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7-12-2008

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芽|Sprouts Working Papers on Information Systems ISSN 1535-6078

Ubiquitous Computing: Surfing the Trend in a Balanced Act

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Abstract
Ubiquitous computing often presented as a third wave of computing, a departure from its predecessorsâ mainframe and personal computing. We examine this claim and argue that ubiquitous computing is not a departure from traditional computing but rather an evolutionary and natural step, which is in-sync with the global trends influencing the development of information technologies. Using two interrelated analytical prismsâ megatrends and equilibriums, this paper provides a new point-of-entry for understanding ubiquitous computing from a perspective that accounts for human nature and the technology they use. We demonstrate that, together, megatrends and equilibriums provide a foundation for understanding information systems, and in particular ubiquitous computing systems. As an illustration, we provide systems architects and mangers with a set of four megatrends and another set of four equilibriums, which must be understood to better develop, implement, and manage ubiquitous computing environments.

Keywords: Ubiquitous Computing, Information Systems Evolution, Computing Trends

Permanent URL: http://sprouts.aisnet.org/3-19

Reference: Avital. M., Germonperz, M. (2003). "Ubiquitous Computing: Surfing the Trend in a Balanced Act," Case Western Reserve University, USA . *Sprouts: Working Papers on Information Systems*, 3(19). http://sprouts.aisnet.org/3-19

Ubiquitous Computing: Surfing the Trend in a Balanced Act

Prologue

Once upon a time, in a kingdom not far from here, a king summoned two of his advisors for a test. He showed them both a shiny metal box with two slots in the top, a control knob, and a lever. "What do you think this is?"

One advisor, an engineer, answered first. "It is a toaster," he said. The king asked, "How would you design an embedded computer for it?" The engineer replied, "Using a four-bit microcontroller, I would write a simple program that reads the darkness knob and quantizes its position to one of 16 shades of darkness, from snow white to coal black. The program would use that darkness level as the index to a 16-element table of initial timer values. Then it would turn on the heating elements and start the timer with the initial value selected from the table. At the end of the time delay, it would turn off the heat and pop up the toast. Come back next week, and I'll show you a working prototype."

The second advisor, a computer scientist, immediately recognized the danger of such short-sighted thinking. He said, "Toasters don't just turn bread into toast, they are also used to warm frozen waffles. What you see before you is really a breakfast food cooker. As the subjects of your kingdom become more sophisticated, they will demand more capabilities. They will need a breakfast food cooker that can also cook sausage, fry bacon, and make scrambled eggs. A toaster that only makes toast will soon be obsolete. If we don't look to the future, we will have to completely redesign the toaster in just a few years[2]."

In our methods of design and research there is a tension similar to the one raised by the engineer and the computer scientist. The "truth" of the mechanical representation is often sought at the expense of the "truth" revealed in the socio-technical facets of our subject of inquiry. This essay aims to shed light on the socio-technical environment of ubiquitous computing.

Introduction

Ubiquitous computing is an emerging branch of computing where networked devices are seamlessly imbedded in the background to serve preconfigured as well as emergent purposes. These devices are designed to blend into people's physical surroundings and are engineered to support work practices and routine activities within and across boundaries. From a technical perspective, ubiquitous computing refers to a coordinated array of task-oriented computing devices that operate semi-independently in net-centric environments enabled by wireless and mobile technologies. This new breed of computing is based on architecture that is not tied to personal devices but instead moves into the fabric of life.

Ubiquitous computing emerged over a decade ago and has recently gained momentum with the development and diffusion of wireless networks and mobile services. It is often presented as a third wave of computing, a departure from its predecessors—the mainframe and

[2] Adapted from unknown internet hero (http://www.rahul.net/alange/humor/019-toaster-cs.html)

personal computers. We argue that ubiquitous computing is not a departure from traditional computing but rather an evolutionary step which is in-sync with trends influencing the development of information technologies. We also assert that ubiquitous computing complements personal computing, and each should be treated as artifacts of opposing socio-technological forces. Consequently, this essay suggests using two interrelated analytical prisms—megatrends and equilibriums, as a new point-of-entry for understanding ubiquitous computing from a holistic perspective.

Megatrends

The prism of megatrends (Naisbitt 1982) provides a dynamic context in which we can make sense of particular social phenomena and the evolution of manmade artifacts. Ubiquitous computing can be understood in the context of the great socio-technological trends that power the information age. Four megatrends that provide context to ubiquitous computing are proposed here.

Convergence and Mobility of Services

The internet has provided a taste of media and communication convergence, and has already subsumed a host of media and communication channels. Both the selection and market share of internet-enabled services are continuously increasing. Another phenomenon that is taking place is the growing demand for mobile and wireless services. It started with the explosive growth of mobile phone services, and has continued with strong demand of SMS messaging and Wi-Fi networks. The marriage between the internet and broadband wireless access to provide unfettered high-speed connectivity to a diverse array of services and information seems to be the natural next step. Increasingly ubiquitous always-on broadband wireless access services have provided users with instant connectivity to the internet-enabled rich resources regardless of where they are.

Traditionally, computing has relied on disparate systems through which individuals interact and actively seek services. These were islands of computing within a larger infrastructure. Ubiquitous computing can help remove the barriers between disparate systems and support a convergence between systems and technologies. For example, in this environment, communication systems are coordinated with calendaring systems and data is defined to an individual and not a single system.

Support of mobility is essential as users move across organizational borders and through heterogeneous computing infrastructures. In a ubiquitous environment, mobility transcends the ability of an individual to move within a single computing environment, instead representing movement across various computing systems. Mobility embodies a seamless transition from one protocol to another, from one procedure to a new, or from one system to a subsequent.

Ubiquitous computing can contribute to a greater convergence and mobility of services. Managers and designers of such devices and applications can treat ubiquitous computing as another way to enhance and extend convergence and mobility in various contexts.

Tailoring and Customization

Off-the-shelf software applications such as Windows, Office Suites, and even ERP applications, dominate the market because they provide a cost effective solutions to recurring tasks performed by many people in many organizations. However, given their generic nature, the tasks for which these applications are designed are not well defined in advance. Turning genericly packaged software into an effective application requires that users are able to adapt the software so it fit with their particular demands and work practices. Therefore, system designers must build applications that can be extensively tailored, and users must understand how to fine tune the default configuration.

Technology tailoring represents user defined modification of a computing system in the context of its use (Morch and Mehandjiv, 2000). Ubiquitous computing is likely to have a twofold contribution within this use context—it can make the tailoring process less user-defined and it can provide new and unique ways to customize systems. Traditionally, tailoring is characterized by modifications at either the presentation or functional layers of a computing system. Ubiquitous computing can enhance tailoring by allowing users to continually redefine the services they need to address an infinite number of usage patterns within an environment. Ubiquitous computing enables user-defined customization of the presentation and functional layers of an individual's computing spaces as uses cases vary. Additionally, ubiquitous computing supports indirect, system-identified customization as users change their daily patterns, interactions, and queries to allow for load balancing and access to relevant data. As users directly define how data is presented and what functional services are accessed across boundaries, a ubiquitous computing environment must support this as well as the indirect tailoring required as users move across technological boundaries.

Managers and designers of ubiquitous computing devices and applications can treat ubiquitous computing as another way to enhance and extend tailoring and customization of systems during their use.

Computing Independence

With advances in computer technologies, machines become increasingly independent of human actors. Computer technologies become less dependent on human initiation and management, and more capable of engaging humans and discovering other computing services that can assist ubiquity. Computing technologies move from the forefront of our daily activities to the background and the emergence of ubiquitous computing is one manifestation of this trend.

So far, computing at any social level revolves around stationary and semi-stationary, physical objects through which users interact with computational logic, communicate with individuals, or send and receive data (e.g., desktop computer, notebook, etc.). Binding a “work station” to people places limits on the pervasiveness of any system. However, ubiquitous computing pushes the envelope of computing by disengaging the cord that binds computational objects and users.

In a “work station” environment, the relationship between users and computers is initiated through user established communication. That is, interactions between a user and a computer are established through user defined channels of communication (Suchman, 1987). Reliance on user established communication tilts the balance of power in the user-computer relationship towards the user. However, in ubiquitous computing the balance of power and subsequent responsibility evolve such that computers are as capable of opening communication channels as users. As computing becomes woven into the fabric of daily life, the establishment of communication becomes a two-way process between humans and computers.

Managers and designers of ubiquitous computing devices and applications can treat ubiquitous computing as a way to transform user-computer relationships. As information technology matures, it should be designed to be less dependent on humans' ongoing instructions and be more responsive and proactive in its own right.

Technologies as Disposable Artifacts

Our patterns of computer use and data generation are becoming not just portable but also technology independent. Seamless integration not only means free flow across platform boundaries, but also a frictionless migration path from current to future versions. Effortless migration paths make both hardware and software artifacts disposable like an old pair of sneakers.

Mobility across heterogeneous computing systems and customization in the support of changing use patterns requires the separation of data from the technology through which it is presented. If there is tight binding between the data and a technology interface, passing the data from one device to another becomes difficult. Ubiquitous computing provides the growing demand for a high level pervasiveness and the unbinding of data and technology. Placing restrictions on which technologies have access to which data demands that users attend to particular technologies to gain access to particular data, bindings that are currently present in the "work station" model of computing. Binding data to technology subjects the data to life cycles of technology—a condition expected to limit the pervasiveness of a system. Therefore, unlike technology, data is unlikely to recede from the visible to the invisible; instead it maintains high persistence throughout the environment.

As computing moves to the background of daily life, and various technologies are abandoned and replaced, managers and designers of ubiquitous computing devices and applications can treat ubiquitous computing as another step in the way to achieve data independence or disjoining data and technology artifacts.

Equilibriums

In our days everything seems pregnant with its contrary, said Karl Marx (1856) in a dialectic fashion. The equilibrium prism explains co-existence of conflicting phenomena by treating them as a dynamic steady state in which both are necessary to maintain a balancing act. For example, life can be understood as a balance between chaos and order, social order as a balance between the common good and individual interests, and price as a balance between supply and demand. Just as megatrends provide a dynamic context to model flow and evolution, equilibriums provide a dynamic mechanism to model status quo.

In the previous section, we discussed how the movement towards ubiquitous computing is in sync with the governing megatrends and long waves powered by strong socio-technological undercurrents. Now, we would like show how ubiquitous computing can be also understood as a counterbalance, not a replacement, for traditional computing. We envision the potential impact of information technologies in the context of yin-yang socio-technological forces and assert that ubiquitous computing devices can harmonize the impact of traditional computing on our lives.

Virtual vs. Physical

We live in both physical and virtual worlds. With the evolution of computer and network technologies many activities have expanded from the physical world to technology mediated or virtual worlds. For example, trade has been moved in part from market squares to emarketplaces, many group discussions stirred away from conference rooms to online sessions via collaboration software, and most of our letters turned to emails. With the transformation of social norms and work practices, we are forced to migrate many of our daily routines into virtual worlds.

Nowadays, we spend significantly more time in virtual worlds. We also move frequently back and forth between the two worlds. The realities described in Life on the Screen (Turkle, 1995) and Virtual Communities (Rheingold, 1993) have become the rule not the exception. Historically, the demarcation between the two worlds was clear—we referred to the tangible world as physical, and to the imaginary and metaphysical as virtual. However, the proliferation of personal computers and internet technologies has blurred this boundary, altering the balance between the physical and the virtual.

Managers and designers can treat ubiquitous computing devices and applications as artifacts that counterbalance the pressure to migrate into the virtual and help reverse the erosion of the boundary around the real. While ubiquitous computing provides many of the benefits associated with information and communication technologies, it does not come at the expense of genuine interaction with people and tangible materials.

Transparency vs. Opaqueness

The proliferation of the internet and ERP systems has made information widely available. In fact, information transparency and availability have been one of the main driving forces of these systems. Information transparency provides personal convenience, enhances process control, and allows for equitable treatment. At the same time, however, it may also reveal impartially private information, facilitate the creation of undesirable dossiers, and subject us to unsolicited interruptions.

The movement of computing and data into the background of daily life is likely to shake once again the balance between transparency and opaqueness of information. The support of new and unanticipated tasks in a ubiquitous computing environment will require making public much information that is considered private in today's standard. For example, in many scenarios of pervasive computing environments one's whereabouts must be tracked continuously. This practice is quite appalling for most people. At the same time, a pervasive computing environment can facilitate concealing some information that we have to disclose reluctantly today. For example, revealing our social security ID number.

With new opportunities come new risks. Data in a ubiquitous environment is seamless just like the technology that supports it. As individuals move across heterogeneous environments, the delicate equilibrium between transparency and opaqueness of information must be carefully considered by managers and designers of ubiquitous computing devices and applications. This requires all parties involved to rethink and redefine the norms and behavior concerning issues such as being reachable vs. being interrupted, being public vs. being private, or being open for scrutiny vs. being confidential.

Specialization vs. Multi-Tasking

We have already discussed the emergence and dominance of generic software applications that provide cost effective solutions to recurring tasks performed by the masses. Whereas the evolution of programming and hardware led to the development of generic multi-purpose platforms (e.g., Windows and personal computer), it also contributed to the development of numerous limited-purpose devices designed to perform a specific task (e.g., chips in carburetors or climate control units). The proliferation of ubiquitous computing will rattle the balance between these two brands of computing.

Dating back to early days of computer programs and subroutines, recurring questions often revolved around how specialized computers and their programs should be. The more specialized the program the greater reuse that the program supports as it can be called as a subroutine as part of a larger program. The less specialized that a program was, the more centralized the computing rules were and the easier the program was to maintain. Movement into a ubiquitous computing environment demands the same attention to specialization and multi-tasking, not at the programmatic level, but at the level of the computing device.

In a ubiquitous environment, specialization enables flexible interaction between devices so that patterns of human-computer interaction can be supported and disbanded across heterogeneous environments. As users turn towards system-identified usage patterns, system-defined tailoring in support of these new patterns and a disengagement of data and technology the need for specialized computing devices increases. Multi-tasking computing provides an all-in-one computing approach, requires a greater amount of direct human to computer interaction, and tightly binds data with technology. The balance between specialized and multi-tasking computing devices is essential as users disengage from traditional ways of computing and weave technology into the fabric of their life.

Managers and designers of ubiquitous computing devices and applications should pay careful attention to the intended and unintended consequences of the shifting equilibrium and relationships between these two breeds of computing. Specialized devices will likely exist to support the ubiquitous computing movement and how this balance is struck requires attention to how a ubiquitous environment is built, distributed, and managed. Further consideration should be given to related trade-offs such as issues of simplicity vs. complexity, breadth vs. depth, concurrency vs. simultaneity, and space sharing vs. partitioning.

Tool vs. Device

Tools are instruments that require skill to operate; devices are designed to be pretty much self-operated. We appreciate beneficial devices but respect tools and the virtuosos who command them. Tools are central in the evolution of mankind and have been at the center of all technological-based revolutions since the Paleolithic Age. Consequently, during the Information Age revolution we learned to appreciate and respect computer-enabled tools, and often attributed our success to having the right computational tool at the right time to provide competitive advantage (mainframe computers, networks of all sorts, ERP systems, databases, and the like). History taught us that the winners were those who took an active position and avoided a reactive position with respect to understanding tools as well as those who took control and guided innovatively their unfolding use situations. Interestingly, we have been captive to the perception that computing tools must be controlled and guided by humans.

Ubiquitous computing can potentially allow us to take a break from this rooted perception. Just as we learned to buy tomatoes in the marketplace rather than grow our own, we need to learn to spend less time managing our computers. Spending less time guiding computer-enabled tools can free human resources to deal with what we are really needed for—creative thinking, social interactions, and expeditions into the unknown.

Disturbing the tool-device equilibrium in respect to computer-based tools by treating computational tools as devices that function as an apparatus to serve a predefined-specialized purpose is one more challenge of managers and designers of ubiquitous computing devices and applications. One can clearly benefit from ubiquitous computing devices and may even be instrumental in their configuration, but ultimately these devices should be transparent, intended to serve in an invisible fashion. Computational devices define the technological basis for a ubiquitous computing environment and through the collection of these devices a ubiquitous environment is formed. From a managerial perspective this requires also the identification and management of individual devices and an ability to recognize how these devices are integrated and used.

Discussion and Implications

Ubiquitous computing is driven by the new possibilities made available by technology and by attempts to provide new solutions to old problems. Whether supply-driven or demand-driven, often ubiquitous computing has been implemented sporadically in an opportunistic fashion with little regard to the greater context of our socio-technological realties. We offer a new perspective toward designing and implementing ubiquitous computing architectures – using the interrelated prisms of megatrends and equilibriums. We suggest that rather than relying on a parochial approach, which focuses solely on cause-effect, we should adopt a systemic view rooted in the larger whole.

We demonstrated that, together, megatrends and equilibriums can provide a foundation for understanding information systems in general and ubiquitous computing systems in particular. As megatrends emerge, they are often opposed to traditional ways of thinking resulting in a new equilibrium state for a particular trend. Likewise, out of equilibriums, singular trends will often emerge that largely dominate a specific way of thinking. In a cyclical sense, these new trends that have emerged from the balancing act of equilibrium states will be subject to new ways of thinking, resulting in a new equilibrium (Figure 1).

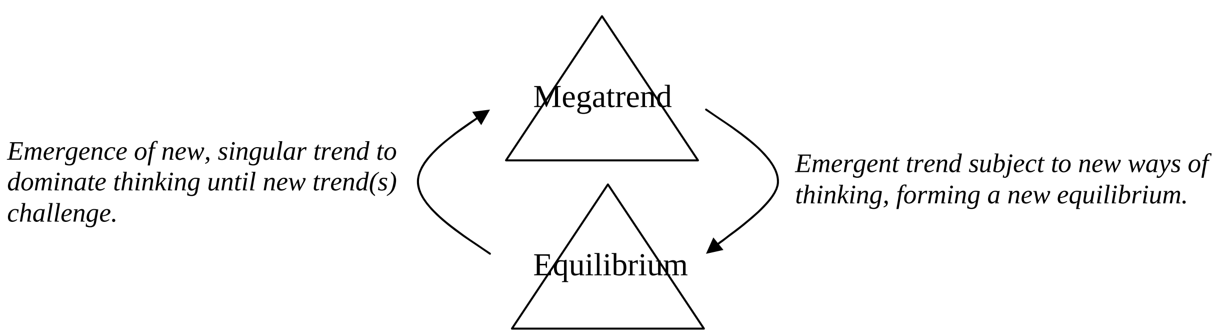

Figure 1. The recursive relationship between equilibrium and megatrends

This essay has provided a new point-of-entry for understanding ubiquitous computing from a holistic perspective. In addition, the essay has provided systems architects and mangers a new way of understanding ubiquitous computing environments by suggesting two sets of four "baseline" megatrends and equilibriums that must be understood to better develop, implement, and manage ubiquitous computing environments.

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Working Papers on Information Systems | ISSN 1535-6078