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ORIGINAL ARTICLE

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Yesterday's tomorrows: notes on ubiquitous computing's dominant vision

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Abstract Ubiquitous computing is unusual amongst technological research arenas. Most areas of computer science research, such as programming language implementation, distributed operating system design, or denotational semantics, are defined largely by technical problems, and driven by building upon and elaborating a body of past results. Ubiquitous computing, by contrast, encompasses a wide range of disparate technological areas brought together by a focus upon a common vision. It is driven, then, not so much by the problems of the past but by the possibilities of the future. Ubiquitous computing's vision, however, is over a decade old at this point, and we now inhabit the future imagined by its pioneers. The future, though, may not have worked out as the field collectively imagined. In this article, we explore the vision that has driven the ubiquitous computing research agenda and the contemporary practice that has emerged. Drawing on cross-cultural investigations of technology adoption, we argue for developing a "ubicomp of the present" which takes the messiness of everyday life as a central theme.

1 Introduction

Ubiquitous computing (ubicomp) research is characterized primarily by a concern with potential future computational worlds. This notion of research by future envisionment has been a feature of ubicomp discourse and reasoning since it earliest days; Weiser [1] foundational article is even entitled "The Computer for the twenty-first Century"—an explicit look towards a possible future. Rhetorically, Weiser situates the research activities that he describes there as initial steps upon a path of technological development inspired by an explicit vision of possible future relationships between people, practice, and technology. Although much of his article describes a research program already under way and some of the early results that it had produced, the dominant theme of the article is the twin challenge of anticipating future trends and meeting future needs.

Weiser's article was doubly influential. Not only did it articulate a research agenda that many have embraced, it also set a rhetorical tone that many have adopted. So, the same concern with technological futures continues to feature in the ways in which ubicomp research agendas are framed and in which technological advances are motivated and measured. Ubicomp is essentially defined by its visions of a technological future. Often, this is taken directly from Weiser's own work; almost one quarter of all the papers published in the Ubicomp conference between 2001 and 2005 cite Weiser's foundational articles, a remarkable number of publications to cite a single vision as fundamental for their own work over a decade later. Even in cases where Weiser's own vision is not a driving factor, the idea that ubiquitous computing research is exploring prototypes of tomorrow's everyday technology and everyday experience is a pervasive one.

Such visions, however, are interesting not just for what they say about the future but also for what they say about the present. This seems to be particularly the case when it comes to normative social relationships. Envisionments of the future, such as those of the Worlds Fairs [2], Disney's Tomorrowland [3], or most popular science fiction [4] have provided a useful analytic focus for considering how the problems of today are perceived, framed, and understood. In this paper, we are concerned with the balance between past, present, and future embedded in conventional discourses about ubiquitous computing. In particular, we are interested in the central conundrum posed by the fact that Weiser's vision of the future is, by this point, not only an old one,

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but also a very American one. The role of technology in everyday life is, in the early twenty-first century, already quite different than it was when Weiser wrote in the late 1980s; among many other things, it is now explicitly acknowledged to have remarkable cultural variation. PARC famously pursued a policy of "time–machine research," devoting its considerable financial and intellectual resources to creating simulations of future computing environments; by this stage, though, conventional computing platforms have vastly outstripped even the "futuristic" environment that Weiser's laboratory was capable of building. Yet, his original framing of the ubiquitous computing vision still occupies an important place in much of the discourse of ubiquitous computing research. As researchers working within and around ubiquitous computing discourses, our own research practices and interests also lie at this intersection of technical and social considerations, and our approach here will attempt to weave back and forth between them. One of us is a computer scientist whose work lies at the intersection of computer science and social science, the other a cultural anthropologist with a primary concern in information technology as a site of cultural production and the consequences for technology innovation and diffusion. The questions we want to ask, then, are as follows. First, how should we understand the relationship between ubiquitous computing's envisioned future and our everyday present? Secondly, what influence does this have on contemporary ubiquitous computing research? And finally, what motivates and explains the remarkable persistence and centrality of Weiser's vision?

We will begin by exploring the ways in which ubiquitous computing researchers have framed their work with respect to anticipated technological and social trends, and consider some of the implications of this approach. We will then present two cases of alternative visions of ubiquitous computing, one from Singapore and one from Korea. These will then provide the basis for a discussion of competing visions of ubiquitous computing and the idea of a "ubicomp of the present."

Ultimately this paper is organized around three framing points.

First, the centrality of ubiquitous computing's "proximate future" continually places its achievements out of reach, while simultaneously blinding us to current practice. By focusing on the future just around the corner, ubiquitous computing renders contemporary practice (at outside of research sites and "living labs"), by definition, irrelevant or at the very least already outmoded. Arguably, though, ubiquitous computing is already here; it simply has not taken the form that we originally envisaged and continue to conjure in our visions of tomorrow. We will draw on a number of case studies to substantiate this point, drawing in particular on models of the ubiquitous world that seem to deviate from conventional images.

Second, the framing of ubicomp as something yet to be achieved allows researchers and technologists to absolve themselves for responsibilities for the present; the problems of ubiquitous computing are framed as implementation issues that are, essentially, someone else's problem, to be cleaned up afterwards as part of the broad march of technology. Essentially, the future framing allows us to assume that certain problems will simply disappear of their own accord. By focusing on case studies drawn from countries in which the vision of ubiquitous computing has played out differently than Weiser envisioned, we will draw attention to the complex settings within which ubiquitous computing is always already embedded.

Third, the seamlessly interconnected world of future scenarios is at best a misleading vision and at worst a downright dangerous one. Homogeneity and an erasure of differentiation is a common feature of future envisionments; the practice is inevitably considerably messier, and perhaps dealing with the messiness of everyday life should be a central element of ubicomp's research agenda. We will illustrate the work involved in continually producing alignments between technological opportunities and social realities.

2 Ubiquitous computing's "proximate future"

The dominant tense of ubiquitous computing writing is what we might call the "proximate future." That is, motivations and frames are often written not merely in the future tense, describing events and settings to come, but describe a proximate future, one "just around the corner." The proximate future is invoked in observations that "Internet penetration will shortly reach..." or "We are entering a period when..." or "New technological opportunities are emerging that..." or "Mobile phones are becoming the dominant form of..." A brief perusal of proceedings of recent conferences confirms the pervasive sense of the proximate future; of the 108 papers comprising the Ubicomp conference proceedings between 2001 and 2004, fully 47% of the papers are oriented towards a proximate (and inevitable) technological future (e.g., from only Ubicomp 2004, [5–9] and more.) Indeed, Weiser's foundational article originally published at the start of the last decade of the twentieth century and entitled "The computer for the twenty-first century" is, similarly, built around a vision of the proximate future, the future just around the corner or over the horizon.

It may be that subsequent ubicomp writing has adopted not only Weiser's technological vision, but aspects of his formulation of how this vision will come to pass. Certainly, this collective envisionment of a future saturated with technology has been a defining characteristic of ubicomp research. What is perhaps most interesting is that ubicomp research has generally shared not only in the notion of a technology-saturated future, but also in the designations of what sorts of technologies it is that will saturate our future. In other words, these collective avowals of future potentialities are ways in which current activities are tied to the self-same agenda that Weiser set out in the late 1980s. In fact, citations to Weiser's article are often phrased not so much as a "look backwards" but rather as a collective "look forwards"; that is, instead of saying "back in 1991, we thought that...", they say "Just as Weiser suggested in 1991, we are soon to enter a world where..."

Latour and others [10] in the sociology of science have talked about the pragmatics of citation practice, noting that citing the ways in which one's own work depends on prior results and writings not only acknowledges intellectual debts, but also builds defensible positions by aligning research with existing paradigms and traditions, and by enrolling others as tacit supporters of one's approach. However, beyond the ways in which citation builds intellectual networks, it is worth stopping for a moment to think about the time dilations involved here. Weiser formulated his vision of ubiquitous computing in the late 1980s [11]; although the Scientific American article was published in 1991, the ubicomp project was already, by that point, well underway, and indeed the 1991 article is not only a compelling vision of the future, but a progress report on the project of realizing it (complete with photographs of devices that had already been designed and built, and reports on their use.) However, the invocation of Weiser's vision as one that we share and continue to prosecute neglects the significant difference between then and now, and changing techno-social contexts.

So, for example, in 1989, at the same time as the ubiquitous computing research agenda was being formulated, Intel introduced the 486DX processor, running at 25 MHz. Apple introduced the Mac IIci, based on a 25 MHz MC68030 processor. They had yet to release a Powerbook laptop, but 1989 also saw the debut of the 16lb, 16 MHz Macintosh portable. In the same year, Sun introduced the Sparcstation-1, running at 20 MHz and with a maximum memory capacity of 64 M. From a contemporary perspective, these would be poor "specs" for a portable MP3 player never mind a scientific workstation. The figures for the telecommunications market are equally salutary. The first US cellular telephony service had begun in 1983; by 1988, there were approximately 1.6 million US subscribers. In Europe, the GSM standard for mobile telephony was not demonstrated until 1991 (with the first network operator becoming active in 1992).

In other words, today's technological landscape is quite radically different than that of the late 1980s when Weiser was outlining the ubiquitous computing vision. The idea that, in the early twenty-first century, we are postulating much the same proximate future vision of ubicomp that motivated Weiser is a somewhat surprising one. Given that the last 20 years have seen such radical transformations of technological infrastructure worldwide, and that Moore's Law suggests a 8,000-fold increase in computational performance, two questions immediately present themselves. First, why is our vision of the future still the same as Weiser's, and second, why has it not yet come to pass? Two possibilities present themselves.

The first possibility is that the ubiquitous computing vision can never come to pass. The proximate future is a future infinitely postponed; when we are continually about to enter a new age, when we are continually anticipating what happens next, and when our attention is continually directed over the horizon, then by definition ubiquitous computing is never about the here and now. Indeed, within this particular model of a technological future, it is hard to imagine how we could ever, as a community, say, "There. It is done."

The second possibility is that ubiquitous computing already has come to pass. Clearly, of course, we do not live in "Sal's world," as described in the scenario outlined in Weiser's paper. But perhaps ubiquitous computing is already here, but took a form other than that which had been envisioned. Arguably, and as we will explore at more length below, our contemporary world, in which mobile computation and mobile telephony are central aspects not just of Western commercial endeavors but also facets of everyday life in the developing world, is already one of ubiquitous computing, albeit in unexpected form.

In fact, these two possibilities are not distinct options, but rather are two aspects of the same observation—that the vision of the future originally envisioned by Weiser, and still motivating much research in ubiquitous computing, is one that is firmly entrenched in its own particular moments, locations and cultural contexts, a vision as much of the past as of the future. From this perspective, the future that ubicomp has been attempting to build is not our own future, but 1989s future—yesterday's tomorrows. Weiser envisioned "the computer for the twenty-first century." Having now entered the twenty-first century that means that what we should perhaps attend to is "the computer of now."

In order to help us see the present day "anew," we present two examples of contemporary computational practice oft neglected in Western research conferences—ubiquitous computing in Singapore and in Korea.

3 Ubiquitous computing environments: Singapore

Located at the tip of the Malay peninsular, Singapore is a small, prosperous former British colony with a robust economy, a technologically literate population, and a reputation for strong government regulation of daily life [12–16]. Singapore is a diverse ethnic and culture mix: more than 76% of Singapore's 4.3 million residents identify as Chinese, another 14% as Malay, slightly over 8% as Indian, and the rest a mix of expatriates. Most Singaporeans are comfortably middle class, and the nation enjoys higher than average per capita household incomes (around S$37,555 per year), and remarkable rates of home ownership (94%). Singapore is also one of the most wired (and indeed, "unwired," that is, digitally connected via wireless networks) countries in the world [17]. Yet Singaporeans do not appear to think of themselves as living on a cutting technology edge—cell phones, hot spots and multi-media mobile messages are at this point naturalized parts of the local cultural landscape. Yet ironically, it is an example of ubiquitous computing out of the lab, out the experimental frame, in the wild, working.

In 1992, 6 months after Mark Weiser's article appeared in the pages of *Scientific American*, the Singaporean National Computer Board launched IT2000 Masterplan, the third in a series of ambitious technology roadmaps for their island nation-state [18]. To achieve the goals of this plan, the board deemed it necessary to develop a nation-wide information infrastructure. This proposed infrastructure would connect up nearly every home, school, and workplace in Singapore, creating an 'intelligent island' (ibid). The island nation-state of Singapore is small, compromising of slightly less than 434 square miles, a land-mass only three and half times that of Washington DC, so making such a vision real seemed more reasonable. As part of the broader IT2000 plan, Singapore ONE (One Network for Everyone) was launched in 1996, bringing together a range of public sector agencies to roll out a high-speed data network test-bed across the island which would in turn support a host of applications and services designed to enhance not only Singapore's economic position globally but also to "improve the quality of life of its citizens" [19]. This plan was not without its technical challenges and delays [20], but is safe to say now, a decade later, the 'intelligent island' vision has been realized. Rather than a proximate future, there were a series of bench-marked achievements and milestones and the setting of a new 10 year agenda.

Statistics tell one story. As of December 2004, 92.2% of the population owns a cell phone. A total of 73.3% of Singapore's 964,000 households have a computer at home, and more than 65% of households have access to the internet—about 42% use dial-up and 41% broadband (though these numbers are changing monthly, with the former declining, while the latter grows). Outside of the home, the two major mobile phone carriers offer 560 wireless hotspots between them, with Starhub boasting that is hotspots cover nearly 115 square miles of the island. In addition to these ICTs, Singapore also has other sorts of ubiquitous technologies, including the world's first electronic road payment system, a blanket i-CCTV coverage network, a computer-driven mass transit system, and an enviable smart-postal network.

It is not so difficult, then, to make the case that Singapore represents a kind of ubiquitous computing environment. Indeed during the SARS outbreak in 2003, the government strategically employed the internet and the cell phone base as a way to distribute critical information, and provide cyber alternatives to ongoing social practices, including the festivals around Ching Ming which fell during the outbreak. Here the government helped create online shrines for the ancestors of Singapore's Chinese community, encouraging them to venerate at home, rather than in Singapore's many cemeteries, hoping by doing to cut the risk of transmission. In thinking about Singapore as a ubiquitous computing environment, then, it is also important to think about what happens on and around the infrastructures built out in accordance with IT2000, and those that just happened (like the adoption of mobile phones). What kinds of experiences, services and applications transpire? What are people doing, or not doing, in an environment so full of sensing and smart technologies?

Almost everyone in Singapore owns a cell phone—it is unlikely that even those without phones are beyond reach of a phone. Phones are utterly pervasive and can be found interwoven into most of the aspects of daily life [21]. In any given month Singaporeans exchange more than 690 million text messages—around 200 messages per phone per month. Indeed, text messaging has become an art form in Singapore; a young Singaporean woman recently took the crown for the fastest text messenger in the world, entering 26 words in 43.24 s. For regular Singaporeans, speed is facilitated by all sorts of local short-hands that have crept into text messaging, including a use of Sing-lish—the local Singaporean patios. The two major mobile service providers offer a wide range of mobile services from *feng shui* advice to the weather; they also offer various translation applications which make good sense in a country with four official languages [22]. The mobile nature of cell phones also creates the new opportunities for location-based services—everyone in Singapore jokes about the impossibility of hailing a taxi without a cell phone. Most public locations in Singapore now have some kind of code that you send in a SMS message to a taxi company who dispatches a taxi to your location—simple, but effective. Singaporeans rely on their phones for everything from basic communication to more sophisticated forms of commerce, social interaction and political engagement.

There are other ways in which Singapore's transportation infrastructure blends different sorts of technological interventions—in both the public and private domains. Again, Singapore's size here is an advantage. The vast majority of Singapore's residents use public transport in their daily lives. In fact, Singapore's mass rapid transit system serves more than 1 million passengers daily in the city's high-density travel corridors, and many more use the bus lines to reach their final destinations. The train system utilizes smart card ticketing and advanced CCTV to provide seamless and safe transportation. Although only about 11% of the population owns a car, there is also a significant infrastructure of taxis and traffic control in Singapore has always been an issue. In 1998, Singapore's Land Transport Authority implemented the world's first electronic road pricing (ERP) system [23, 24]. Utilizing a dedicated short-wave radio communication system, unique in-vehicle identification units, smart cards, distributed data collection points and a centralized data centre, the ERP provides Singapore's drivers with variable pricing schemes for entry into the central business district during the week—saturdays have no tolls. The data is displayed on large LED boards at major intersections ringing the restricted zone—and drivers will make decisions based on the pricing at these transition points and taxi-drivers will consult with price-sensitive passengers regarding appropriate routes. Tolls are debited directly from drivers through a smart card system. Interestingly while the system did not result in a boost to the public transportation system, within the first year there was a noticeable drop in the number of times any single vehicle entered the restricted zone on a given day [24]. Digitally enhanced vehicles, smart toll booths and various forms of technological interventions in the mass transit system, all point to an almost seamless manifestation of ubiquitous computing in the otherwise very prosaic domain of public transportation.

The development of an intelligent island has not been without its challenges—for Singaporeans, this ubiquitous computing environment with its mobile handsets, pervasive internet and smart sensors raised questions about content, surveillance and control. Regulation of ubiquitous computing spaces is not often a subject that is well documented in the relevant literature, save through the vectors of privacy and security. However, the Singapore example seems to offer some interesting re-workings of the consequences of a wide-scale deployment and subsequent accessibility. In late 1996, the Singaporean Ministry of Information and the Arts announced plans to filter all internet use through government proxies to regulate access to political, religious, and pornographic content online. Not only were ISPs, cyber cafes and websites required to register with the Broadcast Authority, but adopting an approach similar to that used in China, the government blocked access to at least one hundred sites it deemed most problematic—including playboy.com. Usenet groups were also subject to scrutiny, intervention and regulation [25]. The head of the Singapore Broadcasting authority was quoted at the time as saying that the regulation was in the service of national safely: “We don’t want objectionable material to be easily available...We just want to keep this part of the Internet within our immediate neighborhood clean.” What is particularly interesting about these censorship moves is that many Singaporeans regarded them as positive and appropriate government actions [25, 26], while outsiders viewed this further proof of a controlling state.

Singapore’s censorship regime has been well documented [27] and is often the subject of derision, scorn and skepticism. However, its collaborative nature, clearly articulated principles and relatively transparency make it worthy of closer scrutiny—as it has interesting implications in the ubicomp space. In 2003, Singapore authorities revisited these questions of regulation and control of the internet in their decadal review of censorship in Singapore [26]. The committee defined censorship not as a confrontation between regulators and the regulated, but rather “it is about collaboration to debate social issues constructively and to help educate members of a society to be more knowledgeable and sophisticated” [26, Sect. 9.4]. In his letter to the chairman of the Censorship Review Committee, the then Minister of Information, Communication and the Arts wrote:

> Your committee has succeeded in keeping the report relevant against the backdrop of our social evolution and changing global landscape. While understanding the need to fan the creative flames of the new generation and to accommodate the diversity of views, you were sensitive not to weaken the ‘glue’ that bonds our society—our core values, our identity, our shared memories, our religious and racial harmony. Your committee also sees censorship as a shared responsibility, thus your approach of encouraging participation comprising regulators, industry players, community and artists in the process....Our common challenge is to achieve a balance where adults can have wider access, whilst our young are provided with a conducive environment to develop morally and socially, without compromising the development of creativity and social capital. These objectives might be difficult but certainly not incompatible [26].

Here technology is understood as always and already operating within a cultural context and a complicated one at that—the religious, cultural and racial heterogeneity of Singaporean society is a constant feature of negotiations around appropriate regulation of technology environments. This construction of censorship happened in the larger context of Singapore’s social/cultural regulation of the internet, in particular the National Internet Advisory Committee (NIAC) continued its charter to promote “the safe and positive use of the internet” [28] (1). In 2002, they reported ongoing concerns about internet accessibility via mobile devices—particularly as it negated the value of parental supervision. While it is possible for parents to put the personal computer in the communal room at home to supervise their children’s online activities; that safety measure is greatly diminished with mobile Internet [28] (4). This continuing concern with children’s safety in particular, promoted the NIAC to launch a new ‘cyber wellness’ initiative—“in the cyber wellness vision, users should not only embrace the Internet in their lives, they should also adopt an attitude of using the Internet for inspiring others and contributing to the community” [28] (7). Furthermore the task force goes on to suggest that this vision of cyber wellness also incorporates a sense of personal responsibility—to not spam, to not spread misleading information, to verify the accuracy of information gleaned online before acting upon it [28]. This language, and its intent, is remarkable. Here the ubiquity of the internet is seen to support collective and community practices, individuals are not just satisfying their own desires and needs but operating within a larger cultural framework. Imaging ubiquitous computing as a collective practice, rather than a set of discrete individual actions, is an important reframing of that technological vision.

4 Ubiquitous computing environments: Korea

So if Singapore, then, is an example of collective uses, as well as computational device and sensor ubiquity, Korea must surely be an example of infrastructural ubiquity and of public/private sector co-operations to achieve it. With its population of 45 million, Korea routinely ranks as one of the most connected countries in the world: 77% of Korea's 16.9 million households have computers in them; the average user spends about 15 h/week using that computer, 11 of those hours online. Just over 70% of the population reports using the internet regularly; a staggering 96% of Koreans, ages 6–20, report using the internet regularly—for everything from email to gaming, data management and education [29]. Furthermore, according to the National Internet Development Agency of Korea, 83% of Koreans have their own email addresses—this includes 85% of those under 20, 91% of those in their 20 s, and a remarkable 67% of those of 60, and just under a third of all Koreans who use the internet report having more than 1 email address. It is safe to say that the internet is a ubiquitous technology in Korea.

Korea is also frequently touted as the leading broadband market in the world, and it is. The remarkable level of connectivity is, in no small part, facilitated by the nature of Korea's urban landscape. More than 81% of Koreans live in urban areas—indeed nearly 25% of the country's population lives in Seoul alone—and most of those live in high-rise, multi-family, high-density dwellings. These tall, heavily populated buildings create a last-mile boon, not available in US urban sprawl—you only need extend the wire to a building, and plug the whole building in, rather than wiring house by house. As a result of readily available, and relatively cheap, high speed data connections (with fat pipes up and down); Koreans enjoy a wide range of internet usages at home, including watching previously shown TV programs, streamed to their home computers. Just as 77% of households in Korea have usable computers at home, 72% of Korean households are connected to the internet [29]. But perhaps more remarkable is the fact that only 86% of Korean homes can connect to the internet, meaning that 14% of Korean households that could connect to the internet chose not to, and a further 14% of households cannot connect at all. Given the strength of recent government actions, it is interesting to see the presence of a lingering form of digital divide, or at least inaccessibility.

In addition to this still high degree of broadband penetration, Korea also happens to be one of the fastest growing markets for 'PC-Bangs' or cyber arcades—gaming parlors with between 20 and 200 machines, designed to support online gaming. These arcades have flourished even as Korea's home-PC uptake has grown. This seemingly topsy–turvy reality makes sense when you know that Korean homes are considered to be extremely private domains, closed often even to one's closest friends, and that socializing, especially when it comes to gaming, has nearly always had a space in the public domain, and is in fact actively sought out that way. While 90% of Korea's online population goes on line at home, 25% also report regularly go online in cyber cafes. Even those people who have computers at home are also frequently using computational devices away from those homes. Further eschewing some of our expectations of technology usage patterns, of the sixteen million or so Koreans who make use of some form of mobile internet access only 30% do so on the move; a full 40% report using their mobile devices to access the internet while at home [29]. Interestingly, women are slightly outpacing men in their consumption of mobile internet experiences—38 to 34%. Less surprising, Koreans using mobile internet access skew young—83% of those under 20 reports using it at some time, this includes everything from surfing the web to engaging in a range of eCommerce and mCommerce where the phone is the dominant mode of payment for online content in any form.

In 2004, against this backdrop of ubiquitous connectivity, devices and content, and also a booming middle class [30, 31], Daeje Chin, the Minister of Information and Communication, and a former senior executive at Samsung, launched IT389—"The Road to $20,000 GDP/capita"—a remarkable technology plan that proposed to transform Korea into a ubiquitous society by 2010 [32]. "U-Korea," as it was quickly dubbed in the press, was a bold plan that relied on the close ties that already exist between Korea's government and many large private sector companies [33–35]. The plan which takes its name from eight services (Wireless Broadband, Digital Multi-media Broadcasting, Home Network, Telematics, RFID, W-CDMA, Terrestrial Digital TC, VOIP), three infrastructures (Broadcast Convergence Network, Ubiquitous Sensor Network, Next Generation Internet Protocol) and nine equipment fields (Next-Generation Mobile Communications, Digital TV, Home Network, IT System-on-Chip, Wearable PC, Embedded SW, Digital Contents, Telematics, Intelligent Service Robot) is designed to boast Korea's production, employment and exports, ultimately raising the entire country's GDP, as well as those of all households. In the press, Chin was quoted as saying that U-Korea meant "a society where all people can enjoy the benefits of state-of-the-art IT at anywhere and anytime." It appears to be well understood that the ubiquity to which Chin refers is a socially experienced one, that it happens to Korean society, not just for Korean individuals. Indeed, even the metric of success of IT839 is at a household level—per capita household income will rise, as will quality of life for all Koreans. Again, the vision of a technology future, here explicitly called out as ubiquitous computing is manifested at a collective cultural or societal level.

5 Visions of ubiquitous computing

Studies of daily life in non-Western environments, even those that are richly populated with wireless and embedded technologies, are remarkably rare in ubiquitous computing research publications, even when, as in these cases, they would seem to be paradigmatic examples of ubiquitous computing.

There are a range of differences between the settings we have been describing and those that more conventionally appear in Ubiquitous Computing research, and these may account for the absence of these sorts of accounts as parts of the ubicomp vision. Perhaps it is that in Singapore computational technology is both embedded in daily life (e.g. CCTV, sensors) and carried around (e.g. cell phones), disappearing into the fabric of everyday life. Perhaps it is that Korea's infrastructural development relied not on the free-market but on a strong relationship between the public and private sectors. Perhaps it is because all these cultural, social and political contexts within which technologies have transpired, and the contexts in which they been deployed, consumed and resisted are unfamiliar and thus unreadable. Perhaps it is because Sal's scenario and other standard visions of digital futures do not accommodate monitoring and restricting car traffic, or centralized governmental control and regulation of infrastructure or content, or dense urban environments, or extended collective public living, or sensing urination in elevators, or electronic consultations about *feng shui* or ambient displays of prayer times on a mosque wall. But if they did, where else might we see ubiquitous computing already happening? Cairo with its freshly deployed WiFi network set to connect all the local mosques and create a single city-wide call to prayer? Indonesia's e-mosque project?

In other words, by looking outside of the research laboratory, we are looking at ubiquitous computing as it is currently developing rather than it might be imagined to look in the future. In these settings, we certainly see concerns with mobile devices, with infrastructures for partial connectivity, and with optimizing applications for devices with restricted input and restricted power. But at the same time, we also see that the ubiquitous computing agenda is one that is fundamentally tied to other important but neglected issues such as multi-generational living, high density housing, public transit, religious observance, the practicalities of calling a cab, the politics of domesticity and the spatialities of information access—the messiness of every day practice.

A focus on current practice and on the diversity of settings in which ubiquitous computing is currently being put to work can, perhaps, help us avoid visions of ubicomp application that are, in their own way, as misguided as 1950s science fiction's speculations about twenty-first century clothing and gender relations.

6 Messiness: an alternate ubicomp?

What these alternative and contemporary views of ubiquitous infrastructure have in common is their messiness. In our collective vision of ubicomp's proximate future, the messiness of our local laboratory infrastructures (the nests of cabling hidden in the dropped ceiling or behind the closet door, the jumble of perl, Java, and python code that precariously conspire to produce results in demos) is replaced by a clean, gleaming infrastructure seamlessly providing well understood services. In practice, though, we see that infrastructures are continually visible and must be consciously attended to in the course of everyday encounters with ubiquitous computing, from the vagaries of network access to the structure of service billing. The critical property of this messy infrastructural regime in the everyday world is that it is most emphatically not a problem of living on the "bleeding edge," as it often is for research labs. Infrastructures remain messy after decades or centuries, as the user of any transit system from urban subways to international airlines can attest. The lesson of the real world of ubiquitous computing, then, is that we will always be assembling heterogeneous technologies to achieve individual and collective effects.

Star [36, 37] has been a particularly prominent advocate of the use of infrastructure as an analytic lens through which to consider the relationship between human action and technology. The crux of her approach is to look at infrastructure as a relational concept; an infrastructure is an infrastructure only from the perspective of specific peoples and technologies. To us as casual users, the sewer system is an urban infrastructure, ubiquitously available and uniform in its operation; to a sewer engineer, however, exposed to the daily practicalities and pragmatics of waste water management and treatment, the sewer is not an infrastructure but a site of work, and not uniform but highly localized and variable.

Star's perspective is particularly instructive here, since, in adopting infrastructure as a site of enthnographic inquiry, she also dispels the myth of infrastructure as quiescent and stable. Infrastructures must be actively maintained, and relationships to them must be continually negotiated. Mainwaring et al. [38] provide a valuable examination of these issues for ubicomp in exploring different attitudes towards infrastructure, and indeed looking at the relationship with infrastructure as, itself, a cultural production. So, for example, amongst their subjects, the rejection of infrastructure (be that commercial or technological) is itself a marker of certain forms of social life, and even a way in which inter-personal relationships are managed (e.g. through a concern with "authenticity" in everyday life and interaction.) McCullough [39] similarly explores the structure of everyday space as a confluence of infrastructural arrangements that overlap to produce effects that reach beyond each.

In other words, infrastructures are messy. The messiness that we experience in laboratory ubiquitous computing infrastructures is not a property of prototype technologies, of the bleeding edge, or of pragmatic compromise; messiness is a property of infrastructure itself. Infrastructures are inherently messy; uneven in their operation and their availability. The notion of a seamless and uniform infrastructure is, at best, a chimera, and at worst, to draw on aboriginal Australian myth, a mulywonk—a fearsome creature that might be invoked to steer people away from certain paths, places, or actions.

This messiness is important. Our suggestion that ubiquitous computing is already here, in the form of densely available computational and communication resources, is sometimes met with an objection that these technologies remain less than ubiquitous in the sense that Weiser suggested. Mobile telephony, after all, offers widespread coverage, but is neither truly ubiquitous nor truly seamless; incompatible standards, spotty regional coverage, etc., seem like obstacles that we must still overcome before the ubiquitous computing vision can be realized. But postulating a seamless infrastructure is a strategy whereby the messy present can be ignored, although infrastructure is always unevenly distributed, always messy. An indefinitely postponed ubicomp future is one that need never take account of this complexity. Consider some examples.

Verrips and Meyer [40] describe the complex networks of support and practice necessary to maintain cars in Ghana. Most vehicles on the road here were not designed for sub-Saharan Africa, but rather are second- or third-hand vehicles imported from Europe and pressed into new life. Their discussions of the travails of keeping a car on the road are framed by the radical departure from their European models of cars as commodity items and elements in a network of technological standardization. Initially surprised (indeed, appalled) by the practices of customization, jury-rigging, and makeshift maintenance that are pervasive in Ghana, they gradually uncover an alternative infrastructure uniquely adapted to local needs and to the problems of maintaining an engineering artifact outside of its natural environment. The same vehicle, moved from Europe to Africa, is embedded in a radically different infrastructure and a radically different web of social values associated with mobility, reuse, exchange, commodification, craftsmanship, etc.

In their work on information infrastructures, Bowker and Star [41] discuss the International Classification of Diseases, a common infrastructure for the collection and comparison of mortality statistics worldwide. Like other boundary objects [42], though, the ICD is less a stable platform upon which everyone can stand, and more a means by which different interests, groups, concerns, and activities can be brought into temporary alignment. What seems like a straightforward process—the categorization of causes of death—is rife with complications, especially because of the uses to which the information will be put later. For example, consider the difficulties faced by AIDS researchers. AIDS deaths are, typically, the direct result of other infections that a patient suffers because of immune deficiency. However, before a category allowed physicians to record death by AIDS, the condition was essentially ‘‘invisible’’ in the medical statistics, making it extremely difficult to mobilize support for research funding. Similarly, the different purposes to which the statistics, once gathered might be put—public health actions, regulation of industries, allocation of resources, and more—result in a host of different pressures that shape the information infrastructure. The uniform structure of the ICD hides the messiness of practice beneath—the way it coordinates multiple different interests (e.g. the needs of medical practitioners, legislators and regulatory agencies, researchers and funding agencies, pharmaceutical companies, etc), the different ways it is put to work in different parts of the world (reflecting not only different power relationships but also different cultural interpretations of disease), the variability in its coverage of diseases associated with different regions (such as the under-representation of tropical diseases), etc.

Third, a significant infrastructure issue for ubiquitous computing endeavors is the problem of power—not MIPS-per-Watt, or even Foucauldian curbs on agency, but the electrical supply that keeps our electronic world (quite literally) humming. World travelers are already familiar with the problems of varying voltage, frequency and socket shapes, but these forms of variability mask a more complex reality where, for example, in many parts of the developing world, the dominant infrastructure for power is based on car and truck batteries. It is not simply that these are improvised replacements for the ‘‘natural’’ arrangement of power distribution available in the West and the developed world, but rather that they constitute an alternative, indigenously appropriate and thoroughly invisible infrastructure for power generation, albeit one quite radically different from our own. Ironically, current developments in what is known as ‘‘distributed generation’’ in the developed world (incorporating solar cells, fuel cells, and micro-turbine generators into a complex infrastructure in which production and consumption are more evenly distributed through the grid) are moving Western power infrastructures in some ways in directions closer to those we might see in the developing world.

Infrastructures, then, be they networks of car mechanics, medical categories, or power sources, are never seamless in the ways in which they are put to work. They are sites of negotiation and contest, compromise and coordination, approximation and partial agreement. They are unevenly distributed and unevenly available. They are continually in flux, and brought into local stability only through active engagement and coordination. Infrastructure itself is a relational property; it describes a relationship between technology, people, and practice. In this environment, then, thinking of infrastructure as stable, as uniform, as seamless, and as universally available is clearly problematic. It is not merely a dream of a world not yet realized; it is a dream of a world that could never be realized.

7 Towards a ubicomp of the present

What this suggests, then, is an alternative domain of ubicomp research—a ubicomp not of the future but of the present. William Gibson famously quipped that "The future is already here; it's just not very evenly distributed" [43]. We take each component of this aphorism as a component of an alternative research agenda for ubicomp.

7.1 The future is already here

The future is already here. The technological trends that Weiser insightfully extrapolated have, just as he anticipated, resulted in radical transformations and reconfigurations of the role of computation in everyday life. Weiser anticipated a world in which computation would be embedded into our everyday worlds—not just physically embedded but also socially and procedurally embedded, becoming part and parcel of how we act in the world. It has not, perhaps, taken the form that he anticipated, although PDAs, cell phones, large-scale displays and digital cameras do bear family resemblances to the devices that Weiser imagined would come to populate our world. However, the fact that the details are different should not blind us to the remarkable accuracy of Weiser's vision. Computation is embedded into the technology and practice of everyday life; we continually use computational devices without thinking of them as computational in any way. The desktop computer has not been displaced, but augmented.

Interestingly, though, while the technological form of ubiquitous computing differs only in its details from the model that Weiser had anticipated, it is perhaps the use of ubiquitous computing which would have surprised him. One notable aspect of Weiser's article is that, as he lays out a vision for a radically different form of computational experience, the settings into which those devices are to be deployed and the activities that they are used to support remain largely unexamined. Weiser's ubiquitous computing technology is used in workplaces; it relies on large fixed infrastructure investments by commercial entities; it is directed towards the needs of corporate efficiency. Weiser's ubiquitous computing is a tool for labor.

From the perspective of a 'ubicomp of the present,' we can note that Weiser was entirely correct in one regard—that the purposes to which people would put computational devices are not radically new ones, but rather reflect existing social and cultural needs. However, again, this did not necessarily take the form that had been anticipated. Computational technologies are embedded in social structures and cultural scripts of many sorts; ubicomp technologies prove also to be sites of social engagement, generational conflict, domestic regulation, religious practice, state surveillance, civic protest, romantic encounters, office politics, artistic expression, and more.

What this suggests, then, is that we need a deeper understanding of how social and cultural practice is carried out in and around emerging information technologies. If ubiquitous computing is already here, then we need to pay considerably more attention to just what it is being used to do and its effects. Interestingly, while considerations of the social and cultural elements in ubicomp's agenda has traditionally been thought of in terms of 'social impacts,' our focus here is more on technology as a site of social and cultural production; that is, as an aspect of how social and cultural work are done, rather than as something which will inevitably transform social practice. Indeed, it may be quite the other way around.

7.2 It's just not very evenly distributed

The idea that the future is not very evenly distributed has traditionally been taken to note differential access to technologies, and in particular the concentration within the research laboratories of universities and corporations of advanced technological infrastructures. Here, we read it in three ways: first, as noting the ways in which power relations are embedded in access to infrastructure; second, as pointing towards the quite different patterns of technology adoption and use in different cultural settings; and third, as signally a primary concern with how inherently messy and uneven infrastructures are encountered and navigated.

First, drawing on analyses of "time–space compression" such as that of Harvey [44], Doreen Massey [45] coined the term "power-geometries" to refer to the ways that spatial arrangements (e.g. the locations of homes and their proximity both to amenities and to sources of noise and pollution) and patterns of access and mobility (e.g. in the competition for resources between different forms of public and private transportation) reflect arrangements of power and control. These power geometries also affect the relationships between spaces and the means by which those relations are brought about; for instance, reflecting on the area of London where she lives, Massey comments: "It is (or ought to be) impossible even to begin thinking about Kilburn High Road without bringing into play half the world and a considerable amount of British imperialist history" [45: 65]. Similarly, when we think about ubiquitous computing technologies and infrastructures, the patterns by which they are introduced into existing spaces and the needs around which they are designed and for which they are harnessed, we are immediately presented with the need to acknowledge the ways in which technologies both exploit and reproduce a range of power concentrations and relationships.

Second, when we see ubiquitous computing as a feature of the present rather than of the future, then we are forced to contend with it as an inherently heterogeneous phenomenon. Standardization and consistency can be imagined in the future, but a technology of the present is one that operates in a thoroughly heterogeneous environment. This applies at all levels. Consider, for example, the radically different forms of governmentality at work in a comparison between the US and Singaporian approaches to Internet information provision (or even, for that matter, between US and European approaches to mobile telephony regulation.) At the same time, on a much smaller scale, the interplay of standards for telecommunications render an apparently "invisible" infrastructure highly visible in terms of the range of concerns to which its users must be oriented. A technology of the present is inherently one that is deployed and operated in a fragmented world.

Third, and relatedly, focusing on ubicomp in the present as an inherently heterogeneous phenomenon suggests that a significant aspect of ubicomp's research agenda should be the ways in which heterogeneity is currently manifested and managed. We have discussed ubicomp as inherently messy; so how do people both manage and even exploit this messiness in current interaction? From an ethnographic perspective, this might take the form of Star [36] 'ethnography of infrastructure,' using the multiple manifestations of infrastructure as an analytic lens as in, for example, Star and Ruhleder's [46] exploration of the infrastructure of scientific collaboration. From a technological perspective, it might take the form of the explorations of 'seamful design' being explored by Chalmers and colleagues [47], in which the variability of infrastructure and of access become a resource for active engagement.

8 Conclusions

Ubicomp has been tremendously successful, on two counts. First, it has been successful as a research endeavor. In addition to being a topic in its own right, it is also a central aspect of the research agenda of many other areas of computer science research, from theory to embedded systems. On the second front, it has been successful as a technological agenda, so that Weiser's model of a single person making use of tens or hundreds of embedded devices networked together—is a reality for many people. However, we have posed the question here of the relationship between these two successes.

Certainly, the foundational elements of the ubicomp vision—a future in which our encounters with the world and with each other are smoothed by the application of technology, a world to be delivered to us by heroic engineering—is remarkably persistent. There is a fundamental technological determinism at work, and Tolmie et al. [48] note the irony of, on the one hand, Weiser's attempt to move beyond the idea of the "dramatic computer" and, on the other, an inevitable research practice celebrating ingenious design. Weiser and other early ubicomp visionaries provided an imaginative vehicle for understanding the encounter between technology and the social world, one in which technology would play a liberating role. This is both an alluring vision and a common one [49]. However, while the majority of ubicomp's research attention has traditionally been devoted to the proximate future—the future just around the corner—we have suggested instead that, some 15 years after Weiser originally formulated it, ubiquitous computing has indeed arrived. If the availability of devices with wireless data communications and powerful computational properties is anything to go by, then it is hard to deny that computation is already ubiquitous. This raises two interesting questions—first, why did we fail to notice it, and second, what should we do as a consequence?

We have suggested that our failure to notice the arrival of ubiquitous computing is rooted (at least in part) in the idea of seamless interoperation and homogeneity. The ubicomp world was meant to be clean and orderly; it turns out instead to be a messy one. Rather than being invisible or unobtrusive, ubicomp devices are highly present, visible, and branded, but perhaps still unremarkable in the sense explored by Tolmie et al. Ubicomp has turned out to be characterized by improvisation and appropriation; by technologies lashed together and maintained in synch only through considerable efforts; by surprising appropriations of technology for purposes never imagined by their inventors and often radically opposed to them; by widely different social, cultural and legislative interpretations of the goals of technology; by flex, slop, and play.

We do not take this to be a depressing conclusion. Instead, we take the fact that we already live in a world of ubiquitous computing to be a rather wonderful thing. The challenge, now, is to understand it.

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