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1.4 HUMAN INPUT/OUTPUT DEVICES

1.4.1 Executive Summary

Input and output are starting to change after about five years of remaining fairly stable. The mouse, keyboard and CRT are still the staples of the user interface, supplemented by desktop printers and - increasingly - scanners. CRTs are getting higher quality, resolution and color for increasingly competitive prices. Scanners and printers are also improving in cost/performance. But these trends just show that it is getting cheaper to do conventional things with higher quality tools.

A more significant change is afoot. First, these more conventional I/O devices are being supplemented by new transducers such as video cameras, microphones and speakers. Second, devices are being packaged in new ways. We are starting to see trends towards portables, for example, that don't just look like shrunken-down desk-top machines. PDAs are one example. But a portable digital voice note-taker that can upload messages to a PC is another. Form and function are starting to converge, and a significant trend that is beginning to emerge is that "one size/form does not fit all." We are increasingly seeing specialized devices for specialized functions, yet still being able to interface with other devices in the "family."

1.4.2 Background

There is a simple game that one can play to capture the significance of this chapter. The next time you have the chance, give a group of colleagues, customers or students the following test. Give them fifteen seconds, and ask them to draw a computer. When you collect the results, what you will see is that practically everyone drew a CRT and a keyboard, about 70% drew a mouse or some other pointing device, and at most 20% actually drew the box with the computer in it. What they drew were the input/output transducers, not the computer.

Now, administer the second part of the test. Tell them to do the same thing; however, this time, have them do it as if it was 1964, not 1994. This time, again, you will see pictures of tape drives, key punches and line printers. And since the CPU was closer to the end user in those days, you will also see some refrigerator-like boxes representing the "computer."

From this simple exercise we can draw some insights that can really help us in understanding what is happening in technology right now. The first lesson is the power of the things we see, hear and touch in shaping our perception, or "mental model" of what computation is. The second is the recognition that these things, the input/output devices, are "accidents of history." That is, they are subject to change and redesign. Together, these two observations mean that by rethinking the nature of input/output, we can reshape the nature of computation and what it is for.

These are not trivial matters. We are at a stage where it is difficult to even talk about "computation" *per se.* Consider the *convergence* of computation with other technologies, such as "the information super highway", consumer electronics, video, telecommunications, or other such trends. The result of this convergence is not some synergistic crystallization, which provides some simplifying and unifying concepts about technology, its applications and usage. Just the opposite is true. From the perspective of business, design, engineering and usage, things are becoming more confused. And while there is immense potential benefit to be gained from this convergence, we run the risk of pushing access to it beyond the "threshold of frustration", or "the "complexity barrier" of our end users.

Now, let's go back to our drawing exercise, since therein lies one of the paths to managing the complexity and realizing the potential of what is happening. By rethinking input/output, we can reshape users' mental models of the technology in such a way as to increase the functionality that falls within their complexity threshold.

We will see the beginnings of this kind of trend in some of the examples discussed in this chapter. By way of preview, one example is in how devices are being scaled to the size and form factor appropriate to the context of usage. This is seen in pen-based computing where the scale ranges from palm-sized personal digital assistants (PDAs) to wall-sized electronic whiteboards. Neither end of the continuum resembles the GUI-driven PC that was the rule until very recently. Each represents a significant change in how we think about computation. And while both the PDA and electronic whiteboard are both pen-driven computers, their difference in scale renders them very different beasts. Here is another twist to our overall theme of *rightsizing.* These variations of scale lead to one more trend that will be of increasing importance, that of *rightplacing.* That is, the delivery of services at the appropriate location and time for the activity, as opposed to "back at the shop."

The nature of technology is changing, and old models of computation, telephony, etc. are breaking down fast. Or, perhaps, they are being augmented by new families of technology that must work in concert. These changes are being driven by sues such as convergence, scale and location of services. Our view is that input/output is one of the most critical components in both shaping these changes, and rendering the potential such that it falls within human's capacity to easily exploit it.

1.4.3 Market Overview

Text Entry

Ergonomic Keyboards
One of the main things that people traditionally do with computers is enter alphanumeric data. While the days of keypunch entry are gone, the QWERTY keyboard which was the transducer used in those days, is still very much with us. This is not likely to change in the near future. There is simply too much invested in not only hardware, but user skill, training, etc. It just does not matter that there might be a better keyboard somewhere. Making the change simply does not make sense from a cost-benefit perspective.

Or does it? The classic (non)answer is: "It depends." Keyboards that provide some improvement in efficiency but require new skills and hardware, such as the Dvorak keyboard (REF), will not likely every take hold of any significant market share from the QWERTY design. However, the one thing that might change the cost/benefit analysis is health and safety issues, not typing speed. The past year has seen an increasing amount of attention being paid to the issue of repetitive strain syndrome, especially with keyboards, and this is beginning to be reflected in the marketplace. Hence, what used to be called "ergo keyboards," that is, low profile keyboards now seen on most PCs, are starting to be replaced by keyboards whose design is a radical departure from what we are used to.

One of the most interesting aspects of such designs is that while the form factor is different, they generally tend to be designed to be operated using the skill set of the traditional QWERTY system. Hence, in principle, the incidence of keyboard-induced injury is reduced, but the operator need not learn a whole new keyboard layout. Existing skills are respected and utilized.

Apple's split keyboard is the first of the new breed of keyboard to reach the "mass" market. Several others are following. Such keyboards cost as much as ten times a conventional keyboard, but that may well be worth the price if it results in reduced health risk. The corporate manager is well advised to follow the press and track the activities of the ISO standards activities in this area, since standards in this area are forthcoming with regulation close behind. The one cautionary note is this: these new designs look promising, but they don't come with a guarantee. Look carefully at the testing data before making a commitment to a new design.

The Sound of 1 Hand Typing
One interesting niche in keyboard design is one-handed typing. This has relevance in three areas: supporting people with disabilities, supporting text entry on very small portables (a one-handed keyboard is smaller than

a two-handed one), and text entry when the other hand is otherwise engaged, such as with a mouse or some other device.

There are two strategies in this regard. One is a special one-handed keyboard. These typically have only five to eight keys and are operated by "chording." That is, certain characters are entered by - like a piano - pushing more than one key simultaneously. Such devices are useful in some applications, but require special hardware and special training.

The other approach is to use half of a conventional QWERTY keyboard. Through a simple software modification, it turns out that touch typists can quickly learn to type with one hand using just one half of a standard keyboard. This is discussed in Mathias *et al* (1993).

Character and Handwriting Recognition
1993 was a bad year for pencentric computing, mainly due to the considerable shortcomings of the recognition of hand printed and written text. Apple's *Newton* was the target of a series of Doonsbury cartoons, and the earlier failure of the *Momenta* pen-based computer was followed this year by that of AT&T's *EO* personal communicator and GO's *Penpoint* operating system.

Does this signal the failure of pen-based computing? We think not. Rather, it suggests that the emphasis on pen-based computing was prematurely placed on recognition. As we will discuss later in this chapter, there is more to pen-based computing than character recognition. In short, have you ever heard anyone say. "Gee, I wish this piece of paper could recognize what was written on it."? I doubt it. However, I bet you have heard people express frustrations such as, "I wish I had that piece of paper with me.", "I wish that I could find that piece of paper.", "I wish that I could quickly sketch that figure/graph/text into my computer." and "I wish that I could quickly mark-up/annotate that drawing/text for you."

All of these are things that pens are good for, and none require recognition. Character and handwriting recognition are currently sufficiently mature for some niche markets, especially vertical ones where the repertoire of characters is small, and the system can be trained for the individual user. In the meantime, algorithms are improving. Even the much-abused Newton has a significantly improved recognizer now than on its first release. The message here in this department is to "stay tuned in" and evaluate your special needs before rejecting the technology. It will only get better with maturity.

On Pens and Keyboards
There is a final point to be made about pen-based computing and the entry of alphanumeric data. This can perhaps be best hit home by a bit of audience participation. Time yourself transcribing this paragraph in each of two ways: printing legibly on a piece of paper, and typing on your

word processor, activating the keys with the eraser end of your pencil (ignore upper case characters in the second condition).

Printing on paper will only be about 10% faster. If you did a similar exercise with numeric data and a keypad, the difference in time would be even less. The point is that character recognition is not the only "pencentric" way to enter alphanumeric data into a computer. Graphical keyboards are a viable alternative in many cases, and are worthy of consideration.

Pointing and Portables

The growing trend towards mobile computing is one of the more visible consequences of *rightsizing.* With improvements in cost and quality of LCD technology (especially active matrix colour), high speed processors, and communications technologies, mobile computers have performance and even connectivity previously only seen on tethered desk-top machines.

One consequence of this is a migration of new applications to the mobile machine, and with this, new demands on the input/output capabilities. Where this is most visible is in the range of input devils that are used for pointing and selecting.

The dilemma is how to provide adequate pointing capability without compromising the size/convenience parameters of the computer. Currently, we see a (too) large number of portables with non-integrated "snap-on" pointing devices. While these enable older computers to be retrofitted for more modern applications, they have little or now place in new designs. They are simply too awkward and inconvenient.

Embedded devices include trackballs and joysticks. With the new generation of Apple *Powerbooks,* we will see a new trend towards touch pads. One key consideration with such devices is *handedness.* Many devices are off to the right-hand side, prejudicing against left-handed users. Consider, alternatively, devices that are mounted in the centre of the computer and which are equally accessible to either hand. Also consider if you are often using your computer in the "economy" section of an aircraft. It is worth remembering that what is good design for a table top may not be ideal when in a tightly constrained position.

The literature is full of scientific studies discussing the relative merits of joysticks, trackballs, touch tablets, etc. One can summarize these results by saying that every device is best for something and worst for something else. The best guide is to try various designs using the full range of applications that you anticipate and in a physical context as close to where you expect to use the device. Devices feel very different in a car, plane or on your lap than they do in a showroom. Likewise, the device that works well in a word-processor may be a disaster in drawing, or dragging tasks, and vice-versa. The last thing you want is to have to stuff your already over-filled briefcase with another mouse or pointing device, because the one built into your portable just isn't up to the demands of your day-to-day needs.

Pen-Based Computing

We have already touched upon pen-based computing in the context of text entry. Here, we address some of the trends that have more to do with scale and application. In terms of scale, or *rightsizing,* we see pen-based technology in three general scales:

- *micro:* this includes devices like the Sharp *Wizard* on the low end, and the Apple *Newton* on the upper end. These are PDA devices that ideally fit into your pocket. Their main function is as a supplement/replacement for your personal organizer, address book, etc. Of real concern with these devices is "speed of access." In the spirit of the wild west, a good test for them is to see how fast they are on the "draw." That is, compare them to your regular address book in terms of how fast it takes to find an address, make an entry into your agenda, or make a sketch of a new idea. Speed and convenience is off the essence with these devices. And this includes interfacing with the rest of your electronic environment.

  This is mentioned because these devices t*hemselves* should be considered input/output devices. The reason is that they generally do not / should not stand alone. Hence, they need to "handshake" with their larger siblings, for purposes such as back-up, calendar synchronization and other communication activities. Increasingly, these will be purchased as part of an overall system, or architecture, rather than as stand-alone devices.

- *mini:* These include note-pad like devices, such as the now defunct *Eo-440.* The real market for these devices today is in vertical markets, such as courier services, where the applications are tailored and specialized. However, this will gradually change. From one side, taking handwritten/drawn notes using digital ink is far less intrusive and often far more effective (especially when there are lots of graphics), than can be captured using a traditional keyboard. From the other side, one quickly bangs against the limitations of PDA scaled devices, with their small screens, when attempting extensive note taking. This class of system is in a bit of a retrenching mode, but it will reemerge within the year.

- *maxi:* This class includes pen-based systems that are on the scale of a whiteboard. This class of pen-based system is only recently emerging in the marketplace. However, it will likely become increasingly important, as it supports a hitherto neglected aspect of workpractice: group meetings. One of the most interesting aspects of this technology is that - with appropriate software and communications - it provides support for meetings which are distributed across sites. That is to say, two or more such devices at different locations can be interconnected so as to enable all sites to share a common interactive virtual whiteboard. Through convergence, rightsizing and rightplacing, the nature of computation within the workplace is being redefined. We will discus some of the technological considerations of this class of application in more detail below.

Retrofitting PC's

Most pen-based computers are "purpose built." They look and feel very different than your typical desktop computer, especially in that the user writes directly on the display surface (typically an LCD panel) with a stylus.

There is a middle ground, however. First, many 'pencentric" applications, such as marking, do not require a stylus. While making a facsimile of my signature with a mouse is difficult, circling and crossing out text or graphical objects is not. Second, one can retrofit existing PC's with pen-driven applications. An example is Communication Intelligence Corp. (CIC), Redwood Shores, CA, which offers a wireless stylus, tablet and software enabling Windows applications to be pen driven.

Hybrid PC's

We are also beginning to see portable computers which are a hybrid between keyboard and pen based. Examples are the Compaq *Concerto* and the *PenExec* from AST Research, (Irvine CA). These are convertible between pen to keyboard operation. This is achieved through highly creative industrial design. The attempt is to achieve the best of both worlds, and it is likely that we will see more of this approach.

Optical Capture

In previous editions of the *Technology Forecast,* this section has been called *scanning.* But things have changed, and scanning isn't what it used to be. The nature of what constitutes a scanner has expanded a great deal, as have the associated applications. On the hardware side, for example, we have:

- scanners
- fax technology
- digital still cameras
- frame grabbers

Our approach to this section reflects our view that one of the main current trends is towards a *convergence* of these technologies. In essence, they are different technologies being used for the same class of application.

Scanners:
These range from hand-held to flat bed. They include hand fed as well as high-end 600 dpi scan engines, like the Xerox *DocuTech*, that scan about a page a second. And, of course, they are monochrome and color. At the low end they are in the low hundreds of dollars. At the high end in the low hundreds of *thousands* of dollars. This is a rapidly moving market which is bringing ever better quality to the desktop at ever lower prices. Magazines, such as *Byte,* are perhaps the best way to get a sense of the current market. What we will do here is mention a few technologies which highlight the diversity of the market.

One trend is towards special purpose scanners with specialized software. An example is scanners specifically for business cards. One is the *CardGrabber* (Pacific Crest Technologies, Newport Beach, CA), which scans business cards and stores them in an address book. It connects to portables and can run off of batteries. Another is *Scan-in-Dex* (Microtek, Torrance, CA), a desktop business card scanner. It scans business cards into a searchable windows database. It is likely that this class of technology will, in the next two years, find itself standard equipment on PDA devices.

Another specialized scanner is for fingerprint scanning/recognition (Startek, Hsinchu, Taiwan). This is a small scanner that stores 1000 fingerprints. It consists of a scanner, AT bus interface card, database and verification software. Scanning and verification takes 2-3 seconds. Such technology will likely find its way into devices such as cellular phones, PDAs as well as desk-top machines over the next few years.

Scanners are not just being used for image capture. Optical character recognition (OCR) is improving, and is an example of how machines can process what they scan. Several other examples follow. But for those who just want to scan documents into a database easily and efficiently, perhaps the most welcome trend is towards a new class of software that can be called *document recognition,* as illustrated by Xerox's *Easy Scan.*

Imagine you have a stack of pages to scan, each of which has color photos, text, gray-sale art and line art. Typically, each page would need to be "tweaked" and if the quality of the color photo was important, the whole page would have to be scanned at 24 bits/pixel. With this new class of software, the scanner first looks at the entire page and *segments* it into areas according to type. Hence, it uses its knowledge of documents to determine what is text, what is black and white, color, etc. It then scans each segment at the appropriate resolution and then uses a compressor appropriate for each segment before storing. The result it not only a great saving in disk space, but software whose only essential control is the "scan" button. Like modern cameras that do auto focus, auto exposure, etc., scanning is becoming a "point and shoot" operation.

Fax Technology

Up until recently, people considered their fax machine distinct from their scanner. No more. First, more and more people have fax engines attached to their computer. Second, the price of such hardware is dropping while the quality is improving. Finally, such units are being shipped with software previously only associated with scanners. So, for example, most vendors of fax modems supply software that not only lets you save the incoming fax in some standard file format, such as TIFF, they also provide OCR software, so that the fax can be read.

Xerox has even tested the market with a fax-based product, *Paperworks,* that lets you store, retrieve and forward PC files by faxing it instructions on special forms. Hence, optical techniques, such as fax, are moving beyond simply techniques for transmitting and receiving data. They are becoming channels for interacting with the computer, capable of providing access to services previously available only via the keyboard, mouse and CRT. This new way of thinking about paper documents for *control,* what can be called *papertronics,* expands the definition of remote computing. It also has real implications on how we deal with other technologies, such as copiers in the future.

Digital Still Cameras

Within the past few years, companies like *Canon* have introduced a new breed of camera that takes single frame video stills. The resulting still images could be shown on your TV much like the output of a VCR. They just didn't move. If you had the right gear, a *frame grabber,* you could transfer these images into your computer. However, this was sufficiently inconvenient that few other than the multimedia die-hards bothered. Most photos were still scanned from conventional prints or slides. However, this is now changing.

Companies such as *Logitech* are now supplying a solid-state digital still camera that is wireless and portable. You can carry it with you and snap images, like with any other camera. The camera is then docked in a base station (much like a cellular phone battery charger), and the images are transferred to the host computer over the SCSI port. The benefit of this device is that you can "scan" 3D objects, and large objects (such as a whiteboard), that could not be capture with a conventional scanner. And, along with our theme of *rightplacing,* the scanner can go to the object, rather than having to take the object to the scanner.

This class of digital still camera, or portable scanner, is going to become more common. Apple computer, for example, has recently released a similar kind of unit. It is color, and connects via the serial port. And, like others of this newer generation, can capture images at much higher than video's 640 x 480 resolution - one of the limitations of the earlier video still cameras, like the Canon.

Frame Grabbers

With the advent of "desk-top video," more and more PCs and workstations have video cameras associated with them. These are mainly intended for desktop videoconferencing. However, they are frequently accompanied by a *frame grabber,* a device that can digitize a frame of video. There are many such devices from numerous vendors; however, they are typically found only with desk-top machines. One exception is the Computer Eyes/LPT (Digital Vision, Dedham, MA), which plugs into the parallel port of portable PCs. It can grab any composite video image, compress it with JPEG compression, and store the resulting frame in any of TIFF, JPEG, GIF, TGA or BMP formats. This product is representative of how this class of application is moving away from the desk-top.

It is still on the desk-top, however, where the higher end models are found. With these, frame grabbing can frequently be done in 1/30th of a second, the frame-rate for NTSC video (or 1/25th of a second, the frame-rate for PAL and SECAM), thereby digitizing entire video streams. Since such streams are memory intensive, such frame grabbers frequently include compression hardware.

What this class of technology buys us is the ability to "scan" time-varying phenomena, including documents, 3D objects, meetings, etc. The result, like the output of any other scanning technology, is a digital document that can be transmitted, saved, annotated, edited, "read" and processed. Since television and VCRs have conditioned our expectations of video, we tend to have a very limited view of what we can do with it. However, the potential starts to emerge if we think about video as just another document format, and video capture as just another form of scanning. Then, we can start to look at the video equivalent of things that we do with other scanned documents, such as OCR and papertronics techniques. By analogy, therefore, we see a path leading to processing video to do face recognition (such as for login verification) or gesture recognition for pointing or control (in a manner analogous to papertronics).

Printers

This is a segment of the marketplace where users are getting ever better quality and performance for ever better prices. Just one year ago, we were celebrating the trend from 300 dpi to 600 dpi for personal printers. Now, 600 dpi is essentially the rule, and we are starting to see engines capable of 1200 dpi emerging. One example of this trend to higher resolution is the 5100 laser printer from Digital Equipment Corp. It is a 600 dpi printer that has a 1200 dpi option. Like many of the newer network printers, it has an on-board processor with RAM that enables much of the computational overhead of printing to be off-loaded from the user's workstation.

The most recent survey of printers can be found in Higgs and Mysore (1994). This is a *Byte* survey of the desktop market. They, quite reasonably, categorize printers as follows:

- *General Business:* 10 pages per minute (ppm) or less.
- *Workgroup Lasers:* 12 ppm or more.
- *Draft Quality:* sub-$1,000 ink-jet printers
- *CAD Desktop Lasers:* capable of 11" x 17" paper.
- *General Purpose Color:* Various technologies (see below), but costing less than $5,000.
- *High Volume:* Dot matrix printers, mainly for printing listing.

What these categories highlight is the fact that various printers are suited for different tasks, and speed of printing is a serious consideration. Of these categories, the first three are dominated by Hewlett-Packard offerings.

Color

Color printing is seeing very big changes in price/performance. In the past, it has been out of range for most users. This is largely due to the fact that a color printer is essentially four printers in one (since it typically takes four passes, or "inks" to get a complete color gamut.) We are now seeing low cost, but reasonable quality printers becoming available. (See Thompson, 1994 for a review.). There is at least one color printer, the that is less than $1000.

Color printers vary greatly in quality. Clearly, what is required by someone in the graphic arts industry is likely very different than someone who want to print out a color pie chart for a business presentation. The higher the quality, the higher the price. There are three main technologies used in color printing:

- *Dye-Sublimation:* This is the high end. Printers can cost more than $10,000, but quality is excellent. Prints cost about $1 or more per page. This class of engine is used mainly in the graphics arts industry. An example is the ColorEase PS Printer from Kodak. It is capable of 24 bit color and costs $8000. It takes 3-4 minutes to print one page, at $.65 and $1.15 respectively, for paper and transparency printing.

- *Thermal-Wax:* This is the middle ground. Printers in this class can cost up to $4,000. The per page cost is about $.50. It is with this class of printer where we have recently seen significant improvements in price. The *Primera* (Fargo Electronics, Eden Prairie, MN) at less than $1,000 is an example. However, with the lower prices comes some compromise in quality and performance. The *Pimera*, for example, achieves its cost savings by having the host computer do the processing that more expensive units do internally.

- *Laser:* This is essentially 4 laser printers in one, one for each of yellow, magenta, cyan and black. The technology is complicated, and there is only one product in the desktop market, the QMS ColorScript Laser 1000. Other options, but far more expensive, are computer interfaces to color copiers, that use laser technology (such as from Sharp, Canon, Xerox, Eastman Kodak, and Minolta). This technology appears to be moving more slowly than the others.

- *Ink Jet:* This is the technology where color is making the highest penetration. Costs start as low as $300, a small increment above monochrome inkjet technology. Per page cost is only about $.08. The problems with this technology are that the ink can run and paper wrinkle, especially if special paper is not used.

A good introduction to color print technology can be found in Zeis (1993).

The High End

It is important to recognize that magazines like *Byte* cover mainly the desktop market. Consider the workgroup market, for example. Here, the fastest printers reported were all under 20 ppm. For document intensive activities, this is slow.

What we have recently seen are high-end printers capable of publishing on demand. This is a very different market from the desktop. Rather than $3,000, such print engines cost more like $300,000. But the performance and quality is awesome, especially to those of us who grew up with high-speed impact printers. A major player in this market is IBM. There current offering is the 3800 series. But where this is going can be seen by looking at their 3900 series, to be released in March 1995. The unit has an 18" paper path that permits large format printing. It also permits "two-up" printing. That is, two pages at a time. Using this feature, the unit is capable of up to 352 8.5" x 11" pages/minute (332 ISO A4 pages/minute)!

Another player in this market is the Xerox *DocuPrint* series. The print engine on the Model 135, for example, is capable of up to 135 ppm on 8 1/2" x 11" paper, and 58 ppm for 11" x 17". These units can print double sided documents, as well as "bind" them.

While this high-end also comes at a high price, as with many things (such as race cars), aspects of the high-end indicate where the mid and low end are moving.

CRT Displays

This is a fairly mature class of technology, so we will spend little time here. Product surveys appear regularly in magazines such as *Byte* (most recently January 1994). The main trends here are decreasing price and increasing quality, especially for color. Multisync monitors are becoming more-or-less the norm, and while a few years ago 640x480 pixels were the norm, 1280x1040 is common, and we are now seeing affordable monitors with up to 1600 pixels per line.

The other area where we are seeing change is in monitor size. Generally, we think of CRTs as part of a desk-top configuration. The most visible exception is the board-room, where large monitors, mainly from Mitsubishi, are used for presentations. As "multimedia" presentations become more common, we will see more monitors in this class. One example is the new 27-inch *4PG* monitor from NEC. Such monitors serve double duty: they must support video as well as multiple computer RGB formats. And, unlike your desk-top monitor, they come with a remote control (a mixed blessing).

Flat Panel Displays

The real action on the display front is in the area of flat panel displays. Here, there is lots of excitement on the horizon, but actually, things are moving much more slowly that many wanted or expected. In general, sped and quality still cost a lot and it is hard to get high resolution. Color is pretty much still restricted to 640x480 and monochrome to 1k x 1k. The two technologies that dominate the LCD marketplace are:

- *Passive Matrix:* This is the most common LCD technology. It is relatively inexpensive. However, it is also relatively slow, so is not well suited for video or animation, for example.
- *Active Matrix:* This is relatively expensive, but rather fast. Hence, it works well with video and animation.

There are, however, promising technologies emerging. A few to watch are:

- *"Smart Slide" (Kopin Technology, Taunton MA):* This is a small high-resolution active matrix. What distinguishes it is that it is implemented on transparent material. It has a resolution of 2000 lines/inch. Because of its size and transparency, it is suited for head-mounted displays and for projection systems. It is relatively inexpensive. Units are expected to ship for about $1,500 in the 3rd quarter of 1994.
- *"Active Addressing"* (*Motif ,Wilsonville OR):* This is much same technology as cheaper passive matrix displays, but provides the speed of an active matrix. Again, this is expected to ship in 1994.
- *Cold Cathode Field Emission Display (FED):* This technology is like a CRT, in that it uses light-emitting phosphors. However, it does not use a cathode ray to excite them. Rather, there is an array of low-

voltage electron emitters behind phosphors. The technology is bright, so it don't require back-lighting. It therefore consume less power than LCD technologies, for example. The technology is being pursued by a number of companies, including Pixel International (France), SI Diamond (Houston TX) with MCC (Austin TX), Micron Display Technology (Boise, Idaho) and Silicon Video (Cupertino, CA). Prototypes are expected to appear sometime in 1994. A summary of the technology appeared in *Byte*, February, 1991.

- *Digital Micromirror Device (DMD) :* This is a new display technology that has been developed by Texas Instruments in conjunction with the David Sarnoff Labs and partial supported by the Advanced Projects Research Agency (ARPA). It is based upon placing a miniature mirror over each cell in a CMOS static ram chip. Each memory cell corresponds to a pixel on the display. Changing state of the cell causes the mirror associated with it to tilt 10° towards ("on") or away ("off") from a light source. When "on", the light is reflected by the mirror onto a display surface.

  The chips are about 2.3 $c.m.^2$, and currently have nearly 450,000 mirrors on the surface. This is sufficient for VGA or NTSC level spatial resolution. This technology is still in the research stage. However, it is promising, and could have a significant effect on the flat panel and projector market in the future.

- *High-Resolution Active Matrix:* Recently, a prototype 3072x2048 active matrix display has been demonstrated (Martin, *et al.,* 1993). This display measures 13 inches, diagonally, so is nearly A4 size. A color version having about 1/3 the spatial resolution has also been shown. The encouraging thing, is that a new consortium, the *United States Display Consortium (USDC)* has been set up to develop this technology. It includes Xerox, ARPA, AT&T, Standish Industries, Electro-Plasma, Magnascreen, Optical Imaging Systems, Photonics Imaging, Planar Systems, Plasmaco and Tektronix. While no commercial version of this technology will appear in the next year or so, it does indicate that the market is heating up and that higher resolution devices will be forthcoming. This is worth watching.

Interactive Electronic "Whiteboards"

One of the more interesting trends emerging over the past year is the migration of computation from the desk-top to the boardroom and the classroom. Normally when we say this, what comes to mind are portable computers. While these are not excluded, that is not what we intended. The trend here is to having rooms with large interactive displays, so as to support group activities such as meetings, presentations and teaching. And, by coupling multiple such devices together through a combination of software and communications technologies, these devices can form the basis for computer supported collaborative work (CSCW) (REF) at a distance, or *groupware.* By their scale and integration, these devices epitomize the trends of *rightsizing, convergence* and *rightplacing*.

Given that large flat panel displays are not yet available, all of the technologies in use today involve some sort of compromise or "kludge." Nevertheless, while not ideal, the implementations are adequate for many applications, and they lead the way in shifting work practice to what we know is coming in the future.

These devices use one of two display technologies: projection or large CRT. Let us quickly survey each:

Projection
There are essentially three projection technologies in common use:

- *LCD panel + overhead projector:* This includes products from vendors such as: Proxima (San Diego, CA), Sharp (Mahwah, NJ), Telex (Minniapolis, MN), nView (Newport News, VA) and Dukane (St. Charles, IL).

- *LCD + integrated light source:* These are self-contained projection units using LCD technology. Vendors include: Sharp (Mahwah, NJ), Proxima (San Diego, CA) and InFocus (Tualatin, OR).

- *Raster-scan projection:* These are self-contained projectors that use scanning technology rather than LCDs. As we will see, this has important implications when it comes to connecting lightpens. Vendors include: Barco (Kennesaw, GA), Electrohome (Waterloo, Ontario), Sony, General Electric, and Panasonic.

A key consideration is projection direction. Projection is frequently from the front, especially with LCD panels and overhead projections. Since we want to treat the projected image as a whiteboard, front projection is a definite second choice. If the only option, then it is far better to front project from the ceiling, not the floor. As it turns out, raster scan projectors are typically better at this than LCD technologies, due to their adjustable *keystoning.*

Rear projection is by far the preferred technique. This way, the illusion is one of a large flat-panel display. The shadow problem is virtually eliminated, and, with the proper set-up, the ambient light in the room can be higher than for a front projection system. The problem here is the need for an adjacent projection room. Many buildings are not equipped for this. The solution here is to box the projector in a manner similar to many consumer projection televisions. Such cases are available from a number of vendors.

Large CRT Displays
An alternative to projection is to use a large format CRT. Most common in the field are units from Mitsubishi. However, both Sony and NEC

make large units. The advantage of CRT technology is that it is much brighter than projectors. The problem is that the screen is smaller than what can be achieved by projection, and the monitor itself is bulky. One solution to this latter point is to flush mount the monitor in the room, thereby getting the same "flat panel" effect achieved with rear projection.

Interaction Technologies

Central to this application is interactivity. Without a means of input, all we have is a big display, not a "whiteboard." There are a number of input technologies that can provide this interactivity. The first group let you work right on the display, as you would with a whiteboard:

- *Tethered stylus (lightpen):* This is the least expensive and in many cases easiest solution. It relies on one of the earliest graphical input devices, the lightpen. These are available from a number of vendors, including Ampower Technologies (Fairfield, NJ), Design Technology (El Cajon, CA), FTG Data Systems (Stanton CA), HEI Inc. (Victorial, MN), Information Control Corp. (Bridgeport, CON) and Interactive Computer Products (Laguna Hills, CA). Most are for the PC, but FTG makes a unit for the Macintosh and Interactive Computer Products makes one for the Sun SPARCstation.

  Lightpens will work with virtually any CRT display, and with *rear* projection *raster scan* projections (i.e., not with LCD projectors). This is a cheap and very effective way to turn an existing data projector into an interactive meeting tool.

- *Untethered Stylus:* This class of device is mostly tied to specific vendors' products. See the discussion of example integrated systems below for examples.

- *Touch screen technology:* While touch screens are familiar, they are not normally seen on very large monitors or in conjunction with projection systems. One creative exception is the *Smart 2000* system, discussed in the examples below. With the touch screen, one can write with any blunt object, as with a stylus, or with the finger.

- *Wands:* These devices are generally used with front projection LCD panels. They mimic the functionality of the long pointers traditionally used by lecturers and teachers. They operate by an LED at the tip which is sensed by an optical system attached to the base of the projector. The InFocus system discussed in the examples uses this class of technology. The technology is adequate for pointing, but poor for writing or marking.

There is also a class of "off screen" pointing devices. Like mice and trackballs (which are included in this class), the user does not interact with the screen directly. Rather, a remote device controls the screen cursor. Some examples are:

- *conventional mice, joysticks, and trackballs:* Essentially, any pointing device used with a regular computer will work. The only issue is that such devices are generally tethered, and may be awkward for a speaker to operate. However, if the purpose is to do a budget using a spreadsheet, then it may be that all participants are seated, the large screen visible for all, and control follows desk-top patterns.

- *untethered pointers:* This class of device provides more freedom of movement than conventional mice, for example. They are closer to conventional laser pointers, for example, except they do not typically share the "line of sight" property. Examples are the *airmouse* (Selectech, Burlington, VT), and the *imp* (ArcanaTech, Pittsburgh, PA). Again, such devices are fine for pointing, but are not suitable for marking, drawing, etc.

Perhaps what is most important to point out is what is *needed* but *not* available: an untethered keyboard with integrated pointing device. Hopefully this will appear from some manufacturer within the year, as this class of usage becomes more significant.

Examples

The following are different approaches to providing electronic whiteboard functionality in an integrated package. These are integrated solutions that present an alternative to the "roll your own" approach of using a rear screen data projector ad a lightpen, for example.

- *Liveboard (Xerox Corp.):* This is the high end of the integrated systems. It is a large cabinet which uses rear projection. It has custom wireless styli, and comes with a 486 machine running windows, networking and has software for distance collaboration, including support for video codecs. The cost is around $50,000.

- *Smart 2000 (Smart Technologies, Calgary, Alberta)*: This unit comes in two versions: front and rear projection. Both use a touch screen technology, but this is far more effective in the rear screen (but more expensive) version. Users can point an mark with fingers or any hard object. It has a clever feature in which it has dummy colored whiteboard markers that sit in their own slots on the front trough. By sensing which pen is picked up, it changes pen color in a manner consistent with conventional whiteboards. The software provided, like the Liveboard, supports both same-room and remote collaboration. You can retrofit the technology to your own computer. These units cost $18k-$25k, depending on features.

- *SoftBoard (Microfield Graphics, Beaverton, OR):* This unit consists of a "real" whiteboard with "real" markers. The "only" difference is that it has a laser mechanism that can sense the position and color of markers writing on the board. This information is captured to a PC.

As a result, people in the room see things in a conventional manner, but the output of the board can be transmitted to a remote site (using provided software) or recorded as part of the meeting minutes. The design is very clever and economical (prices are in the $3k range). However, one shortcoming is that if the remote site wants to write on the "whiteboard", they can do so but it will only appear on the PC screen, not the physical whiteboard. Hence, this is better for "broadcast" type presentations, rather than interactive brainstorming.

• InFocus (Tualatin, OR): This representative of the low end of the market. (There are other vendors of similar systems). The systems use an LCD panel on an overhead projector, software on the PC that may support remote connections (hence whiteboard sharing), and a "wand" for pointing, as described above. The advantage here is price and portability. Costs are in the $5k-$8k range.

Speech Input and Output

Recognition vs Store & Forward

When we think of speech and computers, we typically think of conversing with our computer, much like *Hal* in *2001: A Space Odessy.* Such speech-based user interfaces have been an elusive "panacea" for over two decades. The simple comment on this is, if we can't recognize simple printed characters, how much hope is there for unconstrained speech in the near future?

This isn't to say that there is no place for speech I/O in today's systems. Far from it. Desktop machines, such as the Apple *Power PC* series now come with speech recognition technology as standard. With a limited vocabulary, training and careful use, this and other systems can be of use. Examples include interacting with computers using the telephone.

However, it is important to recognize that even without recognition, speech has a significant role to play. In particular, both speech *messaging* and speech *annotation* can enhance the user interface, yet require no recognition. The reason is, each is used for computer mediated *human-human* interaction, as opposed to human-*computer.*

What we are seeing is speech as a document type, which can be treated much like any other document. Hence, it can be created, edited, saved, output, or mailed. This in itself is fine. Where the real "sweet spot" lies, however, was defined over six years ago in the *Freestyle* system from Wang. While no longer available, Freestyle showed how voice messaging had particular value when coupled with other document types. In particular, it enabled users to annotate a document by free-hand writing and pointing (using a stylus), much as you would with a pen on a printed document, an *recording your voice as you marked.* Hence, the recipient of the document not only got the marked up document, they got a synchronous playback of your voice and pointing/marking gestures as well.

This is where speech technology is moving, and it is likely that - in the short and long run - this class of "multimedia" will have more impact on business than the ability to send digital video to one another.

Recognition
Recognition systems are mainly bounded by vocabulary size and training. In short, the larger the vocabulary, the harder it is to disambiguate what is said. Likewise, if the recognizer is trained to the individual speaker, it is more likely to recognize what is said. Hence, large vocabulary speaker independent systems are unreliable and expensive while small vocabulary speaker dependent trained recognizers are practical, affordable and available. In a related vein, connected speech is very difficult to segment into individual words, and then parse, whereas single word commands are much simpler, and practically, the only viable option.

Store/Forward
Speech store-and-forward, or speech "document" support is where we are seeing the greatest change and where speech will likely have the greatest impact in the near future. Personal computers linked to telephones are now performing the role of answering machines. We are also seeing most email systems being augmented to support the transmission of voice mail. This is coupled with an increasing number of portable and desk-top computers being equipped with speakers and microphones as standard equipment. This is seen with most of the Apple Macintosh line, as well as workstations such as Sun SPARCstations and Silicon Graphics Indy machines.

We are also seeing integrated microphone/speaker systems becoming available for the PC market. These include the *Audioman* (Logitech) and *Windows Sound System* (Microsoft).

One of the places where speech has traditionally had a niche, albeit not in computers, is in portable dictating machines and note-takers. These portable devices have been important tools in highly mobile contexts. What we are now starting to see is a new class of notetaker that is computer compatible. Hence, the speech "document" captured in the field with a very portable recorder can be transferred to one's desktop document processor when back at the office. One early entry into this field is the *Assist,* (PCvoice, Roswell, GA).

1.4.4 Recent Events and Trends

Multifunction Devices

It is likely that in next year's edition of the *Technology Forecast* it will be difficult to talk about scanners, printers and fax technologies in separate categories, since one trend is towards what can be called *multifunction machines.* Consider copier, for example. If it is digital, then it is just a scanner hooked up to a printer. Now, if there is a networked computer and file system between the scan and print engine, either can be used independently. Now, if we have access to a modem as well between the two, we also have fax capability. What this is leading to is a single package, about the size of a laser printer, and costing what a laser printer did two years ago, that has the capability of a copier, fax, printer and scanner.

We are already seeing examples of this trend. One is the Canon CJ10, which is a 24bit 400 dpi color bubblejet copier/printer/scanner. At the very high end, there is the Xerox *DocuTech* series, which incorporates a 23 ppm 600 dpi scanner with an up to 135 ppm printer. Of course, this kind of networked multifunction support comes at about $200k. Significantly scaled down desktop units from various manufacturers will run about $5,000.

From Data Input to Control

Another trend is that technologies that have mainly been used for data input and transfer are being used for control, or part of the human-computer interface. One example of this is fax technology, which has been used for interaction in Xerox's *Paperworks* product. Similar transitions will occur with scanner technology and video input, the latter case, in which, video cameras will be used for login verification and aiding the computer to understand aspects about the environment in which interaction is taking place.

Video and Audio as Document Type

Currently, video is a novel and special data type. This will change, and video will be treated as just another document type that can be processed like any other document. Hence, our desktop machines will enable us to create, read, annotate, edit, store, retrieve and share video documents like any other document. Furthermore, we will increasingly see integrated or hybrid document types, that combine markings, voice, video and more traditional text and graphics.

The End of "Multimedia"

We will move away from "multimedia." Multi*media* is a technocentric word. What it represents is far better viewed in humancentric terms: multi-modal, multi-channel and multi-processing. These human characteristics are invariant. Hence, they are suitable parameters for long-term design. Hence, what currently called "multimedia' is simply technology that better reflects these human properties, i.e., it is a user interface issue. As this becomes increasingly recognized, we will move from the current hype. We will start realizing human potential, by better tapping and exploiting people's inherent skills, acquired from a life-time of living in the everyday world.

Audification

When we think of the use of audio in the user interface, we normally think of speech. Now, consider working and navigating through the information space of our workstations as a complex ecology. Compare how we navigate through this ecology to how we deal with the complexity of the ecology of the everyday world. In the physical world, we would be hard-pressed to cross the street or drive a car without constant acoustic signals providing us feedback about the state of the world. In short, dealing with the complexity of the everyday world would be significantly harder if we were deaf.

Now, consider that it is in just such a deaf state that we approach and cope with the complex ecology of the information domain. As such, we are handicapped, compared to what we could be, if comparable audio cues were available. What we are starting to see is the effective, subtle and non-intrusive use of sound to provide such feedback. Our view is that this will increase and bring with it a significant improvement in the quality of user interfaces for both general and special purpose applications.

1.4.5 Forecast

New Ways of Absorbing and Squeezing Out

As we discussed in the background section, our perceptions of technology are largely shaped by the things we see, touch and hear. It is along this dimension that we will increasingly see changes. Largely, we will see machines tailored to better "absorb" (capture) the artifacts of the physical world and let us integrate them in with our information base in the electronic domain. Likewise, we will become better able to "squeeze out" items from the electronic world into the physical one. Briefly stated, new specialized technologies will increasingly appear that help bridge, in a seamless manner, our two information spaces: that in the physical domain, and that in the electronic.

Place-Based Computation

Of central importance to achieving the seamlessnes described above is delivering and capturing information artifacts "in place." That is, in whatever context we are working (location, etc.), the means of capturing and delivering the relevant artifacts of the work will be provided. The notion of desk-bound or office-bound computation is breaking down. But this goes further than just portable computers which, up to now, are just shrunken down desk-top machines. The emerging machines won't look like current computers, and they may well not be portable: locations for type X work will be equipped with type X appropriate machines.

From Super Appliances to Ubiquitous Media

As a consequence of the thread that we are following, there will be a move from general purpose workstations to very specialized machines. Neither one size nor one style will fit all. Devices will be highly specialized and distributed. With this will come increasing demands on distributed computation, communication and integration.

What is clear is that there will be a move away from the "super appliance" approach to design that dominates today's desktop. By this, we mean the end of desk-smothering (as opposed to "desk-top") boxes that try to be a telephone answering machine, address book, video editing suite, training centre, document processor, fax machine, secretary, etc. all at once. Current designs are just too complicated. They are the hardware equivalent of the JCL of old: something that tries to be all things to all people, but not much of anything to anybody, unless you are prepared to dedicate our life to them.

Specialized devices, integrated and distributed in space at locations appropriate to their function is where we are heading. This can best be called *Ubiquitous Media.*

Background Interaction and Capturing Context

Finally, human interaction with computers has been dominated by foreground "conversational" type activities. Almost everything has to be explicitly set for the computer. Take our earlier example of scanning and *Easy Scan.* Before Easy Scan, the user typically had to go though a laborious iterative process of adjusting parameters to capture a page. This was just like older cameras that required a Ph.D. to make all of the adjustments needed for a good shot. Now, like modern cameras, systems like Easy Scan apply knowledge of the domain to adjust themselves for the task at hand. State which previously had to be set explicitly in the foreground by the user is now set, using a knowledge of context, in the background by the system. Such off-loading represents a significant reduction in cognitive overhead on the part of the user, and makes the benefits of technology far more accessible.

What we are going to see in the future, largely as a result of Ubiquitous Media, is an increase in this shifting of state maintenance from the explicit foreground to the implicit background. Like the satellites that continuously collect knowledge of the earth's environment through *remote sensing*, the various specialized Ubiquitous Media devices will perform a similar function with respect to our more immediate environment. Since it is a little closer, we might call this *proximal sensing.* Through it, our systems will know more about us, our activities and intentions. Thereby, they will better be able to interpret our foreground actions, like *Easy Scan,* based on a knowledge of the context in which they are made - a knowledge gained in the background. As a result, a path to realizing the potential of the emerging technologies will be provided *within the human's threshold of frustration, or complexity.*

1.4.6 References

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