Disability, Inability and Cyberspace*

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1 Introduction

Computers, the internet, and the larger communications network of which it is a part, provide an informational structure within which many of us spend a large part of our working day and a significant part of our leisure. We are, during those periods, "infonauts in cyberspace," using the internet to get information from places near and remote, and acting in various ways through the internet to have an effect on computers and people in those places. This cyberspace revolution is changing the human condition in fundamental ways.

These changes have the potential to reduce differences between disabled and non-disabled individuals. As infonauts, none of us receives the information we need directly from our senses, nor do we produce the effects we intend directly by use of our limbs. We all depend on technology to aid our senses and magnify and transform the effects of our movements. Neither the blind person nor the quadriplegic nor the sighted mobile employee can access the latest government regulations or send instructions to colleagues in distant places without the help of the internet. The difference between

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individuals with disabilities and those without becomes simply a matter of the particular input and output devices that they need to access the computer network. The first person needs voice or Braille output, the second needs voice input, and the sighted employee is used to using a monitor and a keyboard.

From a theoretical perspective the differences in input and output needs seem minor in comparison to the shared dependence on technological infrastructure. As a practical matter these differences can be immense. Increased computing power is complicating the lives of disabled people because more and more applications are becoming available with inaccessible user interfaces. Complex sound, ever faster and more brilliant graphics, and real-time video all create problems for some individuals with disabilities.[1]

Part of the problem is economic. Because the financial resources of mainstream computer companies are linked to applications, access issues take a back seat. But part of the problem is lack of imagination. Too often the designer focuses on the standard mix of sensory and motor abilities, with at most some vague plan to later retrofit solutions for individuals with disabilities.

We believe that decisions and innovations that create difficulties for individuals with disabilities are often more a result of confused thinking than ill-will. In this paper we will try to provide a framework for thinking about design that we hope will lead to better designs for all individuals.

In the next section we distinguish between an *impairment*, a *disability*, an *inability*, and a *handicap*, and we use these to distinguish two perspectives on the connection

[1] A potentially tragic case is the graphical user interface (GUI) problem for blind computer users. Fifteen years ago computers standardly output information on a screen with 24 rows and 80 columns, each cell filled with an ascii character. Such text could be automatically converted to speech by screen-reader programs. Blind computer users usually can adapt to a reading speed of two to three times normal talking speed. Blind computer users could work as efficiently as their sighted co-workers, using the same hardware and software, augmented only by the screen-reader.

The rise of the graphical user interface, of the sort introduced by Macintosh and made ubiquitous by Microsoft Windows, with its icons and multiple windows, has been a disaster for blind computer users. Text-based screen-readers cannot handle the graphic displays. Considerable ingenuity is now being invested in providing an interface to the graphical user interface for blind users. But these efforts are taking time. Access programs for MS Windows 3.1 became available at about the same time as the program was superseded by Windows 95. Much remains to be done before blind users have anything approaching parity with sighted users. In the meantime, many blind workers cannot be as productive as they once were, and some have even lost their jobs. This problem is discussed more extensively in Appendix I.

between disability and handicap, which we call the *intrinsic* and the *circumstantial* perspectives.

In Section 3 we discuss *achievement space*, distinguish *tools* from *infrastructure*, and define cyberspace according to these concepts. We note that individuals who cannot access cyberspace have an *inability*; this inability is a serious handicap in today's information age regardless of whether or not the reason for the inability is a disability. In Section 4 we discuss some dilemmas connected with potential access solutions. In Section 5 we present an architecture for accessible design, the "Total Access System", show how it is based on the circumstantial conception of disability and how it minimizes the difficulties of designing for access, and discuss some implementations. In the last section, we relate the circumstantial model and the Total Access System to the Americans with Disabilities Act (the ADA) and argue that from the point of view of the circumstantial conception of disability and handicap, the requirements legislated by the ADA are simply the application to individuals with disabilities of the same approach to inability that society takes toward others.

2 Two Concepts of Disability and Handicap

In order for individuals with disabilities to become full partners in the cyberspace era, their situation must be considered early in the design process of products and work environments. We believe that the key to good early design is an elimination of a confusion that is all too common concerning the connection between disabilities and handicaps.

In untangling the confusion we use the following glosses on "impairment," "disability" and "handicap" that basically follow the World Health Organization (WHO); we add the term "inability" to fill an important logical gap[9].

- An *inability* is anything a person cannot do.
- An *impairment* is a physiological disorder or injury.

- A *disability* is an inability to execute some class of movements, or pick up sensory information of some sort, or perform some cognitive function, that typical unimpaired humans are able to execute or pick up or perform.
- A *handicap* is an inability to accomplish something one might want to do, that most others around one are able to accomplish.[2]

A disability may be *directly* or *circumstantially* linked to an inability or handicap. The link is direct if having the disability leads, independently of circumstances, to having the inability: there is simply no way a person with the disability can accomplish the task in question. The link is circumstantial if, although in some circumstances there is no way for a person with the disability to accomplish the task, in other circumstances, where the right tools and structures to support them are available, there are ways.

Paraplegia, a disability, is directly linked to the inability to walk. But it is only circumstantially linked to the inability to move around under one's own power. This inability can be removed with a wheelchair. Blindness is directly linked to the inability to see text on computer monitor. But it is only circumstantially linked to an inability to gather the information presented there. The inability to get information from displayed or printed text can be removed through the use of Braille displays and speech-output screen readers. This example brings up an important distinction that must be made between information (the content of the textual message) and the form of information (displayed text, printed text, Braille text, audio text, etc.); we will discuss this concept again in the last section.

The term "handicap" is sometimes now avoided, but we think it can be put to good use, in the way WHO does. A handicap is an inability that leaves one at a comparative disadvantage. So conceived, a handicap is a special case of an inability. The connection between handicap and disability is much looser. We can be handicapped, even when we are not disabled. Americans who do not speak Japanese will be handicapped when they visit Tokyo, because while most people will be able to gather important information by

[2] In the formulation of these definitions we were assisted by comments by James H. Moor, Professor of Philosophy at Dartmouth College (personal communication) and an essay by R. Amundson (see footnote 3).

reading signs on buildings, they will not. And one can be disabled, without being handicapped relative to many tasks, if the proper tools and supporting structures are provided.

The concepts we now want to introduce are the "intrinsic conception of disability, inability, and handicap" and the "circumstantial conception of disability, inability, and handicap". For short we will refer to them in an abbreviated form: the *intrinsic conception* of disability and the *circumstantial conception* of disability.

The intrinsic conception of disability goes like this:

> A disabled individual is one who cannot make some movement that the majority of the population can make, or lacks some sensory capacity that the majority of the population has. As a result, disabled individuals are handicapped in many ways; they cannot realistically expect to accomplish many goals that others can accomplish. A disabled individual must either regain the motor or sensory abilities, or abandon the goals.

In contrast, the circumstantial conception goes like this:

> A disabled individual is one who cannot make some movement that the majority of the population can make, or lacks some sensory capacity that the majority of the population has. As a result, an individual with a disability may need to use different means than non-disabled individuals standardly use to accomplish certain goals. Handicaps are created when the tools and infrastructure to support these alternative methods are not available.

Ron Amundson puts the point this way, in his excellent article "Disability, Handicap, and the Environment"[1]

> "...a disability such as paraplegia becomes a handicap only to the extent that the paraplegic person's environment isolates him from some need or goal. A wheelchair user has virtually no mobility handicap in a building

> with accessible doorways, elevators, and work areas. But he is greatly handicapped when his goals are located up or down a flight of stairs. This is the *environmental concept of handicap*... A handicap results from the interaction between a disability and an environment; it does not flow naturally from the disability alone. We humans frequently construct our environments in handicap-producing ways. The reason is obvious. We design and construct our environments with a certain range of biologically typical humans in mind.[3](110)

The life of Franklin Roosevelt, President of the United States from 1933-1945, illustrates the difference between the two conceptions. Roosevelt was disabled as a result of polio; the muscles in his legs were wasted.[4] For a long time he tried to learn to walk, to overcome the effect polio had had on his legs through exercise, grit and hard work. He was in the grip of the first conception of disability. He was not successful in walking again.

At a certain point he decided to put his time and energy into politics rather than into the struggle to walk again. He used a wheelchair to move about his homes and offices. He had ramps and other structures built to accommodate his wheelchair.

Roosevelt had an impairment, atrophied leg muscles, which left him with a disability, he could not walk. Because of the disability, he was handicapped; he could not move around under his own power. He tried two methods for getting rid of the handicap. First he tried to get rid of the disability. Then he gave up on that, and simply adopted a different method for moving about under his own power.

After Roosevelt died, the ramps were removed from Hyde Park, his home. As a

[3] In his essay, Amundson is concerned to point out that disabilities simply do not fit many of the medical categories under which they are subsumed. Disabilities are not diseases (although they are often the results of diseases); being disabled is not a form of being unhealthy or frail or chronically ill. Amundson defines disability as "lack of species typical functioning at the basic personal level." Although sympathetic to the civil-rights approach to issues of access, Admundson argues that the exact justification and scope of the right to access needs fuller examination by philosophers, who have been handicapped by inadequate conceptions of disability and handicap.

[4] Information about Roosevelt is from Hugh Gallagher's *FDR's Splendid Deception*[3]. We take this opportunity to thank Paul Longmore, Professor of History at San Francisco State University for his class on Disabilities and Society which introduced us to this book. Many of the ideas espoused here had their roots in discussions in this class and in papers Paul has presented, for example [6].

result, for a long time some of the visitors to Hyde Park were handicapped (relative to the goal of moving about quickly and efficiently), in a way that Roosevelt himself had not been.

From the point of view of the circumstantial conception of disability, using a wheelchair was a reasonable decision on Roosevelt's part. It is similar in structure to the decision a commuter makes to buy a car, rather than getting in shape to run to work—or trying to learn to fly. Or the decision a teacher might make to use a microphone, rather than learn to shout. Or the decision an executive might make, to buy a Rolodex rather than enroll in a memory course. It was simply a matter of using technology to get rid of an inability—something each one of us does all the time. The only difference in the case of Roosevelt was that the inability to move around resulted from a disability.

Roosevelt felt that it would be political suicide to reveal to the American public that he used a wheelchair. It's not that Americans wanted to see their President walk everywhere. It was acceptable to the public for him to get from place to place by car—for there he was employing a bit of technology that non-disabled individuals also use. But it was not acceptable for him to use a wheelchair. Roosevelt knew that the American public was in the grip of the intrinsic conception of disability. At meetings in the White House, he would always be seated where he wanted to be, in a regular chair, when guests entered, and remain there when they left. He used heavy iron supports on his legs, that clamped into a position that kept his leg rigid, when he had to give a speech standing up. In certain situations, Roosevelt had to appear to walk to a podium to deliver a speech. In these situations his sons or associates would move him forward in such a way that his legs would swing forward as if he were walking with a little help. In fact he could not supply locomotion at all.

The illusion was thus created that Roosevelt had learned to walk again, but just couldn't do it very well. Being a poor walker was acceptable to the American Public. The truth, that Roosevelt had become an adept and efficient wheelchair user, was not acceptable. Most Americans who were alive when Roosevelt was President were unaware that he used a wheelchair. This fact became common knowledge only years after he died.

This attitude towards the President was pretty silly. As Roosevelt's career demonstrates, it simply was not essential, for the tasks a President needs to perform, that he be able to walk. Applicants for the Presidency of the United States, like applicants for any job, should be judged on their ability to accomplish the tasks that the job requires, not on whether they do them in the standard way.

3 Cyberspace and Accomplishment-space

It is especially important to appreciate the circumstantial concept of disability in the cyberspace era. Cyberspace offers an opportunity to level the playing field for individuals with disabilities for several reasons. First, the number of tasks that can be accomplished via cyberspace is increasing daily and will continue to multiply at rapid rates for the foreseeable future. Second, disabilities are invisible in cyberspace. Third, no stigma attaches to using the tools of cyberspace. Individuals who find it crucial to use cyberspace because of a disability will not be perceived as different from individuals who find it convenient for any other reason. Finally, cyberspace, depending as it does on digital convergence, can, in principle at least, facilitate the need for different forms of input and output. All of these points gain in importance, in the context of the Americans with Disabilities Act; cyberspace provides a structure that can be used to help make many "reasonable accommodations" to the needs of individuals with disabilities.

To argue these points we want to demonstrate that cyberspace is a giant step in the extension of what we call "accomplishment space".[5]

We will say a goal is in a person's *accomplishment space* if it is something he or she can intentionally accomplish. That is, a) there is some sequence of movements the person can execute, which in the person's circumstances, will be a way of bringing about the goal, and b) the person has, or has a way of getting, the information about the circumstances required to know what to do to accomplish the goal.

What we'll call *primitive accomplishment-space* includes only accomplishments

[5] See [4] and [5] for a development of the framework for action implicit in this discussion.

that are done without the help of *tools* or the intervention of other people—accomplishments like reaching out, picking up an apple and eating it. These acts will involve effects on our immediate environment, guided by the information we can pick up from our senses. At one time human agents lived and worked mainly in primitive accomplishment space. Perhaps at that time the intrinsic concept of disability would have been appropriate.

But today we all live in *extended accomplishment space.* One way to extend our accomplishment space is through *communication*. Mary sits in the living room, and asks her husband in the kitchen if there is an apple in the bowl there. She is able to find out relevant facts about the space beyond her senses. If he says "yes" she may ask him to wash it and bring it to her. She has an effect on things she cannot reach.

Another way of extending accomplishment space is through *tools*. If Mary had a long pole, she might be able to shake loose apples high on a tree. Tools magnify or transform the effects of a human movement, giving a movement a quite different effect than it would have otherwise, and changing the shape of accomplishment space. Without the pole Mary's movement would not been a way of getting an apple, but only a way of looking silly, as if she were gesturing to the apple tree. With the pole, executing this movement is a way of getting the apple to fall.

A third way is through *infrastructure.* Suppose that steps have been nailed to the tree. Mary has to move her limbs in a certain "climbing" way to use this bit of infrastructure. Moving her legs in that way wouldn't be a way of doing much of anything without the steps, but with them, it is a way of climbing high into the tree.

Although we find the distinction between tools and infrastructure useful, it is hardly clear and precise. We think of tools as closely related to certain effectors ("moving parts") and types of movements of them. The tool-user learns that certain movements, with the tool in position, have new effects. These become, if not additional basic movements, very low level actions, that the agent can perform at will in a wide variety of circumstances, with many different ends-in-view. And we think of tools as paradigmatically portable and often personal, traveling with an agent, and staying with the same agent. Thus a wheelchair is a tool, that provides a way of moving in various directions by moving one's arms in certain ways[6].

Infrastructure is paradigmatically associated with a structure, and accessible to many agents. A bit of infrastructure changes the effects of movements made by agents that use it, but not in ways that are closely tied to particular effectors and kinds of movements. A ramp is a part of the infrastructure of a building. Everyone can use it. Some walk up and down it, some roll up and down it.

In between paradigmatic tools and paradigmatic bits of infrastructure there are many intermediate cases. If Mary carries a rope ladder with her, it will have some of the feature of tools and some of the features of infrastructure.[7]

The internet is creating large changes in accomplishment space for those who have access to it. Assume Mary lives and works in California. Mary wants to order a book from a publisher in Europe. She finds the fax number on the internet, and then faxes an order for the book, providing her Visa number so that her account can be charged. As a result of her actions in California, various things happen in Europe. Someone pulls the book off the shelf, wraps it, and sends it to her. Mary made these things happen; the movements of the person in Europe are the intentional, planned result of the movements of Mary's fingers in California.

In terms of the movements that are executed, Mary's acts in this case are not much more complicated than eating an apple. But they are much more complicated in the structure on which they depend. The success of Mary's actions depends on the telephone cable and microwave connections that made it possible for her to pick up information on the web and send an order via fax. They also depend on the cultural institutions and commercial mechanisms that make communication via language possible, and the commercial mechanisms that make credit cards possible. When she is operating in cyberspace, using internet, telephone and fax, Mary can obtain information from places she cannot perceive, and affect events that are thousands of miles beyond her reach. Her accomplishment space is immense.

[6] Or some other bodily part, such as one's head or fingers, if the wheelchair is powered.

[7] As Batya Friedman has pointed out (personal communication), our conception of a tool is also incomplete; it doesn't account for tools that enhance our mental capabilities as with an abacus to enhance mental calculations or knots in a string to enhance memory.

Note that the basic structure of action is the same in this case as in eating the apple. Mary has a goal: bringing it about that someone in Europe send her a certain book. She has a way of bringing that about: faxing the order with the Visa number entered. She has a way of finding out the information necessary to fax, so that the order will get to the right hands: look up the number on the World Wide Web. And she has the capacity suit her action to the facts—to dial the number that will get the fax to the right person.

Cyberspace is thus the accomplishment-space created by a huge infrastructure that accommodates communication—communication among people and communication among people and all of the information nodes (web pages, airline schedules, commodities vendors, libraries, etc.) that are stored on the network of computers. Cyberspace is the latest stage in a long process of extending "accomplishment-space" beyond the limitations of our natural senses and abilities.

In general, the more our accomplishment space is extended by communication, tools and infrastructure, the less appropriate the intrinsic conception of disability becomes. It should have been obsolete by the 1930's, when Roosevelt had to cover up his wheelchair use. It deserves to be a dimly remembered fossil in the era of cyberspace.

4 Dilemmas of Access

Unfortunately, the circumstantial concept by itself does not solve all problems. A well-intentioned designer or employer with a good understanding of the circumstantial concept of disability can be presented with many dilemmas when it comes to providing access.

In most cases, the main problem is not the lack of an access strategy that is technologically feasible. Increased computing power makes it possible to implement superb access technologies. Advanced input strategies that are now viable include: special keyboards, document scanning, high performance speech recognition, head tracking, eye tracking, monitoring of facial expressions and interpretation of biological electrical signals. Viable output strategies include: alternative screen technologies such as direct laser stimulation of the retina, high quality speech synthesis, multi-dimensional sound, tactile devices that stimulate the sense of touch, haptic devices that use force feedback, and robotic devices. Advanced access tools such as these have the potential to make almost any disabled individual more independent and highly competitive in the workplace.

However, the fact that a technology has been developed, or could be, does not mean that it is commercially available, much less at a reasonable price. The high cost and unavailability of access technology can pose almost insurmountable problems.

These problems are compounded by the fact that users now often use many computers. Not so long ago, it was unusual for an individual to have access to more than one computer. Now it is commonplace for a person to use several computers each day. Even when it is feasible to modify a single computer to make it accessible to an individual, modifying every computer he or she uses may not be.

Not only do individuals use multiple computers, many computers have multiple users. It quite likely that several of the computers a person uses during the day belong to some institution, such as a bank or school, and will be used by a number of people throughout the day. Devices, such as ATMs and information kiosks are really computers in disguise and pose the same problems.

Computers with multiple users present more dilemmas. Whose responsibility is it to make publicly available computers accessible? Which disabilities should be accommodated on a publicly accessible computer? How is a system made accessible without exposing it to intentional or unintentional vandalism?

The most perplexing problem is how to accommodate all of the necessary disabilities without making the computer so complex that no one can figure out how to use it. Consider information kiosks, for example. A typical information kiosk is designed with a certain "standard" individual in mind. This person can stand close the kiosk and can use arms and fingers to operate keys or a touch screen. She can see the information displayed on a screen, can pick up paper output and read it, and can hear voice output. The inclusive designer cannot make these assumptions. A person who uses a wheelchair may not be able to reach the relevant buttons or see the screen easily; a blind person may be not be able to choose which buttons to push for various purposes, or see the output on the monitor or in print. A deaf person may be unable to hear the tones or spoken output, or be aware that it is occurring.

For each of these problems there is a solution, but is there a solution for all of them at once? Lowering the kiosk for the paraplegic may mean that others have to stoop uncomfortably to use it. Making all the output in speech may solve some of the blind person's problems, while exacerbating those of the person who is deaf. Perhaps a kiosk could be designed that offered every kind of input and output, with monitors and buttons at various heights, comfortable for all, and every needed input and output option built in—but what would it cost?

The Archimedes Project is developing a system that we feel poses solutions to some of these dilemmas. We call this the "Total Access System".

5 An Architecture for Accessibility: The Total Access System

Individuals with disabilities have problems accessing computers because of keyboards, mice and monitors. But these devices only come into play when computers communicate with people. When computers communicate with each other, keyboards, mice and monitors aren't involved. This suggests a way of separating the problem of access into two. First we provide an individual who has a disability with complete access to *one* computer. Then we provide them with access to *any* computer, by letting the one computer to which they have access take over the job of communicating with the rest. The Total Access System is based on a this separation.

The Total Access System was initially conceived by Neil Scott[8], and key pieces of

[8] In 1988 Neil Scott proposed a "Universal Access System" (now called the Total Access System (TAS)) that would make it much simpler for disabled individuals to access any computer or computer-based device. This was in response to inquiries about compliance with the 1973 Rehabilitation Act as amended in 1986 by passage of Section 508 of Public Law 99-506. At that time Scott was a disability access engineer at California State University, Northridge. The Total Access System split the access problem into three separate and much simpler components; an "accessor" to handle the specific access requirements of the disabled individual, a Total Access Port (TAP) to provide a standardized interface to any computer or computer-based device, and a communications protocol to enable any accessor to communicate with any TAP. The Universal Access System project moved to Stanford in 1993 when Scott became one of the founding members of the

the system have been designed and implemented by him and others at the Archimedes Project at Stanford University (see box).

The Archimedes Project is a project at Stanford whose mission is to provide individuals with disabilities access to computers and access to people through computer technology. The Project is based on the philosophy espoused in this paper which it embodies in the following six principles:

- Everyone requires help in gaining and effectively using information, not only those individuals who have disabilities.
- In itself, information is neither accessible nor inaccessible; the form in which it is presented makes it so.
- To be disabled is not necessarily to be handicapped. Handicaps can often be removed where disabilities cannot.
- Handicaps often arise from decisions to design tools exclusively for individuals with the standard mix of perceptual and motor abilities.
- Designed access is preferable to retrofitted access.
- Solutions that provide general access can benefit everyone.

This separation is embodied in the Total Access System in its two main components, the *Personal Accessor* and the Total Access Port or *TAP*. Personal Accessors vary from person to person according to the user's abilities and preferences. TAPs link the Personal Accessor to any host computers that the user wants to work on.[9] The Personal Accessor and the TAP communicate with each other in a high-level functional language we call the *Archimedes Protocol*.

A Personal Accessor is the conceptual solution to the first set of issues: providing an individual with access to *one* computer. A Personal Accessor is a personal computer with the hardware and software for the accessibility devices that a particular person

Archimedes project. Ongoing research is improving the performance of the system and broadening the range of devices that can be controlled.

[9] The Accessor can also serve as a communication aid for face to face conversation by transferring the user's inputs to an output device such as a speech synthesizer or connecting directly with another accessor used by a conversational participant.

needs built into it. A quadriplegic, for example, would have speech and head-pointing or eye-tracking built into his or her accessor. A person with advanced ALS would have eye-tracking, but not speech or head-pointing (since he cannot use these). A blind individual's accessor might include a speech synthesizer or a tactile display.

An accessor can be made small and portable and can travel with the user in the same way that many people now carry palmtops and laptops. It can be exactly tailored to the individuals needs and preferences, containing what is needed and not using memory or physical space for things that are not needed. Its only function is to provide access. Thus it does not become obsolete when host operating systems or applications are changed. Because it is modular, it can be easily upgraded as access tools improve. It separates input and output functions from applications so that it provides a consistent interface across devices and applications. It allows access to any host and computer-driven technology outfitted with TAPs including kiosks and microwave ovens.

A TAP is the conceptual solution to the second set of issues: access to *any* computer. A TAP attaches to a host computer through the keyboard and mouse ports. The connection between Accessors and TAPs is through a (wire or wireless) link that uses a specially developed serial communications protocol that is independent of both the accessor and the host. Standardization of the protocol allows any accessor to operate with any host device. From the perspective of the host, an accessor is indistinguishable from standard I/O devices. Input from the accessor through the TAP emulates a keyboard and mouse; output from the host computer through the TAP is displayed by the accessor in a manner appropriate to the user.

Because the TAP fools the host into thinking that it is getting its own keyboard and mouse input, Personal Accessors work on all applications and interfaces. Some alternative input strategy is used to "press" the key and "move and click" the mouse. It might be voice, Morse code, or single switch scanning. No matter what is used, it is all the same to the host computer; it is interpreted as keyboard and mouse input.

In this sense, accessors work equally well for all applications. Accessors can be made to work more efficiently for a given application by means of user-defined macros that are specific to the task and the way the user likes to work.

The TAP keeps the adaptive work outside of the host and therefore doesn't interfere with the functionality or speed of any of the applications running on the host. It is small (currently slightly larger than a computer mouse), relatively low cost, and simple to install, all of which encourage widespread access adaptation.

Future TAPs will also collect control signals, raw text, raw video, and raw sound from the host and transfer this information back to the Accessor for processing into a form that is accessible to the user. This is a crucial piece of the solution to the Graphical User Interface problem for blind computer users.[10]

Consider Jorge, a quadriplegic who uses his voice to control his computer. While at work Jorge's accessor is usually connected to a Macintosh desk top computer. Jorge speaks into a microphone. His words are recognized by a voice recognition program running on his accessor. The intensive memory and CPU demands of the voice recognition program do not affect Jorge's Macintosh. Jorge's accessor contains a software shell that allows Jorge to use intuitive macros suited to different applications, for example, he might say "begin fax", "read mail", "replace word", "spell checker", "print file", etc. The data from the accessor bypasses the keyboard and mouse of Jorge's Macintosh. The Macintosh-TAP converts the data to virtual keystrokes and mouse movements—Jorge's Macintosh cannot tell that it is being controlled by voice rather than by fingers.

Later in the day, Jorge needs to use a Sun workstation. The accessor stays the same; the macros are the same. The Sun TAP converts the data from the accessor to signals that supply virtual keystrokes and mouse movements to a Sun.

Jorge takes his accessor with him when he goes home. There he could in principle use it not only to operate his home computer, but also to operate his television, stereo, VCR, microwave, and so forth. The TAS design concept would apply equally well to kiosks and ATMs. Kiosks and ATMs outfitted with TAPs would be accessible to

[10] For further information on the Scott/Archimedes implementation of the Total Access System see [7] and [8].

everyone with an accessor.[11]

5.1 Design advantages

The TAS strategy is contrasted with the traditional "in-host" strategy: locating the assistive hardware and software in the host computer that the individual with a disability uses. The basic advantage that the TAS offers over the in-host strategy can be seen as roughly the difference between addition and multiplication. On the TAS strategy, one has to develop an accessor that outputs the Archimedes protocol for each input device and develop a TAP that inputs the Archimedes protocol, for each type of computer. To compute the number of technological problems, we add the number of assistive devices to the number of types of machines. With the in-host strategy, each combination of input device and type of host constitutes a separate problem. To compute the number of technological problems, one needs to multiply the number of input devices times the number of hosts.

There are further advantages, too. First, and foremost, TAS isolates the user from the whims of hardware and software designers. The accessor interfaces to host computers through a TAP which emulates the electrical operation of the physical keyboard and mouse. Keyboard and mouse functions are fundamental to computing and manufacturers get little advantage from changing them in anything but purely cosmetic ways. The IBM PS/2 keyboard and mouse, for example, is becoming a de facto standard throughout much of the computer industry, even among competing products. The ubiquity of the keyboard and mouse makes them a point of stability in an otherwise constantly changing world. They have become part of the infrastructure. Variations to the mouse, such as trackballs, finger pointers, touchpads, and the like, all use the same electrical protocols as a basic mouse. TAS currently supports TAP interfaces to IBM

[11] The Archimedes Project has commercialized TAPs for Macs, Suns, IBM PCs, and Silicon Graphics Machines. TAPs are presently licensed through Stanford University and are being distributed through Synapse Corporation in San Rafael, California. These can be used with a variety of available speech accessors. Other accessors mentioned in this section, namely, combined speech and head pointing, specialized keyboards, input expansion routines, and eye-tracking are in use in the lab as prototypes. Other ongoing work includes the development of additional input devices, improved expansion routines for use in communication aids, and smaller and more portable accessors. A prototype accessible information kiosk is also under development.

PC, SGI, Macintosh, and Sun computers. Any computer based device or appliance can be made accessible by connecting a suitable TAP. The TAP becomes part of the infrastructure.

Another significant advantage of TAS is that it allows a disabled person to use a single accessor to operate any computer or device that has been equipped with a TAP. A properly chosen and configured accessor provides a disabled user with a very high level of independence and will last a very long time. It therefore makes good economic sense to invest whatever it takes to match an accessor to the needs of a disabled individual.

Research at the Archimedes Project has shown yet another real advantage of using the TAS design. Many different technologies are potentially useful for disabled individuals. Developing the necessary hardware and software interfaces to real-world tasks, however, is usually a far from trivial exercise and many good ideas languish due to the effort required to evaluate them in a real application. The TAS provides an ideal vehicle for evaluating and incorporating new technologies because it automatically connects new access devices directly to the existing infrastructure. An eye-tracker, for example, follows the movement of a user's eye and generates a stream of data showing where the user is looking. With suitable software, the eye-tracker can be used to emulate a keyboard or mouse. The question is, which keyboard and mouse should it emulate? This question is moot if we configure the eye-tracker as an accessor. The researcher need not be concerned with what the eye-tracker is to be connected to since anything that can be controlled by a keyboard or mouse can be controlled by the eye-tracker.

The TAS allows several different accessors be used simultaneously on the same host system. This leads to several interesting possibilities. For example, more than one person can have equal access to a single host device and can therefore work cooperatively on a single project. Similarly, a single user can operate several different accessors at the same time and can therefore mix and match different input strategies to suit the tasks being performed. One very effective example of this is the combination of speech recognition and head tracking. The speech accessor handles all text input, program commands, and pressing or clicking of the mouse buttons, the head tracker handles all of the pointing functions. The combination of speech recognition and head tracking is significantly more effective than either technology used by itself.

It is a small step to see that the TAS concept has advantages for non-disabled individuals whose experiences, preferences, or work-conditions may dictate or encourage one type of access over another. For many professors, executives, physicians, and lawyers, for example, talking is easier and faster than typing. Individuals who drive and use cellular phones will need to talk rather than type to their computers. Car radios would be safer if we could operate them with our voices instead of with our eyes and hands. Employees of the tele-marketing industry would be more productive if the spoken words used to confirm addresses and orders could simultaneously enter the data into the computer database. ATMs that could be operated by voice from within one's car would be popular with everyone. As John Thomas puts it in an article in this volume, accessible issues "force designers to think out of the box." He goes on to make the important point that when the communication system is made accessible to individuals with disabilities, everyone gains access to those individuals. He says, "Providing access for people with special needs is not just for them—it's for everyone."

6 Handicapping Practices and the Americans with Disabilities Act

The movement for the rights of individuals with disabilities, which was responsible for passage of the Americans With Disabilities Act in 1990, appealed to the circumstantial conception of disability. The legislation recognizes that handicaps don't result from disabilities alone, but from a combination of disabilities and circumstances, and that changing the circumstances can often eliminate the handicap.

The Americans With Disabilities Act requires that reasonable accommodation be made for people with disabilities in a host of areas, including employment. For example, Title I, Section 102, 5A, says that employers must make

> ...reasonable accommodations to the known physical or mental limitations of an otherwise qualified individual with a disability who is an applicant or employee, unless [the employer] can demonstrate that the accommodation would impose an undue hardship on the operation of the business ...

From the point of view of the circumstantial conception of disability and handicap, *this requirement is simply the application to individuals with disabilities of the same approach to inability that society takes towards others.* Science, engineering, and education in general are devoted to eliminating *in*abilities: creating knowledge, structures and tools that allow people to accomplish what they want and need to accomplish. These energies are devoted to "reasonably accommodating" the needs and aspirations of people, putting the goals they need or want to reach within their accomplishment space, by providing tools and infrastructures that change the circumstances within which they live and work.

6.1 Handicapping practices

This does not yet seem to be the typical way of looking at things. In discussions of the ADA, the following phenomenon is often observed. A person hears about the ADA for the first time (or thinks about it for the first time) and seems puzzled. Eventually, the person makes a comment about the unlikelihood of a blind race car driver, a quadriplegic NFL guard, or a deaf trumpet player. The point of such "joking" often seems to be that there is a sort of absurdity inherent in the law and the idea behind it.[12]

[12] Amundson notes a more serious motivation behind such examples when they arise in a philosophical setting:

> Well known problems of health care ethics have disability-related correlates. One is the problem of the "social hijacking" of resources by extremely needy people. Radical modifications in environmental design for extremely disabled people might be as expensive as radical medical procedures for gravely diseased people. Those unfamiliar with disability issues tend to concentrate on these dramatic examples. . .[a] paralyzed ballerina or a (hypothetical) blind person who wants to become an airline pilot. What conceivable environmental modifications could support the "rights" of those people to their chosen professions? The fact is that such demands are not being made. . ..([1],117)

Cases of social hijacking can certainly be constructed involving access to information. We provide no answer to the philosophical problem, merely sharing with Admundson the hope that clarification of concepts relating to disability will facilitate fuller philosophical examination of the basis of the right to access. In terms of practical problems of the expense of access, we think that in a large number of cases the TAS approach can

This reaction is provoked, we think, by trying to understand the law within an intrinsic conception of disability. The puzzled person thinks of disabilities and handicaps as inseparable, so that there is something simply confusing about the mandate of the ADA. In such a state, the mind is naturally drawn to examples that come closest to supporting the intrinsic conception, examples in which the connection between the disability and the handicap is maximally direct, minimally circumstantial.

This intellectual confusion can lead to practices that create and perpetuate handicaps. We list three.

1. Inadvertent Over-restricting. Inadvertent over-restrictions arise by the following flawed reasoning:

1) The primary function of *X* is to allow people to do *Y*.

2) Individuals with disability *D* cannot possibly do *Y*.

3) Individuals with disability do not need *X*.

And example of this reasoning is:

The primary function of a drivers' license is to allow people to drive.

Blind people cannot possibly drive.

Blind people do not need a drivers' license.

The fallacy is in the word "primary"; things often have important secondary functions that are overlooked in this kind of reasoning. The primary function of a driver's license is to certify that the possessor can drive safely. But in the United States licenses also serve as identity cards. Before the rise of credit cards, a driver's license was the only sort of identification that was widely accepted for cashing checks and similar purposes. So people unqualified to drive (for whatever reason) were not only not permitted to drive, but also had difficulty cashing checks.

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reduce the cost of access significantly.

This seems like the sort of problem that someone ought to be able to resolve with the stroke of a pen. But in fact, the problem was not quickly remedied; it required court action to direct states to provide ersatz driver's licenses for identification purposes, in spite of the clear injustice of the situation.[13]

The same sort of reasoning can be used for not making certain buildings or parts of buildings accessible. Why would a person in a wheelchair need access to a skating rink? Or a swimming pool? Reasons are not hard to imagine, once one stops and thinks. For example, persons who use wheelchairs may have ways of swimming or skating or may want to watch their children or grandchildren swim or skate. Indeed this latter reason was the basis of a court decision that resulted in wheelchair accessibility to a bowling alley.

At bottom, the problem is not so much faulty reasoning, as a lack of foresight. The GUI problem can be seen as an instance of this. When the first graphical user interfaces were developed in the early 1980's, the question of how a blind person would use these interfaces was sometimes asked. The answer was that a blind person would not use these interfaces; they wouldn't want to, because they would provide no advantage over a command line interface. But of course in time the graphical user interfaces became so popular that a great deal of software was not available in any other format.[14]

Stanford has an impressive collection of Rodin sculptures—the largest in the world outside of Paris. Most of these are located in garden next to the Stanford museum, but a few are scattered around campus. Rodin's famous statue "The Thinker" is located on a ten foot high pedestal, near the Stanford Library.

Sculpture is a form of visual art that is enjoyed by blind as well as sighted individuals. Blind visitors to Stanford enjoy experiencing Rodin's sculptures, most of which are accessible to them—but not The Thinker.

By putting The Thinker on a high pedestal, Stanford assured it would be a visually prominent landmark on campus, and perhaps be a bit more awe-inspiring than it would

[13] The cases mentioned in this section were taken from *Enforcing the ADA; a Special Fifth Anniversary Status Report from the Department of Justice.* It can be found on the Department of Justice web page, http://www.usdoj.gov, or by calling 1-800-514-0301 (voice) or 1-800-514-0383 (TDD).

[14] See Appendix I.

be otherwise. But it was also inadvertently restricting the class of those who could enjoy it by touching it.

As a final example, consider the question of elevators in student dormitories. It has been argued that the ADA does not require that wheelchair-using students have access to the upper floors of a dorm, so long as accessible rooms that are equivalent in size and comfort are available on the first floor. But this position—whatever its merits in the courts—uses a definition of equivalence that is too narrow. The social life of dorms often varies in predictable ways from floor to floor. At Stanford, a typical four-class dorm has three stories. The top story rooms are sought after by upperclass males, presumably because of their remoteness from the faculty resident fellow cottages. The parties on the top story tend to be best, at least as measured by prevailing undergraduate values. The faculty and staff committees who plan the dorms might consider the accessibility of such parties of no real value to the serious student—but why should disabled students be more serious on average than any others? Doubtless, one can find successful alumni of Stanford who count such parties as among their most valuable college experiences.

The next two practices have to do with conceptualizing things at the wrong level of abstraction.

2. Confusing a task with a particular way of performing it The only way to walk is to move one's legs. But, as Roosevelt found out, there are many ways to propel oneself around a room, or get from one floor to another—as long as the tools and infrastructure are provided. The only way to type is to move keys on a keyboard. But there are many ways to enter data without typing. For example, one can use speech or an eye-tracker. When a task is confused with a particular way of doing it, designers make decisions that have to do with that particular method, not the essential nature of the task.

3. Confusing information with a particular form that it takes The exact nature of information is subject to philosophical debate, but on any reasonable conception, information is distinguished from the particular forms in which it is expressed, carried or stored in various situations. Consider, for example, the information that the wildflowers are blooming at Stanford. Someone might notice this while driving to work; remember it later in the morning and send an email message about it. That message might be read by Stanford alums in Germany, Korea and Japan, and conveyed to colleagues in those countries in the local languages. It might be printed out in Braille, or read by a screen-reader of a Program Officer at the NSF in Washington D.C. A Stanford researcher may read it on her home computer, and sign the information to her husband in American Sign Language before leaving for work. The same information, that the wildflowers are blooming at Stanford, is first carried by the visual system, then stored in the brain, then expressed electronically in one language. The same information is expressed in other languages, and in various ways, voice, Braille, print and sign.

The multimedia capacities of modern computers and the World Wide Web make it more possible than ever to provide information in various forms, but more tempting than ever to not do so. Suppose someone is designing a web page for a chain of motels. Much of the basic information, such as the name, address, phone numbers and rates of the various motels is naturally conveyed in text. But the web page might also contain pictures of the various motels, and maps on how to get to them from the nearest large highway. Perhaps next to the picture of a seaside motel might be a button that allows one to hear the sound of the surf.

One could argue whether or not it is theoretically possible to convey in text all and only the information that is conveyed in a picture; clearly, as a practical matter, it is not. Nevertheless, it is usually fairly easy to convey the salient information: “this picture shows a one story motel with a parking lot and swimming pool located in front of a large construction site,” “This recording allows one to hear the sound of the surf from a room in the motel; the slightly fainter sounds of the nearby freeway are audible when the surf is quiet.”

The rights of deaf individuals to serve on juries (with the institution providing ASL interpreters as needed) have been upheld as have the rights of blind individuals. One can conceive of cases in which direct inspection of evidence in a particular form—e.g., visual form or auditory form—by jurors would be expected to play a crucial and central role in the decision making process. That is, one can conceive of cases in which, because of our incomplete understanding of what makes different forms of information equivalent, a blind or deaf juror might reasonably be excused because of his or her impairment. But, in the case of a blind juror that was argued in court, such an argument was not made. In this case the juror was excused very early in the selection process, before being assigned to any particular case, simply for being blind.

6.2 Equal access to information

Even if everyone agrees that an accommodation is reasonable, there is still the question of who makes the accommodation and who pays.

On issues of mobility, the division of responsibility is clear legally and intuitively: people don't have to supply their own ramps and don't usually expect employers, stores, and other public facilities to supply wheelchairs.[15]

But in the cases involving computers and other technological equipment, things are not always so clear. We believe the "divide and conquer" strategy exemplified by the TAS system has the potential to lower and distribute the costs of accommodations that provide access to computers. At a first pass we would suggest the following guidelines:

- Employers and institutions are responsible for providing an accessible infrastructure, that will permit use of accessibility tools. On our approach, this would mean computers outfitted with TAPs, so that individuals with disabilities can operate the computer (or devices with computer front-ends) with their accessors.
- Agencies, schools, employers and other agencies that help provide equipment to individuals with disabilities should focus on providing accessors that are suited to the individuals continuing input and output needs and preferences, rather than

[15] There are exceptions. We expect airports to have wheelchairs available for travelers who need them. The rationale is basically that some travelers who use wheelchairs will travel without them (sending their chairs in luggage), and that some travelers will need chairs in airports that might not need them elsewhere.

computers whose utility is restricted to a particular class, grade, job, or other special situation.

To sum up. Philosophically and theoretically, modern technology in general and cyberspace in particular diminish the differences between disabled and non-disabled individuals. We all live in a hugely extended accomplishment space; we all depend on technology to bring us information and augment our action.

Individuals who are not agents in cyberspace have an accomplishment space that is diminished compared to others. Such a person is handicapped. The handicap may be caused by not having the right tool (e.g., an accessible computer) or by not having the infrastructure (e.g., an available phone line) to support the tool. If the individual has a disability, then there may be an additional problem: the right tool may be difficult to find or may be non-existent. The inability is the same whether the individual can't afford the right tool or can't find it; in either case in today's information-oriented society, the inability is a handicapping condition that affects an individual's opportunity to reach life's goals.

Equality of opportunity and equality before the law are recognized as basic American principles; the embodiment of these principles in the concept of equality of access and workplace accommodations is legislated by the Americans with Disabilities Act. In the information age, all of these principles entail another: equal access to information which includes equal access to cyberspace.

Appendix I: The Graphical User Interface Problem

Graphical User Interfaces (GUIs) use icons, pull-down menus, windows and other non-textual devices to enhance communication between computers and the people who are using them. Pointing devices, such as the mouse, are an integral part of the GUI. Such interfaces, as found on Macintoshes, PCs running Windows and OS/2 and almost all of the more powerful workstations, have proven to be a boon for many computer users including those with many types of disabilities. Blind users, however, are an exception.

For them, rather than improving access, the GUI has made computers less accessible than they were before. Screen reading programs for text-based computers are mature products which do a good job of automatically transcribing text from the screen into synthesized speech or Braille. Similar screen access programs for Windows-based computers are still in the early stages of development and are not yet able to provide comparable performance or ease of use.

Screen reading programs for Windows 3.1 took more than four years to develop. Soon after they became available, many businesses moved to Windows 95, requiring another lengthy round of development to catch up. While there are many successful systems for translating text-based screens into alternative sound or tactile representations, strategies for representing GUI screens are still quite primitive and difficult to use, and keeping up with GUI innovations is a never-ending cycle. The scope of the GUI problem for blind computer users increases as GUI interfaces become standard not only for computers, but for appliances of all sorts, video access to telephones, the Internet and interactive cable television.

Before GUIs, specialized access devices gave blind computer users almost equal access to information as sighted users. Now this access is threatened by the widespread acceptance of computers that rely almost totally on vision. Of course we do not suggest that GUIs be taken away from people who benefit from using them. However, as GUIs proliferate, it will be necessary to have access solutions that are much more general than at present, if blind people are to have general access to information comparable to sighted computer users.

One major problem in providing access to graphically displayed information is the lack of standardization in the way graphics is generated and handled by different hardware, operating systems and applications software. Another major problem is much more fundamental; we really don't know very much about how to represent graphical information to someone who can't see it. In other words, there are two critical problems to be solved: the first is how to extract text and graphical information from any computer screen; and the second is how to present graphical information to a blind user in an effective and efficient manner.

Solutions to these problems will require a variety of technologies. Synthesized speech, non-speech sounds, multidimensional sounds, touch, force, and movement are all potentially useful for conveying information to a blind user. The larger question of how to present information content efficiently when shifting from a visual to non-visual modality requires an interdisciplinary investigation of psychological, computational, and logical aspects of the representation of meaning and information in different modalities. The interested reader can found out about ongoing work in these areas by following the links in [2].

The following recommendations for promoting accessible interfaces were developed by members of a conference on Graphical User Interfaces and Blind and Visually-Impaired Computer Users held in Asilomar, California in November of 1993[a]:

- Agencies that fund grant proposals related to computer access should encourage vigorous efforts to develop accessible and efficient interfaces to computers and systems that use GUIs for blind users.
- An independent, vendor-neutral agency should develop and maintain standards and specifications for the inclusion of hooks within operating systems to support special access technologies.
- A vendor-neutral organization should define and widely disseminate Principles of Accessible Interface Design among all hardware and software designers and developers, not only of computer systems, but of all electronic devices that incorporate graphical user interfaces.
- The distinction between information and the form in which it is presented must be preserved in all electronic representations of information to allow the same information to be presented in a variety of ways.
- A considerable investment must be made in the training of individuals who are not visually oriented to ensure they are able to fully use computer systems that incorporate graphical user interfaces and tactile graphics.

[a] For more information on this conference and the succeeding one held in 1995, send email to mckinley@roses.stanford.edu.

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