditionally been entrusted to design and construct the buildings, by new design professionals (such are game designers), and by the society that uses their products.

These impacts are hard to assess, especially since we are still in the midst, if not at the very beginning of this revolution. Nonetheless, or perhaps because we are witnessing only the early effects of Information Technology on the processes and products of architecture, it is necessary to venture an assessment of accomplishments and an informed view of emerging opportunities in need of further development. Because predictions are risky business, especially about the future (Toffler 1970), this paper only deals with trends, rather than specific products, and only in areas where the new technology promises to have major impacts. These include the trend towards a more distributed yet better integrated process of architectural design; the automation of construction technologies and buildings themselves; and the emergence of an alternative inhabitable space—Cyberspace.
2. INTERLEAVED, COLLABORATIVE DESIGN

The design and construction of buildings have always been collaborative efforts, involving many individuals representing many different skills. Managing the collaborative processes that lead to desired results in the building industry is a highly complex and challenging task. A/E/C (Architecture, Engineering, Construction) involves individuals representing often fundamentally different areas of knowledge who, perforce, hold different goals, objectives, and even belief systems. Furthermore, these professionals often belong to independent organizations who temporarily join forces to accomplish a specific project. While they work together to achieve the common, short-term goals of the project, each participant and organization also has its own long-term goals, which might be in conflict with some of the goals of the joint project (including financial, legal, ethical, professional, and other goals), thereby introducing issues that are extraneous to the domain of collaboration. Lastly, although their participation in the project may be short compared to the lifetime of the project itself, the effects of their involvement, in terms of the decisions they made and the actions they have taken when they were part of the project team, may well impact and constrain the freedom of action of other participants long after the original participants have departed the project.

Computational methods aimed at facilitating collaboration have, so far, focused primarily on assisting the communication aspects of collaboration. They have resulted, on one hand, in information sharing means like Building Product Models (BIM) that, in addition to the product’s geometry, also store many of its other attributes, and can convey much more information than traditional drawings and models can. On the other hand, they have resulted in computational systems that can facilitate the management of the design and construction processes by assessing values, tracking change orders, managing different design versions, and coordinating concurrent access to the information.

However, these incremental improvements are very limited in their scope, and fail to capitalize on the revolutionary aspects of Information Technology. That is because they solve the wrong problem, namely—managing communication: they organize the transfer of information among the participants, subject to centralized control. This approach may indeed enhance the efficiency of the process, but it does so at the expense of the quality of its products: it virtually enshrines the “symmetry of ignorance”—the inability of one professional to understand the needs and responsibilities of other professionals—thereby guaranteeing that the integrated composition of the individual solutions, each of which may have been optimized for its own purposes, will not overall be optimal. The benefits and drawbacks of this approach have been clearly demonstrated by lean production techniques used in the automotive and other industries, where they helped streamline existing processes but
failed to improve the products themselves or to stimulate the invention of new products (Womack et al. 1991).

Rather, the key to understanding the link between technological innovations and the design, construction, and use of buildings is to understand the building procurement process as a whole, integrative process, where changes in one component affect—and are affected by—others. Thus, rather than consider the process as largely sequential, it must be considered an interleaved process.

Unlike pre-arranged hierarchical or temporal partitioning of a process, interleaving is a flexible way of interconnecting different parts into a complete whole, much like different pages (or leaves) can be assembled into a book (Aberdeen Group 1999). As far as A/E/C goes, it has ramifications for how design and procurement are done, and therefore for what can be designed. By exchanging information as problems arise and as opportunities are discovered on an on-going basis, it is possible not only to assemble a design-build-use team that can support innovative design ideas, but also to conceive such new ideas in the first place: it is likely that one (or more) of the participants has capabilities that will allow others to come up with design or procurement solutions they are unlikely to conceive on their own.

Interleaving is not dependent on Information Technology. Yet, as a method, it has been largely impractical without the help of Information Technology. The speed and access offered by Information Technology can shrink the lag between the conception of an idea by one participant and its communication to other participants for the purpose of review, comment, or as a springboard for new ideas. Thus, although Information Technology is merely a technical measure, it has qualitative implications as well: it can support, or at least accommodate, the uniqueness and unpredictability of creative design processes.

The principle guiding this approach is a view of information as a distributed, freely-accessible commodity—an object in its own right—rather than a message communicated from a sender to a receiver. The underlying technology comprises high-speed, reliable, secure communication, browser-based standardized user-interfaces, object-oriented product descriptions, URL-style location transparency, secure business tools for bidding, billing, and servicing (updating) products, and business models that are more flexible than traditional contracts. Utilization of such tools substitutes access for the transfer of information: the information may reside at a centralized location, or at distributed locations, where all authorized participants can access it, rather than shipped on-demand from one participant to another. This approach also distributes ownership and responsibility for conforming to each participants’ needs and to the overall needs of the project among the participants, binding them in appropriate contractual relationships (e.g., who may update what parts of the information) instead of ‘work for hire’ relationships. The ‘controller’ is replaced by a ‘facilitator’, a ‘coordinator’, or a ‘configurator’, whose
responsibility is to make sure that individual contributions are made on time and that the overall process progresses towards meeting its goals and deadlines. Decisions concerning the overall direction of the project may still be made by one of the participants (e.g., the client or his/her representatives), but they are transmitted to the affected parties as constraints on their individual contributions rather than as instructions to be fulfilled.

It is not yet clear at this time that architectural design processes in general are amenable to similar techno-organizational changes: the nature the information is much more heterogeneous than in other disciplines, the contractual relationships more complicated, and the goals of the participants are less well-aligned than in other sectors of the economy. Nonetheless, attempts to foster collaborative design through Information Technology have been proliferating. Once accepted, the process of collaboration will not be linear, as it is now, nor parallel, because each solution provided by one participant serve as input, or as constraints, to others.

The most important impacts of a network-based collaborative approach on architectural design will be its transformation from a hierarchical linear process into a distributed, interleaved process, where the sequence of inputs is not pre-determined, but rather opportunistic: opportunities can be recognized and acted upon in time to make the most of them, and problems can be spotted earlier, when they arise, because more specialists will have access to the evolving product. They will not have to wait their turn to be consulted, at which time it may be too late to recognize an opportunity or to avoid a problem. The avoidance of problems will lead to reduced design time, and greater satisfaction of all parties involved.

The roles of the individual participants stand to change as well. The traditional role of the architect as the lead player in the design process may diminish, while the respective roles of other specialists—like consultants and suppliers—may increase. Although the administrative roles of the architect may erode, his/her contribution will not: design will still need the overall creative vision provided by architects, which is different from solving technical problems associated with its realization. On the other hand, the contributions of other participants in the design process will shift from ‘problem solvers’ to ‘contributors,’ increasing their commitment to and involvement in the project, through what Robert Reich calls “collective entrepreneurship” (Reich 1987).

Such a transformation depends on, and is shaped by Information Technology, which provides a means of communication among the specialists, as well as helps them individually gain access to knowledge- and data-bases. However, it is not a simple addition of Information Technology to an existing process and organizational method. Rather, it is a combined techno-organizational change, where the respective roles and links among the participants change along with the technology itself (Benne 2004).
3. BUILDING AUTOMATION

It may seem that the automation of construction processes and of the buildings themselves have little to do with the process of design: after all, by the time construction begins, and even more so—once the building has been completed—the process of design is long done. While it is true that the design phase precedes the construction or use of the building, it is the later two phases that inform the design phase what it can and ought to do, as much as the design phase informs the other two phases of the building’s lifecycle.

The advent of computer-assisted construction technologies, and of computer-controlled buildings, promise to have as much of an impact on the architectural design process and its products as these earlier technological advances have had. On the construction side, computing facilitates a much tighter and better-controlled information sharing between the design team and the builders, as well as within various construction pipelines, permitting the design of more complex structures, tighter control over scheduling (aka Lean Construction), and better management of the construction site. On the building operation side, computing allows for finer control of the built environment, making it possible to design dynamically-stabilized structures that are lighter, taller, and more economical than statically stabilized structures, both structurally and environmentally. Computing also makes controlling the interior of environments more responsive to changing needs, such as different light levels during the day and different heating and cooling needs over the year. By making them more efficient, computers allow architects to design building that clients would have balked at due to maintenance and lifecycle costs, and that are environmentally more sustainable.

The impact of Information Technology on the product of architectural design—the building itself—is beginning to manifest itself through enhanced ‘intelligence’ of the materials from which buildings are made, and their responsiveness and adaptability to changing needs.

The properties of the materials from which buildings are made have always been an inseparable part of the process of architectural design: Pozzolana cement allowed the ancient Romans to build their baths, iron (and later steel) reinforced concrete, invented in 19th century, allowed the design of longer span bridges and taller buildings, and the industrialization of plate glass production made possible the ‘glass box’ International Style architecture of the first half of the 20th century.

It was not, however, until the second half of the 20th century that ‘smart materials’—ones that can adapt themselves to the changing needs of the occupants or the environment—have emerged. Unlike traditional materials, such as wood, stone, steel, and glass, whose properties determine what the building looks like and how it behaves once and for all, smart materials can be engineered to
change their properties to fit the needs of the building as they change over time. This, in turn, determines not only how buildings are designed, but also what can be designed: instead of designing the building for a finite state, designers who use smart materials can design their buildings for a sequence of behaviors. To put it more poetically, instead of “frozen music,” buildings can be designed to “dance” to the music (or, at least, respond to it).

Some materials respond by converting the external stimulus into strain, which elongates the material; or conversely—produce electrical output when mechanical strain is applied to them. Such materials can be used as sensors and actuators, and have found use in detecting stress in walls, foundations, and bridges, even stiffening them as a response to earthquakes or wind conditions. Such actuation or sensing are, of course, picked up and directed by computers that regulate the building’s response according to some pre-determined program.

The significance of smart materials for the design phase of buildings comes from changing the building (or its surfaces) from a static entity into a dynamic one: it can be made an active participant in the environment in which it is embedded, rather than a backdrop ‘prop’ for otheractors’ activities. A building that can behave differently at different times requires, of course, a different approach to its design in the first place. Hence, ‘smart materials’ have a direct impact on the process of architectural design.

The responsiveness of buildings to their environments is not limited to their surfaces: other building systems can be made responsive, or fully automated. For example, feed-back based responsiveness is a relatively simple approach to automation, which has been around since WW II. The simplest application is based directly on the feedback loop, where some action occurs in response to an external stimulus.

Adding a functional model of the environment to networked building systems and appliances allows for a more far-reaching responsiveness and adaptability: it helps to regulate the environment in expectation of events, rather than in response to them. A functional model of a building is one where behavior patterns are programmed in advance, based on learning the typical behavioral preferences of the occupants, so the building environment can anticipate and position itself to support recurring events. For example, elevator schedules can be automatically adjusted by the system to meet peak demand in the morning by stationing empty cabs close to the building’s entrance. In the afternoon, when the traffic is reversed, the empty cabs can be stationed at the top floors of the building, thus saving the trip time an empty elevator cab must make to reach those floors from its station at the bottom of the shaft. Similarly, a house equipped with such a model-based adaptability system could optimize household operations by turning on the water heater an hour before the washer is scheduled to be used, thus conserving energy yet ensuring there is plenty of hot water available by the time it is needed.
A few model-based adaptability projects have been built, including MIT’s *Intelligent Room* project (Coen 1998), the University of Colorado’s *ACHE* (Adaptive Control of Home Environments) project (Mozer 1988), and Ken Sakamura’s TRON house in Tokyo (1989) and his Toyota Dream House PAPI, in Aichi Prefecture, Japan (scheduled to be completed in 2010).

While they demonstrate the potential of model-based responsive architecture, which can anticipate necessary actions, these projects still falls far short of the scenario described in the early 1970s by Nicholas Negroponte in his influential book *Soft Architecture Machines* (1975). Negroponte proposed that an intelligent, self-cognizant environment could replace all the professional functions of the architect, and better serve the occupants. It will not only ‘help’ humans design better habitat, but rather ‘be’ the habitat itself.

The consequences of these progressively more responsive buildings for the design process would be profound: much like smart materials transform the building from a passive object into an active participant in its environment, building automation techniques transform it from a passive container into a responsive ‘partner’ in the process of inhabitation. The architect’s role will be transformed from designing an *object* to choreographing the responses of a ‘living’ machine. The transformation has technical, economic, social, even legal implications (who will be blamed if the intelligent house fails to summon help when an elderly inhabitant falls down and cannot get up to reach the phone herself?).

4. VIRTUAL PLACES

Architecture, above everything else, is about making *places*: environments that support and enhance all kinds of human activities. It is the concept of ‘place’, not merely ‘space’, that connects a building to its social and cultural context, and makes it responsive to such needs as living, learning, working, socializing, and transacting business. While places are made of objects and spaces, they also involve the people who imbue them with social and cultural meaning. In turn, places frame human actions by providing cues that organize social behavior: people rarely sing or dance when they present conference papers, although conference halls and a theatres share many similar spatial features (lighting, orientation, etc.). Conversely, the same space—with no changes to its layout—may function as a theatre at a different time, when the presentation of a scholarly paper would be considered ‘out of place’ (but not ‘out of space’) (Harrison and Dourish 1996).

With few exceptions, Cyberspace designers have not yet begun to capitalized on the theories, experiences, and practices that have been guiding architects in physical place-making. Rather, they have adopted the document metaphor, which has guided computer-human interface design since it was invented by Xerox PARC (‘the document company’) in 1975. But, as the Web matures,
and as it assumes more fully its role as a place rather than as means of communication, there is a growing need and opportunity to design it according to architectural place-making principles: spatial settings that not only afford social interaction, but, like physical places, also embody and express cultural values. At the same time, because Cyberspace lacks materiality, is free from physical constraints, and because it can only be inhabited by proxy (aka ‘avatars’), these ‘places’ need not resemble their physical counterparts.

The advent of virtual places can be traced back to the video game industry. The initial constraints of the technology led to the design and marketing of games with visually crude graphics and simple 2D environments, like PacMan and Tetris. But improving technology allowed for designing games like Myst and Riven, revolutionizing the industry. They created a clear sense of place at both the larger ‘world’ scale, as well as the room scale. These environments are familiar, yet futuristic and unique, which makes the games intensely attractive. While the mystery/puzzle plot of those games is important, it would hardly come off without the rich place-based environments that serves as their context. The ability to link such places to each other, and visually support the presence and activities of multiple players, further enhances the appeal of virtual worlds, as demonstrated by the phenomenal popularity of Blizzards’ World of Warcraft, Linden Labs’ Second Life, and others. They are able to create places people actually want to be in, rather than the environmentally-shallow ‘dungeon’ games that preceded them, where the crude nature of the context hindered, rather than enhanced, the game experience.

It is logical to assume that designing places in Cyberspace can, indeed must be informed by the principles that have been guiding physical architecture for centuries, for the sake of environmental, social, and cultural richness. This transformation, however, is not a matter of simply emulating physical form in electronic environments: Cyberspace cannot be ‘specialized’ by appropriating physically-based metaphors: objects and spaces that were functionally and behaviorally ‘appropriate’ in the physical world lose their appropriateness in Cyberspace. On the other hand, having been conditioned from birth to function and perceive the physical world, we carry the expectations and sense of ‘appropriateness’ to Cyberspace. For example, while it is unnecessary to use a table to support objects in Cyberspace, we sense a rather uncomfortable feeling when objects simply ‘float’ in the air. And while the lack of gravity permits us to walk on the ceiling (if it exists at all), the impression such freedom produces is quite surreal, as has been so aptly illustrated by the Dutch artist M.C. Escher.

On the other hand, the digital realm offers place-making opportunities that do not exist in physical space: distances lose their meaning (they can be traversed in an instant), as do spatial boundaries. Even time can be easily manipulated (we can visit cities that no longer exist, or do not yet exist). Choosing the right balance to engender the desired sense of place, without falling into
the traps of indiscriminate ‘borrowing’ from physical space nor discarding everything we learned from it, is the challenge facing Cyber place-making.

5. A SQUARE PEG IN A ROUND HOLE OR A HORSELESS CARRIAGE?

Technologies emerge as societies evolve, and as traditional tools are transformed by new scientific discoveries. Practices that used the old tools must adapt to the changing context, and new practices that are based on the new affordances emerge. Gradually, the affect of these adaptations and new affordances become known, but by then the practices that employ them have been irreversibly changed, often with unintended consequences: even their purposes and values may be displaced by the qualities and capabilities afforded by the new technologies. In Internet is a case in point: it was developed by the US Department of Defense for specific, military purposes, yet it has found much more far reaching civilian applications, has created vast new industries, and changed the lives of ordinary citizens world-wide.

Design technologies, such as scale drawings, were intended to help architects work more intelligently, more responsibly, more efficiently, more effectively, and more carefully. They are employed to assist architects to reason about and communicate the acts required in designing. But like other technologies, design technologies are not neutral: they interpose the medium of representation between the designer’s intent and what has been accomplished through the technological means used to express that intent. The technology appropriates our “logistics of perception” (Virilio 1984). As the mediator, technology thus serves not only to communicate some knowledge, but also to determine what is knowable.

One measure of the influence technology has on the task it is employed to assist is its affordance: the potential of the technology to enable the assertive will of its user (Gibson 1977). For example, designs derived from working primarily in scale drawings can result in an architecture that is less expressive three-dimensionally than that which results from working with massing models (Halasz 1979). Scale drawings and physical models have certain affordances that emphasize different qualities of the idea at the expense of others. Because the affordance of the tool influences, channels, and even directs the reasoning that goes on during the design process, it must be chosen carefully to match the task at hand.

The introduction of computing technologies into the process of design and its products introduces such new affordances, including efficiency, control, and intelligence. These affordances have become increasingly essential to architectural practices. BIM tools make the production of contract documents more efficient and better coordinated. In a similar fashion, script-based computer modelling, such as Bentley’s Generative Components, makes possible designs that heretofore
were too time- or effort-consuming to conceive and to communicate. In a similar fashion, the ubiquitous proliferation of telecommunication networks has made it possible to involve more experts, more frequently, in the design process. The availability of microprocessors and control systems has made it possible to defer what were early design decisions to later phases of the design, construction, even the use-phased of buildings. And the advent of Cyberspace has opened vast new opportunities for designers to apply their knowledge of place-making in a new domains.

But while it is clear what needs have dominated the development and adoption of computational tools in the profession of architecture, it is less obvious how, increasingly, this technology is influencing its practice beyond the fulfillment of those needs. In many cases, the influence is misunderstood or goes undetected at all. As designers embrace the new technology for all its benefits, they must also become increasingly more cognizant of its less obvious impacts on their work and its products.

In this regard, the uneasy relationship between novel computational principles, methods, and tools, on one hand, and the ancient discipline of architecture, on the other, can be interpreted according to two different paradigms. The first is that of forcing a square peg into a round hole, implying that the use of the new tool is misdirected, or at least poorly fits the processes that have traditionally been part of architectural design. The second paradigm describes a state of transformation, where the new technology is viewed through the lens of the practice in obsolete and ‘backward’ terms, much like the automobile was viewed as a horseless carriage in the early days of the 20th century. It implies a lack of appreciation for the emerging potentials of technology to change the task to which it is applied (Chastain et al. 2002).

The ‘square peg in a round hole’ paradigm describes a problem of adapting a new technology to current practices. As a new technology is introduced into a practice, a dysfunctional relationship can develop between the tools and a task, either because the task is poorly understood or because the process of displacing a traditional technology is largely one of the substitution of habitual tools with new ones that have the wrong affordances. Such inappropriate use of the technology results in a poorer practice. For example, using precise drafting tools such as AutoCAD early in the design process, where ambiguity and flexibility are needed more than preciseness, requires the designer to decide issues whose time has not yet come, thus interfering with the evolution of design ideas. Moreover, it can mislead the viewer of the design (including the architect him/herself) to read more precision into the design than it deserves. Understanding this paradigm (and resolving the dysfunction it brings in its wake) requires a clear identification of the various actions that comprise the design process, and developing computational tools that can truly assist them: what amounts to ‘rounding off’ the square peg.
The ‘horseless carriage’ paradigm views technology as a means to alter the perception of a practice about itself, as it is transformed by a new technology. In using the term a ‘horseless carriage’ at the turn of the 20th century, the nascent automotive technology has been described through the lens of a previous technology, not realizing that the practice of travel had been dramatically changed. Understanding this paradigm requires asking a different question than the first one: rather than how can the new tools assist designers, one should ask how do the affordances they provide change the practice of design itself? Do we understand how having more precision early in the process affects our reasoning about design options? Do we understand how communication via digital models and immersive simulations fundamentally changes the culture of the practice? How does knowledge, once invested only in the designer but now ingrained in the tools, even in the products themselves, affect the practice of design? This paradigm, like the first one, assumes that the fundamental task does not change (i.e. the task of designing of a habitable place). But unlike the first paradigm, it assumes that the practice of design is not only assisted, but is changed through the influence of the new technologies.

In both paradigms, the tools are linked to an image of practice (Boulding 1956). This image is a description of methods, habits, organization, knowledge, and culture of design in relationship to a task. Architects often hold such an image of their practice, but not always explicitly. They may know how something is done, but are less aware of the values implicit in a particular way of working.

The practice of architecture has had only a few decades of experience with computing technologies, as compared to others technologies (predominantly, drawings). It is not surprising, therefore, that the fit between the affordances offered by computing technology and design practice is problematic. The question is how to understand those affordances and evaluate their potential impacts on the profession and practice of architecture.

The first paradigm offers one approach: smoothing off the square peg. It begins by observing what designers do, and adapting the tools to their modes of working. This is an empirical approach, rather than an analytical approach of understanding the design process itself. It is more ‘convenient’ and less ‘messy’ from a computational point of view. The empirical approach is supported by protocol analyses that attempt to capture the reasoning associated with design actions (Goldschmidt 1992). Such studies have provided insight into issues of emergence, analogy, visual reasoning, and the use of representations in design. The connection between these insights and new tools ought to help improve the fit between their affordances and design actions: between the peg and the hole.

The second paradigm is more fundamental and critical to understanding where the profession of architecture is heading. In approaching computational tools as a ‘horseless carriage,’ the observation shifts to include the practice as well as the tools and their products. The promise afforded by the new tools
includes the ability to analyze the products themselves, and the belief systems underlying them: the implicit values held by the discipline, and the organization of the practice of architecture itself. Both may change as the methods and products evolve along with the tools, as will the identity of the designer and the image of practice.

The implications for Architecture are clear: in the 'square peg/round hole paradigm,' matching the affordances of the technology with the design actions it can support in a more inclusive manner, will promote the emergence of new design practices. The 'horseless carriage' paradigm tells us that, through technology, not only will current practices be displaced and new ones introduced, but that the discipline of architecture itself will change as well. The question is: how, and how much?

REFERENCES


Boulding, K.E., 1956, The Image: Knowledge in Life and Society, University of Michigan Press, Ann Arbor, MI.


Harrison, S. and Dourish, P., 1996, Re-place-ing space: the roles of place and space in collaborative systems, CSCW’96 (an ACM publication).


