

Everyware

The dawning age of
ubiquitous computing

by Adam Greenfield

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Everyware: The dawning age of ubiquitous computing
Adam Greenfield

New Riders
1249 Eighth Street
Berkeley, CA 94710
510/524-2178
800/283-9444
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Contents

Introduction	1
Section 1: What is everyware?	9
Section 2: How is everyware different from what we're used to?	35
Section 3: What's driving the emergence of everyware?	89
Section 4: What are the issues we need to be aware of?	121
Section 5: Who gets to determine the shape of everyware?	159
Section 6: When do we need to begin preparing for everyware?	175
Section 7: How might we safeguard our prerogatives in an everyware world?	225
Conclusion	258
Index	262

New York Public Library, where most of *Everyware* was written, and the circa-1961 Swan chair I sat in while writing most of the rest.

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SECTION 1

What is everywhere?

Ever more pervasive, ever harder to perceive, computing has leapt off the desktop and insinuated itself into everyday life. Such ubiquitous information technology “everyware”—will appear in many different contexts and take a wide variety of forms, but it will affect almost every one of us, whether we’re aware of it or not.

What is everywhere? How can we recognize it when we encounter it? And how can we expect it to show up in our lives?



Thesis 01

There are many ubiquitous computings.

Almost twenty years ago, a researcher at the legendary Xerox Palo Alto Research Center wrote an article—a sketch, really—setting forth the outlines of what computing would look like in a post-PC world.

The researcher's name was Mark Weiser, and his thoughts were summarized in a brief burst simply entitled "Ubiquitous Computing #1." In it, as in the series of seminal papers and articles that followed, Weiser developed the idea of an "invisible" computing, a computing that "does not live on a personal device of any sort, but is in the woodwork everywhere."

What Weiser was describing would be nothing less than computing without computers. In his telling, desktop machines per se would largely disappear, as the tiny, cheap microprocessors that powered them faded into the built environment. But *computation* would flourish, becoming intimately intertwined with the stuff of everyday life.

In this context, "ubiquitous" meant not merely "in every place," but also "in every thing." Ordinary objects, from coffee cups to raincoats to the paint on the walls, would be reconsidered as sites for the sensing and processing of information, and would wind up endowed with surprising new properties. Best of all, people would interact with these systems fluently and naturally, barely noticing the powerful informatics they were engaging. The innumerable hassles presented by personal computing would fade into history.

Even for an institution already famed for paradigm-shattering innovations—the creation of the graphical user interface and the Ethernet networking protocol notable among them—Weiser's "ubicomp" stood out

as an unusually bold vision. But while the line of thought he developed at PARC may have offered the first explicit, technically articulated formulation of a ubiquitous computing in the post-PC regime, it wasn't the only one. The general idea of an invisible-but-everywhere computing was clearly loose in the world.

At the MIT Media Lab, Professor Hiroshi Ishii's "Things That Think" initiative developed interfaces bridging the realms of bits and atoms, a "tangible media" extending computation out into the walls and doorways of everyday experience. At IBM, a whole research group grew up around a "pervasive computing" of smart objects, embedded sensors, and the always-on networks that connected them.

And as mobile phones began to percolate into the world, each of them nothing but a connected computing device, it was inevitable that someone would think to use them as a platform for the delivery of services beyond conversation. Philips and Samsung, Nokia and NTT DoCoMo—all offered visions of a mobile, interconnected computing in which, naturally, their products took center stage.

By the first years of the twenty-first century, with daily reality sometimes threatening to leapfrog even the more imaginative theorists of ubicomp, it was clear that all of these endeavors were pointing at something becoming real in the world.

Intriguingly, though, and maybe a little infuriatingly, none of these institutions understood the problem domain in quite the same way. In their attempts to grapple with the implications of computing in the post-PC era, some concerned themselves with *ubiquitous networking*: the effort to extend network access to just about anyplace people could think of to go. With available Internet addresses dwindling by the day, this required the development of a new-generation Internet protocol; it also justified the efforts of companies ranging from Intel to GM to LG to imagine an array of "smart" consumer products designed with that network in mind.

Others concentrated on the engineering details of instrumenting physical space. In the late 1990s, researchers at UC Berkeley developed a range of wireless-enabled, embedded sensors and microcontrollers

known generically as *motes*, as well as an operating system for them to run on. All were specifically designed for use in ubicomp,

Thirty miles to the south, a team at Stanford addressed the absence in orthodox computer science of a infrastructural model appropriate for the ubiquitous case. In 2002, they published a paper describing the *event heap*, a way of allocating computational resources that better accounted for the arbitrary comings and goings of multiple simultaneous users than did the traditional "event queue."

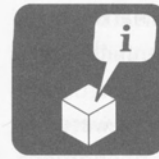
Developments elsewhere in the broader information technology field had clear implications for the ubiquitous model. *Radio-frequency identification (RFID) tags* and *two-dimensional barcodes* were just two of many technologies adapted from their original applications, pressed into service in ubicomp scenarios as bridges between the physical and virtual worlds. Meanwhile, at the human-machine interface, the plummeting cost of processing resources meant that long-dreamed-of but computationally-intensive ways of interaction, such as *gesture recognition* and *voice recognition*, were becoming practical; they would prove irresistible as elements of a technology that was, after all, supposed to be invisible-but-everywhere.

And beyond that, there was clearly a ferment at work in many of the fields touching on ubicomp, even through the downturn that followed the crash of the "new economy" in early 2001. It had reached something like a critical mass of thought and innovation by 2005: an upwelling of novelty both intellectual and material, accompanied by a persistent sense, in many quarters, that ubicomp's hour had come 'round at last. Pieces of the puzzle kept coming. By the time I began doing the research for this book, the literature on ubicomp was a daily tide of press releases and new papers that was difficult to stay on top of: papers on *wearable computing*, *augmented reality*, *locative media*, *near-field communication*, *body-area networking*. In many cases, the fields were so new that the jargon hadn't even solidified yet.

Would all of these threads converge on something comprehensible, useful, or usable? Would any of these ubiquitous computings fulfill PARC's promise of a "calm technology?" And if so, how?

Questions like these were taken up with varying degrees of enthusiasm, skepticism, and critical distance in the overlapping *human-computer interaction* (HCI) and *user experience* (UX) communities. The former, with an academic engineering pedigree, had evolved over some thirty years to consider the problems inherent in any encounter between complex technical systems and the people using them; the latter, a more or less ad hoc network of practitioners, addressed similar concerns in their daily work, as the Internet and the World Wide Web built on it became facts of life for millions of nonspecialist users. As the new millennium dawned, both communities found ubicomp on their agendas, in advance of any hard data gleaned from actual use.

With the exception of discussions going on in the HCI community, none of these groups were necessarily pursuing anything that Mark Weiser would have recognized as fully cognate with his ubiquitous computing. But they were all sensing the rapidly approaching obsolescence of the desktop model, the coming hegemony of networked devices, and the reconfiguration of everyday life around them. What they were all grasping after, each in their own way, was a language of interaction suited to a world where information processing would be everywhere in the human environment.



Thesis 02

The many forms of ubiquitous computing are indistinguishable from the user's perspective and will appear to a user as aspects of a single paradigm: everywhere.

In considering Mark Weiser's "ubiquitous" computing alongside all those efforts that define the next computing as one that is "mobile" or "wearable" or "connected" or "situated," one is reminded time and again of the parable of the six blind men describing an elephant.

We've all heard this one, haven't we? Six wise elders of the village were asked to describe the true nature of the animal that had been brought before them; sadly, age and infirmity had reduced them all to a reliance on the faculty of touch. One sage, trying and failing to wrap his arms around the wrinkled circumference of the beast's massive leg, replied that it must surely be among the mightiest of trees. Another discerned a great turtle in the curving smoothness of a tusk, while yet another, encountering the elephant's sinuous, muscular trunk, thought he could hardly have been handling anything other than the king of snakes. None of the six, in fact, could come anywhere close to agreement regarding what it was that they were experiencing, and their disagreement might have become quite acrimonious had the village idiot not stepped in to point out that they were all in the presence of the same creature.

And so it is with post-PC computing. Regardless of the valid distinctions between these modes, technologies, and strategies, I argue that such distinctions are close to meaningless from the perspective of people exposed to the computing these theories all seem to describe.

Historically, there have been some exceptions to the general narrowness of vision in the field. Hiroshi Ishii's Tangible Media Group at the MIT Media Lab saw their work as cleaving into three broad categories: "interactive surfaces," in which desks, walls, doors, and even ceilings were reimagined as input/output devices; "ambients," which used phenomena such as sound, light, and air currents as peripheral channels to the user; and "tangibles," which leveraged the "graspable and manipulable" qualities of physical objects as provisions of the human interface.

A separate MIT effort, Project Oxygen, proceeded under the assumption that a coherently pervasive presentation would require coordinated effort at all levels; they set out to design a coordinated suite of devices and user interfaces, sensor grids, software architecture, and ad hoc and mesh-network strategies. (Nobody could accuse them of lacking ambition.)

These inclusive visions aside, however, very few of the people working in ubicomp or its tributaries seem to have quite gotten how all these pieces would fit together. From the user's point of view, I'd argue, these are all facets of a single larger experience.

What is that experience? It involves a diverse ecology of devices and platforms, most of which have nothing to do with "computers" as we've understood them. It's a distributed phenomenon: The power and meaning we ascribe to it are more a property of the network than of any single node, and that network is effectively invisible. It permeates places and pursuits that we've never before thought of in technical terms. And it is something that happens out here in the world, amid the bustle, the traffic, the lattes, and gossip: a social activity shaped by, and in its turn shaping, our relationships with the people around us.

And although too many changes in the world get called "paradigm shifts"—the phrase has been much abused in our time—when we consider the difference between our experience of PCs and the thing that is coming, it is clear that in this case no other description will do. Its sense of a technological transition entraining a fundamental alteration in worldview, and maybe even a new state of being, is fully justified.

We need a new word to begin discussing the systems that make up this state of being—a word that is deliberately vague enough that it collapses all of the inessential distinctions in favor of capturing the qualities they all have in common.

What can we call this paradigm? I think of it as *everyware*.

probably the best-known effort to imagine a ubicomp that lets the elderly safely and comfortably “age in place.”

Ranjit Makkuni might argue that well-crafted tangible interfaces are not merely less intimidating to the non-technically inclined but are, in fact, essential if we want to provide for the needs of the world’s billion or more non-literate citizens.

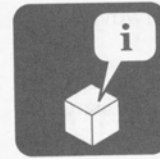
The prospect of so many new (and new kinds of) sensors cannot help but beguile those groups and individuals, ever with us, whose notions of safety—or business models—hinge on near-universal surveillance. Law-enforcement and public-safety organizations planetwide can be numbered among them, as well as the ecosystem of vendors, consultants, and other private concerns that depend on them for survival.

Beyond these, it would already be hard to number the businesses fairly salivating over all of the niches, opportunities, and potential revenue streams opened up by everywhere.

Finally, looming behind all of these points of view is an evolution in the material and economic facts of computing. When computational resources become so cheap that there’s no longer any need to be parsimonious with them, people feel freer to experiment with them. They’ll be more likely to indulge “what if” scenarios: what if we network this room? this parka? this surfboard? (and inevitably: this dildo?)

With so many pressures operating in everywhere’s favor, it shouldn’t surprise us if some kind of everywhere appeared in our lives at the very first moment in which the necessary technical wherewithal existed. And that is exactly what is now happening all around us, if we only have the eyes to see it.

Whether you see this as a paradigm shift in the history of information technology, as I do, or as something more gently evolutionary, there can be little doubt that something worthy of note is happening.



Thesis 07

Everyware isn’t so much a particular kind of hardware or software as it is a situation.

The difficult thing to come to terms with, when we’re so used to thinking of “computing” as something to do with discrete devices, is that everywhere finally isn’t so much a particular kind of hardware, philosophy of software design, or set of interface conventions as it is a situation—a set of circumstances.

Half the battle of making sense of this situation is learning to recognize when we’ve entered it. This is especially true because so much of what makes up everywhere is “invisible” by design; we have to learn to recognize the role of everywhere in a “smart” hotel room, a contactless payment system, and a Bluetooth-equipped snowboarding parka.

The one consistent thread that connects all of these applications is that the introduction of information processing has wrought some gross change in their behavior or potential. And yet it appears in a different guise in each of them. Sometimes everywhere is just there: an ambient, environmental, enveloping field of information. At other times, it’s far more instrumental, something that a user might consciously take up and turn to an end. And it’s this slippery, protean quality that can make everywhere so difficult to pin down and discuss.

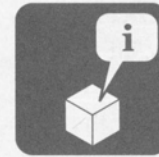
Nevertheless, I hope I’ve persuaded you by now that there is in fact a coherent “it” to be considered, something that appears whenever there are multiple computing devices devoted to each human user; when this processing power is deployed throughout local physical reality instead of being locked up in a single general-purpose box; and when interacting

with it is largely a matter of voice, touch, and gesture, interwoven with the existing rituals of everyday life.

We might go a step further: The diversity of ways in which everyware will appear in our lives—as new qualities in the things that surround us, as a regime of ambient informatics, and as information processing dissolving in behavior—are linked not merely by a technical armature, but by a set of assumptions about the proper role of technology.

They're certainly different assumptions from the ones most of us have operated under for the last twenty or so years. The conceptual models we've been given to work with, both as designers of information technology and as users of it, break down completely in the face of the next computing.

As designers, we will have to develop an exquisite and entirely unprecedented sensitivity to contexts we've hitherto safely been able to ignore. As users, we will no longer be able to hold computing at arm's length, as something we're "not really interested in," whatever our predilections should happen to be. For better or worse, the everyware situation is one we all share.



Thesis 08

The project of everyware is nothing less than the colonization of everyday life by information technology.

Objects, surfaces, gestures, behaviors: as we've seen, all have become fair game for technological intervention. Considered one by one, each intervention may proceed by granular and minuscule steps, but in the aggregate, whether intentionally or not, the effect is to begin overwriting the features of our day-to-day existence with something that never used to be there.

We all have an idea what "everyday life" means, though of course the details will be different for each of us. Your conception might be organized around work: rushing to catch the train, delivering a convincing presentation to your colleagues, and remembering to pick up the dry cleaning on the way home. Someone else's might reside primarily in frustrations like paying the phone bill, or waiting in stalled traffic on the freeway.

My own sense of everyday life resides in less stressful moments, like strolling through the neighborhood after dinner with my wife, meeting friends for a drink, or simply gazing out the window onto the life of the city. However the overall tenor diverges, though, we have this much in common: We all know what it's like to bathe and dress, eat and socialize, make homes and travel between them.

Our lives are built from basic, daily operations like these. We tend to think of them as being somehow interstitial to the real business of a life, but we wind up spending much of our time on earth engaged in them. And it's precisely these operations that everyware proposes to usefully



Thesis 11

Everyware appears not merely in more places than personal computing does, but in more different kinds of places, at a greater variety of scales.

In principle, at least as far as some of the more enthusiastic proponents of ubicomp are concerned, few human places exist that could not be usefully augmented by networked information processing.

Whether or not we happen to agree with this proposition ourselves, we should consider it likely that over the next few years we'll see computing appear in a very great number of places (and kinds of places) previously inaccessible to it. What would this mean in practice?

Some classic sites for the more traditional sort of personal computing are offices, libraries, dorm rooms, dens, and classrooms. (If we want to be generous, we might include static informational kiosks.)

When people started using wireless-equipped laptops, this domain expanded to include coffee houses, transit lounges, airliner seats, hotel rooms, airport concourses—basically anywhere it would be socially acceptable to sit and balance a five-pound machine on your knees, should it come to that.

The advent of a mobile computing based on smartphones and wireless PDAs opened things up still further, both technically and interpersonally. On top of the kinds of places where laptops are typically used, we can spot people happily tapping away at their mobile devices on, in, and around sidewalks, cars, waiting rooms, supermarkets, bus stops, civic plazas, commuter trains.

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 above situations, 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?

The expansion not merely in the number of different places where computing can be engaged, but in the range of scales involved, is staggering. Let's look at some of them in terms of specific projects and see how everyware manifests in the world in ways and in places previous apparitions of computing could not.



Thesis 12

Everyware acts at the scale of the body.

Of all the new frontiers opening up for computation, perhaps the most startling is that of the human body. As both a rich source of information in itself and the vehicle by which we experience the world, it was probably inevitable that sooner or later somebody would think to reconsider it as just another kind of networked resource.

The motivations for wanting to do so are many: to leverage the body as a platform for mobile services; to register its position in space and time; to garner information that can be used to tailor the provision of other local services, like environmental controls; and to gain accurate and timely knowledge of the living body, in all the occult complexity of its inner workings.

It's strange, after all, to live in our bodies for as long as we do, to know them about as intimately as anything ever can be known, and to still have so little idea about how they work. The opacity of our relationship with our physical selves is particularly frustrating given that our bodies are constantly signaling their status beneath the threshold of awareness, beyond our ability to control them. In every moment of our lives, the rhythm of the heartbeat, the chemistry of the blood, even the electrical conductivity of the skin are changing in response to evolving physical, situational, and emotional environment.

If you were somehow able to capture and interpret these signals, though, all manner of good could come from it. Bacterial and viral infections could be detected and treated, as might nutritional shortfalls or imbalances. Doctors could easily verify their patients' compliance with a prescribed regimen of pharmaceutical treatment or prophylaxis; a wide

variety of otherwise dangerous conditions, caught early enough, might yield to timely intervention.

The information is there; all that remains is to collect it. Ideally, this means getting a data-gathering device that does not call undue attention to itself into intimate proximity with the body, over reasonably long stretches of time. A Pittsburgh-based startup called BodyMedia has done just that, designing a suite of soft sensors that operate at the body's surface.

Their SenseWear Patch prototype resembles a sexy, high-tech Band-Aid. Peel the paper off its adhesive backing and seat it on your arm, and its sensors detect the radiant heat of a living organism, switching it on. Once activated, the unit undertakes the production of what BodyMedia calls a "physiological documentary of your body," a real-time collection of data about heart rate, skin temperature, galvanic skin response, and so on, encrypted and streamed to a base station.

Other networked biosensors operate further away from the body. The current state of the art in such technology has to be regarded as Matsushita Electric's prototype Kenko Toware, an instrumented toilet capable of testing the urine for sugar concentration, as well as registering a user's pulse, blood pressure, and body fat. In what is almost certainly a new frontier for biotelemetry, a user can opt to have this data automatically sent to a doctor via the toilet's built-in Internet connection.*

Is such functionality of any real value? While nominally useful in the diagnosis of diabetes, urine testing is regarded as a poor second to blood testing. Most other types of urine-based diagnostics are complicated by the necessity of acquiring an uncontaminated "clean catch." Nevertheless, the significance of Kenko Toware is clear: From now on, even your bodily waste will be parsed, its hidden truths deciphered, and its import considered in the context of other available information.

**One can only hope that such communications would be heavily encrypted.*

What of that unfolding just the other side of the skin? Without leaving the scale of the body, we encounter a whole range of technical interventions less concerned with the body as process or oracle than with its possibilities as a convenient platform—one that follows us everywhere we go. These have generally been subsumed under the rubric of “wearable computing.”

Early experiments in wearability focused on the needs of highly mobile workers—primarily couriers, logistics personnel, law enforcement officers, and other first responders—whose jobs relied on timely access to situational information yet required that they keep their hands free for other tasks. A series of successful academic studies in the 1980s and 1990s, including those at the MIT Media Lab, ETH Zürich, and the Universities of Bristol and Oregon, demonstrated that deploying informatic systems on the body was at least technically feasible.

They were less convincing in establishing that anything of the sort would ever be acceptable in daily life. Researchers sprouting head-up “augmented reality” reticules, the lumpy protuberances of prototype “personal servers,” and the broadband cabling to tie it all together may have proven that the concept of wearable computing was valid, but they invariably looked like extras from low-budget cyberpunk films—or refugees from *Fetish Night* at the anime festival.

University of Toronto professor Steve Mann has easily trumped anyone else’s efforts in this regard, willingly exploring full-time life as a cyborg over the course of several years (and still doing so, as of this writing). Mann attempted to negotiate modern life gamely festooned with all manner of devices, including an “eyetap” that provided for the “continuous passive capture, recording, retrieval, and sharing” of anything that happened to pass through his field of vision.

It was difficult to imagine more than a very few people ever submitting to the awkwardness of all this, let alone the bother that went along with being a constant focus of attention; Mann himself was the subject of a notorious incident at the U.S.-Canada border, soon after the September

11th attacks, in which his mediating devices were forcibly removed by immigration authorities.*

But happily for all concerned, the hardware involved in wearable computing has become markedly smaller, lighter, and cheaper. As ordinary people grew more comfortable with digital technology, and researchers developed a little finesse in applying it to the body, it became clear that “wearable computing” need not conjure visions of cyberdork accessories like head-up displays. One obvious solution, once it became practical, was to diffuse networked functionality into something people are already in the habit of carrying on their person at most times: clothing.

In 1999 Philips Electronics published a glossy volume called *New Nomads*, featuring a whole collection of sleek and highly stylish fashions whose utility was amplified by onboard intelligence. While the work was speculative—all the pieces on display were, sadly, nonfunctional mockups and design studies—there was nothing in them that would have looked out of place on the sidewalks or ski slopes of the real world. Philips managed to demonstrate that wearable computing was not merely feasible, but potentially sexy.

Nor did the real world waste much time in catching up. Burton released an iPod-compatible snowboarding jacket called Amp in 2003, with narrow-gauge wiring threaded down the sleeves to a wrist-mounted control panel; by winter 2004-2005, Burton and Motorola were offering a Bluetooth-equipped suite of jacket and beanie that kept snowboarders wirelessly coupled to their phones and music players. The adidas_1 sneaker did still more with embedded processors, using sensors and actuators to adjust the shoe’s profile in real time, in response to a runner’s biomechanics.

Beyond the things you can already buy, hundreds of student projects have explored the possibilities of sensors light and flexible enough to

**This sudden deprivation of the massive input he had become accustomed to was apparently a harrowing experience for Mann. He described it as one of deep disorientation and nausea.*

be woven into clothing, typified by Richard Etter and Diana Grathwohl's *AwareCuffs*—sleeves that sense the digital environment and respond to the presence of an open Wi-Fi network. Given how often the ideas animating such projects have turned up in commercial products just a few years (or even months) later, we can expect the imminent appearance of a constellation of wearables.

And while none of these products and projects are as total as the digital exoskeleton Steve Mann envisioned, maybe they don't have to be. For all his personal bravery in pioneering wearable computing, Mann's vision was the product of a pre-Web, pre-cellular era in which computational resources were a lot scarcer than they are now. When more such resources are deployed in the world, we probably have to carry fewer of them around with us.

So what's the next step? After decades of habituation due to the wristwatch, the outer surface of the forearm is by now a "natural" and intuitive place to put readouts and controls. Meanwhile, with the generous expanse it offers, the torso offers wireless communication devices enough space for a particularly powerful and receptive antenna; a prototype from the U.S. Army's Natick Soldier Center integrates such an antenna into a vest that also provides a (near-literal) backbone for warfighter electronics, optics, and sensor suites. (The Army, at least, is prepared to attest to the safety of such antennae for its personnel, but I'm less certain that anyone not subject to military law would be so sanguine about wearing one all day.)

We'll also see garments with embedded circuitry allowing them to change their physical characteristics in response to external signals. The North Face's MET5 jacket takes perhaps the simplest approach, offering the wearer a controller for the grid of microscopic conductive fibers that carry heat through the garment. But more than one high-profile consumer fashion brand is currently developing clothing whose fibers actually alter their loft, and therefore their insulation profile, when signaled. When coupled to a household management system, this gives us shirts and pants that get more or less insulating, warmer or cooler, depending on the momentary temperature in the room.

Finally, there are a number of products in development that treat the clothed body as a display surface, the garment itself as a site of mediation. The U.S. Army, again, is experimenting with electro-optical camouflage for its next-generation battle dress, which suggests some interesting possibilities for clothing, from animated logos to "prints" that can be updated with the passing seasons. (Real-world approximations of the identity-dissimulating "scramble suits," so memorably imagined by Philip K. Dick in his 1972 *A Scanner Darkly*, are another potential byproduct.)

Considered in isolation, these projects—from toilet to eyetap, from "body area network" to running shoe—are clearly of varying degrees of interest, practicality and utility. But in the end, everything connects. Taken together, they present a clear picture of where we're headed: a world in which the body has been decisively reimagined as a site of networked computation.



Thesis 13

Everyware acts at the scale of the room.

If even the body is subject to colonization by ubiquitous computing, the same is certainly true of the places we spend most of our time in and relate to most readily: architectural spaces of room scale.

As we've seen, most of the early experiments in ubicomp focused on the office environment, and supported the activities that people typically do there. But many aspects of these investigations were applicable to other kinds of spaces and pursuits as well, with processing deployed in features that most rooms have in common: walls, doorways, furniture, and floors.

If you want to provide services to people as they roam freely through a space, it's quite important to know exactly where they are and get some idea of what they might be doing. If their identities have not already been mediated by some other mechanism, it's also useful to be able to differentiate between them. So one strong current of development has concerned the floor beneath our feet, quite literally the perfect platform for sensors able to relay such information.

As far back as 1997, the Olivetti and Oracle Research Lab at the University of Cambridge had developed a prototype Active Floor, which monitored both weight distribution and the time variation of loads. Georgia Tech's Smart Floor followed, improving on Active Floor not least by its attempt to identify users by their "footfall signature," while the University of Florida's Gator Tech Smart House uses flooring throughout with impact sensors capable of detecting falls and reporting them to emergency services.

Two current strains of thinking about smart flooring are represented by very different projects announced within the last year. On one hand, we

have NTT DoCoMo's CarpetLAN prototype, which uses weak electrical fields to afford both wireless networking and positioning accurate down to about one meter of resolution. CarpetLAN bears all the marks of a highly sophisticated effort to understand what kinds of functionality can be practically subsumed in a floor.

And then there is inventor Leo Fernekes' Sensacell capacitive sensor grid system, developed in collaboration with architect Joakim Hannerz. It has to be said that Sensacell is not the world's most versatile system. It relies on changes in capacitance to detect presence and location and can therefore pick up conductive objects like the human body, but that's about it. Sensacell returns no load information, offers no way to differentiate between individuals, and certainly isn't designed to establish connections with mobile devices. It's not even necessarily fine-grained enough to distinguish between your transit of a space and the midnight errands of the family cat. And given that its presentation to date has focused on output in the (admittedly quite pretty) form of banks of embedded LEDs, Sensacell seems destined for applications in a relatively narrow swath of high-concept bars, lounges, and retail spaces.

But Sensacell has three big advantages over its predecessors: It's modular, it comes in sizes that conform to the square-foot grid actually used by contractors, and it is commercially available right now. What's more, the luminous cells can be integrated into vertical surfaces, even furniture, and their stream of output data can be jacked into just about any garden-variety PC. The pricing is on the high side, but not absurdly so, and will surely fall in the event of any large-scale production. For all of these reasons, Sensacell is accessible, within reach of the kind of tinkering ubihackers who may be key to the wider spread of everyware.

In addition to flooring, instrumented doorways have also begun to appear. Knowledge of door status can be very useful in context-aware applications—whether an office door is open or closed can imply something about the relative intensity with which the occupant is engaged in a task, while a change in state is generally a marker that a user is transitioning between one activity and another. But door sensors can also be used simply to count how many people enter or leave a given room. (Fire

inspectors might want to take note.) California startup InCom's recent pilot program InClass aimed to cut down on teacher administrative time by doing just this, producing a tally of classroom attendance as students wearing RFID-equipped nametags passed beneath a transom-mounted reader.*

If the doorway produces both headcounts and inferences about behavior, and the floor is occasionally called upon to be everything from impact detector to transmission medium, walls' have it relatively easy. Most ubiquitous projects to date have treated the wall first and foremost as a large-scale display surface, with its use as a communication hub following from this.

This, of course, conforms to a venerable tradition in science fiction, but such ultraflat, ultrawide screens are now on the verge of practical reality. Motorola's Physical Science Research Laboratory recently presented sections of a prototype carbon nanotube screen 160 cm across diagonally by a single centimeter thick. If either Motorola or its competitors manage to produce nanotube displays at commercial scale, truly wall-spanning displays cannot be far off, although they're still probably years and not months away.

For some interested parties, this may seem like a long time to wait, given the wallscreen's centrality to their visions of the "digital home." In the more elaborate of such schemes, the wall becomes some combination of home theater, videophone, whiteboard, and family scratchpad—a site where downloaded media objects are delivered for consumption, a communication medium in its own right, and the place where other networked devices in the home are managed.

You can already buy appliances ostensibly designed with such distributed control in mind: the first generation of Internet-capable domestic appliances, typified by LG's suite of refrigerator, air conditioner, microwave, and washing machine.

*Parents objected to the program on privacy concerns, and the system was withdrawn from operation after less than a month.

Whatever their merits as appliances, however, they completely fail to capitalize on their nature as networked devices capable of communicating with other networked devices, which tends to rule out the more interesting sorts of interaction that might otherwise be envisioned. Users address LG's appliances one by one, via a superficially modified but otherwise entirely conventional Windows interface; the advertised functionality is limited to use cases that must have struck even the marketing department as forced. The webcam-equipped refrigerator, for example, lets family members send each other video memos, while the air conditioner offers new patterns of airflow for download, presumably as one would download polyphonic ring tones. The "Internet" microwave is even worse, forcing a user to connect an external PC to the Web to download recipes.

True utility in the digital room awaits a recognition that the networked whole is distinctly more than the sum of its parts. In contrast with such piecemeal conceptions, there have been others that approached the ubiquitous systems operating in a space as a unified whole.

The MIT Tangible Media Group's 1998 prototype ambientROOM was one such pioneering effort. Built into a free-standing Steelcase office cubicle of around fifty square feet, ambientROOM was nothing if not an exercise in holism: The entire space was considered as an interface, using lighting and shadow, sound cues, and even the rippled reflection of light on water to convey activity meaningful to the occupant. The sound of birdsong and rainfall varied in volume with some arbitrary quantity set by a user—both the "value of a stock portfolio" and the "number of unread e-mail messages" were proposed at the time*—while "active wallpaper" took on new qualities in reaction to the absence or presence of people in a nearby conference room.

*Conveying the quantity of unread e-mail is apparently an eternal goal of such systems, while explicitly calling out one's stock portfolio as something to be tracked by the minute seems to have been an artifact of the go-go, day-trading era in which ambientROOM was designed.

Projects like ambientROOM begin to suggest how systems made up of media hubs, wall-screens, networked refrigerators, and all the other appurtenances of room-scale everyware might work when designed in recognition of the person at their heart.

Some of the first to get a taste of this in real life have been high-margin frequent travelers. Since mid-2005, rooms at the Mandarin Oriental in New York have loaded preference files maintained on a central server when the hotel's best customers check in, customizing settings from the shades to the thermostat, lining up entertainment options, and loading frequently dialed numbers into the phone.* "Digital home" solutions that propose to do many of the same things in a domestic setting can be expected to reach the market in the near term, though whether they'll afford experiences of reasonably seamless ubiquity is debatable.

And so we see it cropping up again, here at the scale of the room, this pattern that may by now seem familiar to you: Our discussions of everyware have much less to do with some notional future than they do with a blunt inventory of products already finding their way to market.

**As you may have suspected, yes, the hotel does keep track of what you're watching. The potential for embarrassment is real, and is something we'll deal with extensively in Sections 6 and 7.*



Thesis 14

Everyware acts at the scale of the building.

In this thesis and the next, which concerns the extension of everyware into public space, we reach scales where the ubiquitous deployment of processing starts to have consequences beyond ones we can easily envision. When we find networked intelligence operating at the scale of whole buildings, it doesn't even necessarily make sense to speak of how the everyware experience diverges from that of personal computing—these are places that people using PCs have rarely if ever been able to reach.

The idea of a building whose program, circulation, and even structure are deeply molded by flows of digital information is nothing new. As a profession, architecture has been assuming that this is going to happen for quite awhile now. The design press of the 1990s was saturated with such visions. Anyone who regularly read *Metropolis* or *wallpaper* or *ID* in those years will likely remember a stream of blobjectified buildings, all nurbly and spliny, with tightly-kerned Helvetica Neue wrapped around the corners to represent "interactive surfaces," and images of Asian women sleekly coutoured in Jil Sander Photoshopped into the foreground to connote generic urban futurity.* But the role played by networked information in such projects mostly seemed to mean some variation on Web-on-the-wall.

For all the lovely renderings, we have yet to see the appearance of buildings structurally modified in any significant way by the provision of real-time, networked information.

Yet since the 1970s, it has been commonplace of commercial architecture and engineering, at least, that information technology allows impressive

**Architects: I kid. I kid, because I love.*

efficiencies to be realized when incorporated in the design of buildings. It is now rare for a new, premium commercial building to break ground without offering some such provision.

Circulation and delivery of services in so-called “smart buildings” can be tuned in real time, in pursuit of some nominal efficiency profile. Instead of stupidly offering an unvarying program of light, heat, and air conditioning, energy management control systems (EMCS) infer appropriate environmental strategies from the time of day and of year, solar gain, and the presence or absence of occupants. And security and custodial staffs are assisted in their duties by the extension of computational awareness throughout the structure. It would be a stretch to call such systems “routine,” but only just barely.

Other computationally-enhanced building systems are becoming increasingly common, like Schindler Elevator’s Miconic 10, which optimizes load by aggregating passenger groups based on where they’re going. Instead of the time-honored principle of pressing an “up” button, and then waiting in a gaggle with all the other upbound passengers, the Miconic 10’s clever load-optimization algorithm matches people bound for the same floor with the elevator cab currently offering the shortest wait time. (It’s simpler to do than it is to explain.) Schindler claims the elevators make each individual trip 30 percent faster, and also allow a building to handle a proportionally increased flow of visitors.*

When such systems are coupled to the relational, adaptive possibilities offered up by everywhere in its other aspects, we start to get into some really interesting territory. The Arch-OS “operating system for architecture,” for example, a project of the School of Computing, Communications and

**What gets lost, though, in all of this—as with so many digitally “rationalized” processes—is the opportunity for serendipitous interaction that happens when people from different floors share this particular forty-five-second interval of the day. Isn’t the whole cherished trope of the “elevator pitch” based around the scenario of a kid from the mailroom finding him- or herself willy-nilly sharing a cab with the CXO types headed for the executive floors?*

Electronics at the University of Plymouth, suggests some of the possible directions. As its Web site explains, the project aims to capture the state of a building in real time from inputs including “building energy management systems...the flow of people and social interactions, ambient noise levels and environmental conditions,” and return that state to public awareness through a variety of visualizations.

While there’s ample reason to believe that such ambient displays of information relating to building systems will become both prevalent and useful, most of the Arch-OS projects to date lean toward the artistic. While it sounds fascinating, for example, it’s unclear from the project’s documentation whether the “psychometric architecture” project—the recording of activity in a building throughout the day, for playback on its outer envelope at night—was ever attempted. The generative soundscapes and abstract visualizations on hand do seem to mesh well, though, with other recent efforts to equip the outer surfaces of a building with interactive media.

Consider dECOi’s 2003 Aegis Hyposurface, a continuously-transformable membrane that allows digital input—whether from microphone, keyboard, or motion sensor—to be physically rendered on the surface itself, showing up as symbols, shapes, and other deformations. Its creators call Aegis “a giant sketchpad for a new age,” and while its complexity has kept it from being produced as anything beyond a prototype, it at least was explicitly designed to respond to the kind of inputs Arch-OS produces.

Meanwhile, similar systems, which have actually been deployed commercially, fail to quite close the loop. UNStudio’s recent digital facade for Seoul’s high-end Galleria department store, developed in association with Arup Engineering and lighting designer Rogier van der Heide, is one such project. The architects wrapped a matrix of LED-illuminated disks around what used to be a drab concrete box, turning the whole surface into a field of ever-renewing data and color. It’s a success—it currently bathes the Apgujeong district with gorgeous washes of light nightly—and yet the images flowing across the surface seem to cry out for some generative connection to the inner life of the building.

But already a vanguard few are wrestling with challenges beyond the mere display of information, exploring the new architectural morphologies that become possible when computation is everywhere in the structure itself. Los Angeles-based architect Peter Testa has designed a prototype building called the Carbon Tower: an all-composite, forty-story high-rise knit, braided and woven from carbon fiber.

Unlike conventional architecture, the Carbon Tower dispenses with all internal bracing, able to do so not merely because of the mechanical properties of its textile exoskeleton, but due to the way that exoskeleton is managed digitally. As Testa envisions it, the Carbon Tower exhibits “active lateral bracing”: sensors and actuators embedded in its structural fiber cinch the building’s outer skin in response to wind load and other dynamic forces.

And if building morphology can be tuned in response to environmental inputs, who’s to say that those inputs should be limited to the weather? Arch-OS-style polling of foot traffic and social interactions, coupled to output in the form of structural changes can take us in some genuinely novel directions. Something resembling fondly remembered and much-beloved Archigram projects of the 1960s such as Instant City, Tuned Suburb, and the Control and Choice Dwelling may finally be realized—or so fans of the visionary collective can hope. When compared to the inert structures we now inhabit, everywhere-age architecture—for better or worse—will be almost certainly be weirder.



Thesis 15

Everyware acts at the scale of the street and of public space in general.

At present, the most often-pursued applications of everyware at scales beyond the individual building concern wayfinding: knowing where in the world you are and how to get where you’re going.

We’ve become familiar with the idea that dashboard navigation displays using the Global Positioning System (GPS) will help us figure these things out. But GPS is a line-of-sight system—you need to be visible to at least three satellites currently above the horizon in order for it to triangulate your position—so it doesn’t work indoors, in tunnels, or in places where there’s lots of built-up density. This makes GPS a fairly poor way of finding your way around places like Manhattan, although it seems to work satisfactorily in lower-density conurbations like Tokyo.

Other systems that might help us find our way around the city have their own problems. Schemes that depend on tracking your various personal devices by using the local cellular network can’t offer sufficient precision to really be useful as a stand-alone guide. And while the kinds of sensor grids we’ve discussed in the context of indoor spaces can be accurate to sub-meter tolerances, it would clearly be wildly impractical to deploy them at the scale of a whole city.

But what if the city itself could help you find your way? In 1971, in a landmark study entitled *The Image Of The City*, MIT professor and urbanist Kevin Lynch explored a quality of the city he called “legibility.” How do people read a city, in other words? What sorts of features support their attempts to figure out where they are, which paths connect them to a given destination, and how best to actually go about getting there?

Lynch identified a few systems that have historically helped us find our way in the city: signage, of course, but also explicit maps, even street numbering conventions. Such systems function best in a city that itself offers distinctly characterized districts, clearly identifiable paths between them, and above all, the kind of highly visible landmarks that allow people to orient themselves from multiple vantage points, such as Manhattan's Empire State Building, Seoul's Namsan Tower, and Berlin's Fernsehturm. Other kinds of landmarks play a role, too: prominent, easy-to-specify places—the clock in Grand Central Station—where arrivals are readily visible to one another.

All of these features are now subject to computational enhancement. Street furniture such as lamp posts, signage, even manhole covers can provide the urban sojourner with smart waypoints; Tokyo's Shinjuku ward is currently tagging some 10,000 lamp posts with RFID panels that give visitors information on nearby public toilets, subway entrances, and other accommodations.

Meanwhile, maps themselves can offer dynamic, real-time information on position and direction, just as their automotive equivalents do. At Lancaster University, in the UK, just such a prototype public navigation system—dubbed GAUDI, for “grid of autonomous displays”—helps visitors find their way around campus, using adaptive displays as directional signs.

The system's initial release is intended for use as temporary signage for events—lectures, academic conferences, concerts, and the like. Upon being switched on, each portable GAUDI panel queries the navigational server for its current location. It then displays the name and direction of, and approximate distance to, the selected destination. Moving a GAUDI display from one place to another automatically updates it; an arrow that points left to the destination will reverse when placed on the opposite wall.

Nor is GAUDI limited to a selection of fixed campus landmarks. It can direct visitors to that wide variety of campus events that are regular but subject to frequent changes in location—a professor's office hours, or

a meeting that has outgrown the auditorium in which it was originally scheduled.

It's easy to see how something like GAUDI, suitably ruggedized and secured, could transform the experience of citying, especially when combined with other locational and directional indicators carried on the body or integrated into clothing. Taken together, they would render the urban domain legible in a way Kevin Lynch could not have imagined in 1970. In such a place, locations self-identify, notices of congestion immediately generate alternative paths to the destination, and services announce themselves. (Anyone who's ever spent the day on foot in one of Earth's great cities will appreciate the prospect of knowing where the nearest public restroom is, even at what time it was last cleaned.)

Information architect Peter Morville calls such interventions in the city “wayfinding 2.0”—an aspect of the emerging informational milieu he thinks of as “ambient findability,” in which a combination of pervasive devices, the social application of semantic metadata, and self-identifying objects renders the built environment (and many other things besides) effectively transparent to inquiry.

But as we shall see in some detail, everywhere also functions as an extension of power into public space, whether that space be streetscape, commons, station, or stadium—conditioning it, determining who can be there and what services are available to each of them. More deeply still, there are ways in which the deployment of a robust everywhere will connect these places with others previously regarded as private. Our very notions of what counts as “public” cannot help but be changed in the aftermath.

Conclusion

ALWAYS CRASHING IN THE SAME CAR

Each morning, upon waking, I indulge myself in the austerities of Buddhist meditation—Korean Zen Buddhism, to be precise, of the Kwan Um School. I sit, empty my mind to the extent that I am able to, and...breathe.

I've been doing this every day for more than 10 years now, absolutely without fail. I've meditated in apartments, barracks, mountain temples, hotel rooms beyond number, on more than one 747 deep in the trans-Pacific night, and once, particularly memorably, in the canvas-webbed cargo bay of a Chinook helicopter chattering its way into a landing zone. It's become one of the few constants of a willfully nomadic and fluid life.

And it's one of the many things in my life that I cannot conceive of being improved by an overlay of ubiquitous information technology. Going for a long run in a warm gentle rain, gratefully and carefully easing my body into the swelter of a hot springs, listening to the first snowfall of winter, savoring the texture of my wife's lips...these are all things that acquire little or no added value by virtue of being networked, relational, correlated to my other activities. They're already perfect, just as they stand.

Even where the application of ubiquitous technology would clearly be useful, I know enough about how informatic systems are built and brought to market to be very skeptical about its chances of bringing wholesale improvement to the quality of my life.

Sure, I'd love to know when my friend Jamie is within a few blocks of my present location and available for a few pints of Guinness. I'd surely appreciate a little help finding the variety of tools and important documents I've stashed somewhere around the house and immediately

forgotten. And I would not at all mind if my daily excursions and transactions were eased by the near-universal adoption of something along the lines of Hong Kong's Octopus system.

But I have a hard time buying into the notion that such ubiquitous interventions in the world can be had without significant cost. I see how readily the infrastructure that gets us these amenities also lends itself to repression, exclusion and the reinscription of class and other sorts of privilege. Above all, I see it occasioning hassle...unending hassle. I can't see that we'll derive much net improvement in quality of life from these and the other things everywhere promises us—not unless we are exceedingly careful in devising and implementing the technology that undergirds them.

Nor do I see any reason to follow Teruyasu Murakami of Nomura Research in asking how the users of ubiquitous systems can "change their basic value systems to adapt to the new situation." Not only do I think this is a very, very bad idea, but it's also likely to be a painfully drawn-out exercise in futility.

We are who we are, in other words, in all the infuriating and delightful lineaments of our humanity. No matter how "convenient" it would be for us to learn to think and act in ways that accord with the technology we use, I very much doubt whether such a thing is practically achievable. Besides, we've seen what happens when we attempt to forge a New Man: the results are not pretty, to very large values of "not."

So maybe it would be wiser to develop an everywhere that suits us, as opposed to the other way around—not that this will be very much easier. In fact, if you get nothing else from this book, I hope you at least come away from it with an understanding of how richly nuanced everyday life turns out to be and how difficult it will be to design ubiquitous systems sophisticated enough to capture those nuances.

We seem to have a hard time with the notion that some aspects of life are simply too important, too meaningful, and too delicate to subject to the rather clumsy interventions of our present information technology. Moreover, anyone venturing to question the wisdom of such interventions

risks being branded a neo-Luddite, or worse. In his 1999 *e-topia*, MIT Media Lab professor William Mitchell rather blithely mocked “dogmatic and deterministic Chicken Little” perspectives on technology, dismissing out of hand “those now-familiar glum assertions that the digital revolution must inevitably reinscribe the nastier existing patterns of power and privilege, while trampling on treasured traditions as it does so.”

Frankly, I find Mitchell’s disdainful tone unjustified, even bizarre. While I don’t believe anything in the world is engraved in stone, I do think that each technology we invent contains certain inherent potentials for use. I also think we’re foolish if we do not at least consider these potentials and where they lead to undesirable outcomes, take pains to circumvent them.

What seems lost on Mitchell, and on the many others holding similar views, is that the point of raising such questions—at least as far as I am concerned—is not to scuttle ubiquitous technology, but to improve it.

It is axiomatic in the field of biofeedback that “control follows awareness”—you cannot seek to steer some process, that is, until you become conscious of it. My hope in writing this book is to foster a wider awareness of the deep issues raised by everywhere, so we can together make the decisions about its emergence that we so urgently need to. And my fundamental point is that the outcome does not have to be something that simply happens to us. To the degree that we, the users and consumers of ubiquitous computing, educate ourselves and take action correspondingly, we get to choose the outcome.

When the stakes are as high as they are here, we must interrogate without mercy the value propositions we’re presented and adopt only those ubiquitous products and services that really do improve our lives. In life, on balance, I come down ever so slightly on the side of hope: I think that given enough time and accurate enough information, people eventually do make wise decisions.

The trouble is that in the present situation, time and useful insight are both in short supply. While we have a window of time left in which to consider the manifold challenges of everywhere, and to articulate a meaningful response to them, that window is closing. Ubiquitous computing

appears in more places, in more guises, and in more ambitious conceptions with every passing day, and we’ve barely begun to confront it in the depth of understanding it demands.

The real struggle will be in finding an appropriate place for ubiquitous computing in our lives—reserving it for those applications where it will be able to do us the most good, while ensuring that our more intimate choices and moments remain autonomous and unmediated. The English proverb has it that “the devil is in the details.” The architect Mies van der Rohe famously restated this in more optimistic terms; in his version, the details of implementation are precisely where one might go looking for God. In the case of everywhere, we can only hope that Mies knew what he was talking about.

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