Interactive Architecture
Challenges of Digital Technology and Placelessness

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FORWARD

The goal of this investigation was to thoroughly research how the architectural profession and related design fields will begin to respond to imminent changes occurring throughout society as a result of digital technology and the trend towards ubiquitous, or pervasive, computing. Computers and other digital devices have greatly influenced our lives that it is difficult for us to perceive of a life without them. For some of us who use such technology regularly, computers have simply become a natural component in our daily routines so much so that we typically do not think twice about using them. For others it is not so simple. Therefore, architecture has a new critical problem to solve. How can technology be so user friendly and non-protruding in our spaces that it feels natural and invisible for the majority of a building's users?

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Do we really want to live within a world saturated with computers and digital devices? Whether we want to or not, it is something we will be faced with in the coming decades as we gradually find our physical environments filled with computers, sensors and other digital media with access to all information at our fingertips at any given time and location. At the same time, this technology will be so gracefully integrated into our physical environments that it will essentially disappear and will exist in our lives as seamless as our cars or other appliances we use daily. Rather than utilizing a mouse and a keyboard, our methods of control will consist of gestures and spoken words in a more natural way.

So how does this begin to affect architecture and physical space? Essentially, users will require more from our environments, expecting them to respond and have a pre-determined level of intelligence. Should buildings also be responsive and interactive in a similar manner? Is the technology readily available now to begin investigating the implications of a shift towards interactive architecture? Architects and designers can no longer turn their backs on the considerable changes digital technology is having on society and we have only begun to see the initial effects of what is to come.

1 TRENDS IN DIGITAL TECHNOLOGY

The last decade has seen dramatic changes and improvements in digital technology that continue to change our lives and how we experience with the world around us. The Internet, once used solely for information and data exchange merely fifteen years ago, has prospered into the fundamental method in which people communicate and interact as technology has become smaller, lighter and considerably faster. The minimalist nature of new technology allows it to embed itself unrecognizably into everyday objects around us, which ultimately will lead us to ubiquitous computing environments in the coming years.

1.1 smaller, faster + lighter

The last decade has seen extraordinary expanses in available technology not only in digital and computing technology, but also in construction, production and manufacturing. The Internet has been the primary leader in technological advancement

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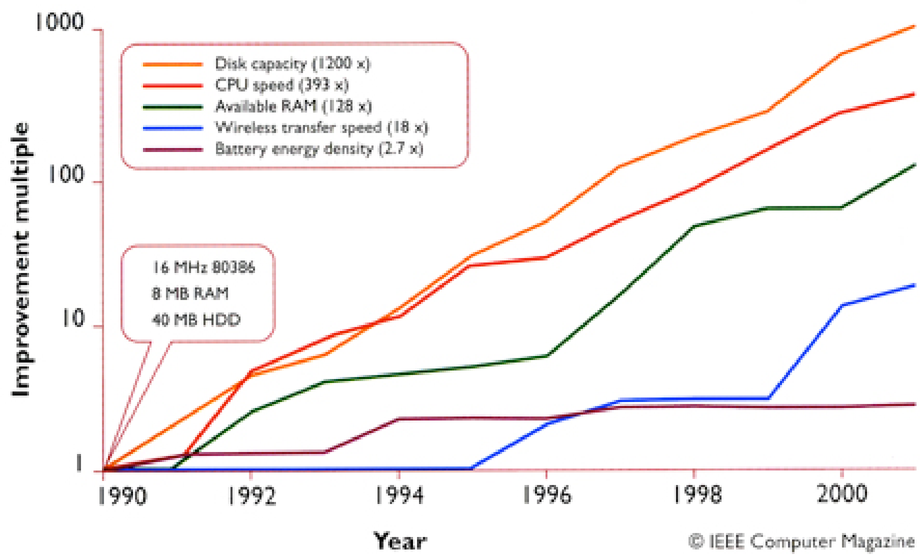
during this period and the most important technological development in our generation whose effects will eventually rival those of the television and the printing press.[1] As technology continues to evolve, it also continues to become smaller and faster with remarkable levels of processing power. Since the early 1960s, the trend has been to increase the capacity of technological components while decreasing their size and cost--an idea known as Moore's Law. Moore's Law, an observation made by Intel co-founder Gordon Moore in 1965, states that "innovations in technology would allow a doubling of the number of transistors in a given space every two years, and that the speed of those transistors would increase." As silicon-based components gain in performance, they also become exponentially cheaper to produce, and therefore "more plentiful, more powerful, and more seamlessly integrated into our daily lives."[2] Memory, CPU speed, storage capacity, wireless transfer speed and battery energy density are reflecting similar increasing trends as processor circuit performance.



Technology trends, ©*The New Everyday*

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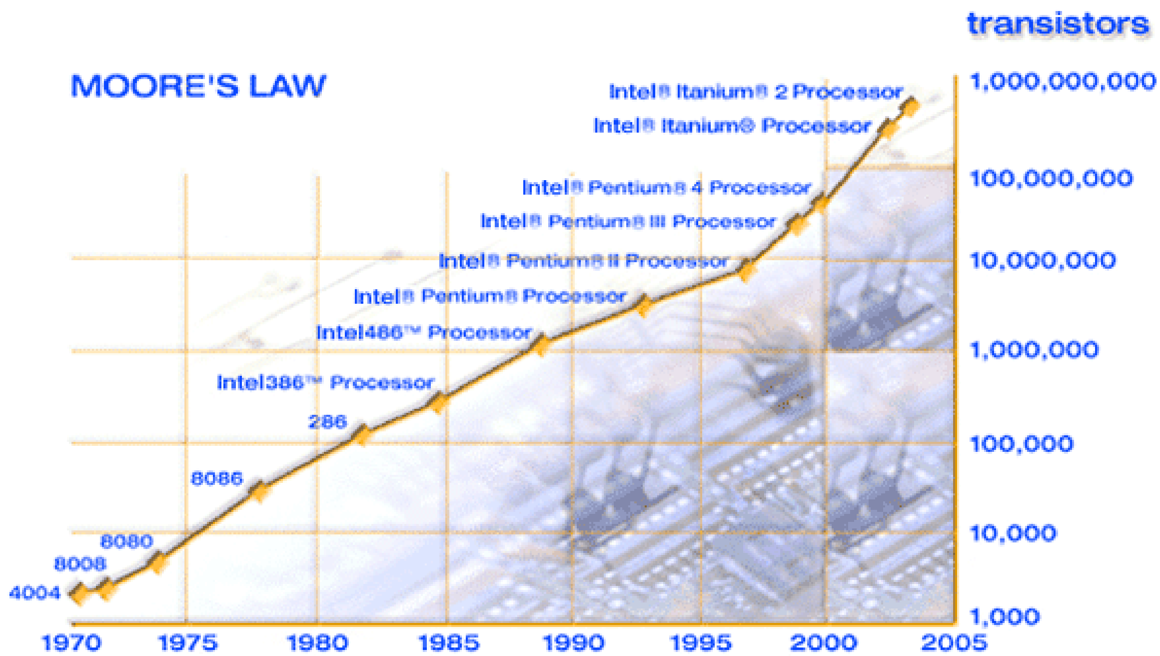

Moores Law relative to Intel processors and number of transistors, ©*Intel.com*

1.2 digital networks, communications + interaction

Originally, the rise in networked computing was a response for the desire to exchange files between clients (users), which gave rise to the Internet's widespread existence in the early 1990s. The Internet was a place for information and data that correlated to the sole purpose of the personal computer--processing and computing. The personal computer "relationship is personal, even intimate. You have *your* computer, it contains your stuff, and you interact directly and deeply with it. When doing personal computing you are occupied, you are not doing something else."[3] However, as we approached the turn of the century and the possibilities in computing and the Internet expanded exponentially, especially during the technological bubble, computing moved into a new paradigm. Users no longer utilized personal computers simply for computing but rather for a variety of different purposes like text, graphics, databases, spreadsheets--all beyond the initial paradigm of data and information. As dynamic web technologies developed and evolved to allow for online transactions and entertainment, the Internet was no longer a place solely for information.

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Network servers, ©*Getty Images.*

Consumer electronics to date has existed in the "age of the box". Hardware and stand-alone boxes, such as the television, video recorders, DVD player and stereos, provide their own independent function.[4] Once again, we as users of such hardware are frustrated with having these obtrusive boxes accumulate in our physical environments over the years due to all the focus being placed on engineering the technology rather than interactivity and usability. Fortunately, those same technologies that provided the independent functions have become smaller and smarter to allow for multi-integrated functions within single hardware components. The same technologies can conceivably be integrated into any object and all of the everyday objects that we interact with. Our physical environments will reside in a highly communicative, networked world--merging it with the once foreign virtual world. The Internet is carrying us through an era of widespread distributed computing and moving towards ubiquitous computing. Over time, the results of extensive interconnection of personal, commercial and governmental information will strengthen a new paradigm currently surfacing in which new relationships between people and technology will emerge.

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1.3 embedded technologies

As we moved into the new century, the role of the PC and its normative interactive components, such as the keyboard, the mouse and the screen, began to evolve. Additionally, software has become bloated with features, files and lines of code so that the PC is no longer "personal" nor is it really used for computing. [5] Currently, the computer industry is developing clusters of smaller, more specialized and localized systems over the vast networked systems that were the theme during the 1990s. The combination of networked digital systems and trends in developing smaller and more intelligent technology has lead to wider access to any source of information at any given place and time. Ubiquitous computing, also known as pervasive computing, "integrates computation into the environment, rather than having computers as distinct objects." Embedding computation into the environment and everyday objects "would enable people to move around and interact with information and computing more naturally and casually than they currently do."[6] Ubiquitous computing will be of primary concern for architects and designers in the coming years as it greatly affects the perception and interaction of space as well as one's experience while within that space. This topic will be of greater concern later during the discussion of interactive architecture and pervasive computing.

Embedding digital technology in everday objects, ©*The New Everyday*

2 TRENDS IN DIGITAL ARCHITECTURE

Architecture has been taking advantage of the availability of digital technology in the design process and has allowed new building typologies and forms to emerge. Digital tools and software now easily perceive intricate geometries that were once too complex to draw or envision. These same tools in conjunction with digital fabrication machines have manipulated the complete input/output design process and have made it more direct, efficient and less time-consuming to achieve a physical representation of the digital model. New investigations have also emerged that look at how intelligent software applications can begin to manipulate or even "design" form using complex generative algorithms to develop the most efficient form through parametric design. Recent research in material science has also lead the way to a new palette of materials that are dynamic and responsive to various environmental variables that can also be used in parametric design.

2.1 digital design

Digital technologies have transformed the architectural profession for the last two decades primarily through production. Only recently has design and its input/output process been influenced by a more prominent interaction with digital technologies. Rather digital technologies assisting traditional methods of design, which we know as computer-aided architectural design, architects are shifting towards "totally computer-mediated architectural design" by utilizing complex 3D software like Form-Z, Maya, 3d Studio Max and Rhino.

Some perceptions of this trend see architecture as dissolving into fragmented and disconnected specialties, whereas the other perceives the shift toward digital architecture as redefining the "master builder." Ganapathy Mahalingam, currently an Associate Professor of Architecture and Architecture Program Directory at North Dakota State University, further elaborates on this evolution:

> "The digital representation of architectural entities and the digital manipulation of those entities have provided alternate means to product

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architecture. Drawing, modeling, performance simulation, design collaboration, construction management and building fabrication are now routinely performed using computer-based technology. This success has revealed the untapped potential of computational representation of architecture.

Advances in computing based on the study of natural processes such as neural processing, genetic evolution and emergence now suggest that the elusive nature of creative architectural thought can be articulated enough to be applied in a technologically-mediated environment. Digital tools may finally reveal what other architectural tools have hitherto concealed--the architectonics of architecture. Therein lays promise. The future of digital tools rests on the extent to which architects can accept that exemplary architectural design can be created in a computer-mediated environment and that digital thinking is indeed architectural thinking."[7]

Digital design and tools have allowed architects to move traditional design paradigms and into one that understands a higher level of complexity--integrating concepts of organization, structure and space which exist beyond the everyday. However, using digital technologies during the input/output process does not guarantee digital architecture. The author must still verify such projects with his/her base architectural knowledge of space, form and usability. Without "rigor and critical dimension" or relying on basic architectural foundations, digital projects austerely become interesting rather than true digital architecture--"[remaining] only exercises in software."[8]

Architectural representation also transforms with the use of digital technologies as our perceptions of place, space and time are redefined. Drawing has always enabled architects to quickly represent abstractions and continues to do so, but the medium of drawing has begun to shift away from paper. Additionally, the two dimensional constructs provided in a flat drawing may no longer be appropriate for representing the more complex designs arising from digital design. So, do we turn away from two-dimensional drawing altogether? It still offers the abstracted clarity of one's thesis

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through diagram. Three-dimensional modeling with intricate modeling software (input) and computer-numerically controlled (output), or CNC, has given way to new architectural forms. When combined as a complete input/output cycle, we complete the process from design to production much more fluidly and accurately.

2.2 digital fabrication

The current trends in the digital ages have created a direct link representation and construction through "file-to-factory" computer-numerically controlled fabrication (CNC). Modeling software and NURBS have expanded the potential of what can be represented virtually, while digital fabrication has extended the possibilities of what can be constructed. The immediate result has been an increased complexity of building form, structure and organization over the last five to ten years. According to Branko Kolarevic, Associate Professor of Architecture at the University of Pennsylvania, there is "an unprecedented directness with which digital design information can be used in the construction of buildings. The consequence is that architects are becoming much more directly involved in the fabrication, as they can efficiently create the information that is translated directly into the control data that drives the digital fabrication equipment."[9] Collaborative roles and relationships within architectural projects are also evolving due to the fluid "file-to-factory" input/output process offered by digital fabrication and the ability to generate actual construction information from directly from design information--essentially merging both the architectural and construction professions.[10]

Digital fabrication has already been at work in the industry for the last decade and more so within the last few years. Mark Goulthorpe and the small design team of dECOI, founded in Paris in 1991, integrate a wide network of professionals in related fields of mathematics, material science and programming to produce their experimental scope of projects. dECOI is interested in the broad cultural effects of technology, how it influences architecture and modes of production as well as social reception. They construct many of their projects' components physically directly from the three-dimensional computer models using CNC machines. Digitally, they often use generative algorithms adapted to the specific characteristics of the design problem in order to achieve the final form.

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Digitally fabricated model of the Miran Gallery, dECOI Architects, ©*decoi. architects*

2.3 generative processes + form

The role of calculation and programming in the design process is becoming increasingly significant due to the progressive integration of computers and digitalization into the architectural practice. As previously described, dECOI relies heavily on digital tools for their projects, especially three-dimensional digital modeling and generative algorithms. Their Miran Gallery project was a research project focused on the implementation of a parametrically controlled generative algorithm adapted to the specific constraints and requirements of the design, which was intended to be part of an interior renovation of a Parisian fashion atelier. The collection of scripts, which were written in Visual Basic scripting language and then hosted by the Rhinoceros CAD application, "introduced in an intermediate phase of the design, for automating the processes of rapid prototyping and digital fabrication."[11] The inspiration for the Miran script used to generate the final form arose from the actual rapid prototyping fabrication process used for actual construction. Mark Goulthorpe explains that "pronouncements of architects as being 'digital'... requires that the new territory be *thought* of as such, which

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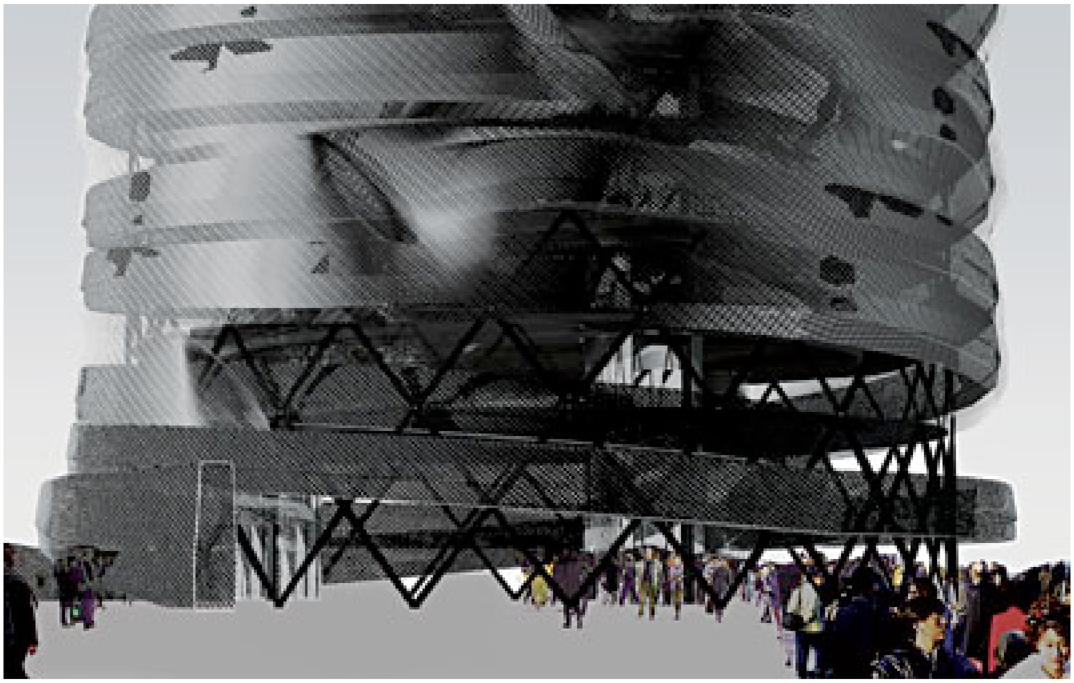
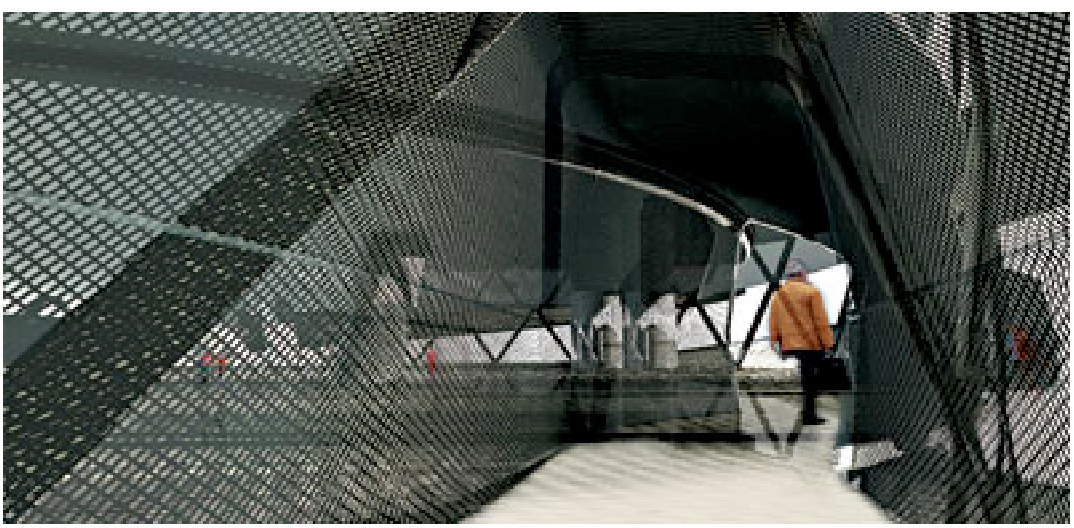
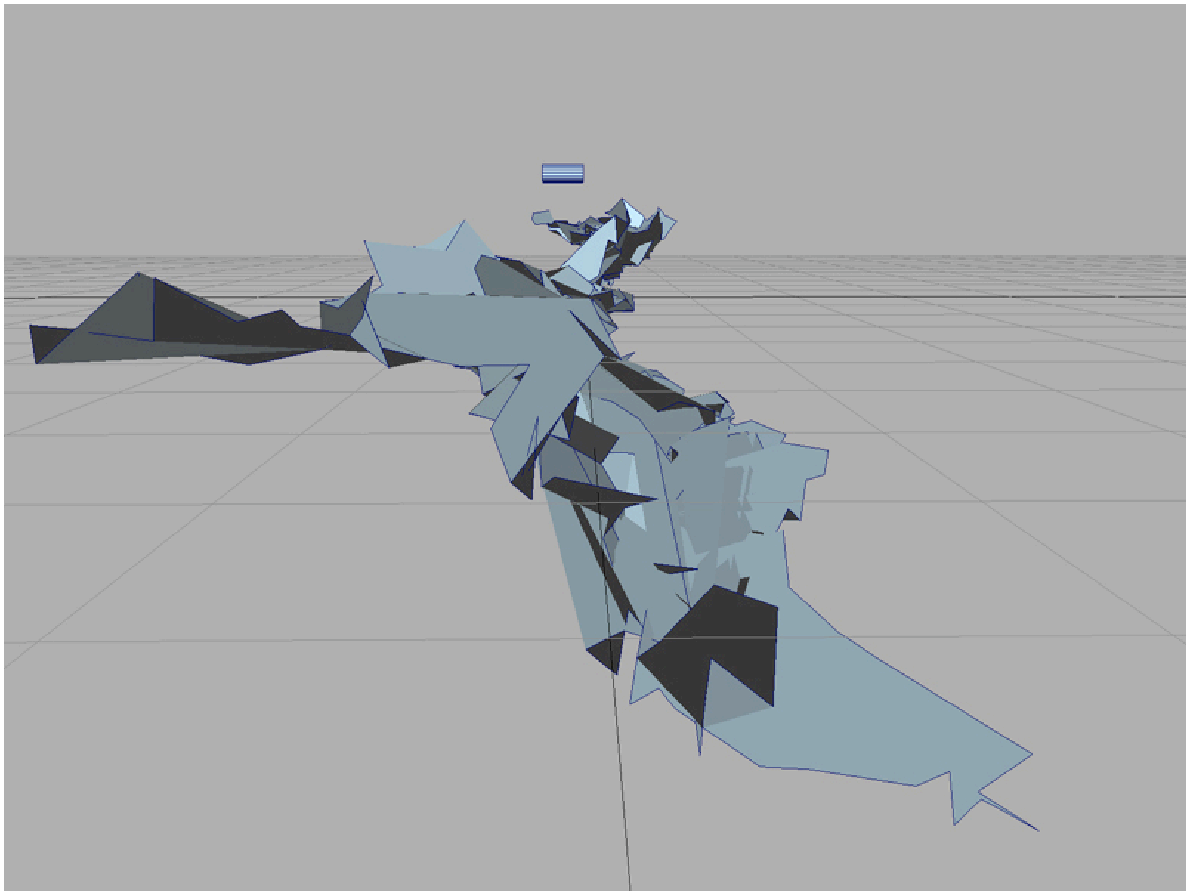
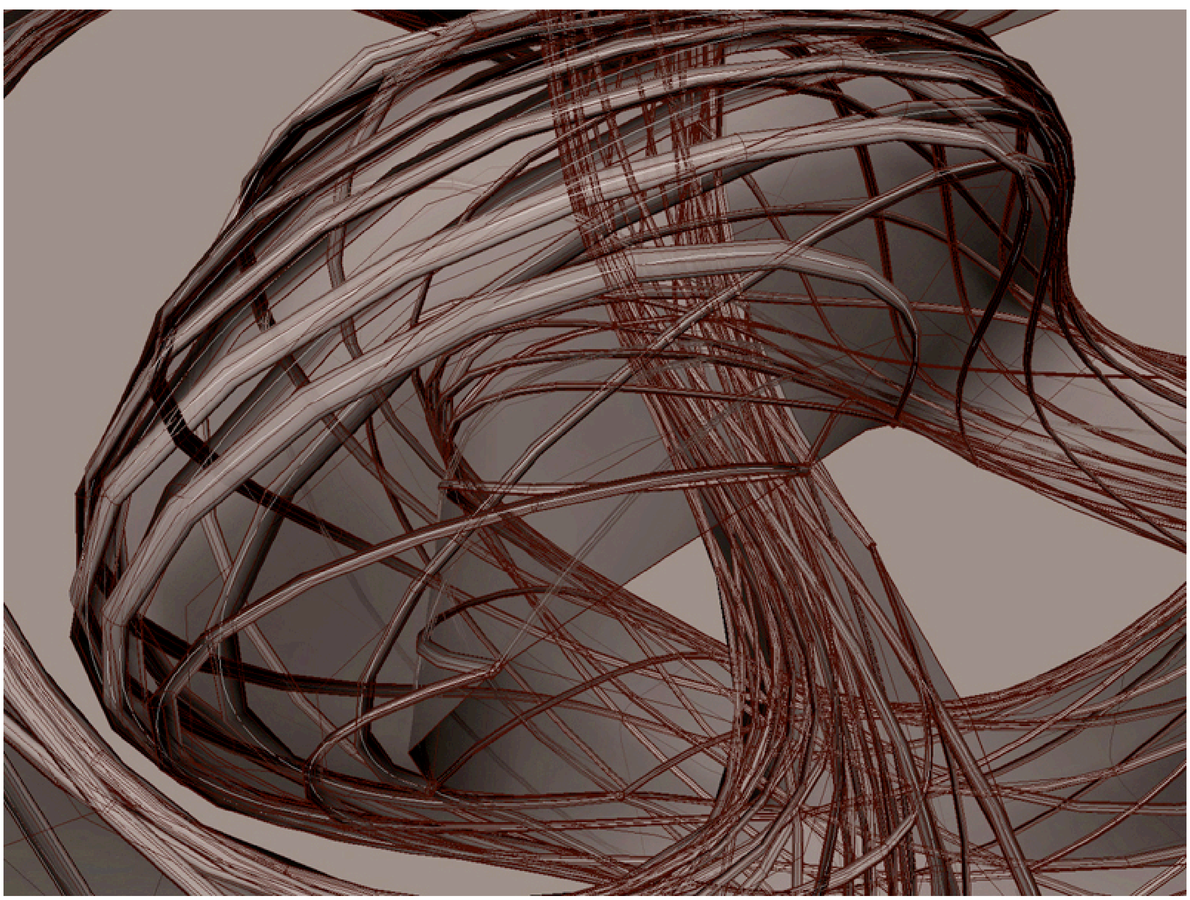
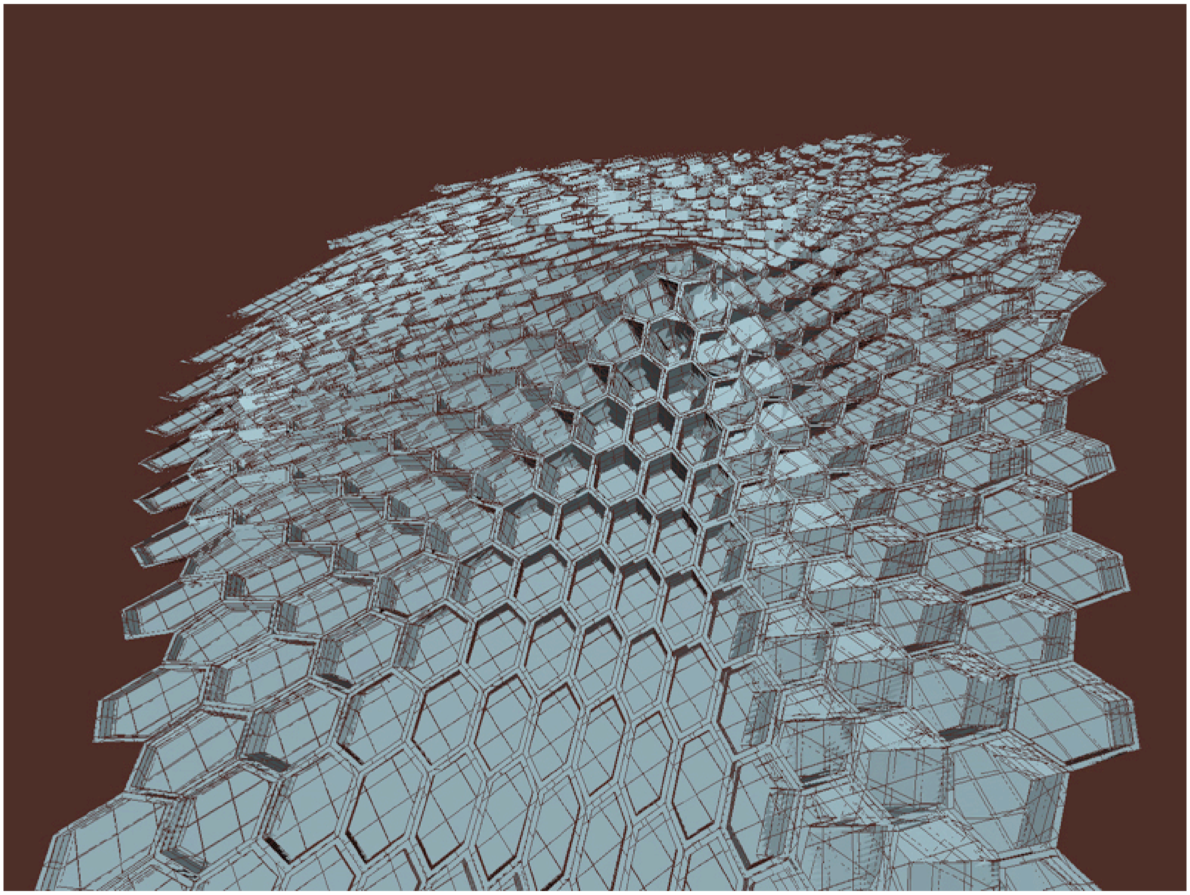


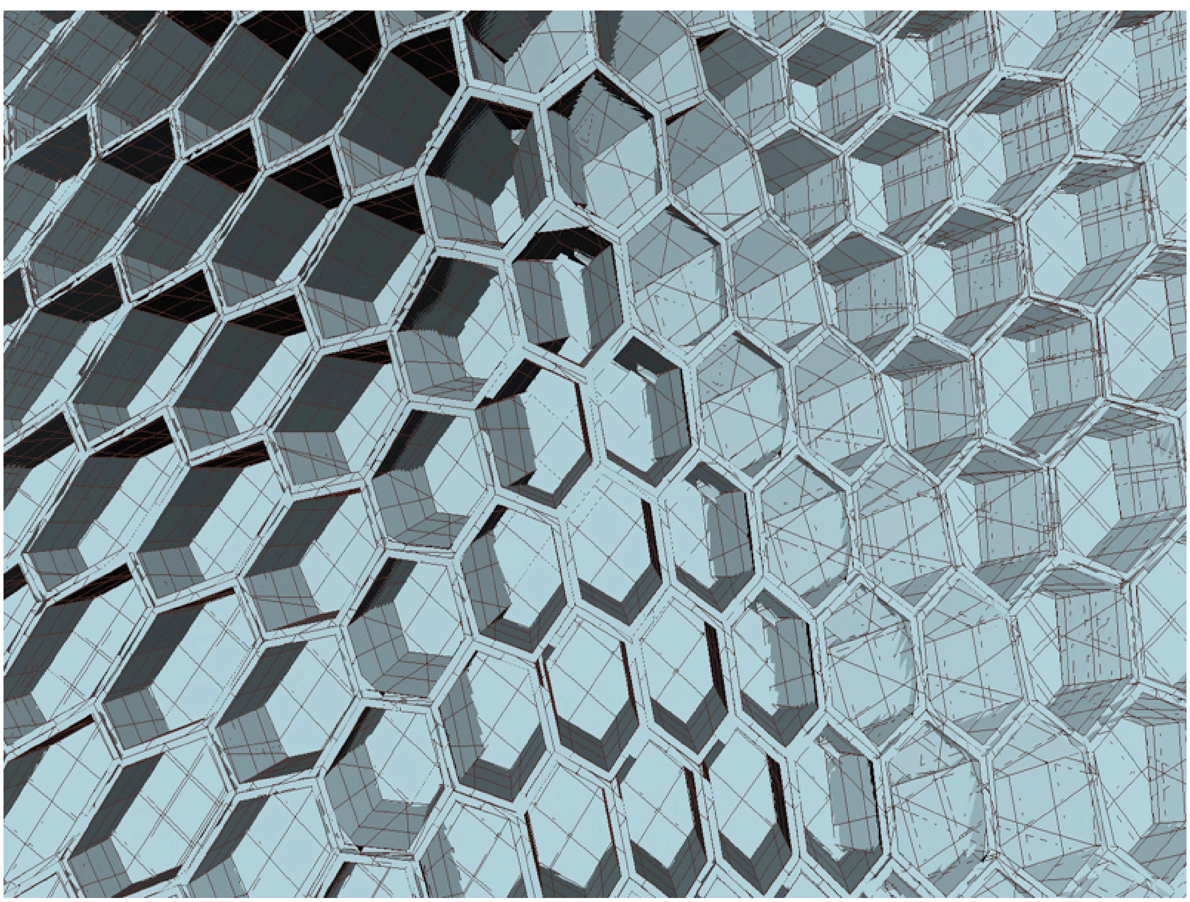


Peter Testa, carbon fiber tower









suggests learning from those who already inhabit it effectively (programmers, mathematicians, etc.); these have long since recognized the algorithmic, programmatic and parametric nature of such technology."[12]

Peter Testa is another proponent of digital architecture and fabrication who engages heavily in the collaboration with materials and technologies industries. Testa is well known for his use of new and innovative materials, such as his forty-story Carbon Tower that uses a crosshatched lattice skin made of carbon fiber rather than steel, making the structure several times stronger. He is involved in MIT's Emergent Design Group (EDG), whose main goal is to "research structural morphology and new spatial models with a focus on the emergent properties of material forms in architecture" and includes researchers in the fields of architecture, artificial intelligence, computer science, engineering and media arts/sciences.[13] The EDG has developed a series of Maya plugins, scripts and algorithms as a series of research investigations in computationally and numerically generating form. GENR8, developed in 2001 by Testa and Una-May O'Reilly, is "an innovative design tool that fuses an expressively powerful universe of growth languages with evolutionary search" to create a collection of evolutionary algorithms.[14] Weaver, written in MEL for Maya and developed in the same year, applies a pattern of interwoven strands onto a user-defined surface. The resulting form highly depends on the complexity of the parameters for the weave pattern and the object onto which the weave is applied to. Unlike dECOI, however, Peter Testa is more interested in the digital input/output cycle rather than the physical manifestation dECOI constructs using rapid prototyping and digital fabrication methods. Both, however, are taking advantage of the available technology and architecture's design to utilize it in the near future in order to push the design profession into innovative directions.

2.4 smart materials

The advancements made in science and technology is not only limited to computers and digital networks but also appears in the actual materials that define our physical surroundings. Until recent years, we have been restricted to using static materials that have a limited set of physical properties that could not be manipulated instantly. Now, smart materials have been the focus of attention for product designers

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and material scientists as it allows a person to instantly manipulate the properties of the material dramatically, giving it new characteristics. Materials can be manipulated and altered by their viscosity, volume and conductivity, which ultimately influences which applications certain smart materials can be used for. The technologies encompassed by intelligent materials are diverse and include electrorheological fluids, fibrous materials, ceramics, photonics, microsensors, signal processing, piezoelectrics, biomimetics, shape memory allows, neural networks, nanotechnology, conducting and chiral polymers, liquid crystals, microactuators, biotechnology and information processing.

Shape memory allows, one of the better-known smart materials especially within the field of architecture, are metals that exhibit two unique properties: pseudo-elasticity, an almost rubber-like flexibility, and the shape memory effect. The "memory" of the materials are made possible through a solid state phase change--a molecular rearrangement in which the molecules remain closely packed to keep the material a solid. The two phases in shape memory alloys are Martensite, "the relatively soft and easily deformed phase", and Austenite, "the stronger phase... [that] occurs at higher temperatures."[15] The shape memory effect occurs when the substance exists or is cooled below a certain temperature, which allows the material to be easily deformed and manipulated. In order to return the substance back to its original state, the material is then heated at or above a certain temperature in order to reconfigure the molecular structure of the material back to its original configuration.

Nanotechnology has been a popular field of research during the last decade and is a technology that examines phenomena and structures at the nanometer scale of several atoms and small molecules. The benefit of nanotechnology appears across a wide range of professions and industries, from communication and information technology to biomedical. According to the Futurist.com's article "Nanotechnology: Science of Small Things", there are many potential uses beyond the realm of biology. "By bonding a molecule with a nanoparticle, or single atom, scientists are able to create substances such as fullerenes, molecules or carbon atoms that when put together they form tubular fibers, called "nanotubes". When those fibers are threaded together and crystallized they can act as metal, but one hundred times stronger and four times lighter than steel".[16] Such a material in buildings and structures would greatly alter the architectural profession by

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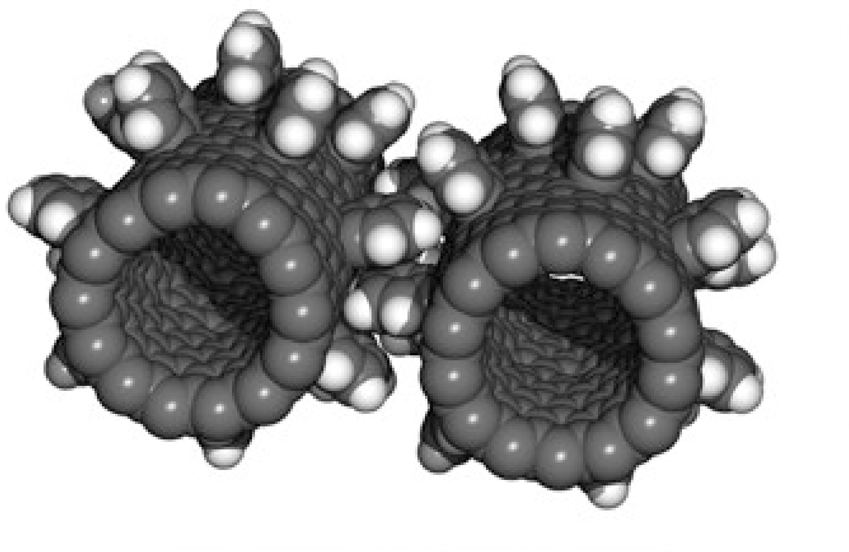
requiring less material yet permitting new forms to emerge. Additionally the technology would be environmentally beneficial as well, being able to manipulate the atoms of harmful toxic chemicals to render them harmless.



Nanotechnology, molecular binding, ©*NASA*

Digital technology affects many people on a global scale as it embeds itself into our everyday lives. We currently find ourselves in a social shift, or transformation, between the digital and non-digital generations. Time is speeding up. Our lives are constantly occupied by deadlines, schedules and thousands of options. Increasing the number of options gives way to increased customization and control. The effects of our digital culture are finding themselves in all aspects of society as we continue to evolve with technology.

3.1 a hyperactive society

Our world has evolved into one of multi-tasking and increasing the number of actions we can partake in at the same time, which overtime has also decreased our ability to focus on any single action for a longer period of time. Time has sped up and we have become progressively more hyperactive, overstretched and overbooked. Technology has definitely made society more productive and much more efficient, but it has also allowed

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us to take on much more and has opened up many more potential options. The digital tools we have available shorten the amount of time to complete certain tasks that frees up time in our lives. However, this free time is then again filled with even more tasks rather than less active events. One's work and life are beginning to merge together into a single existence as digital networks and communications have allowed many to work from home or remotely away from the physical office. Driving or walking down the streets of our cities, we are overwhelmed by colorful advertisements, logos and other visual pollution that being able to focus on any one single element is a difficult task. If we are participating in multiple actions at any single moment then we are being inefficient and essentially wasting time. Furthermore, people often have too many options available to them that they become overloaded with information.

As more options continue to become increasingly available to us, eventually we will reach a demand for total control over the products we buy, the events we participate in, and potentially the spaces we inhabit. Mass customization is replacing mass production in many manufacturing industries, which increases manufacturers' profits while at the same time satisfies the consumer's need for control. Users of buildings will find themselves frustrated at the static nature of the structures, unresponsive to their continuously changing needs, and soon architects and designers will be faced with a new design problem--how can physical space be variable and customizable?

3.2 customization demands

As technology rapidly improves, a shift in production and manufacturing of consumer products has taken place that allows for increased customer customization. From a company's perspective, online customization allows manufacturers to greatly reduce the cost of materials and mass production and only produce what their customer wants, which also eliminates finished goods inventories. As for the customer, online customization offers enhanced customer service by manufacturing products specified to the users' needs and desires with near mass production efficiency.

Five years ago online customization was seen as a major bust as customers were deemed to lack interest in its potential and the costs to companies offering it were still considerably greater than traditional methods of mass production. Additionally, the

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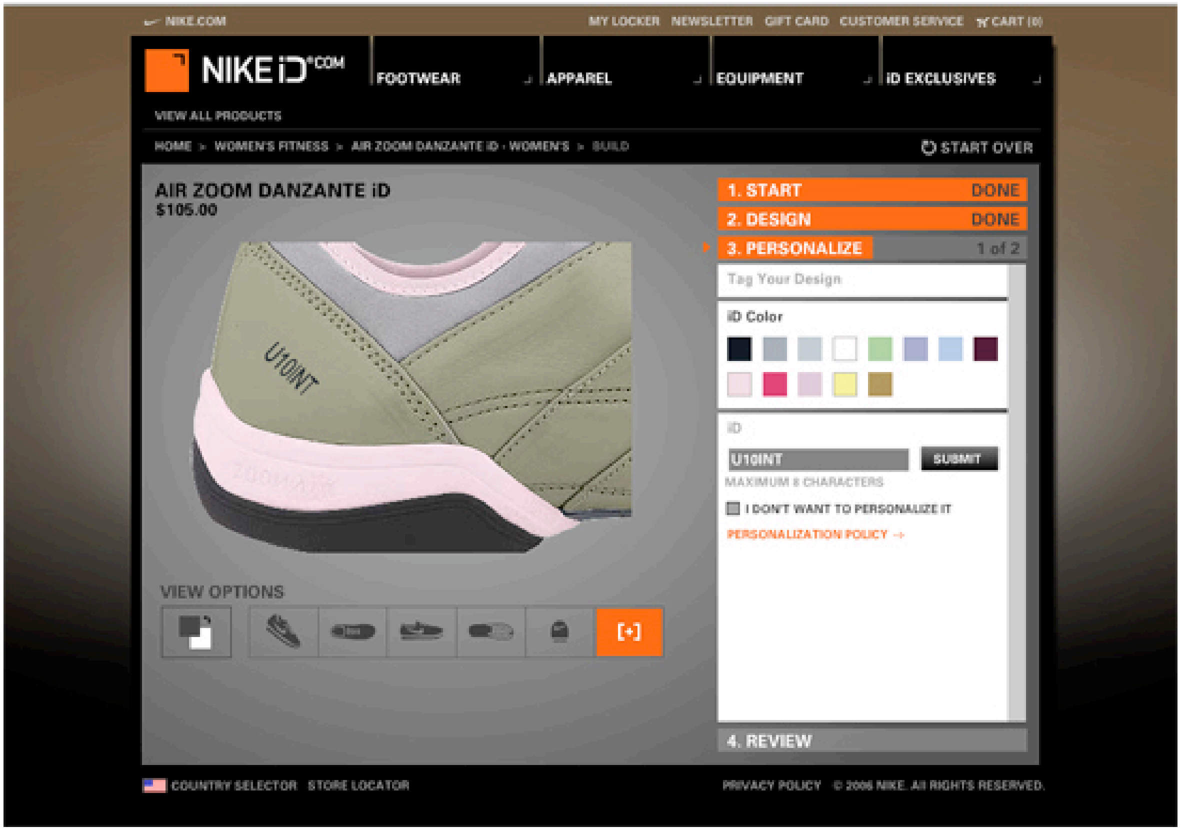

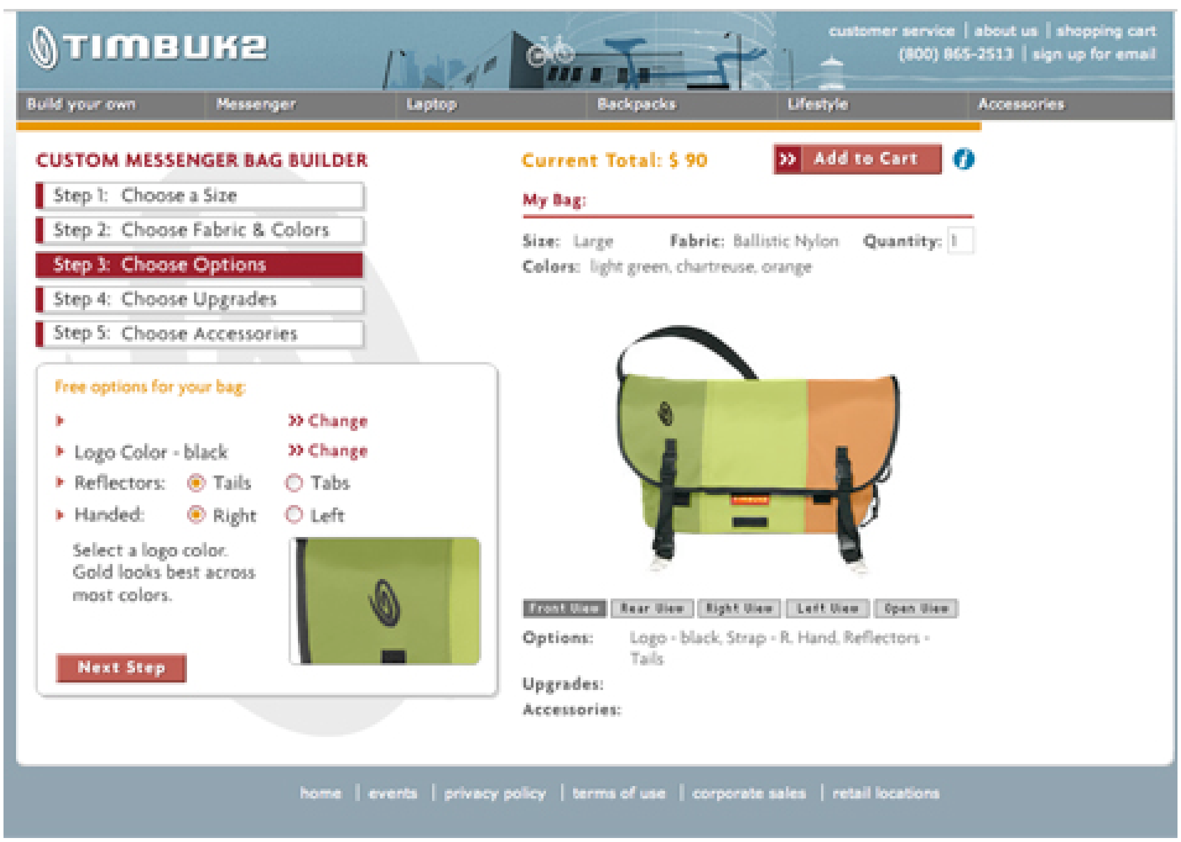

Web-based custom design software, nike.com and timbuk2.com

initial technology was not fully developed enough to allow for an efficient experience for both the consumer and the company. Fortunately, those hurdles have been cleared and as internet security has increased more people feel comfortable shopping online, many of which are turning to online customization of their favorite products. Many companies have witnessed the tremendous value from offering online customization with an average fifty percent increase in unit selling price. There are often too many different permutations for a product that it would be difficult and costly for a company to offer all of them in a traditional retail setting. Online customization offers consumer access to all available options while greatly reducing the manufacturing burden Data mining is another benefit to companies that allows them to shift from current trends in mass marketing to a more personalized relationship marketing model, increasing awareness of their customers' needs.

Several major corporations have implemented online customization applications since the late 1990s, some were highly successful while others failed due to a different targeted demographic. In 1999, Nike launched its online customization service to allow customers to design and order their personalized pair of sneakers through a "kit of parts" system. Nike has allowed a predetermined set of components of the sneakers to be customized, such as colors, patterning, text and graphics. The initial complaints about the new system arose from the limited product selections and availability, after which Nike added additional products and more options that are customizable.

With the success of online customization applications like Nike's, hundreds of other corporations and smaller companies followed, especially once the programmability of rich Internet applications (RIAs) as well as online security improved. Now, major companies like Levi's, Puma, Timberland, and Timbuk2 have implemented online customization. The same system has benefited several other industries as well, from custom t-shirt and sign printing to online home designing, an application which has appeared within the last five years. The demand for customization will only continue to increase as web-based applications improve and people become more comfortable with the technology.

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3.3 production of goods

Production and manufacturing have also seen innovative progression because of increasingly smarter technology. Such industries are focusing more on automation, which Wikipedia defines as the "use of control systems such as computers to control industrial machinery and processes, replacing human operators." Computers are important in the manufacturing industry due to the inherent repetitive nature of the work that is necessary. Digital computers and technology (over hybrid and analog technology that existed prior to the 1970s) is superior at performing simple, repetitive tasks and processes in a fast and efficient manner, essentially replacing human's positions in such recurring task positions. Currently, for manufacturing companies, "the purpose of automation has shifted from increasing productivity and reducing costs, to broader issues, such as increasing quality and flexibility in the manufacturing process.[17] The error rates of computer manufacturing have also greatly dropped, which further increases quality substantially. Manufacturers are now requiring more flexibility in their production lines so that they can producing multiple products on a single line "without having to completely rebuild" the lines.[18] Additionally, it drastically reduces the time products become available on the market, the time spend on changes and the time spend on the manufacturing planning process. Computerized manufacturing has allowed for a greater level of product customization that has been highly successful for corporations like Nike who have take advantage of the technology.

3.4 digital communities and networks

There are major social consequences to the increasing use of digital technology that are likely to change the way in which people interact in not only virtual space but physical space as well. Digital technology has been highly embraced due to its ability to easily and quickly sort and distribute complex information. Within the last five years, we have seen this extending into your social structure through the birth of hundreds of online social networks, which bring together large groups of people with similar interests from all over the world and various social groups. Powerful innovative tools that allow for digital distribution of information, online identity systems, and ubiquitous computing

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between devices and embedded within our physical environments promise to work with us, the user, more securely and efficiently than ever before.

Current popular online social networks.

The technical architecture that is embedded into digital communication systems implicitly carry certain agendas and cultural values since the actual architecture does set limitations for what the system can and cannot do, although one cannot predict exactly how people will use the technology as unexpected uses will continue to emerge. Most people who use the Internet extensively see it as a democratic model--open access to information from all over the world that is not controlled or owned by any single entity. There have even been criticisms related to the private sector's increasing interest in controlling the Internet through defining the parametric technology and setting standards of limitations. By participating in online social networks we are empowering ourselves to communication with others which potentially leads to social action.

At the Planetwork conference in San Francisco in 2003, an article titled "The Augmented Social Network" was presented whose goal is to contribute to a stronger 21st century democracy through digital technology and information. The article explains that "Personal empowerment--the ability to take effective action to shape society--occurs when an individual can make the link between information and the opportunity to act on that information. You might say that there is an "algorithm for empowerment" that transforms information into knowledge by providing a context for interpretation and action."[19] We have already been witness to instances in which information provides such power with the Iraqi war and the alternative new sources that do not filter information as most United States media outlets do. The Internet is vast and highly unorganized--primarily a result of its explosive growth in the 1990s. In the upcoming next generation of the Internet, the goal is to create a new networked system that enables more efficient and effective information sharing between people across institutional, geographic and social boundaries.

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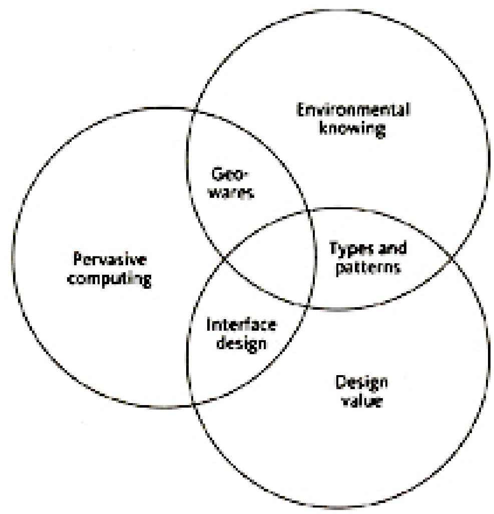
4 INTERACTIVE ARCHITECTURE

With the situation of the world, a world that is becoming saturated with sensors, microchips and processors as dependence on technology increases, designers should be concerned with this new design problem. Unfortunate that is hardly the case as designers resolve problems in much of the same fashion as a couple decades ago. Digital technology requires an alternative and innovative way to look at architecture and our built environment, connecting it with what we value in the world. Digital networks are no longer separate from architecture, and pervasive computing must be inscribed in the social and environmental system of our physical world. "Human life is interactive life", and it is through the combination of architecture and cities with information technology that people will begin to interact on a much higher and sophisticated level.[20] Therefore, architecture can no longer turn its back on digital networks and technology. "The role of computing has changed. Information technology has become ambient social infrastructure. This allies it with architecture. No longer just made of objects, computing now consists of situations."[21]



Intersecting domains of experience, ©*Digital Ground.*

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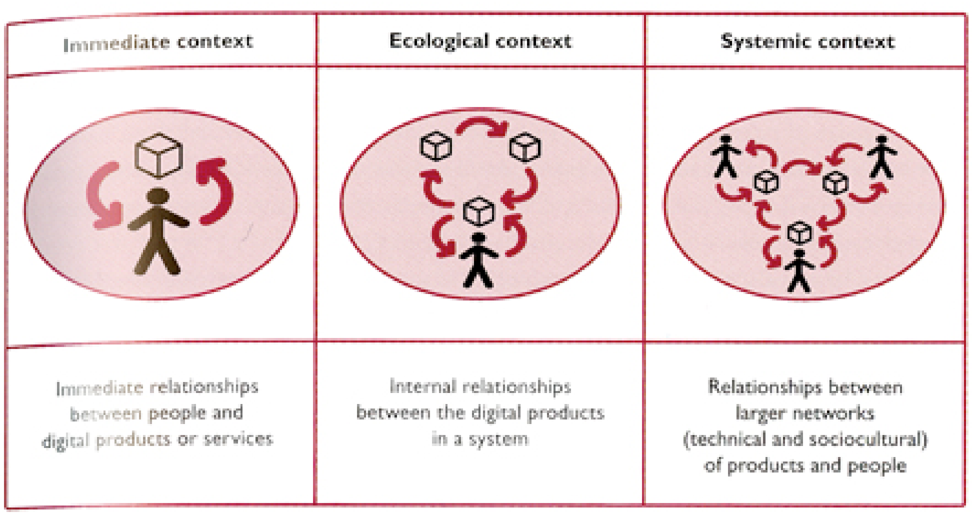
4.1 interface design

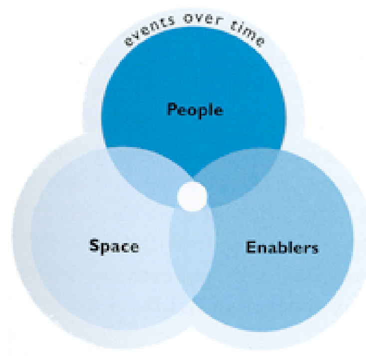
Interaction design is a field of design that deals with objects that think and spaces that sense how we communicate with other people and interact with information. Just as electric technology disappears into everyday life, so will interactive technology as it embeds itself into the everyday experience and our lives--becoming an even stronger subject matter for design and design related professionals. The difference between interaction design and more traditional design fields like architecture is that interaction design requires an understanding and consideration from a broad range of disciplines, especially functional, social, aesthetic, psychological and to some extent philosophical. However, interaction design and architecture are beginning to merge as both are concerned with use, space and function, one learning from the other and vice versa. Even product design now plays an increasingly important role in architecture. Henry Dreyfuss, chief designer of Futurama and a proponent of this new field of interaction, observed: "If the point of contact between the product and the people becomes a point of friction, then



Three types of personal contexts, ©*The New Everyday*.

the industrial designer has failed. If, on the other hand, the people are made safer, more comfortable, more eager to purchase, more efficient, or just plain happier, then the design has succeeded."[22] Therefore, interaction design and architecture must approach this new field of design carefully due to the many questions that have to be asked when designing for the user and a positive user experience.

Just as architects focus directly on how user see and interact with buildings and our built environment, interaction designers focus on how users see and interact with software-based products. To interaction designers, "the word *architecture* describes technological arrangements that, like buildings, are costly to build, are at least metaphorically scaled to be inhabited, are infrastructural in use, and are irreversible as results. Like buildings, computer networks in particular have been recognized as representations of their owners, major fixed assets, and agents of organizational change... When operations are collected in locally distinct, relatively persistent, and bodily memorable ways, the activity takes on aspects of architecture."[23] At some level it can be argued that interaction design, and even architecture, can be more appropriately be called "experience design" as it tends to focus more on the spatial consequences of the design, where the user is ultimately forgotten. With experience design, satisfaction is the key goal through the persistent alteration of perception. The problem with experience design and the manipulation of perception to change experiences is that it is a highly controlled environment that is not as predictable as one may think. Upon further observation, users actually prefer quite the opposite so that their experiences are not predigested as John Thackara further explains:



Elements of experience, ©*The New Everyday*.

> "I tend not to like or trust any all-encompassing experience that has been designed for me, and not with me: theme parks, shopping malls, air travel, most websites, 98 percent of e-learning products. The majority of architects and designers still think it is their job to design the world from the outside, top-down. Designing in the world--real-time, real-world collaborative design--strikes many designers as being less cool, less fun, than the development of blue-sky concepts. To be fair, many younger designers feel free to set the stage for what is experienced. But the big money still goes to the control freaks. People do like to be stimulated, to

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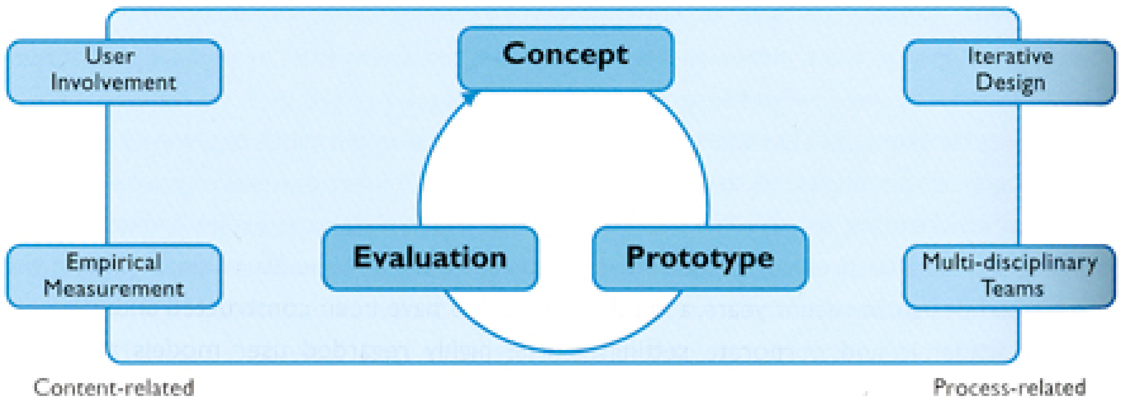
have things proposed to them. Designers are great at this. But the line between propose and impose is a think one. We need a balance."[24]

Spaces and products nowadays are manipulative and culturally sterilizing as they forcefully impose their exact experiences onto its users. However, we need to move more towards allowing cultural freedom of expression by defining certain parameters of



User-centered design process, ©*The New Everyday*.

To better resolve the problem with pervasive computing and the rise of digital technology, architecture and our buildings will need to become user-friendly and user-driven interfaces to this technology and to the widespread distribution of information. Additionally, spaces should empower the user with options so that spaces are not highly controlled nor are predigested, which ultimately limits the amount of cultural and social freedom of expression. These problems will continue to be a primary concern to both architects and interaction designers as new digital technology ultimately leads to pervasive and ubiquitous computing.

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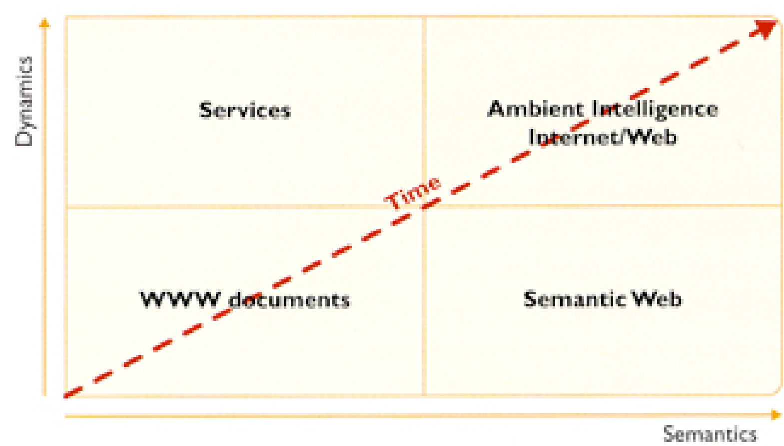
Activity	Design activities, not objects
Cognitive ergonomics	Minimize astonishment; maximize intuitive accessibility
Collective memory	Provide affordances for history; use enduringly legible elements; commemorate events; leave traces
Context	Expect physical location to provide protocols and constraints
Coordination	Versatility and satisfaction increase when actions involve tightly synchronized acts and multimodal reinforcement
Errors	Prevent errors; don't scold the people who make them
Flow	Satisfaction emerges when abilities are fully engaged toward objectives that are just about manageable
Latency	More satisfying designs tap latent ability
Scale	Images, objects, and actions have different meanings at different scales, especially relative to the body
Suspension of disbelief	Help people take part in representing shared objects and activities, but don't expect them to take that for reality
Tuning	Don't predict the state of complex systems; do let people customize demonstrate,and accumulate the states of their technologies
Unintended consequences	Expect resources to be borrowed by insiders for unforeseen uses with discovered benefits, but also with revenge effects
Work practices	Tasks occur with a larger stream of conventions, the representation of which is essential to design

Common wisdom, axioms of interactive design, ©*Digital Ground*.

4.2 responsive systems

In order to allow the user more control over their built environment, the environment must be responsive and intelligent--saturated with sensors and microprocessors that measure all aspects of that environment. Such an environment will not only allow for user manipulation but also increase environmental efficiency as buildings observe changes in the surrounding climate and respond accordingly. The specialization of the fourth dimension, time, is transforming the previously understood notion of space through the application of promising technologies like Wi-Fi, Bluetooth, Radio Frequency Identification (RFID) tags and GPS tracking. An RFID tag is a small object, such as an adhesive sticker, that can be attached to or incorporated into a product. This tag contains antennas to enable them to receive and respond to radio-frequency



Ambient web intelligence, ©*The New Everyday*.

queries from an RFID transceiver. Imagine that every object in your home has its own RFID tag, whose transceiver is networked with a GPS unit. Tracking everything will be remarkably simply and fast. If you lose anything, you can just do a search for it and the transceiver works with the GPS system to track its precise location in your home through a series of map specific to your floor plan. This technology is not far away and has been implemented in several experimental cases. Physical objects can be treated and searched for ("Googled") in the same way that we search for information on the Internet.

The responsive systems go beyond searching capabilities. The technology is also readily available for your building systems and spatial definitions to adjust according to

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the user. The architectural firm dECOI, who was mentioned previously regarding their dependence on digital fabrication techniques in their works, have also performed investigations into how space can be variable and dynamic. The group recently developed the Aegis Hyposurface, an art and architecture device that effectively links information systems with physical form to product dynamically variable, tactile informatic surfaces. Digital information translates into physical form. This device is constructed using standard materials--a facetted metallic surface driven by a bed of 896 pneumatic pistons. The innovative response system arises from its ability to deform physically in response to electronic stimuli from the surrounding environment in real-time calculations, including movement, sound and light. The dynamic manipulation of actual surfaces in three-dimensional space in response to sensor feedback greatly increases the potential for user-defined and user-customized space. Space will no longer be static nor will it only be characterized by specific programmatic definitions. Instead, space will evolve into one of programmatic indeterminacy as it can accommodate multiple users and functions at any given time.

Environmental solutions also arise from intelligent systems and pervasive computing. Solar technology has progressed extensively, but until recently the solutions for dealing with solar heat gain and ultraviolet infiltration have dealt with applying one system, sun shading and filtration, over another system, the window glazing itself. Modern technology has allowed both of these systems to co-exist into a single surface--a performative surface. Electro-chromic glazing is a system that incorporates an electrically responsive film that adjusts its opacity according to the level of electric current passing through it. It remains in a transparent state until an electric current, automated by a computer or user-controlled, is sent through the film, and the film's opacity increases to a level of translucency or completely opaque. With this technology, the sun shading and radiation reflectance occurs within the system by the film. One can combine this with thermo-chromatic film that responds to either heat or light and the environmental efficiency of the space increases dramatically, reducing interior cooling costs by thirty to forty percent annually.

The technologies previously discussed already exist in premature stages but are maturing just as technology becomes more intelligent. As more architects and designers

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experiment with such responsive technologies, we will find that pushing architecture to become more user-oriented by allowing for user-defined space through pervasive computing will become easier with time.

4.3 spatial customization

Relative to the notion of responsive technologies and systems in our built environments is the idea of spatial customization, empowering the user to control and manipulate their surroundings. Working with responsive systems, especially smart architectural surfaces, will allow space to be highly dynamic and respond to user's preferences. These preferences will be saved by sensors embedded either in devices the user carries or within the actual garments worn by the user. Some experiments with this technology in physical space have been successful, primarily through responsive indoor climate systems (HVAC) and other electrical systems. The technology has not quite reached the level of sophistication in order to accommodate true spatial deformation through pervasive computing and digital technology. The demand, nonetheless, is there as "socio-cultural developments indicate a need for solutions that provide simplicity, flexibility and sustainability, and a technology for people should allow people to choose and shape those features of products and services which they themselves perceive as desirable, meaningful and appropriate."[25]

4.4 ubiquitous computing

Computing and digital technology is taking on a form in which processing power will be so widely distributed into our physical world that is essentially disappears into everyday objects and surfaces. Ubiquitous, or pervasive, computing is this new interactive paradigm. Information that we currently rely on phones and web browsers to provide will be accessibly anywhere and provided to us appropriately based on our location and time. This new paradigm, again merging both architecture and interaction design, places the user needs first in order to allow a comfortable experience and simplicity in workflow. The complex algorithms and processes that operate on the

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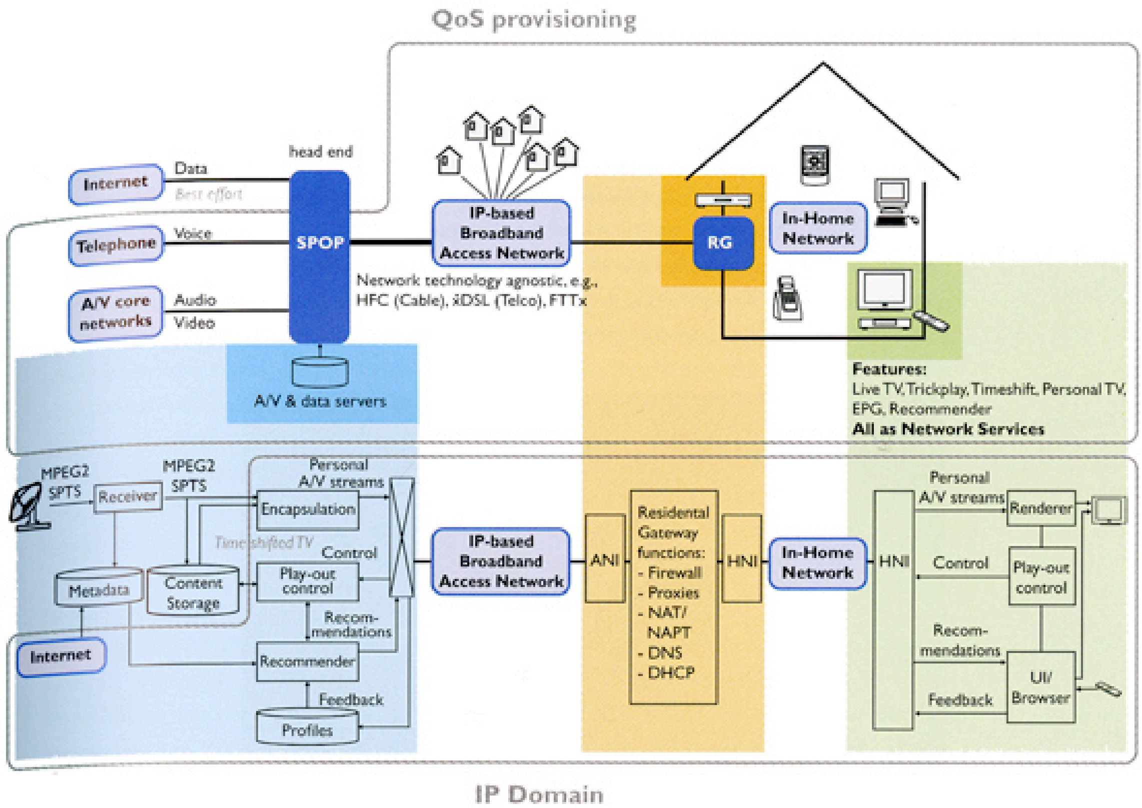
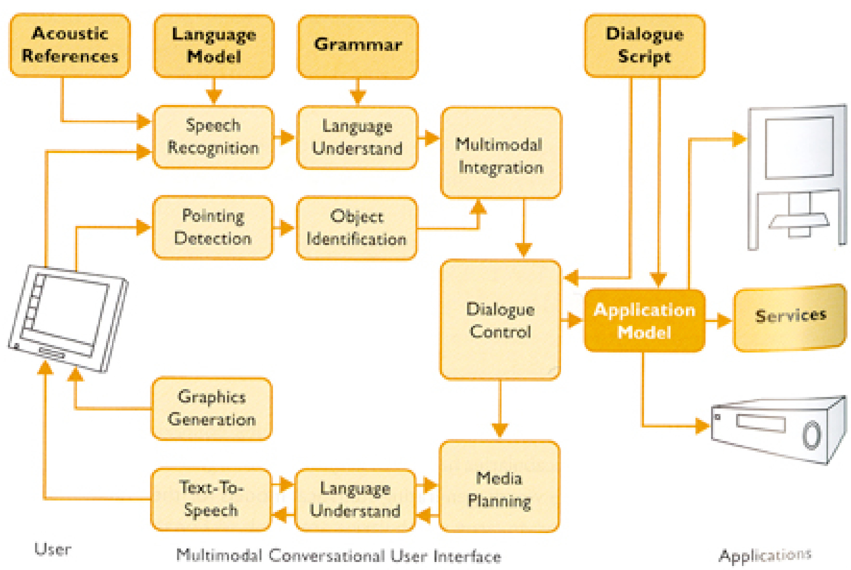


Service delivery model to the ambient intelligent home, ©*The New Everyday*.



Architecture of a spoken dialogue system, ©*The New Everyday*.

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backend, behind the scenes, never surfaces nor is it apparent to the user. With ubiquitous computing, computation is embedded into the environment rather than having computers as distinct and separate objects in order to allow users to interact with the technology and information more naturally than the current model of input/output devices. A ubiquitous system also relies on ubiquitous communication, continuous communication among devices and sensors through an embedded secure network infrastructure with a wired core and wireless components that communicate with the core.

The most appealing aspect of ubiquitous computing is the way in which it offers a natural method for input and output in the system, primarily through sensors, physical gestures and spoken language. Successfully building applications and software that constantly adapt to highly dynamic computing environments is the most complex challenge of implementing such a system. These "smart spaces" bring together two worlds that have until recently existed separately--digital (computing) and physical (building) infrastructure. For example, a room can automatically adjust the heating, cooling and lighting requirements based on the current user's electronic profile, and it can then behave differently depending on where in that space the user is located. Pervasive computing must also disappear from the user's consciousness in order to impose the least user distraction. "If a pervasive computing environment continuously meets user expectations and rarely presents him with surprises, it allows him to interact almost at a subconscious level. At the same time, a modicum of anticipation may be essential to avoiding a large unpleasant surprise later--much as pain alerts a person to a potentially serious future problem."[26] A balance is necessary between invisibility and anticipation within the environment to promote natural and comfortable use. A third concern for

Embedded	Many networked devices are integrated into the environment
Context-aware	These devices can recognize you and your situational context
Personalized	They can be tailored towards your needs
Adaptive	They can change in response to you
Anticipatory	They can anticipate your desires without conscious mediation

Elements of ambient intelligence and pervasive computing, ©*The New Everyday*.

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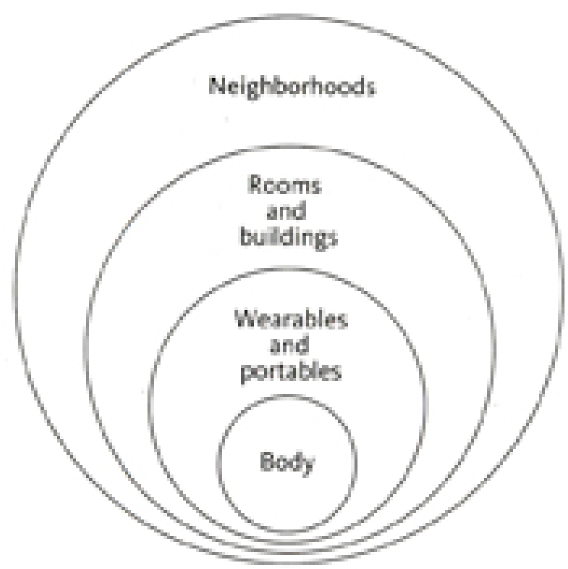
pervasive computing is localized scalability such that interactions are local to the system to avoid being overwhelmed by the density of interactions within a single space that may be of little relevance to all responsive systems. "As smart spaces grow in sophistication, the intensity of interactions between a user's personal computing space and his surroundings increases. This has severe bandwidth, energy and distraction implications for a wireless mobile user. The presence of multiple users will further complicate this problem."[27] A final area of development deals with masking uneven conditioning of environments to handle the huge differences in "smartness" of different environments, which will most likely be problematic and distracting to the user. This problem responds to the rate of penetration of the technology into the physical infrastructure, which "will vary considerably depending on many non-technical factors such as organizational structure, economics and business models."[28] A pervasive computing environment must be proactive (yet still remain transparent) and must be intelligent enough to understand a user's intent in order to assist rather than hinder the user. Furthermore, the environment and its embedded systems must consist of context- or location-aware services in order to provide only the appropriate content to the user for the area in a space or city in which they find themselves.

Pervasive computing offers promise primarily due to the inherent problems and constraints that exist by the current usage of PCs. Those computational boxes that we use on our desks or on our laps are so unfriendly and complex that they tend to turn their backs on the user and user-friendliness. Most software engineers develop applications and software in a way that promotes efficient code, and not until later is the user introduced into the process with the actual design of the



Scales of place, ©*Digital Ground.*

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interface. Developers do not understand the deep social and psychological needs or desires of the users of their applications. Rather than being a particular kind of hardware or software, pervasive computing, or as Adam Greenfield refers to it, "Everyware", is more of a situation and set of circumstances or interactions. Mobile computing based on smartphones and wireless technology has begun to open this idea further to society both technically and interpersonally. "But extending this consideration to include ubiquitous systems is almost like dividing by zero. How do you begin to discuss the "place" of computing that subsumes all of the [pre-existing conditions], but also invests processing power in refrigerators, elevators, closets, toilets, pens, tollbooths, eyeglasses, utility conduits, architectural surfaces, pets, sneakers, subway turnstiles, handbags, HVAC equipment, coffee mugs, credit cards, and many other things?" Greenfield explains that Everyware, or pervasive computing, acts at all scales: the scale of the body, the room, the building, the street and of public space in general.[29]

Architecture and designers have the advantage of incorporating this technological potential, especially when it comes to the user and what the user needs. In fact, it can be argued that architects will no longer be able to ignore pervasive computing environments and must respond by participating in the ongoing research of user's interaction with information technology. Smart materials and responsive systems should be understood better and implemented more efficiently in order to offer a customizable user experience that performs more than only spatially.

5 POTENTIAL PROBLEMS

There are several concerns that arise with the idea of interactive digital space and architecture, however. The interaction between a machine and its user has been an ongoing area of research and observation due to the inherently complex and unfriendly nature of technology. These issues are well-understood and must be resolved in order for ubiquitous computing to be welcomed and accepted into our everyday lives.

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5.1 human-computer interaction

Human-computer interaction is "a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them." Human-computer interaction has aspects in science, engineering and design. More specifically it is "concerned with the joint performance of tasks by humans and machines; the structure of communication between human and machine; human capabilities to use machines (including the learnability of interfaces); algorithms and programming of the interface itself; engineering concerns that arise in designing and building interfaces; the process of specification, design, and implementation of interfaces; and design trade-offs." Since communication between a human and a machine occupies most of the research within this field, "it draws from supporting knowledge on both the machine and the human side. On the machine side, techniques in computer graphics, operating systems, programming languages, and development environments are relevant. On the human side, communication theory, graphic and industrial design disciplines, linguistics, social sciences, cognitive psychology, and human performance are relevant. And, of course, engineering and design methods are relevant."[30] This detailed definition of human-computer interaction is necessary to fully understand how to best implement pervasive computing environments in order to achieve the most efficient, most natural and least distracting user experience.

The interface becomes the most technically sensitive part of these systems since humans are sensitive to response times and ease of usability. The future of human-computer interaction must concentrate on several key components in order to create viable human interfaces: ubiquitous communication in which data and services are portably accessible from many or all locations; high functionality systems that have multiple functions associated with; mixed media in systems that handle image, voice, sounds, video, text, and formatted data that is exchangeable across communication networks (separate consumer electronics will merge with computers); group interfaces to allow groups of people to coordinate; and user tailorability that allows users to customize applications to their own use.[31] The primary problem with computers and technology nowadays is the time spent having to learn a system or application before fully taking

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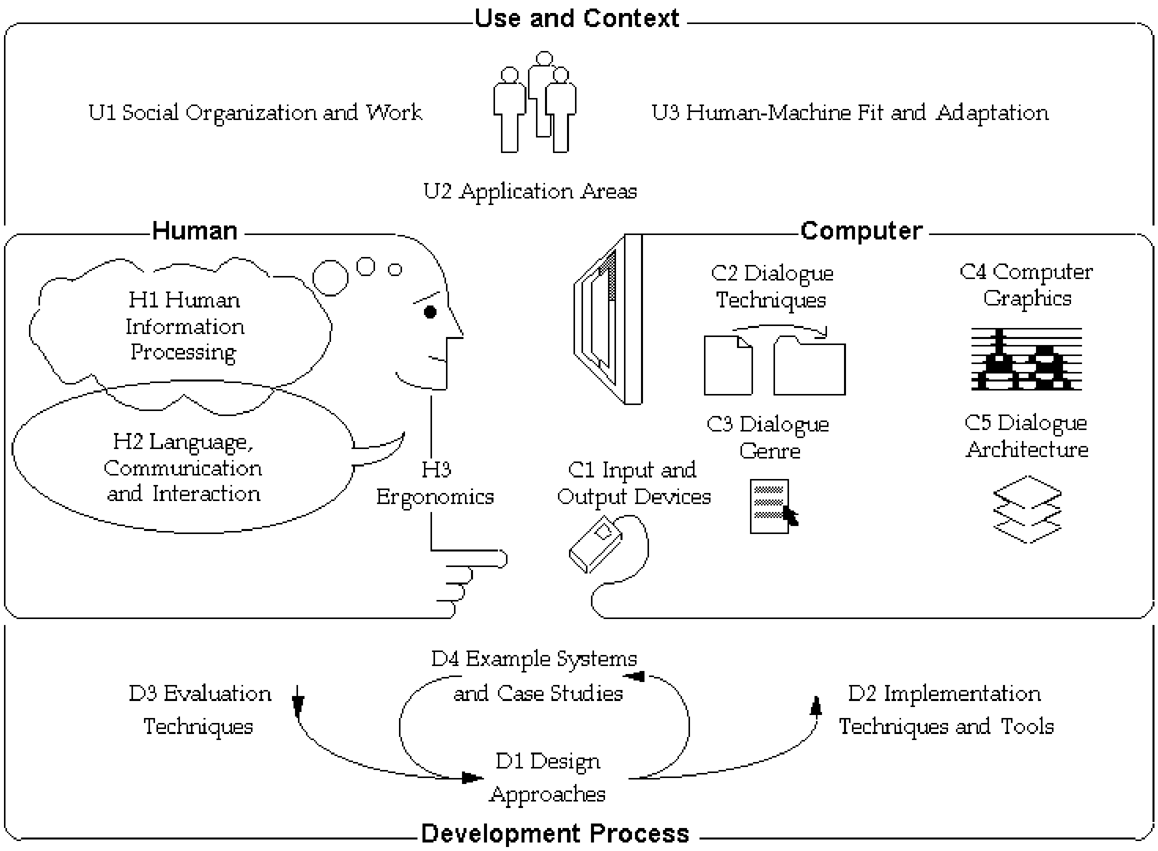

Human-computer interaction model, ©*xxxx*.

advantage of it. As more systems appear independent of each other, this time increases exponentially due to differences in performance and user interfaces. As a result, there is still a certain level of fear, known as cyberphobia, in society when it comes to the use of computers and technology, which ultimately eliminates the democratic access to information and data offered by the Internet.

Most of this fear arises from the early days of the Internet in the 1990s in which operating systems and the Internet were primarily information-based, especially before the introduction of the graphical user interface (GUI) and the mouse as a user-friendly input device. Those who have not grown up with computers, unlike the current younger generation who see computers as another everyday part of life, tend to have a greater

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frustration with computers and see them as being overly complex and difficult to use--afraid that computers are easy to break or harm if used incorrectly. A lack of knowledge and understanding of computers generates such fear in which people are afraid of things they do not know or understand.

Beyond the difficulty of using a computer, fear also arises from security concerns particularly over the Internet. Before online shopping became as widespread as it currently is, some of the first security issues people had with the Internet were the use of cookies on websites, that saves and stores information about user preferences and site usage in small text files on the users local computer. Even though cookies do not store personal information or a user's identity, people feared the fact that web sites "remembered" things about them and eventually led to people disabling cookies within their browsers. Again, this fear arose out of a lack of understanding and knowledge about cookies and how personal information is not stored. Instead, one's preferences are saved in order to create a user-friendly experience by displaying only the content relative to the user's preferences. As online shopping progressed further and began to define the online commerce industry, security was a major factor in determining who participated in online purchases and who refused for fear of releasing their personally sensitive information over the Internet, such as name, address, social security number and financial account information. The media continuously reported cases of identity theft over the Internet, which in fact were quite rare. Internet users felt that security and identity theft were major threats to online activity since that is all they heard about from the media in regards to Internet use. Security was an issue in the early days of e-commerce, but since the mid-1990s it has improved considerably and now security is less of an issue due to improved data encryption methods. Virus and worms also scared many people away from using the Internet for fear of damaging their computers or losing valuable data. Once again, the lack of knowledge about issues of security and how to effectively protect oneself from such vulnerabilities results in such fear.

If pervasive computing and interactive architecture are to be successful in society then we must address these areas of concern when dealing with human-computer interaction. The users must feel secure about intelligent environments in which computers are aware of their presence and know information about them. They must

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realize that these systems are secure and are primarily scaled to local networks. Furthermore, the interactive experiences that users participate in must feel natural through new input methods like voice recognition and gesturing. Finally, architects and designers of these systems must persuade users that the systems exist to help rather than hinder them, yet offer an opportunity for the user to opt out of participating with responsive systems if they continue to have concerns about personal security.

5.2 the digital divide

The digital divide, which looks at those who have Internet access and those who do not, has been steadily narrowing as computers are now at some of their lowest costs they have ever been. However, the gap is not closed as new divides emerge with the influx of newer technologies and more widespread use of that technology. According to *The Digital Future Report* in 2004, "75 percent of Americans can access the Internet from some location--home, work, school, libraries, and other locations. The fastest-growing Internet user populations are groups that were once considered the primary victims of the digital divide: Latinos, African Americas, and older Americans."[32] However, a divide still exists among the population who has Internet access at home and those who have broadband access versus telephone modem access. As pervasive computing relies heavily on faster connections and higher bandwidth as well as the expectation that most users have some previous experience or knowledge about computing and the Internet, the problem arises with those who only have access to older technologies and unfamiliarity with current trends in computing and the Internet.

According to the same *Digital Future Report*, there are three primary reasons why one-quarter of Americans are not online, some of which have already been discussed in this paper. "First, many non-users fear technology in general, and the Internet in particular--fear caused by lack of knowledge, or lingering concerns about privacy, security, or other issues. Second, many non-users simple see no need to use the Internet; sixty percent of "electronic dropouts" (former Internet users who are now non-users) miss nothing because they don't go online. The third reason...is cost. Many non-users don't go online at home because they don't have a computer, or can't afford one, or they believe their current computer is not capable of linking to the Internet."[33] Although cost was

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reported as being one of the three primary issues preventing users from going online, that factor has reduced considerably in the last five years as the cost of computers have dropped fifty to seventy-five percent of what they were a decade ago. However, all of these issues are important as they lead to differences in behavior between users and non-users that will become more evident with an economy that increasingly functions online for many of its activities. What will happen to those non-users as pervasive computing and interactive architecture finds itself more widespread within our built environment? How will such a system be implemented throughout society, gradual or immediate and what dictates who benefits first?

5.3 placelessness

Place, the "sense of place", and placelessness are some of the more important philosophical issues currently facing us. Placelessness and loss of place is becoming an even larger concern due to the increase in "global economics, industrial ecology, digital divides and the disappearing boundary between nature and technology...The contextual design of information technologies must now reach beyond the scale of individual tasks in order to embrace architecture, urbanism, and cultural geography."[34] If we are not careful about how we embed technology and layer digital systems into our physical environments, we run the risk of eliminating a sense of place as we saturate places with the same systems and information. Therefore, places must be location-aware in which systems respond appropriately to the geographic location in which it and the users exist in order to uphold and reflect differences between physical communities.

According to the urban historian M. Christine Boyer, "disembodiment accelerates as electronic representation of the city engenders a receptivity to the virtual" in several ways. "First, people retreat into private gated zones with their media, where the 'clean' computer contrasts with public squalor, and so they spend less time in the physical places of the city. Second, the imaging of the city resorts to increasingly commercial and privatizing strategies to lure people back outside from their screens. As predictable trademarked formulas are applied, brands become places and places become brands. Third, the spread of those nonpublic urban spaces subverts any preexisting legibility--or mental mappability of the city."[35] Boyer further explains that "We have seen how

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throughout history the body has been projected onto the image of the city, and how the city has been described as a simulacrum of the body. As body awareness withers, space becomes immaterial; as we retreat into the privacy of our media-altered realms, the direct experience of the city disappears. We no longer read the city as a totality."[36] Such an event can be detrimental to society as it is our cities that remain the memory of culture that reflects its "inhabitants' history and aspirations."[37] In a world saturated with digital

Service ecologies within a neighborhood, ©*Digital Ground.*

systems, distance and differences across physical geography and social hierarchy are eliminated and in time virtual passes for reality. Furthermore, place and time are the primary constructors of experiences rather than place and sense of place, which architecture currently concerns itself with. Therefore, it will be necessary to architects and designers, especially at the urban scale, to explore potential solutions from the loss of place and identity in our social constructs like cities and communities.

Although the definition of place typically refers to a sense of uniqueness, Edward Relph argues that "Places are defined less by unique locations, landscape, and communities than by the focusing of experiences and intention onto particular settings."[38] Identification of a place must also deal with identification with a place since there are not

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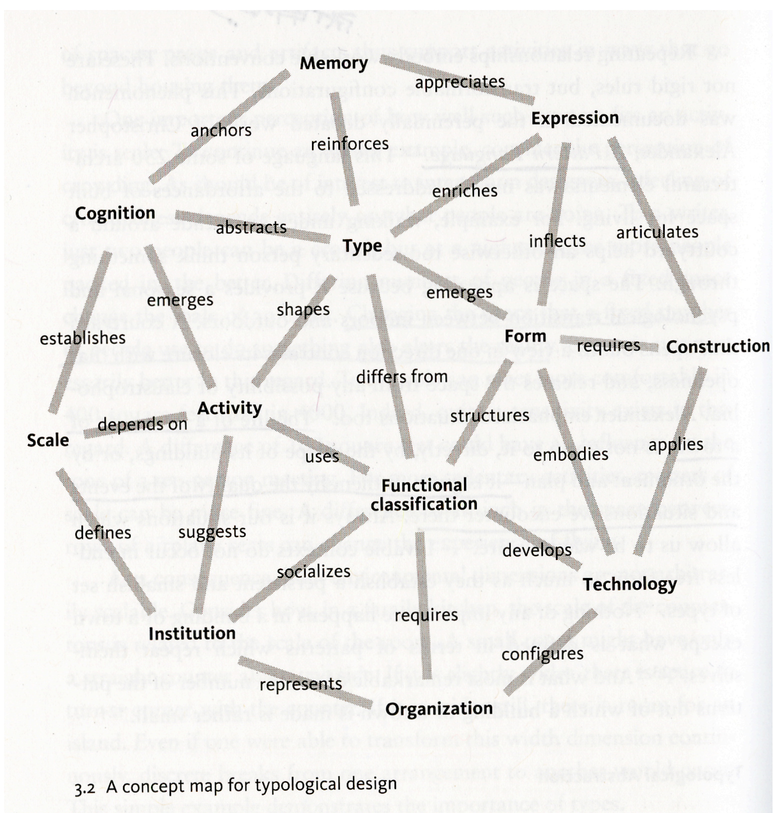
Cognitive map of embodied activty, ©*Digital Ground.*



Cognitive map of typological design, ©*Digital Ground.*

definite boundaries to a place. When we exist within a place, we are able to take advantage of the many services available from which we can select from in order to shape our daily routines and lives. The combination of services within a place is known as a service ecology, which can be further understood as clusters of activity. These clusters are dynamic entities that also become increasingly subject to mediation by digital technology and digital networking. Again, we are confronted with another problem of interaction design in which "the notion of ecologies translates from service ecologies into design problems at four fundamental levels:

> "To begin, *device* ecologies emerge within the ad hoc encounters of mobile and portable technologies in contexts. Here the principle applies that optimizing the parts may disoptimize the whole...Next, designers increasingly recognize *information* ecologies...[which] manage knowledge by a combination of software models, contextual configurations, and human reflection in action...Third, such situational types increasingly become subject to the design of *interaction* ecologies. Diversification in interfaces makes as much sense as diversification in the urban form...Ultimately, these agendas become those of *architecture*. In setting the stage for habitual activity, in representing organizations to the constituents, in creating enduring structures that reflect and perpetuate particular attitudes about interaction, designed service ecologies are architecture."[39]

Architecture is the ultimate end in finding appropriate solutions to the many problems of pervasive computing as the profession is more aware of place-making and spatial experiences. However, architects will no longer be able to find resolutions on their own but rather must work with other industries, especially computer scientists and interaction designers, in order to fully understand the consequences of digital networking and ubiquitous computing in our built world. In the end, "flow is of course an essential goal of interaction design, and fixity is an essential goal of architecture. Now the two join. To compliment the spaces of information with the contexts for getting into place, it helps to think in terms of ground."[40]

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CONCLUSION

What if we would rather lead a simpler life and do not want to live in a world saturated with digital technology? One may argue that technology can never be natural no matter how embedded or invisible it becomes. To some extent that is true, if obeying the strict definition that natural is not artificial. However, natural is also related to adaptation and although our information systems, highways, cars and other everyday machines are artificial, they still feel natural. They are "forms of adaptations within a living ecosystem" and "in our age of technological saturation, response to place becomes the most practical adaptation strategy of all."[41] No matter how much we disagree with its role in society, we cannot reject technology. Architects, urban planners and designers definitely cannot reject technology but should learn from it. They are the ones who must understand it and its role in our lives. They must ensure that technology in our physical environments is natural and well adapted. Finally, they must define what it means for architecture to be interactive and what that means for the future of place.

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[37] McCullough, p180.
[38] Relph, Edward. *Place and Placelessness*. Pion, London, 1976. p141.
[39] McCullough, p188-89.
[40] McCullough, p191.
[41] McCullough, p213.

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