Ubiquitous Computing in the Jet Age: its Characteristics and Challenges

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Abstract - In traditional computing environments, users actively choose to interact with computers. However, ubiquitous computing applications are embedded in the users' physical environments and integrate seamlessly with their everyday tasks which offer a new opportunity to augment people's lives with technology that provides increased communications, awareness and functionality. We review the importance of computer in the jet age and propose a set of defining characteristics, requirements, and research challenges for ubiquitous applications to raise awareness of the existing literature on the adoption, use, and history of domestic technologies, as well as the use of situated studies, and the benefits that these can bring to bear on the design and evaluation of technologies for the home. The idea of such an environment emerged more than a decade ago and its evolution has recently been accelerated by improved wireless telecommunications capabilities, open networks, continued increases in computing power, improved battery technology, emergence of flexible software architectures and improved web services. The aware homes are already becoming a reality.

Keywords - Ubiquitous Computing, Nanotechnology, Interoperability, Natural Interaction, Wireless Technology, Social Environment, Smart Home

1. Introduction

There is no field more challenging than information processing and computers. The field change significantly almost every month, it is a field that combines all other disciplines. Virtually everybody needs a working knowledge because nearly everybody now uses computer either for office or personal applications to manage household finances, writing, learning, entertainment and even shopping. Ubiquitous computing is a post-desktop model of human-computer interaction in which information processing has been thoroughly integrated into everyday objects and activities. In ubiquitous computing, computers become a helpful but invisible force, assisting the user in meeting his or her needs without getting in the way [1].It is a practice whereby computers are made so common and accessible that users are not even aware of their physical presence. An ideal ubiquitous computing is a high-speed network that covers any kind of geographical areas and is easily installed and automatically maintained. Users have access to a variety of digital devices, whenever and wherever they need them. It is omnipresent and appeared to be available everywhere all the time, it may involve many different computing devices that are embedded in various devices or appliances and operate in the background. Ubiquitous technology is often wireless, mobile, and networked, making its users more connected to the world around them and the people in it.

Ubiquitous computing as an aspect of both knowledge creation and information dissemination that changes daily activities in a variety of ways, when it comes to using today's digital tools users tend to communicate in different ways using today's digital tools, be more active, conceive and use geographical and temporal spaces differently and have more control. In addition, ubiquitous computing is global and local, social and personal, public and private, invisible and visible. The research method for ubiquitous computing is standard experimental computer science: the construction of working prototypes of the necessary infrastructure in sufficient quantity to debug the viability of the systems in everyday use, using ourselves and a few colleagues as guinea pigs. This is an important step towards insuring that the infrastructure research is robust and scalable in the face of the details of the real world. The idea of ubiquitous computing first arose from contemplating the place of today's computer in actual activities of everyday life. In particular, anthropological studies of work life teach us that people primarily work in a world of shared situations and unexamined technological skills. However the computer today is isolated and isolating from the overall situation, and fails to get out of the way of the work. In other words, rather than being a tool through which we work, and so which disappears from our awareness, the computer too often remains the focus of attention. And this is true throughout the domain of personal computing as currently implemented and discussed for the future, whether one thinks of PC's, palmtops, or dynabooks. The characterization of the future computer as the intimate computer or rather like a human assistant makes this attention to the machine itself particularly apparent. Getting the computer out of the way is not easy. This is not a graphical user interface (GUI) problem, but is a property of the whole context of usage of the machine and the affordances of its physical properties: the keyboard, the weight and desktop position of screens, and so on. The problem is not one of "interface". For the same reason of context, this was not a multimedia problem, resulting from any particular deficiency in the ability to display certain kinds of real-time data or integrate them into applications. (Indeed, multimedia tries to grab attention, the opposite of the ubiquitous computing ideal of invisibility). The challenge is to create a new kind of relationship of people to computers, one in which the computer would have to take the lead in becoming vastly better at getting out of the way so people could just go about their lives. A few places in the world have begun work on a possible next generation computing environment in which each person is continually interacting with hundreds of nearby wirelessly interconnected computers. The aim is to achieve the most effective kind of technology, that which is essentially invisible to the user. To bring computers to this point while retaining their power will require radically new kinds of computers of all sizes and shapes to be available to each person. This is the concept of Ubiquitous Computing.

2. Review of current trends in computer technology

The Jet age have revolutionized the way computer works. For instance, the fifth generation computers concentrate on advances in the way computers are used, not on the electronic refinements that characterized the previous four. Rather than the processors of data, computers are now an intelligent processor of knowledge [2]. Already a number of computer programs called expert systems are widely in use [3]. Physicians use computers to help diagnose disease, lawyers plan litigation and scientists and engineers simulate biological growth, astronomical events and social behaviours. We have seen the dreams of the computer pioneers fulfilled as computers evolve the ability to learn from their own experiences. These pioneers saw the computer as a heuristic device, that is, a machine that controls its own behaviour based upon the results of its past activities [4]. This intelligent machines link information together, much as the human mind does, to arrive at logical conclusions [5]. The perfection of artificial intelligence devices requires new concepts in processing and memory design. Scientists are already experimenting with computer processors that are grown biologically rather than manufactured as electronic components. Using living molecules that function as electronic components, a computer with the power of today's largest model would be microscopic in size [6]. Our civilization has the potential for creating a life-form vastly superior to that which has produced it. Currently, researchers have perfected a microcomputer storage device that store billions of characters. This is enough room to store the names and addresses of 200 million people which is more than the population of Nigeria. The present jet age computer can be consider as a "monster computer" because they tap into data storage devices thousands of time larger than their predecessors. The cost of computing and computers are now much lower. Computers are now given away as promotional items. The drastic decline in computer hardware costs has continued for some time as new technology development occurs. Computer is now increasingly available; they are now as common as the telephone GSM. Already, communications devices like IPhone, IPad that combine the functions of television set, video, telephone, data terminal web services, office applications and other desktop computer capabilities are being marketed. Computers are now programming themselves. The user enters specifications for a job to be done, and the computer will write its own program to do it [7]. A great deal of work has already been done towards this end. Program generators (programs who write other programs) has been perfected, lay person can now develop specialized programs to satisfy unique needs [8]. The propriety data banks that serve the public have now been consolidate into information utility. Electronic communications including electronic mail and teleconferencing have now replaced the paper mail systems [9], [10]. Computer now exercise an ever-increasing influence on human affairs, our economy has evolved from a national one to an international one. Keeping track of international business transactions and monetary flow is done largely by computer systems. The computer's ability to communicate financial data around the world almost instantaneously makes it a powerful force for bringing people closer together. It is my personal believe that, to be successful in the near future, one should be skilled in one particular language: Computer! More people throughout the world are now conversant with C, Java or Visual Basic programming language than Spanish, English and German language combined. Another significant trend that has accompanied the high-tech revolutions is the so called high touch trend towards increased human-to-human contact. The computer offers us the opportunity to tailor working, studying and shopping arrangements to our personal needs and tastes. Increasing numbers of employees are working at home, using computers to transmit their day's production to the main office [11]. Increasing numbers of students are taking high school and college courses over the internet and communicate with their school and instructors. More and more consumers are purchasing goods and services electronically, using computers to send in their orders and payments. These increases in electronics communication have engendered rising expectation for increases in opportunities to communicate directly with people, as opposed to machines. Electronic funds transfer systems, which relieve us from the need to go to the bank, have disappointed the banking industry. It appears that many prefer visiting a bank if for no other reason than to say hello to someone. People enjoy going to a shopping centre. It has become a form of family entertainment that electronic shopping will have a tough time replacing. Taking college courses electronically is fine for some, but most students prefer the campus experience. Going to college is a matter of human contact. For younger students, it is part of the transition to adulthood, as well. The high tech revolution can liberate us from travelling to distance job sites, difficulties in communication, and repetitive, manual tasks. But it is the accompanying high touch revolution that speaks most directly to our new sense of freedom, the freedom to use our newly found time to intensify our human-to-human contacts and seek new experiences for personal and social growth. Today the Internet has become the ultimate platform for accelerating the flow of information and is, today, the fastest-growing form of media, and is pushing many, if not most, other forms of media into obsolescence. Therefore, we offer one last prediction: that the high tech revolution will result in a society more human, not less, more responsive to individual needs, not less, and more personally fulfilling, not less.

3. Characteristics of ubiquitous computing

3.1 Task dynamism

Ubiquitous computing applications, by virtue of being available everywhere at all times, adapts to the dynamism of users' environments and the resulting uncertainties. In these environments, users may serendipitously change their goals or adapt their actions to a changing environment [12]. New information about the data center can arrive unexpectedly, thus changing the wanted. This requires programs that dynamically adapt to changes in either the goals or the plan structure by which those goals were to be achieved [13]. Sometimes the user might actively reconfigure the system to adapt to the new task settings; at other times the system might have to infer from its sensory input that the user changed his or her mind. Applications will, furthermore, have to be able to explain why they inferred those task changes and learn from their right and wrong inferences.

3.2 Device heterogeneity and resource constraints

The omnipresence of ubiquitous applications is typically achieved by either making the technological artifacts (devices) move with the user or by having the applications move between devices tracking the user. In both cases, applications have to adapt to changing technological capabilities in their environment. If the device itself is mobile (following the user or being carried around by him/her) then it usually has some con physical constraints limit resources, such as battery power, screen size, networking bandwidth, and so forth. A PDA, for example, has relatively little usable screen area and limited battery power; a cell phone has an even smaller screen size but typically a longer battery life and is at least connected to a network. Furthermore, applications might also experience variability in the availability of resources. The second approach to mobility is having the application follow the user and move seamlessly between devices. Applications will thus have to adapt to changing hardware capabilities (different types of pointing devices, keyboards, network types, and so on) and variability in the available software services.

3.3 Computing in a social environment

Another major characteristic of ubiquitous computing technology is that it has a significant impact on the social environments, in which it is used, any introduction of a ubiquitous computing environment implies the introduction of sensors, which irrevocably have an impact on the social structure, no matter how unobtrusive they seem to be; Imagine, for example, that our residence is outfitted with all kinds of sensors to provide information to a ubiquitous computing system. Are we going to allow neighborhood police station to be able to monitor which room we currently occupy (as indicated by the alarm system's motion detectors) and how much alcohol we are consuming (as inferred from our food inventory system)? There are also policy questions: Who owns the data from a ubiquitous computing system? How can we avoid making people feel like they are in information panoptical [14]? Can one subpoena the data collected by ubiquitous computing systems? Since the answer is probably yes, there might be demand for ubiquitous computing systems in which the raw sensor data cannot be accessed at all, but processed inferences from the data, such as "burglar entry,"

3.4 Nanotechnology and wireless technology

If computers are to be everywhere, unobtrusive, and truly helpful, they must be as small as possible and capable of communicating between themselves. Technological movements supporting these goals are already implemented under the rubrics *nanotechnology* and *wireless computing*. The trend toward miniaturization of computer components down to an atomic scale is known as nanotechnology. Nanotechnology involves building highly miniaturized computers from individual atoms or molecules acting as transistors, which are the heart of the computer chip. The number of transistors in a chip is indicative of its power. Therefore, nanotechnology's extreme miniaturization of transistors allows for impressive levels of computing power to be put into tiny packages, which can then be unobtrusively tucked away. Wireless computing refers to the use of wireless technology to connect computers to a network. Wireless computing is so attractive because it allows workers to escape the tether of a network cable and access network and communication services from anywhere within reach of a wireless network. Wireless computing has attracted enormous market interest, as witnessed by consumer demand for wireless home networks, which can be purchased from service providers.

3.5 Context-awareness and natural interaction

Small computers that communicate wirelessly provide a necessary infrastructure for ubiquitous computing. However, infrastructure is only half of the battle. The ubiquitous computing movement aims to make computers more helpful and easier to use. Indeed, computers should be able to accurately anticipate the user's needs and accommodate his or her natural communication modes and styles. These themes are captured within the ubiquitous computing movement's focus on context-aware computing and natural interaction. The promise of context-awareness is that computers will be able to understand enough of a user's current situation to offer services, resources, or information relevant to the particular context. The attributes of context to a particular situation vary widely, and may include the user's location, current role, past activity, and affective state. Beyond the user, context may include the current date and time, and other objects and people in the environment. The idea behind natural interaction is for the computer to supply services, resources, or information to a user without the user having to think about the rules of how to use the computer to get them. In this way, the user is not preoccupied with the dual tasks of using the computer *and* getting the services, resources, or information.

4. Challenges

4.1 The smart home

We are yet to achieve the dream smart home concept, but the technology to achieve this notion is already in place through information structure, personal computing environment, value added services through the web and other media as illustrated in Figure 1.

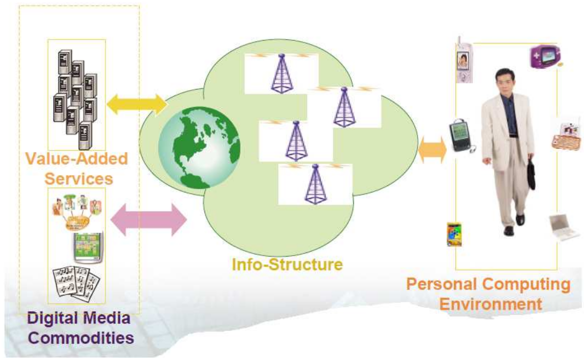

Figure 1: Pervasive Computing Environment -Past, Present and ready for the Future

The pervasive infrastructure for ubiquitous computing does not exist in today's homes; houses must be explicitly outfitted for these sorts of technologies to thrive. New application software must be created specifically written to serve as a test bed for smart home research. While new homes may eventually be purpose-built for such smart applications; existing homes have to be upgraded to support these new technologies. The general question, then, is how will occupant-users build up a model of how to control, use, and debug technologies that will interact with one another in the environment? What will the experience of the home as a whole be when these technologies are brought in gradually, and without the benefit of a top-to-bottom design? Will the occupant-users be prepared to manage their smart home when the time comes? Particularly when these complex technologies offer fewer physical affordances than we are used to? Perhaps future models of connection will require that homeowners set a security key for all of their devices. Assuming a few homes in the real world will ever be designed as a holistic system of well-meshed, interoperable components then a number of questions will have to be answered:

- What kinds of affordances do we need to provide to occupant-users to make the system intelligible? (e.g., Is the device recording, displaying, manipulating in-formation about us)
- How can we tell how my devices are interacting? (e.g., what are my devices interacting with, and how do they choose what to interact with?)
- What are the boundaries of my smart home? (e.g., what are the walls? How much privacy do I have?)
- What are the potential configurations of my devices? (e.g., what connects with what, what won't connect, and why?)
- How can users be made aware of the affordances of the entire home itself? (e.g., what are the possible and impossible configurations of this home?)
- Where will the locus of interaction be in a system that exists in no one place, but rather represents the sum of many interoperable (and changing) parts? (e.g., where does the UI *live*?)
- How do I control these devices, and the whole system? (e.g., Where are the controls, what visualizations of the whole system do I have?)

Current domestic technologies have limited capability to connect with one another, and strong affordances of connection do not provide good models for the smart home. Ubiquitous computing homes will need to present its occupants with an intuitive sense of possibilities it can afford, the current state of the systems within the home, interfaces for controlling the systems in the home as a whole, and a means by which "accidents" (such as a neighbor hijacking their devices) can be repaired or prevented. These abilities must be provided and maintained in an environment in which new devices are added, old devices are removed, devices from different manufacturers may coexist, and wireless connectivity may extend beyond the walls of the home itself. The challenge for homeowners with these devices will be to understand when their houses make the transition from dumb to smart and manage that transformation. The challenge for ubiquitous computing is to help homeowners understand their accidentally smart homes by providing insights into what these devices can do, what they have done, and how we control it.

4.2 Spontaneous interoperability

We believe that spontaneous interoperability is not just the simple ability to interconnect, but the ability to do so with little or no advance planning or implementation. With fluid, spontaneous interoperability, individual technologies have the potential to create a fabric of complementary functionality. Without it, the smart home of the future is likely to be characterized by islands of functionality, as the sets of devices that were explicitly built to recognize each other can interoperate, but other sets of devices cannot. (Such a world is likely to be one of software upgrades, version mismatches, and driver installations. Such interoperability, while a challenge in its own right, increases the challenges of intelligibility. Every device or software service must be explicitly written to understand *every other type* of device or software that it may encounter. If the applications on PDA are to be able to print, then those applications (and the operating system on which it is built) must be explicitly written to understand and use the notion of a "printer" such it can communicate with it without *a priori* agreement on syntax and semantics. Through interoperability it is possible that the existence of a rich fabric of devices and software, somehow all seamlessly will interconnect with one another. Must we agree on a complete set of standards for how these entities will be defined and used, known to all parties before any implementation can begin? Will we have to restrict our environments to only using devices and software that agree with the protocols already in place? The challenge goes beyond mere standards. While standards for particular domains i.e., printing, image capture, data storage allow an entity to communicate with an entire *class* of devices or services using a standard protocol, they do not alleviate the core problem; it is implausible to expect that all classes of devices or services will be known to all others, and that we can thus define standards for every type of device or service *a priori*. Instead, new models of connectivity are needed. Research has begun to explore such models. Most of these models work by standardizing communication at the syntactical level (protocols and interfaces) and leaving to it a human to impose semantics. Our challenge is to ensure that the future of the smart home is not one of incompatibility and isolated islands of functionality, but rather one in which occupant-users can expect the systems in their home to work together fluidly. We believe that this challenge requires radical new models of connectivity and interoperability that reach beyond simple prior agreement on standard protocols and interfaces.

4.3 No need for systems administrator

As computers enter the home in greater numbers, individuals find themselves becoming systems administrators [Figure 2]. The average home computer user now has to be concerned with chores that would seem familiar to a mainframe systems operator from the early days of first generation computers i.e., upgrading hardware, performing software installation and removal, and so on. The advent of always-on broadband connections and in-house networks have finally brought to our homes the few systems administration tasks that had so far eluded us i.e., network and security administration. These are chores that are overwhelmingly complex and understood by few, even among "early adopters."

Figure 2: Personnel Computing Environment at present with users as system administrator

What will the situation be when our homes are filled by complex technological artifacts that are meant to interoperate with each other and with the outside world? As designers of technology, we cannot plausibly expect such advanced knowledge of potential occupant-users of the smart home, if we expect anyone to actually wish to inhabit such homes. Indeed, if the lack of ability or interest in home "administration" chores as mundane as plumbing, electrical wiring, or appliance repair is any indication to go by, there will effectively be *no* systems administrator in the smart home. How, then, will we design technologies for the smart home that require no on-site expert? Fortunately, there are models for administration-free use of complex technologies other than general-purpose computing systems. Traditional appliances, for example, are single-function devices that provide simple controls, straightforward affordances, and generally good ease of use (most people can use the office microwave oven without reading the instruction manual, for instance). When such a device breaks (which happens rarely), users are not expected to fix it themselves. Instead, an expert is called who comes to the house to make the repair. There has been a move, recently, toward "appliance-centric" computing in which digital devices embody some single function [15]; how well this approach will scale, especially when such appliances are asked to interact with other sorts of devices in fluid ways is an open question. Perhaps a more fitting model for administration in the smart home can be found in existing utilities, such as the telephone and cable television networks. In the utility model, most of the intelligence in the system resides in the network itself. The home contains only the most simple and minimal front end functionality needed to access the network. The telephone system is, of course, the most well-known example of this model: a simple, rotary telephone can be used to access any other telephone in the world, including cellular telephones that didn't exist at the time the rotary phone was built. This expanding functionality is available because the sophistication of the back-end network is increasing. The cable TV network, with its set-top boxes, is another example of the utility model, as are ISPs such as AOL and MSN, who bundle and preconfigured their networking software to create turnkey internet access points. Generalizations of this model have been proposed by others as a solution for out-sourced home administration, by organizations such as the Open Services Gateway Initiative [16]. Either of these approaches, the appliance model or the utility model brings with it a number of attendants technical and design challenges. In the appliance model, the challenges are largely in the design domain: how can these small devices deliver rich interactions with an ever-expanding coterie of technology in the home, without losing the simplicity that it’s their raison d’être? In the utility model, how can we design technical solutions for remote diagnosis, administration, and software upgrades (in particular, with the security to prevent the kid next door from performing his own, unwarranted, remote diagnosis, administration, and upgrades)? Regardless of the overall model chosen, occupant-users will still have some administration that they will have to do, simply because not all of the dynamics of the home can be known by the developer of the appliance, or the owner of the utility. The particular ways in which individual devices are used by members of the home, for example, may need to be reflected in configurations, security parameters, and device interactions that can only be implemented by the owners of those devices, not some external third party.

4.4 Designing for domestic use

We agree with [17] that there is a need for studies of domestic settings to inform design. The telephone should be among the most ubiquitous technologies in the home. The study of its adoption reveals that while its inventors foresaw a social role for the phone, its initial vendors did not [18]. The telephone company did not believe that sociability was an important or appropriate use of their technology. It was not until several decades, and after the telephone was broadly adopted, that the Bell System promoted the device as a mechanism for having conversations with distant friends and family. The adoption of the landline telephone could be viewed as a triumph of user persistence over vendor beliefs. Recently, phone adoption has received new attention because of wireless devices. [19] Observed that individuals tend to purchase wireless phones for emergency and coordination reasons, and do not consider sociability to be important. However, within weeks of purchasing the phone these same owners used it for social calls. The adoption of landline and wireless phones suggests that vendors and even users find it hard to foresee how they will use a technology. Electricity, another pervasive domestic technology, shows that new uses sometimes do not last. At the turn of the century, the homes of the wealthy were often outfitted with electrically-conducting rails in the floors; "electricity girls," equipped with metal shoes and wearable light fixtures, would entertain party guests by moving from room to room, carrying their own illumination [20]. Findings from these analyses reinforce the need for conducting studies of domestic settings and relying on analysis of the stable and compelling routines of the home, rather than supposition, company dictate, fad, or marketing. Recent studies of domestic settings have taken this approach. They highlight a variety of findings, many of which stem from the fact that domestic technologies are not "owned" by an individual. Many are governed by household rules that determines who uses what device, when, where, whether they pay, how old they are, and for what purposes. For example, in their study of set-top box use in various homes, Hughes et al. [21] describe a relationship between technology use and space "ownership" within the home. They observed that occupants used technologies such as the television to indicate that they controlled behavior in that part of the home. They found that others knew and respected these routines. When occupants had conflicts over television use, they settled disputes by buying another television or making the current one more mobile. Finally, they observed that the television accommodates multiple usage requirements by making it possible for different occupants to watch their own programs [21]. Video and TiVo technologies make the television even more accommodating. Television and its associated technologies fit into the home by being portable and flexible to occupants' requirements. Our study of wireless text messaging in the home shows how devices are used and shared. We found that the teenagers used text messages to arrange times to talk on the landline phone or use the computer to Instant Message [22]. Since both the phone and the computer were shared devices in their own homes and their friends' houses, teens used a technology that they individually owned to coordinate times when they all had access to those shared devices. We also found that teenagers used "quiet" technologies such as text messaging to avoid disturbing the routines of other people. Quiet technologies do not ring or require voice interactions. Text messaging was quiet, and consequently allowed the teenagers to communicate without other household members being aware of or disturbed by the interaction. In this case text messaging meets the requirements of its users as well as those who are not using it but are sharing the same space. In summary, smart technologies and indeed *any* technologies will be disruptive to the home environment. Predicting these disruptions is difficult. The challenge for designers, then, is to pay attention to the stable and compelling routines of the home, rather than external factors, including the abilities of the technology itself. These routines are subtle, complex, and ill-articulated, if they are articulated at all; thus, there is a great need for further studies of how home occupants appropriate and adapt new technologies. Only by grounding our designs in such realities of the home will we have a better chance to minimize, or at least predict, the effects of our technologies.

4.5 Social implications of aware home technology

[17] Have addressed the social implications of ubiquitous computing, privacy in particular. We believe this focus is very appropriate, since privacy is important. However, we believe that there are other broad social implications of domestic technologies which are not as widely explored by members of the ubiquitous computing community. Studies illustrate other potential consequences of domestic technologies, and we focus on two of these: "labor saving" and good parenting. Some historical studies have challenged the belief of technologies as being labor saving devices. The washing machine is one of those technologies. The washing machine was pitched as a labor saving device, and even though initial models did not go through a cycle automatically or spin-dry, they did reduce the labour of wash day. Over time, these devices changed society's expectations about what things would be done, how often, and by whom. Indeed studies of domestic technologies do not show conclusively that work was reduced; more significantly, some suggest that the amount of unpaid work in the home done by women rose dramatically [23]. The washing machine encourages us to take a critical perspective on whether smart home technologies are "labor saving" or whether they, like other devices already at home, merely shift the burden of work. Who will do that work and why? Other studies show how technologies do not just affect occupant-users, but can be-come part of broader national debates. Studies of the television and mobile phone show that these devices have influenced how many parents think about "good parenting" [21], [24]. With television, good parenting discussions focus on how much and what kind of programming children may watch. The mobile phone appears to be taking a similar role, particularly in countries that have high rates of mobile phone adoption among teenagers and pre-teens [24]. There, "good parenting" emphasizes two values of mobile phones. First, giving children mobiles helps them learn how to manage bills and money. Second, mobiles allow parents to safely give children increased independence. As others have noted, smart homes have privacy implications. However, privacy is just one of several social implications of domestic technologies.

4.6 Reliability

Vital concern of occupants (developers) of smart home technologies is reliability. The range of domestic technologies present in the home today i.e., televisions, telephones, washing machines, microwave ovens are by and large, exceedingly reliable, even though these are devices of great complexity. A modern digital television set-top box, for example, contains a number of specialized microprocessors devoted to high-bandwidth decompression, cryptography, rendering, and network communications back to the service provider. And yet, these devices virtually never crash, unlike our desktop computer systems. Achieving expected levels of reliability, especially when coupled with the ad hoc accretion of devices that may be expected in smart homes, is a great challenge. Dealing with that challenge depends on understanding the reasons that these devices are so much more reliable than "traditional" desktop software systems. Some of these reasons include differences in: development culture, technological approaches, expectations of the market, and regulations. The development cultures of domestic technologies differ widely from those of desktop, general purpose computing systems. Embedded systems developers have tended to be much more wary of systems crashes, since it is unwieldy to patch or upgrade a device in the field. A washing machine vendor, for example, would likely fold if it had to recall its products for upgrades as often as traditional software vendors issue patches. Of course, reliable software systems do exist. These kinds of systems give us in-sight into how much work it may take to make reliable ubiquitous technologies for the home. Telephone switches illustrate this well; for example, Lucent Technologies 5ESS maintains its reliability goal of 99.9999% (less than 10 seconds of downtime a year) [25]. Meeting this reliability goal means that regular upgrades, such as the ones that provide occupant-users with new services, must be performed while the switch is processing other calls. In other words, this reliability requirement manifests itself within the system architecture. Other parts of the system work on monitoring events that could lead to downtime and either fixing them or reporting them as appropriate [25]. Designing for reliability requires devoting substantial time and resources that will affect the system architecture. Practices such as these must be integrated into the development cultures that will build smart home technology. In the technological approaches, the current connected domestic technologies and its bulk of functionality is placed in the *network*, not in the device itself. In the telephone system, for example, the telephone itself is the least complicated part of the system. And yet it provides access to new functionality available through the network without an upgrade or patch. Digital television systems, likewise, place the bulk of functionality in the network, rather than the client-side device. This is a "utility" approach, in which the client technologies are shielded from upgrades and enhancements in the network, and yet can take advantage of new functionality when available. It is significant to note that embedding intelligence in the network is precisely counter to many of the approaches taken by developers of Internet-based technologies, in which most intelligence resides at the edges of the network. For ubiquitous computing applications, one design challenge will be determining what kind of balance of intelligence to maintain between the edges and the center of the network. Additionally, the technological approaches taken by designers should account for the need to degrade gracefully. By this we mean that if a component in a richly inter-connected system fails it should not bring down the rest of the system. Traditionally, systems have achieved the ability to degrade gracefully through redundancy for example, data and services are replicated and available on multiple machines. Such an approach may, however, trade off against the goals of simplicity, intelligibility, and ease of administration, which are all requirements for domestic technologies. How to address this tension is a challenge for system designers. For the expectations of the various marketplaces, consumers expect that their appliances will not crash (they have, unfortunately, developed a tolerance for crashes in general purpose computing systems). It is the reliability of so many technologies that has allowed the consumer to actually forget about them as complex technical entities. One hardly thinks of administering the phone or configuring the television. Instead, in large part these technologies blend into the home and become part of the fabric of the home. Crashing phones or televisions would be unwelcome in this setting. Finally, there are differences in regulation. While the home, as [26] say, is a "free choice environment" for its occupant-users, it is a highly regulated environment for those who provide services into that space. In many Western countries the various utilities that service your home are obligated to deliver a certain level of service, or face regulatory punishments. Insurance companies may demand to see certain levels of safety (such as building upgrades, seismic retrofitting, electrical system changes, and so forth) before they will insure a home. In addition to this *de jure* regulations are *de facto* standards for the home. All these differences have contributed to services being reliably delivered into the home. Bringing the benefits of ubiquitous computing into such environments may involve creating a development culture that can produce reliable devices consistently, making design choices about how to handle intelligence at the edges of the network robustly, meeting expectations set by other devices, and working toward regulations and standards set by a multitude of agencies. This challenge extends beyond the research community to those who develop, deliver, regulate, and consume these new services.

4.7 Inferences in the presence of ambiguity

Systems in which machine processing is used to control or assist human behavior have a long and less-than-storied track record in the history of computer science. Examples of such systems come from domains as disparate as workflow tools that force users into formal patterns of work [27], and more recently Clippit, the Microsoft Office Assistant, which attempts to intuit the actions of a user and offer help. And yet, much of the literature of ubiquitous computing depicts machine inference of human state and intent as being a crucial factor in the benefits such environments will bring. Intelligence in such a world can take a number of forms, some of which make greater assumptions than others. Some of the more obvious of these include:

- The environment can interpret the meaning of sensor data to reflect some state of the world. For example, the system might assume that I am in a room because my active badge is in a room.
- The environment can infer that some state exists by aggregating a number of other factors. For example, if a number of people are gathered together in a meeting room, the system might assume that a meeting is taking place.
- The environment may attempt to infer my intent from its view of the state of the world. For example, the system might assume that because I am in a meeting, I might want to share my meeting notes with others in the meeting.
- Finally, the system may preemptively act on assumptions of intent. For example, if the system assumes I may want to share my meeting notes, it may go ahead and make those available to other meeting participants (or ask me if it should do so).

All of these modes of intelligence can be found represented in the literature of ubiquitous computing (see [28], for a similar categorization). And all are subject to error, of varying degrees and types. For example, the simple sensing case may report that I am present in a room when, instead, I have simply left my active badge on the desk. These are what might be called "phenomenological" problems—do sensors reflect reality or merely the state of the sensors and can, in all likelihood, be largely overcome by more and better sensor technology (although perhaps at a cost of privacy and user control). And—perhaps more importantly—the cost of incorrect inferences is low if the system does little with the inferred information. More dramatic problems become apparent as uncertain inferences and decisions are compounded. Most troubling is the attempt at inferring some internal human intent and then, perhaps, taking action on it, especially when such an inference is based on layers of ambiguous interpretation and input, or requires a level of intelligence that even humans would find difficult. Our challenge, then, is to discern what functions of the smart home are possible with limited inference, which are possible only through inference, and which require an oracle. The first category comprises good candidates for implementation, since limited machine interpretation means that there is limited possibility of error. The third categories, systems that require omniscient understanding of human intent in order to function well, are perhaps better abandoned. The middle category, we feel, is the most interesting, and presents important problems in design and technology. Systems that rely on inference will never be right all of the time, and thus users will necessarily have to have models of how the system arrives at its conclusions. These models must not only concern themselves with the actual rules of inference ("when people gather in the living room, display the television schedule"), but also the capabilities of the system's sensors ("how does the system know I'm in the living room in the first place?"). Users must know what to expect from their homes in the same way that, say, a user knows that dropping temperature outside will cause the thermostat to turn on the heating [29]. Such predictability depends on: The systems expected behavior in the face of this condition is known, the system's facilities for detecting or inferring this condition are known and Provision is made for the user to override the system's behavior. Achieving these three conditions is more complicated when the inferences made by the system are more complex, and when even basic sensing is unreliable or open to interpretation. The challenge for smart home designers is to create systems that ensure that users understand the pragmatics of sensors, interpretation, and machine action as well as they understands the pragmatics of devices in their homes now. From a technical perspective, the challenge of developers is to ensure that ambiguity is not hidden from the parts of the system (or the users) that need access to it, and to ensure that inference when performed at all is done in a way that is predictable, intelligible, and recoverable.

5. Concerns

The power ubiquitous computing promises carries with it significant risks. One such risk is associated with the amount of privacy that must be sacrificed to see the benefits of truly helpful computers. Another is that early; "bleeding edge" applications of ubiquitous computing will turn out to be more ambitious than effective, leading some to prematurely conclude that the idea is a failure. We address each of these concerns below.

5.1 Privacy issues

The more software tracks users, the more opportunities exist to trample on their right to privacy. To some degree, these issues are already being argued in the contexts of corporate e-mail snooping and the use of IT software that can track user activity down to the level of individual keystrokes. However, factoring in the idea of software that can track and act upon a user's physical presence and form of activity leads to privacy concerns of a magnitude beyond those currently debated. The privacy implications of ubiquitous computing implementations must always be accorded the most careful consideration. Without powerful standards surrounding user privacy, the future world of ubiquitous computing may very well shift from one of ease and convenience to one where each of us has an inescapable sense of being watched, at best, and no control over our personal information, at worst. Such prospects are clearly far from desirable.

5.2 Growing pains

Systems that can act as subtly as those described will not come without a substantial developer learning curve. As system developers learn from their mistakes, there will undoubtedly be at least one premature declaration that truly ubiquitous computing is an impractical ideal and that the interim efforts are too riddled with problems to be usable. We cannot guarantee that ubiquitous computing will fulfill its promise. However, we would argue that it *ought* to do so, based on the strong trend we have observed toward more powerful, more usable software. Usability is definitely a recognized goal in software design, and much has been learned to make new software even unique, new applications very easy to use.

6. Discussion

The promise of ubiquitous computing is of a life in which our endeavors are powerfully, though subtly, assisted by computers. The idealistic visions painted by the ubiquitous computing movement stand in stark contrast to what we see when we boot up our computers each day. There is an immediate barrier because you have to know how to use a computer to use a computer. If you sit down in front of a computer without knowing how to use a mouse, you will not be able to get anything done. The computer won't help either, one have to know how to use the computer to ask it for help on how to use it! When computers do offer assistance, it still tends to fall short of the mark. Much application software tries to cater to new users and power users alike by offering simple, task-focused "wizards" and detailed help systems.

Unfortunately, the wizards are often too limited to offer sufficient power for day-to-day use, and the help systems often don't cope well with the many ways in which a user can express a need for a given piece of information. The next step, of course, is to go down to the local bookstore and buy a book that promises to give straightforward instruction on how to use the program in question. Most of us get by just fine on the tasks we are well-used to performing. However, there *should* be an easier route. We are still a long way away from seeing the promise of ubiquitous computing fulfilled. Yet, physical barriers to ubiquitous computing are falling, thanks to technological advances such as nanotechnology and wireless computing. Further, as we have argued, software is getting easier to use all the time. As the themes of context-awareness and natural interaction are adopted by hardware and software makers, we will begin to see successive approximations of ubiquitous computing as illustrated in Figure 3.

Figure 3: Ubiquitous Computing Environment for the Future

There are many issues to resolve and a steep learning curve to face as we consider this close integration of computers into our lives. Computing power doubles about every two years, and an equally rapid performance increase applies to other important technological parameters such as storage capacity and communications bandwidth. This continuing trend means that in the foreseeable future, computers will become considerably smaller, cheaper, and more abundant. Computing will be ubiquitous. In particular, we can expect tiny processors and sensors being integrated into more and more everyday objects – household appliances, toys, tools, but also such mundane things as pencils and clothes. All these devices will be interwoven and connected together by wireless networks. There are, of course, some important challenges that need to be addressed when building such an "Internet of everyday items." Highly scalable software infrastructures and new interaction paradigms are just two examples. A world filled with smart and interacting everyday objects offers a whole range of fascinating possibilities. Some foresee a future where computers, functioning invisibly and unobtrusively in the background, serve people in their everyday lives, freeing them to a large extent from tedious routine tasks. But will technology make people happier? Since ubiquitous computing will pervade almost every aspect of our lives, possible economic consequences, but also social aspects such as privacy, will become issues of prime importance. Ubiquitous computing clearly has the power to change the world! Promoters of ubiquitous computing hope that embedding computation into the environment and everyday objects would enable people to move around and interact with information and computing more naturally and casually than they currently do. One of the goals of ubiquitous computing is to enable devices to sense changes in their environment and to automatically adapt and act based on these changes and preferences. Ubiquitous computing is considered to be virtual reality turned inside out. Virtual reality invites the user into the computer and part of a world beyond mediation. Ubiquitous computing forces the computer to live in the world with people. Everything is a medium because everything is or contains a computing device [30]. Other terms for ubiquitous computing include *pervasive computing*, *calm technology [31]*, *things that think* and *everyware* [32]. Some enthusiasts of ubiquitous computing imagine a world of wearable computers that could be placed in watches, hats, belts, and shoes. There are some who are in favor of having microchips placed everywhere throughout the environment, even inside of human bodies for medical purposes [30]. some systems of ubiquitous computing, especially wearable computers, carry with them the possibility for total surveillance [30]. This brings up many areas of concern, especially the issue of privacy [33].

7. Conclusion

As Weiser Mark described in his seminal article [34], ubiquitous computing is about interconnected hardware and software that are so ubiquitous that no one notices their presence. This will enable people to focus on their tasks and on interacting with other people. This far-reaching vision is still far from our reach [35], and will require fundamental advances in semantic modeling, context-aware software infrastructure, application modeling and tools, and user experience validation. We need major advances in each of the challenge areas we identified (as well as in others we have not mentioned). Most important, all these advances must be integrated in a seamless manner into our life so that we can use them without constantly worrying about either the underlying mechanics or social appropriateness. The future holds exciting prospects indeed, and the ubiquitous computing revolution is still in its infancy. Changes in human and technical activities become revolutions in as much as they lead to solutions of the problems of the present and the future. As we cope today with the menace of computer crimes, abuses of privacy, and threats of depersonalization, we are learning to apply these solutions to the larger, more complex problems promised by the decades ahead. The assertion that all human knowledge is encodable in streams of zeros and ones- philosophically, it is very hard to swallow; there is a whole world of real problems, of human problems, which is essentially ignored. At the inception many people share a computer through Mainframe computing, in the present many computers are beginning to share each of us, in the future computers will be more enhanced to share each of us without being aware through the ubiquitous computing. The internet has deeply influence the business and practice of ubiquitous technology by bringing together elements of the Mainframe era and PC era with client-server computing on a massive scale with the web clients. The future belongs to the problem-solvers, to those people who are able to combine knowledge and action in creative efforts to improve the quality of life for all.

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