GROUND

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Architecture, Pervasive Computing, and Environmental Knowing

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3 Habitual Contexts

Not all is flux. Much as a river needs banks unless it is to spread aimlessly like a swamp, the flow of information needs meaningful contexts. Even in an age in which distance has been annihilated, location still matters.

The built environment organizes flows of people, resources, and ideas. Social infrastructure has long involved architecture, but has also more recently included network computing. The latter tends to augment rather than replace the former; architecture has acquired a digital layer. As with past layers of technology, such as electrification, mechanical equipment, and transportation, so now digital technologies extend architecture's reach. In doing so they take advantage of architecture's duration. The older and more persistent the grounding structure, the more likely that it has shaped environmental predispositions. In contrast to more ephemeral electronic works that compete for the momentary attention of casual viewers, built environments act as enduring background, and their design is directed inward toward their regular inhabitants.[1]

There, in our most habitual contexts, embodiment provides a continuing basis for human-centered design. For much as the body imposes a schema on space, architecture imposes a schema on the body.[2] The proportions, image, and embellishments of the body are reflected in the proportions, image, and embellishments of buildings. Similarly, cities reflect the form of their buildings, cultural landscapes reflect the structure of their cities and towns, and mythologies orient all of these in the world. Although the sciences have extended this scale of artifice farther into the immense and the microscopic, the orders of magnitude nearest to human dimensions still affect everyday experience most directly.

The disciplines of architecture and interaction design both address how contexts shape actions. Architecture frames intentions. Interactivity, at its very roots, connects those mental states to available opportunities for participation. These processes are ambient. Their benefits are to be found in the quiet periphery, and not in the seductive objects of attention. Why this is so was put well by one of architects' favorite thinkers, Walter Benjamin, who reminded us that "architecture is experienced habitually, in a state of distraction."[3]

In turning from embodiment in person to embodiment in the built world, it will help to define some terms. To begin, let "setting" describe objective, a priori, space. "Context" is not the setting itself, but the *engagement* with it, as well as the bias that setting gives to the interactions that occur within it. "Environment" is the sum of all present contexts. According to the cognitive principles laid out thus far, environment is not an other, or an empty container, but a perception of persistent possibilities for action.

"Space," like embodiment, has occupied philosophers from the ancients to the latest wave of cyberpunks.[4] Because it allows motion, space has been intrinsic to modernity. Space is a means, and not a mere setting, at least according to the philosophical traditions charted by Kant. It is the form of external experience as distinguished from the things encountered within that experience.

"To speak of 'producing space' sounds bizarre," wrote the critical theorist Henri Lefebvre in 1974, "so great is the sway still held by the idea that empty space is prior to whatever ends up filling it."[5] Notions of preexisting space now give way to emergent phenomena. Wherever goods, people, or electronic communications flow, spaces form around them. This emergence has been particularly evident in the case of disembodied electronic channels. In what the sociologist Manuel Castells named the "space of flows," global capital has apparently invented a new kind of space for itself—one whose spatiality emerges from, rather than preceding or containing temporal activities. But as Castells explained, this net changes relations between physical places more than it does away with them. "The space of organizations in the informational economy is increasingly a space of flows.... However, this does not imply that organizations are placeless. On the contrary, we have seen that decision-making continues to be dependent upon the milieu on which metropolitan dominance is based; that service delivery must follow dispersed, segmented, segregated markets.... Thus each component of the information-processing structure is place-oriented."[6]

Places emerge at crossovers between infrastructures. Where one flow prompts, regulates, or feeds another, development occurs. Where the boats met the trains, great cities grew. Increasingly, such connections occur between digital and physical infrastructures. Electronic communication has intensified, not undermined, the hubs of activity in the world's entrepots. This intensification is reflected in the current practices of urban design. As cities everywhere move to correct the separation of use wrought by the industrial age, we have rediscovered how the flows of people, goods, and information are most valuable wherever they are most closely intermingled.

In movements we have seen described as "after cyberspace," information technology contexts are no longer valued for immersiveness so much as for "periphery." Information technology design has occupied itself with tools for deliberative reasoning—a process that occurs in the foreground of human attention. In a recent standard text on interface design, Apple Macintosh project creator Jef Raskin emphasized the term *locus* of attention. "We cannot completely control what our locus of attention will be.... For our purposes, the essential fact about your locus of attention is that there is but one of them. This underlies the solution of numerous interface problems."[7] Unfortunately this attention remains finite while the number and complexity of tools continues to increase. In what has become a problem for almost all design disciplines, the foreground is full.[8]

In response, most agendas of physical computing share a belief in "periphery." As defined by John Seeley Brown, the former director of the open research center Xerox PARC, "periphery is background that is outside focal attention but which can quickly be given that attention when necessary."[9] This is one way to deal with information overload. "Periphery is informing without overburdening."[10] Trying to keep too much in the locus of attention tends to be stressful. We find it more natural to use our considerable powers of sensing the surroundings, and then to experience more capacity and resolution where our attention is focused. Thus, as Brown observed, bringing something back from the periphery to the center of attention is a fundamentally engaging and calming process.

Pervasive computing takes this approach beyond the information context to include physical architecture. Graphical user interfaces have long been built on principles of shifting focus—picking up a tool,

opening and closing a window, etc.—but they still leave us staring at a cluttered screen. Portable and embedded systems take the information processing out into the physical realm, where the capacity for periphery is deeper and the act of bringing things to the center is more intuitive. For example, tagging systems can mark parts inventories for direct use by hand-held devices without recourse to a desktop database. Principles of periphery can help reduce contention on a screen, of course, but they also suggest a larger shift in our goals for natural interactions.

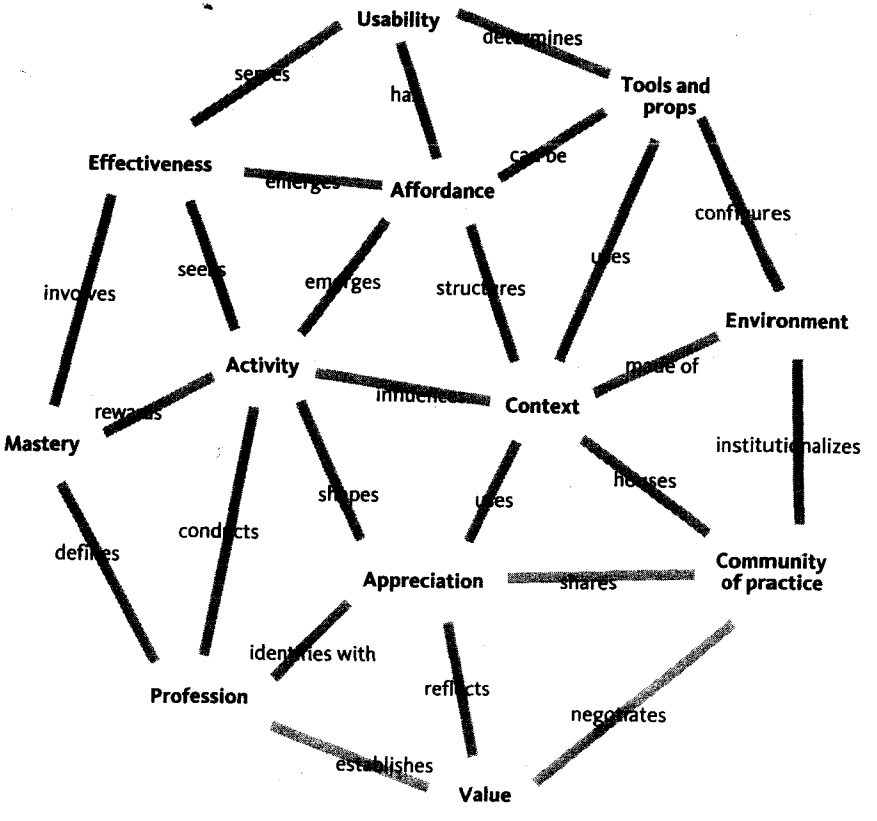
This is mainly a matter of embodiment in context. Our embodied predispositions have been underfed while our foreground deliberative attention has been oversaturated. To change that balance, we need to change what we expect of interactive technology, and where we expect to find it.

Context and the Roots of Interactivity

As reflected by so much recent emphasis on embodiment, contextual factors matter more than early researchers in interactivity anticipated. If more recent study finds the phenomenology of engagement at the roots of interactivity, it is because these designers build technologies around everyday life. This shifts design values from objects to experiences, from performance to appropriateness, from procedure to situation, and from behavior to intent.

With its new emphasis on intentions in activity, contextual design departs from an earlier generation of inquiry into environment and behavior. Whereas that work aimed to reduce design to a linear, predictable process, based on measurable models of conditioned response, the current work recognizes the importance of expectations.

"When we speak of 'direct manipulation,' 'intelligent agents,' 'expert behavior,' and 'novice behavior,' we are really positing concepts in which consciousness is central," the anthropologist Bonnie Nardi has explained.[11] Intent makes people different from machines in any flow, and it gives an asymmetrical cast to the relation between people and things (figure 3.1). Cognitive science has emphasized mental representations at the expense of context. "Thus we have produced reams of studies on mentalistic phenomena such as 'plans' and 'mental models' and 'cognitive maps,' with insufficient attention to the world of physical artifacts."[12] Designers more interested in rich description than in predictive models tend to welcome such emphasis on artifacts. As a way of describing the intrinsic unity of context, activity, and intentionality, "activity theory" has become a useful expression.



3.1 A concept map for embodied activity in context

The word *situation* keeps us mindful of the ethnographic perspective. Ethnographers remind us that actors play their settings. An improvisatory action grows out of the immediacy of a context. Situated action theory explains how experts engage contexts. As voiced by the work practices ethnographer Lucy Suchman, who introduced the theory into a still very mechanistic field in the late 1980s, "The organization of the situated action is an emergent property of moment-by-moment interactions between actors, and between actors and the environments of their action."[13] Within the situated action model of work, actors operate within a stable institutional framework, or "arena," to create personally ordered versions of the environment matched to their respective habits and goals.[14] Habitual contexts support courses of action in which effectiveness has been internalized enough that it need not rise to the level of a conscious mental model. For example, a competent intern makes hospital rounds according to well-established procedures, but an expert doctor makes his or her rounds according to more tacit and personalized criteria.

Many processes of everyday life involve such sensibilities. For example, a resident who walks through his or her neighborhood on the way home from work casually notices incidental changes to objects and surroundings, and these may prompt improvisatory shifts of intent about what to do that evening.

Persistent Structures

The more enduring the environment, the more it shapes our expectations without saturating our attention. The phenomenology we have examined suggests the need for more design emphasis on lasting backgrounds.

Designers do seem to understand the importance of contextual perceptions. This has been demonstrated by the overexposure of Gibson's word *affordance.* A coupling of perceived resources to active intent creates a context for that action.[15] The sum of all such contexts present is the environment. One's active state heightens this impression. Thus affordances are inherent properties of environments. When affordances are perceived similarly by different people, the identity of the environment is reinforced. Sensibilities shared longer or more frequently become the basis of place identity.

As people learn from their settings, they come to associate them with particular states of intent. Intent is important because it causes engagement of context to be, as Nardi put it, "about" something.[16] This is why meditation teachers insist that a particular spot in the house be set aside for no other purpose.

Habits matter. Accumulated experience of intent and action allows more abstract mental models to develop. It is especially in habitual context that perceptions of affordances, persistence, and situation emerge.

These ideas about activity in context have become fundamental to the field of interaction design (figure 3.1). Although they are vexing to some researchers because they are difficult to measure, they are encouraging to architects, or to those who understand the design technology as architecture, because they make it easier to raise questions of cultural identity.

Developments in pervasive computing amplify the importance of these arguments. "At the heart of tangible computing is the relationship between activities and the space in which they are carried out," interactivity scholar Paul Dourish has observed. "Tangible computing expands this in three ways: through the configuration of space, through the relationship of body to task, and through physical constraints."[17] Embodiment is not just a state of physicality, but a situation in real time and place.[18]

Henceforth the design of information technology expands its subject from artifacts to their contexts. Through context, designed objects become expressions of identity, signs of differentiation, tokens of communication, and a natural support for relationships.[19] The production of environments, organizations, services, and communication among all these becomes the domain of design.

Scale and Pattern

The habitual experience of an activity employs an ever-increasing flow of symbols and inevitably occurs in some setting. Fixed configurations

of spaces, props and artifacts thus support activities in ways that go beyond housing them.

One important perception of how well such support fits an activity is scale. To continue an earlier example, consider the perception of crowding. As should be of interest to interaction designers, a feeling of crowdedness depends entirely on what people are doing. To a writer, just two people can be a crowd, but at a nightclub, the more people packed in, the better. Differing numbers of people in a fixed space change the scale of an event. Changing the space that a fixed number of people use to do something also alters the reality. Bigger is not necessarily better in this regard. Ten people can meet more comfortably in 400 square feet than in 4000. Indeed, quite a sensitivity exists in this regard. A difference of 100 square feet could have an influence on the tone of a ten-person meeting. For more sedentary activities, matters of scale can be more fine. A difference of an inch in the space between rows of airplane seats can change the experience of flying.

As a consequence, built environmental dimensions are not arbitrarily scalable. Consider how, in a family kitchen, the scale of the countertops is related to the scale of the room. A small room might have only a straight counter along one side. If it is slightly wider, there is space to turn a corner with the counter. If it is wider still, there is room for an island. Even if one were able to transform this width dimension continuously, discrete breaks from one arrangement to another would occur. This simple example demonstrates the importance of types.

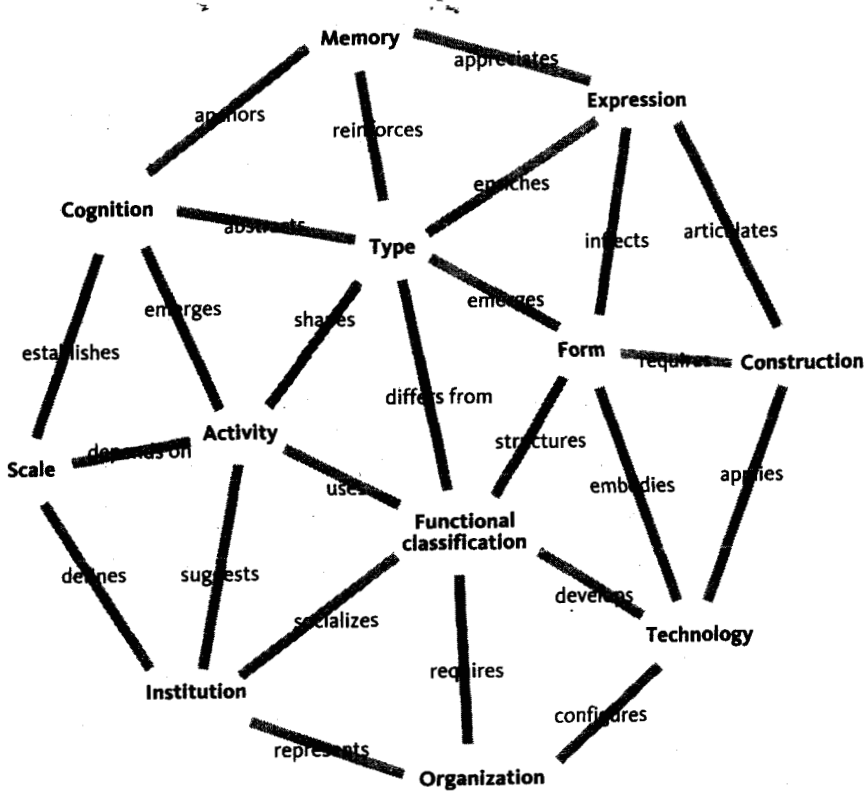
Living systems tend to maintain rich interrelationships of scale. Popular notions of ecological design emphasize this. Similarly, the appeal that draws tourists to traditional landscapes and towns has much of its basis in a complex interweaving of scales. In contrast to the monoculture of suburbs designed for the automobile, the center of a European city offers narrow streets and lofty monuments, grand boulevards and intimate courtyards. Traditional areas of the island of Java, one of the most densely populated places in the world, retain more appeal than much less densely settled places in the automobile-centered world, simply because the settlement patterns are intensive rather than extensive. That is, they make much more sensible use of intimate scale.[20]

Repeating relationships embody workable conventions. These are not rigid rules, but transformable configurations. This phenomenon was documented in the perennially debated work of Christopher Alexander, *A Pattern Language*.[21] This language of some 250 architectural elements was mainly addressed to the affordances of built space for living. For example, walking under an arcade around a courtyard helps an otherwise too-sedentary person think something through. The space is appealing because it provides a seasonal and psychological transition between indoors and outdoors. A courtyard that opens out to a view in one direction contrasts its closure with that openness, and releases the space from any possibility of claustrophobia. Alexander emphasized situations too. "The life of a house, or of a town, is not given to it, directly, by the shape of its buildings, or by the ornament and plan—it is given to them by the quality of the events and situations we encounter there. Always it is our situations which allow us to be what we are."[22] Livable contexts do not occur in endless free form so much as they establish a persistent and smallish set of types. "Nothing of any importance happens in a building or a town except what is defined in terms of patterns which repeat themselves."[23] "And what is most remarkable of all, the number of the patterns out of which a building or a town is made is rather small."[24]

Typological Abstraction

A theory of place for interaction design incorporates embodied cognition into a workable design philosophy through types (figure 3.2). In a single design notion, type unites periphery, passivity, phenomenology, adaptability, affordance, facility, appropriateness, and scale. Thus it is a difficult term, which means different things to different disciplines. For present purposes, consider type not as a mere functional classification, but as a generative design abstraction. This is a central idea for more context-based pervasive computing, and it should help bring interaction design into closer relationship with architecture.

A type may be as much about form as function. For example, the town square is a distinct urban type more on the basis of its intrinsic



3.2 A concept map for typological design

form than on its uses, which may vary from week to week, and century to century. Indeed the square is memorable for how its configuration affords so many uses, the accumulation of which increase its resonance as a type.

The psychological importance of type is not only a consequence of activity in context, but also of cultural identification. This is a foundational notion because enduring structures become repositories of human, cultural, and organizational capital. The patterns of activities

first become means toward those activities, then come to suggest and represent them. Stability, duration, fixity, and repetition are all qualities of experience by which human contexts acquire value. Arrangements for the fixity of cultural proceedings are generally known as institutions.[25]

As the anthropologist Mary Douglas succinctly put it, "institutions confer identities." Physical sites embody expectations. "The whole approach to individual cognition can only benefit from recognizing the individual person's involvement with institution-building from the very start of the cognitive enterprise."[26]

The casting of daily life into particular scales of form reflects lasting social agreements about categories and values. Here is the inevitable "social construction." This is how an institution can be said to have scale. Through not only its endurance, but also the way it manifests convention, built form provides identity for both an association and its constituents.[27]

Such value is especially evident in cities. A livable city is made up of types. Some of these, such as the sidewalk café, become valued for all the experiences that have accumulated there. Any institutionalization is purely unofficial. Other sites declare values and expectations more deliberately; a public library does this well, for example. Cultural distinctions in handling these typological elements become sources of exchange and identity in themselves. Particular places are known for their types. New Orleans has its patios, and Brooklyn has its brownstones.

If types are a way of representing livable arrangements, it is because they help make the link from body to building to city to landscape to universe. From this basis, Douglas was able to argue that types are "foundational analogues," and moreover that these correspond to archetypes of living systems. "There needs to be an analogy by which the formal structure of a crucial set of social relations is found in the physical world, or in eternity, or anywhere, so long as it is not seen as a socially contrived arrangement. When the analogy is applied back and forth from one set of social relations to another, and from these back to nature, its recurring formal structure becomes easily recognized and endowed with self-validating truth."[28]

Architecture demonstrates these principles particularly well. As an enduring framework that is used habitually, architecture provides an obvious basis for a more context-based approach to interaction design. Architecture surpasses most other technological productions at institutionalizing spatial arrangements to the extent that they shape cognition. A culture's perennial spatial forms perpetuate a particular cognitive background. This is why one of the best criteria for appreciating architecture is whether it is memorable.

Architecture serves the body and not just the gaze. It is not just perceived, but inhabited. At a mundane level this means that architecture includes such things as stairs, toilets, and heating systems; but at a more imaginative level, this embodiment gives architecture the power to order the external world according to our inner topographies.[29] When this anthropomorphizing function is working, architecture helps us move from personal to societal scale.

Like the human body itself, an architectural type supports endless variations whose appeal is in their subtlety, not their shock value. As in people's faces, we appreciate variations on architectural themes mainly in terms of the relationships of familiar details.[30] These details remain in memory better than radical aberrations. The brownstones of Brooklyn are distinct from the marble-stooped row houses of Baltimore, for example, and they are also subtly varied among themselves.

As a generative abstraction, architectural type is essentially morphological. In the case of dwelling, for example, important types range from palazzo to terrace to tent.[31] Particular forms and their variations become distinct to particular cultures and locales. The pleasure of these arrangements is built in part on the richness of their architectural components. Elements such as portals, pathways, canopies, and courtyards represent archetypes too fundamental to be exhausted or ignored.[32] Especially when aggregated into neighborhoods, design that inflects these achieves more humane detail than design that invents alternatives.

Typological design seeks a balance of convention and invention. Too much convention becomes stultifying; too much invention becomes inane. In the review of embodiment and context, we have seen how skills and knowledge build from accumulated knowledge of persistent structures. From this it follows that in the language of design, types enable at least as much as they restrict. Typological design is not a rigid set of rules, but instead a body of phenomenal essences which play themselves out differently in each instance. This inflection provides a richer basis for building workable arrangements than does radical atypological invention.

More so than the purveyors of pervasive computing, architects have learned the costs of world making. Alas, too much of today's built world is the environmental crisis that we can touch. To many of us this crisis has largely been a lapse of typology. Picture a split-level four-plex apartment building squeezed onto one narrow lot on a street full of Victorian workers' cottages. Whether or not the newer building performs better (mechanically, electrically, thermally, etc.) it just isn't appropriate, and so it has a negative impact on the street.

According to many of recent architecture's critics, the most insightful of whom has perhaps been Stewart Brand, the quest for invention everywhere has undermined the value of the built environment. To Brand, "Aspiring to art means aspiring to a building that almost certainly cannot work, because the good old solutions are thrown away."[33] Part of the problem is that architects are taught to seek the anti-typological. Emblematically, "The roof has a dramatic new look, and it leaks dramatically."[34]

Wealthy patrons of signature architects can pay to make new forms work; everyday design failures occur mostly in everyday building. This is especially true at the scale of the neighborhoods. As critics of sprawl and advocates of sustainability explain, monocultural neighborhoods built from single-function building types do not function especially well as larger systems. The relevance of this critique to the relationship between architecture and interaction design is basically a matter of cognitive background.

As noted in our review of embodiment, some fundamental skills and orientations are being lost. Here with respect to habitual contexts, consider one such orientation: cultural memory. The city is a repository; its landmarks, types, and forms are the access structure. Its civic

space—so dear to architects—is a design for interaction. That aspect makes it worth recalling Aristotle's assertion that man is an inherently political being, and the city is the best arrangement for realizing that aspect of human nature.

In addition to questioning the advantages of anytime-anyplace technological freedom, interaction designers should question pure functionalism. As architects know, places aren't just locations with assigned uses or trademark formulas. Cities have histories, in which they have been appropriated for this and that. Accumulated experience of appropriations makes people come to identify with places. Built contexts are collective memory devices, and manifestations of collective cognitive background. As long ago as the 1960s, urbanist dissidents such as Jane Jacobs and Aldo Rossi anticipated today's shift toward these ideas. Rossi's book *The Architecture of the City* remains the seminal declaration of typology. It is of interest to the question of interaction design for its critique of what Rossi called "naive functionalism." To begin this argument he drew particular attention to the monumental nature of urbanistic chunks. "In almost all European cities there are large palaces, building complexes, or agglomerations that constitute whole pieces of the city and whose function now is no longer the original one. When one visits a monument of this type, for example the Palazzo della Ragione in Padua, ...one is struck by the multiplicity of functions that a building of this type can contain over time and how these functions are entirely independent of the form."[35]

"Ultimately we can say that type is the very idea of architecture, that which is closest to its essence," Rossi declared. "Naive functionalism ends up contradicting its own initial hypothesis. If urban artifacts were constantly able to reform and renew themselves simply by establishing new functions, the values of the urban structure, as revealed through its architecture, would be continuous and easily available. The permanence of buildings and forms would have no significance, and the very idea of the transmission of a culture, of which the city is an element, would be questionable."[36]

Technological Change

Technological change has reconfigured buildings and cities in the past, but it has seldom done away with them. Because types adapt in response to conditions and needs, technology can contribute to the resiliency of types.

This is familiar enough in architecture. For example, the high-rise office building was made possible by elevators, and less obviously, the telephone. (The latter allowed offices to be separated from factories and docks, and it allowed a large organization to occupy several smaller floors more conveniently.) The elevator transformed the apartment block, as well, both by allowing it to be built higher and by taking over the space traditionally left for a central courtyard, thereby turning the plan form inside-out, from an O to an X. Plumbing also transformed the apartment block. In the ancient Roman form of the type, the *insula*, only the ground floor had running water, and so this is where the wealthy owner lived.

Electrification, in particular, reshaped domestic life, health care, manufacturing, and transportation.[37] The proponents of pervasive computing often draw analogies with this phase of technological history. The usual explanation holds that embedding sensors and microchips in appliances has similarities to embedding electric motors in appliances. Embedded systems let work be carried out where it is most convenient, and not necessarily at some centralized site. In the factory, portable electric motors transformed manufacturing, and made the assembly line possible, which opened up mass production, which created standard building components—and of course automobiles, air conditioners, and so on. Soon embedded systems were taken for granted.

Two aspects of this explanation are mentioned less often. First, electrification produced uncanny effects. Lighting, for instance, reverses the privacy relation between indoors and outdoors at night by making the former visible to the latter. It also reverses the architectural modulation of classical facades by lighting them from below, rather than from above like the sunlight for which they were designed. These are examples of ways in which new technology makes the familiar seem strange.

Second, new technology produces design opportunities mainly in relation to existing technologies. For example, electrification transformed passenger rail traffic by making it possible to light (and thus build) subways and subterranean train stations. Grand Central Station as we know it was a consequence of smoke-free locomotives and electrical lighting.[38] It also changed timekeeping. Daily lives became arranged around train schedules. Tightly timed commutes were intrinsic to the machine age. They were not just a product of train timetables but also a reflection of a will toward synchronization and metering so powerful that Lewis Mumford declared that the most essential machine of industrialism was the clock.[39] Railroads created a remarkable interplay of space with time. In what has become a favorite story among network technologists today, trains with long enough range and high enough speed eventually forced a remake of timekeeping itself, that is, time zones. We now take those for granted, too, but at the moment of their adoption in 1884 the newspapers lamented how "God's time" had been abandoned for (New York Central owner) "Vanderbilt's time."

Schools, stores, libraries, theaters, banks, trading floors, workplaces, and homes endure, but in often radical new combinations, as a result of technological change. "Recombinant architecture," as William Mitchell called the impact of software on building typology, takes apart many of the spatial linkages we have come to expect, and reassembles them into new forms.[40] This is not the first such period of change: industrialism, electrification, and modernity remade classical types according to radical new programs of functionality and resource use. In the classical city, form announced civic aspirations; in the modern city, form followed mechanized function. In the digital city, form must provide the periphery and the ground for our swapping of bits, our multiplexing of activities, and our continued need for an enduring environment.

Building Backgrounds

By acknowledging its foundations in embodied activity in habitual contexts, interaction design becomes a defense of architecture. In contrast to earlier stages of interface design aimed at building attention-saturating virtual worlds, this new paradigm in information technology turns to building physical backgrounds. The more that principles of locality, embodiment, and environmental perception underlie pervasive computing, the more it all seems like architecture.

The way in which a built environment shapes an organization's activity and represents its aspirations now interests information technologists. This is because information technology, like architecture before it, has become social infrastructure. The word *architecture*, which more literally means "master builder," has been appropriated to describe all manner of technological designs that are infrastructural and irreversible, and that cast everyday activity in a particular way. When the configuration of action is not conveniently alterable, where it has arisen from some particular intent, and where it embodies some clear model of understanding, operating, or cultural aspiration, then it is fairly called architecture.

This has already been beneficial to architecture. Interactivity becomes a remedy for architecture, which as a discipline has ignored usability, performance, and inhabitation in its quest for attention-seeking novelties in form. Architecture needs to rejuvenate itself with interaction design.

The newer field of interaction design benefits as well, for example by becoming more sophisticated about environmental perception. It extends, and does not abandon, previous works of place making. It takes advantage of physical contexts as frames and cues for its social functions. It begins to reflect scale and type in its pursuit of site-specific technology, context-aware systems, and location-based services. It shifts focus from technological novelty to more enduring cultural frameworks.

Together, these shifts suggest more emphasis on quiet architecture. As digital technologies surpass their predecessors at expressing the culture of the moment, particularly in its visual aspects, physical architecture is relieved from its struggle to be at the fashionable center of attention, and returns to what it does better in any case, namely the enduring formation of periphery. Would-be designers of pervasive computing environments should consider an architecture of

periphery. Architects of built periphery should emphasize the affordances of everyday life rather than fashionable statements in form. Buildings should be valued for their duration. In contrast to information technology's rapid churn of data, devices, and techniques, quiet material permanence seems like a welcome source of calm. Digital systems are then applied to buildings to give them adaptability, and hence more duration.

In this respect, physical building absorbs pervasive computing, like so many other technological layers before it. Since it is transformed by successive layers of technological development, the fixity of the built environment is not absolute. Since it accumulates, it does have fixity relative to any potentially new layer of systems. Some of that fixity is obsolete legacy, and some is useful armature for extensibility. The endurance of these layers of infrastructure sustains cultural capital of a sort. Identifying, valuing, and contributing to the appreciation of the cultural capital that is the built environment should be an important role for pervasive computing, the latest layer of spatial adaptation. Successful applications toward that goal will become regarded as natural, or at least appropriate technology. Others will just get in the way.

Architecture provides a fixed form for the flows engineered by pervasive computing. As a much older form of technology it has shaped expectations more fundamentally. It remains an important part of our cognitive background. In the relation of environment and technology, buildings are among the oldest, best understood, and least obtrusive of artifices. Quiet architecture may be our most natural technology.

II Technologies

4 Embedded Gear

Universal	Situated
Anytime-anyplace	Responsive place
Mostly portable	Mostly embedded
Ad hoc aggregation	Accumulated aggregation
Context is location	Context is activity
Instead of architecture	Inside of architecture
Fast and far	Slow and closer
Uniform	Adapted

4.1 Universal versus situated computing

When everyday objects boot up and link, more of us need to understand technology well enough to take positions about its design. What are the essential components, and what are the contextual design implications of the components? How do the expectations we have examined influence the design practices we want to adapt? As a point of departure, and with due restraint on the future tense, it is worth looking at technology in itself.

To begin, consider how not all ubiquitous computing is portable computing. As a contrast to the universal mobility that has been the focus of so much attention, note the components of digital systems that are embedded in physical sites (figure 4.1). "Embedded" means enclosed; these chips and software are not considered computers. They are unseen parts of everyday things. "The most profound technologies are those that disappear," was Mark Weiser's often-repeated dictum. "They weave themselves into the fabric of everyday life until they are indistinguishable from it."[1]

Bashing the Desktop

Some general background on the state of the computer industry is necessary first, particularly regarding the all-too-familiar desktop computer. By the beginning of the new century, technologists commonly asserted that a computer interface need not involve a keyboard, mouse, and screen.[2] Ambient, haptic, and environmentally embedded interface elements have become viable, and these require more concern

If the tuning of smart environments were to rely exclusively on ad hoc inventiveness, work would proceed slowly. If it were to reduce its considerations to functions that could be modeled more predictably, this effort would produce sterile results. In between these approaches, something is needed in the way of continuous, if not fully formalized knowledge. Invention needs to play off convention. Unless engineers are to face a debilitating agglomeration of gear, some aspect of context has to help with tuning and protocols.

That aspect is type. Persistent structures of form and environment should be able to accomplish half the work of tuning aggregations of portable and embedded technology. If, for example, one is tuning smart gear for a café, a lot of the work should be accomplished by the fact that this is a café. Location and type have to matter. Otherwise, with everything possible all the time, mostly chaos will result.

sion sequences. To a software engineer faced with ad hoc networking, several of these approaches appear pertinent. Nevertheless contextual computing begins from the physical geometry. We have seen how this is a question of scale. Without some sort of local model, and without some sort of physical scope for local connectivity, pervasive interactivity quickly becomes too complex. Location models must tame this complexity with representations of presence, protocols, and better-presented possibilities for action.

Geometry Still Matters

By now it is common knowledge that at some level the net "negates geometry."[2] It is all about being able to obtain information without having to know where it is stored. If location matters, it is more likely logical than physical. Factors of access, bandwidth, addressing, and security affect who and where you are on the Internet. Position does not.

But even if "you are your address," as is commonly said, that address tends to be somewhere physical. Internet Protocol (IP) addresses are often bound to the hardware addresses of connection devices, which in turn are managed by physical location. For example, dynamically served addresses are only valid within particular security boundaries, and most of those are limited by physical connections and service areas as well. Server farms are big, power-hungry physical sites in locations convenient to the companies that use them. Fixed infrastructures support most mobile systems. Some of these, such as the global positioning system, track position continuously. Others can infer the position of mobile devices at short range as those communicate with fixed network nodes. Others add their own position to information taken from active transactions. When you swipe a magnetic card to enter a building, you are declaring your location.

All this affects us. How many mobile phone conversations casually begin with a declaration of location? How many monitored physical perimeters does each of us cross in a day? Recent obsessions with security make us think about that. Still more than any government, and a huge economic power by any measure, it is the target marketing industry that wants to know where you are.

Geolocation services on the web can trace the country and most often the city of origin of connections to clients' sites. This is useful for setting language, observing music broadcast rights, restricting sales of banned goods, and of course defining saleable market segments. Whether laws belonging to physical jurisdictions should apply to the Internet remains one of that medium's most significant questions, for if every state could insist on web publishers modifying content to fit local regulations, the net would grind to a halt. On the other hand, publishers often voluntarily modify content on the basis of user research that employs geographic tracing. As companies such as Akamai and Quova took geocoded market research online, the business press declared that while distance no longer matters, location most certainly does.[3]

Meanwhile, according to many early developers of intelligent environments, the existing representations of physical space are not enough. The act of bringing a mobile device into contact with a site-embedded system dictates a need for location models, and for several reasons (figure 5.1).[4]

First, there is no guarantee that casual ad hoc connections will make use of, or have their implicit locations inferred by, fixed infrastructures of the Internet. Much interoperability will be simpler, and at lower networking levels, than that.

Second, many situations involve physical relationships that occur at a finer resolution than can be recognized by a global positioning system, or that occur in urban indoor sites not necessarily in view of that system, or that involve spatial relationships more particular than simple co-location.

Third, specialized site-embedded systems cannot operate independently in large numbers. They need to corroborate their respective representations. Individual systems for sensing motion, establishing position, or controlling environmental elements may accomplish their work without the need for a location model, but the more such systems aggregate and accumulate, the more they need to share some representation of who else and what else is present. Otherwise they may produce contradictory results, as well as a great redundancy of hardware.

5. The geodata industries are exploding, and geocoded marketing remains the most powerful alternative to that ever-elusive goal of "marketing to one."

6. Architectural elements of physical space often frame and cue actions. Sites of interaction involve geometric relationships at fine resolution.

7. Accumulations of technology generally need to be housed, owned, maintained, and tuned. And those accumulations may still represent owners to their constituents.

5.1 Arguments against universal technology

key in passwords, and plug in cables to declare o
a dilemma in this. Which is preferable, being sub
having to take active part in identifying oneself? I
require carrying and using a device, such as a ca
assenting to the presence of a recognition systen
These are questions of how to present oneself
questions are answered by social customs.

The only alternative is architectural: as alwa
come with different protocols. Architecture in
intentions, etiquettes, and actions.

Each of these factors points to a general ne
ing of digitally mediated action. In contrast to th
about formless dematerialization, the rise of p
restores an emphasis on geometry. The hyperspa
ing aspects of electronic communication do not
ingly are complemented. In locally intensified isla
interactivity becomes a richer experience. Genera
recognition of relationships in scale. These may b
son, person to group, group to site, or from
Generally there is much to understand and build,
els present greater technical challenges than des
they also offer more kinds of realizable rewards.

In terms of practical implementation, Micros
Brumitt and Steve Shafer have presented the m

These settings accentuate the social aspects of information technology. Identification remains essential to place, to belonging, and to trust. This is highly subjective, of course. People tend to identify with settings they have casually appropriated, such as some corner of a park where they go to exercise—and not, by contrast, with settings that monitor, control, and foist a guaranteed experience on them. They are also more likely to identify with recurring experiences, especially those that result from social choices. Thus as technologies broaden choices in life, designers must address the source of the insiders' trust. Some scenarios of pervasive computing have fallen far short of this trust, as expressed in the common fear that devices are watching and talking to each other about us.

For these and any number of other reasons already explored, human interactions continue to exhibit categories, strata, and patterns. Such recurring configurations are natural; just about any species has them. Contexts remind people and their devices how to behave. That framing has often been done best and understood most easily as architecture. Something about the habitual nature of an environmental usage gives it life. Like device protocols and personal conduct, architecture has been a form of etiquette. Like most etiquette, architecture exists not out of pompousness, but because it lets life proceed more easily. Situated computing extends this age-old preference, whereas anytime-anyplace computing does not.

Typology

In short, we need a typology of situated interactions. By extending living patterns of inhabited space, we can strive to make technology simpler, more adaptive, and more social. The alternative is chaos. Much as free-form experimentation with unprecedented technologies in modern building often led to socially detrimental results, now pervasive computing creeps toward huge design failures.[2] Expect wrecks.

Recall that as a design philosophy, typology recognizes how creativity does better with themes and variations than with arbitrary innovation. It provides a framework for convention and invention to temper one another. Between conformity to a one-size-fits-all design and the chaos of infinite combinatorial possibility, there is a manageable range of recognizable situations. Design seldom benefits from infinite possibilities. It is more likely to be beneficial and appreciated when its variations occur on a few appropriate themes. Much as music finds richness in endless play within a relatively small number of specific genres, so now interaction design turns toward a less than infinite set of combinations. Much as architecture depends on habitual patterns for its livability, so the ad hoc local networks of devices must produce recurrent types. Whether those types reflect technological possibilities or human patterns becomes a matter of design.

As design participation broadens in digital technology, architects should awaken to these issues. As in architecture, where arbitrary freedoms often yielded dysfunctional spaces, type-defying free-form configurations will mostly not work in digital environmental technologies.

With the benefit of a longer historical perspective, architects understand how types are morphed, extended, and only occasionally made obsolete by new layers of technology. They have confronted dematerialization, and they know that all things digital will neither replace the built environment nor allow anything to happen anywhere in it. At a practical level, architects understand a component-based approach to designing macro-scale environments. As a scholarly discipline, architects have explored patterns of human activity independently not only of computers but also of buildings. The same cultural sensibility that finds substance in quiet architecture now turns its attention to situated gear.

Here follows a rudimentary typology of thirty situations (figure 6.2). These are by no means definitive and, as in most categorizations, could easily have been classified some other way. They could be organized by types of spaces, by types of technology used, by types of social conventions, or by types of activity.[3] All would interrelate. All would provide a reasonably short list. As it is, the groupings used reflect the usual categories of place: workplace, dwelling place, the oft-cited "third place" for conviviality, and an ever-increasing "fourth place," as it were, of commuting and travel. Given the emphasis on interaction in context, activity seems the right way to group these situations. A map of activities says the most about the usability of technology-modified places.

(at work...)

1. Deliberating (places for thinking)
2. Presenting (places for speaking to groups)
3. Collaborating (places for working within groups)
4. Dealing (places for negotiating)
5. Documenting (places for references resources)
6. Officiating (places for institutions to serve their constituencies)
7. Crafting (places for skilled practice)
8. Associating (places where businesses form ecologies)
9. Learning (places for experiments and explanations)
10. Cultivating (places for stewardship)
11. Watching (places for monitoring)

(at home...)

12. Sheltering (places with comfortable climate)
13. Recharging (places for maintaining the body)
14. Idling (restful places for watching the world go by)
15. Confining (places to be held in)
16. Servicing (places with local support networks)
17. Metering (places where services flow incrementally)

(on the to town...)

18. Eating, drinking, talking (places for socializing)
19. Gathering (places to meet)
20. Cruising (places for seeing and being seen)
21. Belonging (places for insiders)
22. Shopping (places for recreational retailing)
23. Sporting (places for embodied play)
24. Attending (places for cultural productions)
25. Commemorating (places for ritual)

(on the road...)

26. Gazing/touring (places to visit)
27. Hoteling (places to be at home away from home)
28. Adventuring (places for embodied challenge)
29. Driving (car as place)
30. Walking (places at human scale)

6.2 One set of situational types

At Work

Deliberating (places for thinking)

A thinker dislikes interruptions, and so knows when to close the door. Prior to the existence of electronic communications, this simple architectural tactic was sufficient. The door was necessary because this solitary space was preferably linked to a complementary, more public space for sharing results and deciding on courses of action. The classic metaphor is "caves and commons." Whether monastic cells and churches, or corporate cubicles and conference rooms, the relationship remains the same.

Communication technology obviously upsets this pattern. The telephone can ring behind the closed door. Receptionists become gatekeepers of incoming calls as well as the doorway. Outgoing calls can be useful to deliberation; one can acquire missing information without leaving one's desk. Larger volumes of calls can be pooled. Long before the use of cubicles, it became a standard image of early twentieth-century office work to see a group of workers sitting at a row of desks, making telephone calls all over the city. This was neither truly cave nor common, but an intermediate condition of cooperative work. (Meanwhile the solitude necessary for reflection could be linked to the commons remotely. If one had an idea while out walking around town, it was now possible to phone it right in.)

Today when different windows on one's screen constitute work and play, solos and collaborations, and privacy or its absence, the tactics of establishing solitary space have become much more complicated. Meanwhile the means of leaving the workplace to find that solitude have become much more practical. This is one reason why the "fourth place" of mobility has become more significant. To address the fixed workplace, where accumulations of technology are generally more sophisticated, "groupware" or collaborative systems have become a substantial domain of the software industry. Now pervasive computing adds a hardware and environmental component to those systems. With regard to address the basic need to close the door and think, Bill Buxton's simple "door mouse" was a significant early demonstration of situated computing. This real-space hack mediated

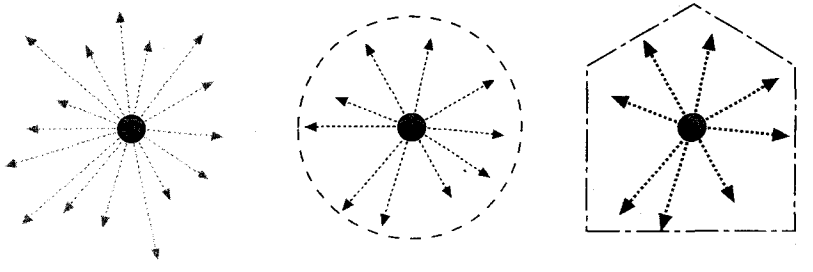
Activity recognition	Aware home	Georgia Tech
www.cc.gatech.edu/fce/ahri		
Building performance	Intelligent workplace	Carnegie Mellon
www.arc.cmu.edu/cbpd/html/iw/iw.html		
Linking from home	House_n	MIT
architecture.mit.edu/house_n/		
Meeting support	Kumo interactive	Fuji/Xerox
www.fxpal.com/smartspaces/		
Narrative playspace	Kids Room	MIT
vismod.www.media.mit.edu/vismod/demos/kidsroom/		
Office systems	BlueSpace	IBM/Steelcase
www.research.ibm.com/MobileComputing/BlueSpace.html		
Passive learning	Adaptive house	University of Colorado
www.cs.colorado.edu/~mozer/nnh/		
Person recognition	Easy living	Microsoft research
www.research.microsoft.com/easyliving/		
Trade magazine/convention/catalogue		Electronic house
www.electronichouse.com/		
Training toy	Lego dacta	Lego
www.lego.com/dacta/products/		

6.3 Ten projects of smart space

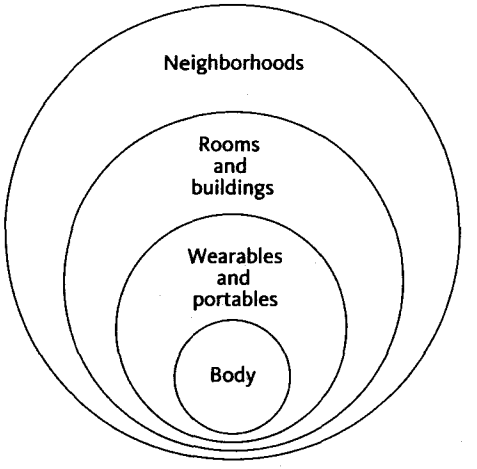
The difference between ubiquitous and situated computing appears vital. Ubiquitous computing as promoted by the information technology industries has mostly been a matter of pure mobility, with little regard for locally embedded systems. It has emphasized access to the same information everywhere. It has been geared toward connectivity 100 percent of the time for a few people, rather than providing information when useful for 100 percent of the people in a specific location. It has sought a one-size-fits-all solution for technological interoperability.

By contrast, situated computing is based on the belief that such universality is neither attainable nor desirable. This approach questions total mobility, advocates local protocols, recognizes forms of tacit knowledge, and taps into more kinds of embodied predispositions (figure 6.4).

At least as much as we need to connect to the same net everywhere, we need different places in our lives to help differentiate, structure, and facilitate our activities. How do connections between mobile and embedded technology adapt to our intuition of being in a place,



6.4 Toward niche protocols in communication



6.5 Scales of place

give us a sense of scale (figure 6.5), and how do they help us assimilate the conditions we find? To understand our places in an ever more mobile world, we must develop better patterns, protocols, ownerships, and trust in location-aware, situated gear.

Situational types suggest one provisional basis for designing this emerging digital layer of space. Since no universal standard can support local particulars of interactivity, differentiated categories of local technology must arise. Since not every situation can be subject to custom engineering and tuning, classes of adaptable technology must arise. Typological design should advance the appropriateness of location-aware technology more quickly than universal standards or one-time circumstantial configurations.

If the means are not yet clear, we may at least agree that the ends of design must include some approach to appropriateness other than solely technological features and their performance specifications. An open standard could establish practices for any particular type. This seems a matter of *protocols*.

Could there be a way to embed situational instructions into particular physical locations so that arriving mobile devices could properly configure their behavior while visiting? By crude analogy, physical