The visible problems of the invisible computer:
A skeptical look at information appliances

Andrew Odlyzko
AT&T Labs - Research
amo@research.att.com

Revised version, September 7, 1999.

Abstract

The future is said to belong to information appliances, specialized and easy to use devices that will have the car tell the coffee pot to brew a cup of coffee just in time for our arrival home. These gadgets are supposed to eliminate the complexity and resulting frustrations of the PC. The thesis of this essay is that while information appliances will proliferate, they will not lessen the perception of an exasperating electronic environment. The interaction of the coffee pot, the car, the smart fridge, and the networked camera will create a new layer of complexity. In the rush towards the digital era, we will continue to live right on the edge of intolerable frustration.

The paradox of information appliances is that while they are presented as products for a mature market, their main effect will be to unleash a tidal wave of innovation. When technology changes rapidly, greater ease of use serves to attract more users and developers, creating new frustrations. The most we can do is ameliorate the spread of the information appliance products and services. To do this, it appears necessary to recognize that flexibility and ease of use are in an unavoidable conflict, and that the optimal balance between those two factors differs among users. Therefore systems should be designed to have degrees of flexibility that can be customized for different people. It will also be essential to provide for remote administration of home computing and networking.

1. Introduction

The PC is dead. Technology gurus assure us that the PC is passe, and we are entering a new era of computing, often referred to as ubiquitous or pervasive computing. It is to be dominated by information appliances, specialized and easy to use devices that avoid the complexity of the PC. An enthusiastic cover story in *Newsweek* heralded the wonders of the coming new age: "Your alarm clock might ring later than usual if it logs on to find out that you don't have to get the kids ready for school – snow day!"

[Levy]. The most prominent proponent of the post-PC movement is Don Norman, whose influential book, *The Invisible Computer,* presents detailed criticisms of the PC and a vision of an information appliance future.

Even Bill Gates accepts most of the gospel of the invisible computer. He argues that the PC will continue to play a central role, but that it "will also work in tandem with other cool devices," and that we will be able to share our data across different machines in a seamless fashion [Gates].

Are we entering a new era, and is it going to fulfill all the extravagant promises that are made for it? There are reasons to temper our enthusiasm and be skeptical. We can distinguish three main predictions by the advocates of the invisible computer:

(a) There will be a proliferation of information appliances.

(b) Information appliances will eliminate the frustrations of the PC.

(c) The dominance of computing by the PC and Microsoft will end.

My prediction is "yes" on (a), a decided "no" on (b), and a "maybe" on (c). Information appliances will be popular, since they will provide many novel services that the PC is ill-suited for, and will do so in user-friendly ways. However, they will introduce their own complexity, and the level of frustration with technology will not decrease. This is a result of the conflict between usability and flexibility. The human-centered engineering advocated by Norman is feasible, but only when technologies and markets are mature. The information appliance market will be anything but mature for a long time to come. The emphasis in information processing has been, and is likely to continue to be, on development of novel applications. Further, the PC, in spite of its shortcomings, may indeed manage to play a key role in the new era. Arguments supporting these predictions are presented in later sections.

If the level of frustration is not going to decrease, is there any point in developing new technologies, and in paying any attention to ease of use? There certainly is. We will still be frustrated, but at a higher level of functionality, and there will be more of us willing to be frustrated. Just consider the Mosaic browser. It lowered the complexity of accessing the World Wide Web below some magic threshold and drew millions of people onto the Internet. These millions of new users then created new content, which drew in millions of additional users. That is how the Internet graduated from a research toy to a revolutionary tool that is transforming mainstream society. However, we now get frustrated by unreliable servers, network congestion, and stale URLs, problems that we did not worry about just a brief half-dozen years ago.

The main point of this essay is not to debunk information appliances, but to temper the overenthusiastic promises that are being made for them. In Section 7 some suggestions are also made for a smoother introduction of information appliances. It appears essential to develop systems that allow for setting the flexibility at different levels for different users. It will also be necessary to provide for remote administration of home networks by experts, leading to the rise of a new outsourcing business.

2. Information appliances will proliferate

Information appliances are not an overhyped fad such as interactive TV, push technology, or "buddy lists." There is substance to their promises, and the Palm Pilot is just one early example of the devoted following they can acquire. As another example, in "Finland, people are using their Nokias to pay bills, access bus schedules on the mobile-phone display and punch in payment codes for car washes or juke-box tunes" [Levy]. We will want all these services, as well as a variety of others that have not been thought of yet.

Fuller and more eloquent expositions of what information appliances will bring us can be found in [Levy, Norman]. I will mention briefly just two key points. One is that the information appliance is the natural outcome in the evolution of information processing. That is why they were foreseen a long time ago, with the late Mark Weiser the most influential early pioneer. Digital computers started out as expensive mainframes accessible to a few. The next step was the PC that individuals could own. Yet even the PC was for a long time an expensive instrument, and there was seldom more than one per house. Thus it was essential to have as much functionality in the PC as possible. Technology is making feasible small and inexpensive devices that are smart. This helps push the intelligence closer to the people, the ultimate customers.

The second point is that there is already a proliferation of primitive information appliances. The average middle-class American household already has around 40 microprocessors, in cell phones, microwave ovens, self-focusing cameras, and the like. Furthermore, many of these microprocessors are astonishingly powerful. For example, the latest game consoles have more processing power than the supercomputers of a decade ago. However, this power is hidden from the users, who see only a simple interface designed to provide just the basic functionality the device is designed for. Thus the "invisible computers" are already with us in large numbers. What is still lacking is the pervasive communication system that will link them together.

3. The visible problems of the invisible computer

The central paradox of information appliances is that they are aimed for a mature market with a mature technology, but their wide spread will ignite an explosion of innovation that will destroy any stability that might exist. Don Norman argues in his book *The Invisible Computer* that the PC was aimed at the "early adopters" (in the terminology popularized by Geoffrey Moore [Moore], see also [Rogers]). The next step is to design information appliances for the mass market. He advocates a "user-centered, human-centered, humane technology of appliances where the technology of the computer disappears behind the scenes into task-specific devices that maintain all the power without the difficulties" (p. viii of the Preface in [Norman]).

Norman's vision is certainly an appealing one. His book cites the instructive story of radio. It started out as a complicated device that required much practice from users to obtain even a noisy signal. The user instructions for an early radio reproduced in [Norman] illustrate beautifully how far we have come. Whereas the first radio users had to have the patience of Job, today we can select any radio from among hundreds of models, take it home, plug it into the electric outlet, push some buttons, and listen to our favorite music station. There is great technology inside the radio (technology that keeps improving from one generation to another), but we do not have to know anything about it.

Don Norman would like computers to evolve the way radio receivers did. The problem is that with radio, we know well what we want, since the basic services we desire (such as music, talk shows, and news reports) are well understood and stable. That is simply not what we will see with information appliances, not for a long time. We cannot know how people will want to use information appliances. Note that even the Palm Pilot, beloved of millions of users, and frequently cited as the ideal outcome of the human-centered engineering advocated by Norman, is not stable. Not only is there a succession of new models from its manufacturer, but there are myriads of accessories offered by outside suppliers for wireless communication, control of other devices, and so on.

Even the user-friendly radio that makes such an effective case for Norman's proposals is not likely to remain stable and user-friendly. It is likely to be swept up in the whirlwind of change that information appliances will unleash, since we will want our radios to communicate with our other gadgets.

Thus even from a high level systems view, there are reasons to be skeptical about the ability of information appliances to fulfill all their promises. Next we look at what specifically is likely to go wrong.

4. The inevitable frustrations of information appliances

Careful design that is focused on human factors, and incorporates powerful processors and software, can provide information appliances that are a delight to use. The Palm Pilot and game consoles prove this. However, that does not mean that we will be delighted with the new electronic environment full of such gadgets, even if (and this is a big if) each is excellent by itself. Information appliances are not supposed to be standalone devices. In Don Norman's definition (p. 53 of [Norman]), "[a] distinguished feature of information appliances is the ability to share information among themselves." Information appliances are meant to be "cooperating devices," a felicitous term coined by Bob Frankston. We will want our car to tell our house control system to warm up the family room in time for our arrival, and "the refrigerator [to] know it was low on milk and eggs and place an order with the local supermarket" [Lewis]. Once all the radios, refrigerators, dishwashers, clocks, coffee pots, and other devices in our houses are replaced by new models that are information appliances, the current 40 isolated microprocessors per household may grow to perhaps 400 communicating devices. Will they all interoperate smoothly? They certainly do not do so now. Consider just the difficulty of setting up home networks, even for simple connections of PCs [Lewis]. Similar problems arise in setting up cable modem and ADSL connections. Once the number of devices to be connected increases, and wireless communication expands, the difficulties will increase. No single problem will be insurmountable. However, the range of problems to be solved will be growing rapidly with increasing complexity of the system.

Don Norman recognizes the difficulty this poses (see Chapter 3 of [Norman]) but forecasts that a solution can be achieved through "world-wide agreement on the appropriate infrastructure that will allow appliances to share their information with appropriate other appliances." Bill Gates promises to fulfill that vision, so that "when you buy a new device, you'll know it will function with your existing equipment" [Gates]. Yet will Microsoft deliver, given that it now creates software that does not allow for easy transfer of information from one Microsoft software package on a PC to another copy of the same package on a different PC [Alsop]?

It helps to compare information appliances to programs on a PC. Each application might be delightful to use, but it is the interaction of these applications with each other, and with the operating system, that creates most of the complexity and frustration (cf. [Alsop]). The PC is used widely in spite of its shortcomings because most people rely on just a few applications, and in an application, they usually depend on only a small subset of its features. They thus learn to live with the complexities of the PC by avoiding them. However, those complexities are there. Einstein said that "everything should be made

as simple as possible, but no simpler." Unfortunately we are asking our computers, whether standard PCs or the information appliances of the future, to do complex things. Even if a spreadsheet and a word processor work fine, asking for the ability to bring in a graph from the spreadsheet into the word processor creates a new level of complexity, with more opportunities for bugs.

In the information appliance environment, complexities similar to those of the PCs will also be present, and in many ways will be magnified. After all, on a PC everything is in a single box, and the standard procedure for dealing with problems is to reboot the PC. Will we have to go around the house rebooting the potentially hundreds of information appliances that we might own? Even if we could do it, it might not solve the problem if the difficulty is in interaction with our neighbor's system, or that of our in-laws on the other side of the continent. A small taste of the problems that are likely to plague us is given in [Levy]:

> ... Bill Joy [of Sun Microsystems, a vocal critic of the PC and an advocate of information appliances] offers to print out a paper that illustrates a salient point. He reaches for his laptop, which is equipped with the sort of wireless high-speed Internet connection that, one day, may be a routine adornment in all our cameras, palmtops, game machines, medical sensors and, yes, dishwashers. According to the theory, these will all be linked together, ot course, in an infrastructure that will virtually eliminate crashes and glitches. He keyboards the command to print the document in the adjoining room. And nothing happens. "You know what?" he finally says. "I think this did get printed–on the printer back in my house across town."

The proponents of information appliances promise that technologies such as Bluetooth and Jini will solve the problem. Yet one should be skeptical of whether these promises will be realized. The problem is not necessarily that the technologies are inadequate to achieve the promised goals. Rather, it seems likely that, just as in the past, the computing and communications industry will not concentrate on those goals. Consider again the PC. Graphical user interfaces, object-oriented programming, and Java are just three of the technologies that were supposed to revolutionize computing and make life simpler. Remarkably, these three did succeed and our computing would be much more primitive without them. Still, their main effect has been to create more complicated systems, not to simplify old ones.

Building complicated systems that work is hard. Building ones that work and are user-friendly is much harder. Further, it is necessary to balance the demand for user-friendliness with the demand for

more features. Although most users complain that they want simpler versions of applications such as Microsoft Office, their "responses support Microsoft's contention that while few people use more than a tiny percentage of the programs' features, everyone wants a different 10%" [Wildstrom]. The history of the past two decades shows that when the choice was between new features and ease of use, new features have won. The victory of the PC over the Mac is just one example of this. As Edward Tenner [Tenner] pointed out,

> Microsoft has triumphed because it has given us what we asked for: constant novelty coupled with acceptable stability, rather than the other way around. ... People talk simplicity but buy features and pay the consequences. Complex features multiply hidden costs and erode both efficiency and simplicity.

In the evolution towards the information appliance era, we can expect similar outcomes, not because they are preordained by technology or dictated by Microsoft, but because that is what people are willing to pay for. The premium will continue to be on being first to market with the latest innovation, not on ease of use.

5. The dominance of the PC and of Microsoft

Centralized Web servers are already usurping much of the PC's role. Will information appliances deliver the final blow, and lead to the Post-PC era in which the PC is marginalized, as Microsoft's competitors predict? Or will they lead to the PC-plus era, in which the PC plays a central role, as Microsoft hopes [Gates]? It appears impossible to predict because of uncertainties in both technology and industrial politics.

The complexity of managing the interaction of all the invisible computers could be tamed most easily, at least initially, by using a powerful central processor, a role that the PC can naturally aspire to play. That would also simplify the integration of existing PC software with the new information appliances. On the other hand, the strength of the PC in legacy applications is also a weakness, in that the PC is not well suited for the new distributed environment. This creates an opening for potential rivals such as the Aperios and Epoc operating systems.

If Microsoft concentrated exclusively on the PC, one could easily foresee a future in which information appliances would play the role of a disruptive technology [Christensen]. They would develop in the shadow of the dominant PC, serving new markets, until those markets would dwarf the basic PC

industry. At that stage information appliances would relegate the PC to a secondary role, just as the PC did to the mainframe. However, Microsoft is vigorously pursuing the information appliance market [Gates, Lewis], and may become a rare case of an established player that is nimble enough to change directions. Whether it will preserve its dominant role depends not just on technology, but also on political alliances. There are many other powerful players that are reluctant to concede the leadership role to Microsoft. Thus the eventual outcome will be less a matter of technology than of politics, and is much harder to predict.

The emerging competition between Microsoft and its rivals for dominance of the information appliance market is a bad omen for the ease of use that we are promised. Just as with PCs, victory will go to the camp that gains the allegiance of developers, who will be creating all the enticing new devices and services that will attract customers. Hence the premium will be on making the developers' task easy, not on users' convenience. That was a major factor behind the evolution of the frustrating PC [Odlyzko].

6. The unavoidable tradeoff between flexibility and ease of use

The PC is extremely flexible. In Bill Gates' words [Gates],

[s]itting at your PC, you can do your taxes, surf the Web, write letters, e-mail friends, play games, plan a business, buy a car, do your homework ... in fact, do whatever you want.

A network manager found 350 different software packages on the 1,000 PCs in his company [Jaffe]. Even more remarkable than the variety of applications that run on a PC is that the PC was not designed with them in mind. The basic architecture of today's PC is not much different from that of the early Atari machines marketed to hobbyists. Yet spreadsheets and desktop publishing, the two "killer apps" that propelled the PC to its current dominant status, could run on it. More recently, the rise of the Internet in public consciousness can be dated to the mass distribution of the Mosaic browser. It penetrated as widely and as rapidly as it did because it could be easily installed on millions of PCs that had been acquired for other purposes. The idea of a universal information processing engine, which is what the PC embodies, is extremely powerful.

Unfortunately, as Don Norman says (p. 181 of [Norman])

Computers are general-purpose devices, designed to do everything. As a result, they can't be optimized for any individual task.

That is one difficulty with the PC. Another, related, problem is that in the design of the PC, many choices were made intentionally to make it as flexible and as user friendly as possible. (Yes, paradoxically, it was the desire for ease of use that led to many of the problems the PC is derided for.) Users have complete control over their machines, and can even modify the operating system at will, just by clicking on an email attachment. This model makes any real security impossible. Further, it makes it hard even for experienced computer experts to fix problems (cf. [Alsop]). Thus long-range ease of use has been given up in favor of short-term convenience, in enabling users to modify their machines on the spur of the moment. This is great if you care about rapid diffusion of the next Mosaic, but it leads to frustration when things go wrong, as they often do. To provide stability, security, or transparency requires limiting users' flexibility.

A tradeoff between flexibility and ease of use is unavoidable. However, there is no single tradeoff that is optimal for everyone. Don Norman argues that the PC was aimed at the "early adopters," and that its lack of success in penetrating about half of the households in the U.S. is a sign of its poor design. Popular perception of the PC is certainly one of "infuriating complexity that makes us want to toss our beloved PCs out the window about, oh, once an hour" [Levy]. The success of the iMac is another sign that consumers do value simplicity. Norman argues that information appliances can and should be designed for the mass market. Proper design of simple interfaces, appropriate when a restricted set of tasks is to be enabled, does make this possible.

The problem, as was explained earlier, is that we should not be thinking just of individual information appliances. Those can be made to appear simple through careful design, and in particular by limiting their functionality. We have to be concerned with the whole system, which is likely to be complex. Further, there is no single tradeoff of flexibility versus ease of use that is optimal for everyone. There is not even a single tradeoff that is likely to be optimal for any individual for long. A person learning a new system can usually handle progressively more features. Thus we cannot hope to design information appliances to a single standard. Norman cites the example of the evolution of radio receivers as models of how computers should change. However, there is a substantial difference between radios and computers. We need a much greater variety of computers than of radios. Further, in the networked environment, the full range of information appliances with varying capabilities will have to interoperate.

To appreciate the wide range of computing that we have, and are likely to have in the future, consider open source software. It is often touted as a proof that a viable competitor to Microsoft's

Windows can arise. Yet it seems that that the main lesson to be drawn from the success of Linux and Apache is different. These systems are built by experts to be used by experts. There are many people (although a tiny fraction of the whole population) who know what regular expressions are, and can use text commands to execute programs much faster than a graphical user interface would let them. They also tend to be in charge of important resources such as Web servers, and appreciate (and use effectively) the flexibility that access to source code provides. Apache and Linux are ideal for them. They are not satisfied with the black-box software from commercial vendors. On the other hand, it is doubtful whether those among them who contribute to the code, as opposed to just using it, have the interest in creating the easy to use but much less flexible interface that would appeal to a wider market. That is the province of Microsoft, Apple, and other software companies. (There might be a business opportunity for companies to put simple interfaces on top of Linux for the mass market, though.) These expert users do not account for a large fraction of desktop computers, but do control a a large share of computing budgets. They form a substantial market for computers where flexibility is dominant, even at the cost of ease of use.

At the other extreme, about half of the households in the U.S. still do not have any computer, and often this is because of the perceived difficulty of using current PCs. Further, there are millions of VCRs whose clocks flash 12:00. The owners of these VCRs are ignoring the ability to program video-taping on their devices. This is the standard response of consumers to features that do not provide enough value compared to the hassle of using them. What it means is that information appliances will have to be extremely attractive and easy to use to gain wide acceptance. Further, the full range of users, from the computer experts using open source systems, to the totally non-technical folks, will have to operate within the same communications infrastructure.

7. Customizable flexibility and computing and communications outsourcing

Flexibility does conflict with ease of use and the optimal balance varies widely among users. Further, flexibility is valued even when it is not used. There are millions of VCRs with 12:00 flashing in their clock display because their owners use them exclusively for playing prerecorded tapes, and have not felt the need to set them up for programmed recording. However, play-only units, although less expensive, have had disappointing sales. Being able to record at a moment's notice has significant value. Similarly, there is value in being able to install the next Mosaic on an existing device without hardware modifications.

The problem is how to balance flexibility and ease of use in a way that can be customized for people with different needs. Furthermore, the right balance is likely to vary for different people in the same household. It seems that the only way to solve this problem is through the logical evolution of the approach that is already followed in corporations as well as universities. Almost all such institutions have groups of experts that provide computing and networking assistance. These groups often specify what types of equipment and software they will support. Exceptions can be made for specialized needs, but then users are often told that they have to be responsible for the operation of the special systems. Most users live within the limits imposed by the support group.

The home information appliance environment is likely to be more complicated than the office environment today. Also, many users will be less knowledgeable about electronics than the typical office worker. Therefore it will be essential to outsource the setup and maintenance of home computing and electronics to experts. It will not be economically feasible for them to visit in person every time something goes wrong, or a new device is to be added to the system. Therefore all devices will have to be designed for remote administration. (Most of it will be automated, and it will be facilitated by, and may essentially require, broadband access to the home.) Perhaps even more important, all these new information appliances will have to be designed for customizable flexibility, so that only the administrators will have full control of them. Users will be given varying degrees of control, depending on their skills and trustworthiness. The operating system will need to be rigidly isolated from the applications, and the applications will have to be tested for compatibility by the administrators before they are installed. This will reduce users' freedom to modify their systems. However, it should bring in some sanity to the potentially chaotic scene and make possible deep penetration of information appliances into society. If Aunt Millie wants to give a new toy to your son Bill for Christmas, she may first have to check with your system manager whether that toy will interoperate with all the other information appliances in the house. Most users are likely to accept such restrictions to simplify their lives.

8. Conclusions

We were frustrated with computers a decade ago, we are frustrated with them now, and will continue to be frustrated in the future. As long as technology offers enticing new products and services, we will continue to live on the edge of intolerable frustration. However, by providing for customizable flexibility and developing outsourcing services for computing and networking support, we can smooth the transition to the information appliance era of computing.

9. Acknowledgements

References

[Alsop]   S. Alsop, Have I told you lately that I hate Windows?, *Fortune,* July 5, 1999, pp. 177-178. Available at ⟨http://www.pathfinder.com/fortune/archive⟩.

[Christensen] C. M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail,* Harvard Business School Press, 1997.

[Gates]   B. Gates, Why the PC will not die, *Newsweek,* May 31, 1999, p. 64. Available at ⟨http://www.newsweek.com/nw-srv/printed/us/st/sc0122_1.htm⟩.

[Jaffe]   B. Jaffe, So much software, so little time, *PC Week,* May 17, 1999, p. 84. Available at ⟨http://www.zdnet.com/pcweek/stories/columns/0,4351,402631,00.html⟩.

[Lewis]   P. H. Lewis, The once and future network: Wiring the home has come a long way but has a way to go, pp. G1 and G7, and State of the art: Carrying Windows around, in your pocket, pp. G1 and G3 in *New York Times,* July 15, 1999. Available at ⟨http://www.nytimes.com/library/tech/99/07/circuits/articles/15home.html⟩ and at ⟨http://www.nytimes.com/library/tech/99/07/circuits/articles/15pete.html⟩.

[Levy]   S. Levy with J. Sandberg, J. Tanaka, and B. Stone, The new digital galaxy, *Newsweek,* May 31, 1999, pp. 57-62. Available at ⟨http://www.newsweek.com/nw-srv/printed/us/st/sc0122_1.htm⟩.

[Moore]   G. A. Moore, *Crossing the Chasm: Marketing and Selling Mainstream Customers,* Harper-Collins, 1991.

[Norman]   D. A. Norman, *The Invisible Computer: Why Good Products Can Fail, the Personal Computer is so Complex, and Information Appliances are the Solution,* MIT Press, 1998.

[Odlyzko]   A. M. Odlyzko, Smart and stupid networks: Why the Internet is like Microsoft, *ACM netWorker,* Dec. 1998, pp. 38-46. Available at ⟨http://www.research.att.com/~amo⟩.

[Rogers]   E. M. Rogers, *Diffusion of Innovations,* 3rd ed., The Free Press, 1983. (First edition, 1962.)

[Tenner]   E. Tenner, The Microsoft we deserve, *New York Times,* Op-Ed page, March 8, 1998.

[Wildstrom] S. H. Wildstrom, Technology & You column in *Business Week*: Office lite: Less would be more, p. 28 of June 14, 1999 issue, and Give us a simpler "Office," p. 20 of July 5, 1999 issue, both available at ⟨http://www.businessweek.com⟩.