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The Electronic interpreter for the deaf

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The Electronic Interpreter for the Deaf

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I. Introduction

Technological advances have brought a lot of benefits to hearing-impaired people to reduce their communication gap. Cumbersome, heavy and only nominally effective hearing aids were replaced by compact, easy to use hearing aids. The development of Telecommunication Device for the Deaf (TDD) allowed a deaf person to make a telephone call directly to another person. Cochlear implants have contributed to restore some hearing to those with a hearing loss. With closed captioned TV, hearing-impaired individuals were able to enjoy television news and movies.

Along with the technological advances, popularization of sign language interpreting has given more ways to relate to a highly verbal society. It has played an integral role in connecting hearing-impaired persons to hearing people in many circumstances. However, while it is evident that sign language interpreting provides a very substantial benefit to hearing-impaired persons, it still retains many problems and limitations.

Some hearing-impaired individuals, for instance, doubt the precision of interpreting. They also voice specific ethical concerns about confidentially. But the most critical problem is that it often causes a serious occupational hazard. Repetitive use of the hand can result in Carpal Tunnel Syndrome, in extreme cases, leading to permanent nerve damage and disability.[1] A significant number of interpreters have been affected by repetitive motion injury and many of them have had to leave the field.

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[1] Susan Cergol. "Repetitive Motion Injury." *NTID Focus,* Winter/Spring,1991. p.11.

Considering this situation, I realized that an electronic product, which would eliminate the possibility of a significant occupational hazard and enhance the independence of hearing-impaired persons, would be desirable. The underlying technology required for such a product is Automatic Speech Recognition (ASR). The most obvious application of large-vocabulary ASR systems is the creation of written documents by voice. The Electronic Interpreter for the Deaf, which was chosen as my thesis project provides a visual readout of the spoken words, while a deaf person's handwritten document on touch sensitive display will be conveyed to hearing people in artificial voice.

Designing a product for the handicapped requires special concern about its user. Experience has shown that many products for the handicapped have been rejected by the user group for their institutional look, no matter how well they work. Since a hearing-impaired user is typically quite normal in every respect except hearing, considerable time and effort was spent exploring the form. During this process, product semantics was introduced as a form determinant. It was a real challenge to design a product which can be semantically understandable, yet not conspicuously different from general consumer products.

In addition to the description on exploring the form, human factors consideration will be explained ; for instance, the effective way of manipulating the display readout or the appropriate positioning of an input handset. Also the applications of color and graphics will be added. The final sections of the thesis will be dedicated to evaluation, which includes opinions of hearing-impaired individuals and related specialists.

II. Common Problems of Hearing Impairment

Designers often make mistakes when designing products for the handicapped by considering only their physical impairments. While making efforts to solve the problems which is related to the physical handicaps, designers often miss to reflect on the other considerations such as psychological conditions of the disabled. Even though these products function very well as prosthetic devices, we have seen that they were ultimately rejected by their users. In relation to this, learning about hearing-impaired persons, and their problems which are raised by lack of hearing, is critical to design of effective hearing equipment. Communication is the biggest challenge and frustration for hearing-impaired persons. This communication handicap has an enormous impact upon a hearing-impaired person's educational, psychological and social well being.

The term 'hearing impairment' is a generic one covering a wide spectrum of between deaf and hard of hearing, affecting approximately 16 million Americans. Of this number, some 2 million can be classified as 'deaf'.

> The deaf have been defined as those in whom the sense of hearing is non-functional for the ordinary purpose of life. People in this category have no usable hearing. Some are congenitally deaf, either born deaf or becoming deaf before acquiring speech ; the others are 'deafened' meaning that their sense of hearing became non-functional later in life, probably through disease or accident. In contrast, hard of hearing are those in whom the sense of hearing, although defective, is functional with or without a hearing aid.[2]

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[2]Kenneth Lysons. *Your Hearing Loss.* p.5.

Hearing-impaired persons experience difficulties with verbal communication. This communication handicap retards the educational development of the deaf students. It is especially difficult for a born deaf or early deafened child to learn language. Although hearing aids and visual cues are used to develop speech, vocabulary development is delayed. This lack of access to a spoken language results in a serious delay of language acquisition, but more importantly a serious restriction in the acquisition of content material and structure.

The inability to understand speech in everyday life results in a considerable degree of isolation. This isolation imposes an important influence on the psychological adjustment of the hearing-impaired person. A person losing his hearing progressively, has to cope with misunderstanding and anxiety of contemplating the possible consequences of progressively deteriorating hearing. A sudden profound deafness is a significant shock, which will result in feelings of fear and loneliness.

Hearing-impaired persons are also socially handicapped. For instance, they are often excluded from good jobs because they and hearing co-workers can't communicate with each other. Sometimes, an employer may hire a deaf person, but a communication inability would force the employer to dismiss the deaf person.

When a person becomes deafened or hard of hearing he or she is likely to become aware of the extent of their deviance from normal people. The deaf person who signs is likely to be labelled "deaf and dumb." They feel prejudice towards themselves and loss self-esteem. A hearing-impaired individual may shrink from wearing a hearing aid because this advertises the disability. There also may be a refusal to seek help since this would mean being identified with a stigmatized group.

The feeling of stigma is likely to be reinforced by negative attitudes on the part of people with normal hearing such as discrimination in employment or promotion situations or a changes in a social status or traditional roles.[3]

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[3]Kenneth Lysons. *Hearing Impairment.* p.57.

III. Sign Language, Hearing Aids, Interpreters

The deaf person may receive information through lipreading, the use of hearing aids, sign language, and fingerspelling. An interpreting service may be provided to facilitate the communication between the deaf individuals and hearing people. Although, the means of communication mentioned above play an important role in eliminating the communication handicap of the hearing-impaired person, they still have many problems and limitations.

Sign Language

A sign language (for example, American Sign Language) is a system of gestures using the hands, arms, face, and shoulders to convey a particular thought. Finger spelling is part of the sign language system. In finger spelling a special sign representing each letter of the alphabet can be created using the fingers of one hand. Words are finger-spelled when there is no available sign for a particular concept, or when the signer wants to convey an English word.

Formal signs are another part of the sign language system. All of the signs in a particular system are composed of four features (hand shape, orientation, location, movement). The gestures that help make up a formal sign always stay the same. Pantomime, or the telling of a story with body movement, is also part of the sign language system. So are facial expressions and body language. By using these devices a deaf person can show moods and feelings.

Unlike hearing people who express their feelings by varying their voice tones, pitch or volume, hearing-impaired persons may repeat a sign several times or speed up a body movement. Language must be able to express concepts and ideas. In sign language, concepts are represented by specific combinations of the above.

American Sign Language (ASL) is one major sign system used by deaf people in the United States. ASL has its own grammatical structure, which differs from English grammar. Like all other languages, ASL has dialects: thus people in the Northeastern part of the United States sign differently from people in the Southwestern part. "There are also differences between the dialects of ASL spoken by the black deaf community, by the Hispanic deaf community, and by the white deaf community."[4] These dialect differences may result in confusion in communication.

Hearing Aids, Communication Devices

There is no question that hearing aids have been changed dramatically. Heavy, cumbersome, and only nominally effective hearing aids have been replaced by compact, easy to use ones. In-the-ear (ITE) type hearing aids, for instance, are compact enough to insert into the ear and they generally have only one control that needs to be adjusted. Current hearing aid types can be classified as either ear level, or body styles, according to their placement on the person.

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[4]Harry W. Hoemann. *Introduction to American Sign Language.* p.4.

ITE type aids, which are one of the four basic types of commonly used hearing aids, are getting very popular. The major user group varies from those with mild to those with moderate hearing losses. Because of its size, the aids are almost invisible to others from a front or back view. ITE type aids take advantage of certain acoustical features that are desirable for optimal hearing.[5]

Another popular type of aid is the over-the-ear (OTE) type, also called behind ear and post auricular. The hearing aids can be worn behind the ear. Or, the aids can be built into a pair of glasses. OTE type aids can be used for a wide degree of hearing losses from mild to severe.

Another type of hearing aid is the body-type. The body-type hearing aids are typically worn in a harness or garment bag or clipped to the clothing. The receiver is either air or bone conduction which is connected by a cord to the amplifier. The body-type hearing aids are versatile and can be adjusted to a wide range of loss degrees.

Most publicized among the special type hearing aid devices is the cochlear implant. The cochlear implant requires a special surgical procedure. The concept behind cochlear implants is restoration of some hearing to those with a hearing loss caused by cochlear or inner ear damage. A cochlear implant bypasses the damaged auditory hairs located in the inner ear and directly stimulates the auditory nerve, enabling profoundly deaf individuals to perceive some sound.

Along with these,Telecommunication Devices For the Deaf (TDD) opened up a new world for the deaf. A TDD lets a deaf person make a telephone call directly to another person having similar equipment, without the need for an

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[5]Alfred L. Miller. *A Practical Guide To Hearing Aid Usage.* p.15.

interpreter. The conversation is typed through one machine to another machine instead of spoken. TDD saves time, reduces dependency, social isolation and enhances the chances for employment and promotion. Many businesses have purchased TDDs for their deaf employees and customers. In many states, TDDs have been installed in government offices, libraries, hospitals, churches, and vocational rehabilitation offices.

With closed captioned TV, a deaf person is now able to enjoy live shows, such as news, sports, and special events. Real-time captioning is now in use and eliminates the time lag which is usually required to caption program before broadcast. " This captioning method combines the skills of court stenographers with special computer translation systems to provide almost instantaneous captioning." [6] For the deaf community, closed captioning made a major impact on their language by making them more aware of words that are used daily by the general population.

All of these benefits were provided by technological advancements, but unfortunately, this technological advance, so far, has not done away with the large variety of problems that hearing aids and other communication devices present.

ITE type aids, for instance, are not recommended for young children since the hearing aid would have to be refitted frequently to fit the growing child and this would bring additional expenses for their parents.

Although body-type hearing aids are versatile and can be adjusted to a wide range of loss degrees, they have disadvantage of requiring a cord and external receiver as well as the custom made earmold.

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[6] Nan Decker and Betsy Montandon. *Captioned Media in the Classroom.* 1984.

Cochlear implants are an important step to limiting hearing impairment but they have many shortcomings. Foremost of these is that implantation does not restore normal hearing. Suitable candidates for cochlear implants are less than 1 percent of the hearing-impaired persons. In addition, the surgical procedure and device are expensive, and there is usually a training period required for its proper use.[7]

Because television captions are part of the broadcast signal, problems with TV reception can result in problems with captions. Even marginally poor TV reception can cause caption problems.

Interpreters

Interpreting refers to explanation of another person's remarks through the language of signs and informal gestures. Communication difficulties between hearing-impaired individuals and hearing people can be eased through the use of an interpreter. For an interpreting service, there is a need for trained individuals who possess the skill and the ability to convey one person's message to others. To make communication as complete as possible, interpreters must relay accurately the meaning of the message being presented, whether those messages are in American Sign Language or other types of signed communication. Thus interpreters must be skilled in both American Sign Language and English.

While interpreters have played integral roles in reducing hearing-impaired persons' communication problems, it still retains many problems and limitations. Followings are some examples of these :

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[7]Alfred L. Miller. *A Practical Guide to Hearing Aid Usage.* 1991.

- Deaf individuals are concerned with the accuracy of the translation from sign to voice and vice-versa. Only veteran interpreters have polished this most difficult skill.

The use of sign language interpreters would exclude orally-oriented hearing-impaired people, as well as that group of people who lost their hearing later in life from accidental causes, illness, or old age.

Deaf individuals raised specific ethical concerns about confidentiality.

- Interpreters are not always available.
- Often interpreters are unable to keep up with the speakers' pace.

With an interpreter between a hearing-impaired person and the TV, the viewer has to move his head back and forth all the time.

If a lecture is continued after passing the expected lecture hour, some interpreters will go out of the classroom leaving deaf students on their own.

To the non-hearing-impaired students in the classroom, the presence of the interpreter making movements at the front of the classroom is distracting.

- An enormous amount of mental processing and concentration is required to interpret highly technical information.

But one critical problem is that interpreting often can result in a serious occupational hazard for the interpreter. Repeated hand and arm motions such as those required for educational interpreting often result in repetitive motion injury.

"Repetitive motion injury has emerged as a significant occupational hazard within the interpreting profession as well as within several other fields. The disorder, a variety of inflammations of the hands, arms, and shoulders caused by repetitive motions, can result in permanent disability and is the single most frequently reported work related injury in the country."[8]

Also known as cumulative trauma disorder or overuse syndrome, repetitive motion injury refers to a variety of inflammations of the hands, arms, neck, and shoulder. "Whether it appears as Carpal Tunnel Syndrome, or a number of other ailments that affect the nerves, tendons, and joints of the hands, repetitive motion injury often results in considerable pain and can, in extreme cases, lead to permanent nerve damage and disability."[9]

According to Susan Cergol, a reporter of *NTID Focus*,[10] a significant number of Rochester Institute of Technology's 65 interpreters, who provide a vital link between the hearing and hearing-impaired students, have been affected by repetitive motion injury and 14 of them have had to leave the profession since 1985 because of this injury As many as 25 other interpreters have experienced related pain and temporary disability.

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[8]Williams E. Castle. "Signs of Concerns." *NTID Focus*, Winter/Spring 1991. p.2.

[9]Susan Cergol. "Repetitive Motion Injury." *NTID Focus*, Winter/Spring 1991. p.11.

[10]*NTID Focus* is published by the Division of the Public Affairs at the National Technical Institute for the Deaf, a college of Rochester Institute of Technology, Rochester, New York.

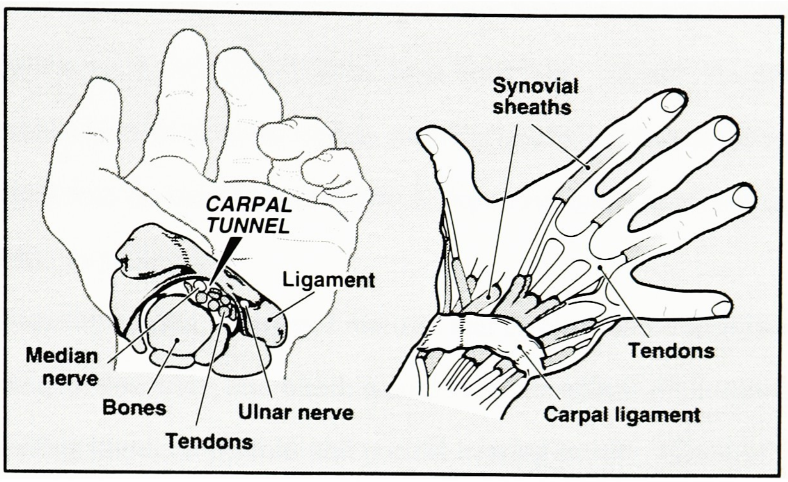

Fig 1: A pain in the wrist. 1990 by The New York Times Company. Reprinted by permission.

In addition, the cost of providing interpreting service can not be overlooked. Section 504 of *the Rehabilitation Act of 1973*, requires that almost all public institutions, such as school systems, police departments, libraries, courts, jails, transit systems, and public assistance programs should provide sign language interpreters as well as TDD. For doing so, considerable amount of money is necessary, and it is burdensome to the institution.

Sign language interpreting has played an important role in providing deaf people with access to a mainstream environment. The problems mentioned previously limit the desirability of relying on sign language interpreting for communication. Along with this, it has been found that conventional hearing aids and other communication devices could not address the problems that a large variety of hearing impairments present. For example, in the case of deaf people whose loss of hearing is severe most conventional hearing aids, which only provide amplification, are not beneficial. Also, cochlear implants, which raised substantial expectations from the deaf community, have since been found not to fully restore hearing, and the number of beneficiaries have been few. At best, the operations will allow patients to function as well as severely hearing-impaired persons[11] and it has been found that the surgical procedure is expensive and a special training period is required for its proper use.

Considering this situation, I realized that an electronic communication product would be desirable; one which would facilitate effective communication between hearing-impaired persons and normal hearing people, eliminate the possibility of significant occupational hazard to interpreters, and minimize expense of providing auxiliary aids. I felt that a machine which could act as a deaf person's ear and voice regardless of place and time, and ultimately provide a complete communication independence to a deaf person, would be the goal of my efforts.

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[11]Birgitta Soderfeldt. Cochlear Implants and the deaf community. *A Deaf American Monograph.* 1991. p.141.

IV. Electronic Interpreter for the Deaf

While trying to decide the design direction for the electronic communication device, I found that providing a visual output of what hearing people are saying for deaf people would be a desirable characteristic. I found the technology related to it was available even though the technology was not very sophisticated. I also found that a deaf person could express himself or herself by inputting into a computer by writing on a touch-sensitive display. A message written in this manner could then be made audible by a speech synthesizer. Before starting the concrete design work, I named the device "Electronic Interpreter for the Deaf".

The Electronic Interpreter for the Deaf helps hearing-impaired persons communicate with hearing people. It provides a visual readout of spoken words, while a deaf persons handwritten document on touch screen display will be conveyed to hearing people in artificial voice. Actually, a considerable amount of time was spent to decide on the input/output device such as a touch sensitive display, and an input pen that will be discussed later. Large-vocabulary automatic speech recognition and speech synthesis technology are required for this design. These are available for the conversion of spoken words into computer text, and the generation of machine voice.

This product can give substantial benefit to hearing-impaired and deaf persons. With this product, a deaf student could not only see a teacher's message, but also ask questions whenever he wants to without the need of an interpreter. This will give more independence to hearing-impaired persons. By using this machine, they don't have to be concerned about the absence or presence of an interpreter or the breach of confidentiality while they are getting interpreting service. They can have "give and take" in real time to speed up the communication process.

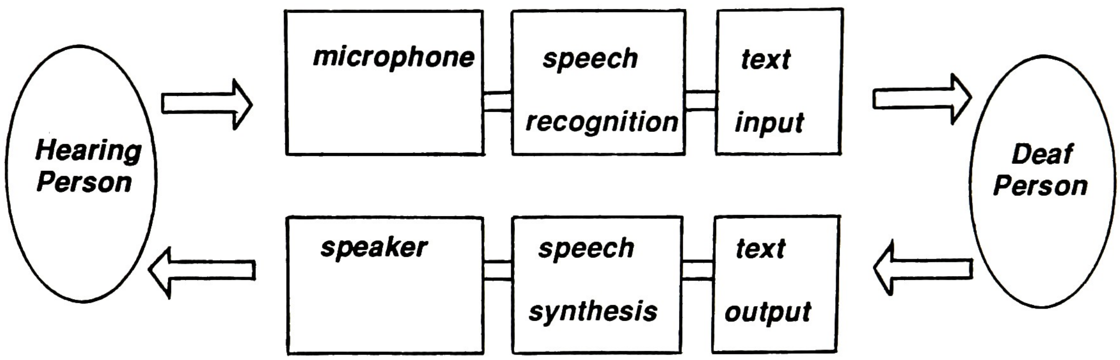

Fig 2: The Information Flow of the Electronic Interpreter for the Deaf.

Goals

- The Electronic Interpreter for the Deaf should be easy to use. To do this, all the parts including a display, controls, speaker, et cetera, should be arranged according to the sequence of operation, the frequency of use, the importance, and other considerations.
- A suitable size of display readout should be designated while maintaining the compactness of the machine. Text on the display should be easy to read.
- The Product should be durable.

The product should be lightweight so that it can be carried easily. This feature is very important because this product should work at anytime, anyplace.

The product should be unobtrusive.

It has to be esthetically interesting and pleasing to avoid stigma. Since hearing-impaired persons are typically quite normal in every respect except hearing, the appearance of it should be similar to other consumer products.

- Maintenance should be easy. The power supply should not restrict use to only certain locations or short amounts of time. In relation to this, the possibility of using both a rechargeable battery and DC adapter which connects directly to an electric current at home can be considered.
- The price of the product should be reasonable. The target price range would be $ 400-500 so that deaf persons can purchase it for themselves if it is not provided through an institution.

V. Explanation of the State of Art

Developing the Electronic Interpreter for the Deaf represents a considerable technological challenge. The underlying technology for this machine is called speech recognition and synthesis. Large-vocabulary Automatic Speech Recognition (ASR) technology could be used to translate non-hearing-impaired people's speech into the written word for the deaf people. In response, a hearing-impaired person's written document can be changed to voice by speech synthesis technology.

Large-vocabulary Automatic Speech Recognition

Among the many media of communication with the computer available for input, speech is one of the most desirable means of communication with it. Sometimes no medium is as speedy and natural as human voice. Because of this advantage, ASR is getting considerable attention. Voice recognition is the conversion of spoken words into computer text. Speech is first digitized and then matched against a dictionary of coded wave forms. The matches are converted into text as if the words were typed on the keyboard. The commercial applications of it include credit card verification, sales order entry, banking and other financial transactions, and many others. In the telephone companies, these systems will begin to replace the human operator for services, such as collect and credit card calls, for example.

While the applications mentioned recognize only a small vocabulary of a few hundreds words, larger markets are projected for systems that can handle large vocabularies. Large-vocabulary means a vocabulary of about 10,000 words or more.

The most obvious application of large-vocabulary ASR systems is the creation of written documents by voice.[12] For example, with this technology, if a doctor's prescription is displayed on a screen of a computer based machine as it is being dictated, it would have advantages in terms of speed, accuracy, and convenience.

Large-vocabulary ASR also can provide considerable benefits to the handicapped. People with insufficient manual dexterity to operate keyboards can still create written documents by speaking to a computer equipped with ASR.[13] According to Kurzweil, a world renowned speech researcher, the greatest potential use to the handicapped for an ASR-based device would be in providing a visual readout of what people are saying for the deaf.

To develop the Electronic Interpreter for the Deaf, a large-vocabulary ASR combined with speaker independence and continuous speech is required.

James Gleen defined some terminology to describe ASR as follows[14]:

- Speaker-Dependent Recognition : A procedure for speech recognition which requires a speaker to "train" the system before reasonable performance can be expected.
- Speaker-Independent Recognition : A procedure for speech recognition which requires no training of the system from the individual who is to use the device.

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[12]Raymond Kurzweil. *The Age of Intelligent Machines.* p.69.

[13]Raymond Kurzweil. *The Age of Intelligent Machines.* p.69.

[14]James Gleen. *Speech to Text : Today and Tomorrow.* p.164

- Isolated Words : Words spoken with pauses (typically with duration in excess of 200 milliseconds) before and after each word.
- Connected Words : Words spoken carefully, but with no explicit pauses between them.
- Continuous Speech : Words spoken fluently and rapidly, as in conversational speech.

Speech-independent recognition, which recognizes speech from any new speaker, is a very difficult task. Because most parametric representations of speech are highly speaker-dependent, a set of reference patterns suitable for one speaker may perform poorly for another speaker.[15] Because of these difficulties, most speaker recognition systems are speaker-dependent, requiring training of the system by a speaker before getting reasonable performance. In isolated-word recognition, word boundaries are known, however word boundaries in continuous speech are not clear. Therefore, the error rate in continuous speech is higher than in isolated word recognition.

In spite of these problems, many researchers are concentrating on developing systems capable of accepting very large-vocabulary, continuous speech dictation, and speaker-independent recognition, because there are limitations to speaker-dependent systems. For example, in the case of speaker dependent systems, the training session is an inconvenience to the user. Certain applications, such as telephone directory assistance of banking inquiries, cannot tolerate the delay of a training session. Pauses between utterances in the isolated-word recognition systems hinder rapid input of spoken commands.

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[15]Kai-Fu Lee. *Automatic Speech Recognition.* p.3.

Thanks to many researchers' continuous efforts, the capabilities of ASR systems are rapidly improving.

> "As of 1989 ASR systems could either recognize a large vocabulary (10,000 words or more), recognize continuous speech, or provide speaker independence (no user training), but they could provide only one of these capabilities at a time.[16] In 1990, commercial systems were introduced that combined speaker independence within the ability to recognize a large-vocabulary."[17]

Kurzweil expects that we'll see large-vocabulary systems that can handle continuous speech at a time in the early 1990s.

Speech Synthesis

" One of the most exciting applications of speech synthesis technology is to provide a voice prosthesis for the speech impaired."[18]

Speech synthesis is the generation of machine voice by arranging phonemes into words. It is used in text to speech applications, which turns text input into spoken words. There are many text-to-speech systems today. These

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[16]Kai-Fu Lee introduced SPHINX system which was the first system capable of recognizing continuous speech from a large vocabulary and from any speaker. The development of the system was described in a book named *Automatic Speech Recognition.*

[17]Raymond Kurzweil. *The Age of Intelligent Machines.* p.270.

[18]A.F. Newell. *Speech Input/Output: Technique and Applications.* p.3.

include study and teaching equipment for children, automatic reading machines for the blind, and diagnostic tools of speech problems. A major group which can benefit is people whose speech is not sufficiently intelligible to allow effective communication with others.

Although the quality of speech made by speech synthesis is not perfectly human, it is good enough to be intelligible. Many researchers expect the speech output will become more natural in the very near future.

VI. Design Development

"What needs to be articulated, regardless of the format of the man-machine relationship, is the goal of humanism through machines." [19]

For a long time a designer has been regarded as the adroit producer of sketches, as the creator of attractive styling. But today, in addition, a designer needs to understand real human needs and make technology more user-friendly. Basically the thesis so far has been dedicated to explaining the need for a new communication device for deaf people and the technology required for developing it. Chapter 6 is dedicated to explaining the design process of the Electronic Interpreter for the Deaf in terms of user-friendliness. The process of concept exploration, form exploration, the applications of color and graphics will be described. In concept exploration, the process which I undertook for choosing the final concept among three different concepts will be explained. In the form exploration, mainly the application of product semantics which deals the study of the symbolic qualities of form will be described.

Concept Exploration

I had some difficulties in conceptualizing the Electronic Interpreter for the Deaf. Since it was a completely new product there were no similar products available providing references. I came up with three different design concepts.

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[19] Nicholas Negroponte, Professor, MIT.

The first concept was an idea of combining a pair of eyeglasses with two projectors which were attached to each arm of eyeglasses. In this concept, the spoken words are translated from sound in the processor by speech recognition technology which then are displayed to the user as a virtual image. The projectors on each arm project the spoken words toward the lenses of the eyeglasses. The information ,which was translated from sound, is sent through a cord from the main unit to the projectors. The main unit can be worn on a belt like a portable radio. For the user to express himself or herself, a stylus pen is used for input on a touch sensitive display. The display is built into the main unit.

The reason I chose this concept was that I thought an eyeglass type hearing product would be ideal, since many people wear eyeglasses, and some people even wear them for enhancing their appearance. To examine the possibility of this concept, I met several experts including some professors specializing in imaging science and optics. Although they agreed that it was possible to realize the concept, they doubted the feasibility of making the small projectors that I envisioned.

The second concept was an idea of using a transparent display for output of spoken words. By using a transparent display which can be extended to the height of user's faces by a connector, a deaf individual not only could see spoken words but also look a speaker's movement at the same time. The unit is hung down on a user's chest by a strap when it is in use and can be carried on a shoulder by the strap when it is not in use. In this concept, a user doesn't have to lower or lift his or her head to see the spoken words on a display and to look a speaker's movement. Unlike the first concept, which consisted of two parts of eyeglasses with projectors and a main unit, this concept consisted of one piece when it is not in use. In use, the transparent display, as mentioned, can be extended from the main unit to the front of a user's face. I found the underlying technology for the transparent display had progressed considerably in some companies including Apple Computer and Taliq Co., although the display by this technology was not perfectly clear (it's a little foggy).

A foam board soft model was made to test the possibility of this concept. Looking at the result, it was pointed out that a transparent display between a user and the other party might still be a barrier to smooth conversation and might draw attention to the handicap of deafness. Some hearing-impaired students I interviewed didn't like the idea of hanging a device on their chest, because they didn't want emphasize their handicap while they were using a hearing device.

Another concept was a somewhat conventional one. Like many other portable electronic products, the design could be foldable and have a display. The differences are that this design uses a stylus for input instead of a keyboard and the touch sensitive display could be separated from the main unit so a user could operate it by holding it in his hand. The advantage of this concept was that it was the least conspicuous among the three ideas. Carrying it in their pockets or bags when it is not in use, users could take it out whenever needed.

Considering the advantages and disadvantages of three concepts, I decided upon the final concept of the Electronic Interpreter for the Deaf. Basically this concept combined concept 2 with concept 3. The concept 1 was excluded because, as mentioned above, unless the size of the projectors is small enough, it would be too conspicuous.

In the final concept, the product could be used regardless of place and time. A deaf person could use it by putting it on a desk or by holding it with his or her hand. One could carry it on a belt, or by a shoulder strap when going out so that hands remained free.

As a result of the interviewing people concerned with deafness, including deaf students and professors in NTID, and trying to find a suitable place to put the product on the body, I concluded wearing it on a waist belt would be desirable.. Since many products exist which are put on waist belts like radios and beepers, I thought that deaf people would accept the placement of the product.

For hands-free use, a deaf person could extend a display unit to the front of his face by using a connecter which is built in the main unit.

Form Exploration

"As technology minimizes required form, design can invest form with both practical and emotional communication through the working metaphor." [20]

Before deciding the form of the Electronic Interpreter for the Deaf, I conducted research on product design for the handicapped. I realized that many designs for the handicapped were boring and tasteless in appearance. Setting aside the products for the other handicaps, the products for deaf people such as telecaption decoder, TDD, and body-type hearing aids are plain looking. They are not warm and friendly-looking. In many cases, deaf people use those products because they can't find any alternative. These cumbersome designs harm the dignity of the disabled and reinforce their feeling of isolation and inadequacy.

In relation to this, some Swedish designers' approach to product design for the handicapped is worthy of notice. These designers successfully combined functional innovations with attractive appearance (see Fig.3). I realized that a

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[20] Michel McCoy. Defining a New Functionalism in Design. *Innovation.* Spring, 1984. p.18.

Fig 3: Cane. 1983.
Mfr: ETAC, Sweden.
Designer: Jens Moller-Jensen.
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New York. Reprinted by permission.

product for the disabled should be as attractive as other consumer products while it functions well for reducing their handicap, and this knowledge helped me during the whole design process.

Along with the knowledge of design for the handicapped, I applied product semantics as a form determinant. Exploring the symbolic qualities of form, product semantics[21] is gaining popularity within the design community. Today the faceless technology doesn't give any information about a product such as its function, and its usage, unless a designer expresses it through the form of the product. People can more easily understand a new concept whose presentation connects it to an already familiar concept. "One of its most appropriate uses in product design is on products where the mechanical design doesn't give any clue to the object's meaning, as in micro-electronic components."[22]

The appropriate application of product semantics to the situation is still necessary. "Certain design situations call for simplicity and clarity while others call for complexity and ambiguity, the difference between designing a stop sign and designing a book of poetry."[23] Its appropriate application helps to communicate the proper use of a product and thus minimize the need for instruction.

To design the Electronic Interpreter for the Deaf from the metaphorical and semantic perspective, I thought, defining this product's meaning was necessary. Since the product is a machine which translates sound (speech) to text and vice versa for deaf people, I found the keywords for this product were 'sound', 'text', and 'the deaf people.' I thought 'communication', and 'information' could be

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[21] Visual form that contains metaphors of meaning.

[22] Michael McCoy, IDSA. Defining a New Functionalism in Design. *Innovation.* Spring, 1984. p.16.

[23] Michael McCoy, IDSA.

added as keywords. Because this product is a communication device, the function of this product is to transmit and receive information. The effort to find the related images continued. The related words to the keywords in various terms were: speaker, sound wave, ear, mouth, character, number, phonograph, display, sign language, communication, information, diskette and so forth.

Many sketches were made mainly on the basis of these related words. For example, several sketches in which an ear combined with sound waves were made. But later, I found that using an ear as the metaphor for a hearing aid might not be appropriate because this might advertise the handicap of deaf people. I had learned that the good design for the handicapped is the design which functions well yet doesn't reveal its function.

Another series of sketches were to combine the form of a diskette with the form of a rectangular display. In these sketches, the diskette form suggested that the Electronic Interpreter for the Deaf processed computer information. The shape of a display suggested there is a display for information output in the product. But I was afraid that the shape recalling a floppy disk might be misconceived as a product that could store computer data.

The other series of sketches, which were further developed for the final design, were shapes combining the round form of sound waves and a rectangle representing a display. I thought these objects were appropriate to express the product and its function, because I had found that sound waves were one of the most frequently appearing symbols in the references for hearing aids, and display was a very important part as an input/output medium of this product.

The idea sketches, which had been introduced so far, were two-dimensional, and dealt mainly with combining the related images to this product. The sketches which were made since then included the studies of three dimensional form and human factors as well as further application of product semantics.

Since the Electronic Interpreter for the Deaf was supposed to be put on a user's waist belt, I found that a curved profile was more suitable than a straight profile. I also found that this curved profile had esthetic advantages as well as being functional. To find a proper radius of the curve, I referred to human factors information and I found a 250 mm radius curve would fit the most people.

Several rigid plastic foam models were made to examine the selected ideas from the sketches which had been made so far in terms of human factors, function, and esthetics. Experience had shown that the three-dimensional form study was significantly important, because various factors including the problems and advantages of a design which was not revealed in sketches often appear in three-dimensional forms.

The arranging of the product whether horizontally or vertically extended was studied, and I realized that a horizontally-extended shape had more advantages. First of all, a vertically-extended shape is not suited to incorporating a display whose width is longer than its length (An explanation of the appropriate proportions of the display will follow later). Also, putting the product on a user's belt horizontally is safer since there is more space for contact. Finally, removing the display unit from the main unit by hand from the rear to the front is more convenient than pulling up.

The suitable size for the display was also closely examined because the front dimension of this product mainly depends on the size of its display. For this, the proper size of a character, and the proper number of characters for effective reading had been studied. Through the use of this study, the width of the display was decided. The length of the display was chosen by adding the height of three columns of characters and the space between lines. Finally, the proportion of the display showed the width was much greater than the length of it. I found that the proportion, as in a caption decoder, would enable text to flow naturally without cutting it frequently.

The display, located inside of the display unit, has a curved (concave) profile. This profile will reduce screen glare. This gently curved form of this display would provide a sense of privacy to the users.

The profile of the final design (when all parts are put together) has a convex curve. The folds in the middle of the design represent sound waves, and express the process of turning sound into text. The bumps on the right end of it represent the text which is the result of the process. I abstained from incorporating a display relief with the sound waves and the texts, because I thought too many expressive shapes in one product would have been chaotic.

The imagery of the main unit evokes a telephone handset, especially since a concave circle is similar to the shape of a transmitter. The two parallel lines suggest the information flow. I was cautious to place speaker holes on a concave circle. Instead of placing the holes on the circle, I positioned them between the extension of the parallel lines. I found that placing holes only on the part of the circle provided a change (variety) for the space, and resulted in a better composition.

Attaching an electronic input pen and telescopic connector, whose shapes are straight, to the main unit with a curved profile was difficult. After some study, I found that the connector should be located on the right of the product, so that it could connect the display unit to the main unit in the shortest distance. Since an input stylus pen was placed on the left end of the main unit, a user can pick it up easily by pulling back the tip of the pen when he wants to express himself.

There are three controls and two release buttons. The position and the size of these components was decided according to the convenience and the importance of use of each components.

This product can be carried either on a belt or by a shoulder strap. Unlike the belt clip of a portable radio, the belt clip was built into the center so it wouldn't look as though it had been added later. Similar to the main unit, the belt clip has a curved profile so that it is in harmony with the main unit. Bumps were placed on the surface of the belt clip to evoke a similar imagery to that found on the front of the unit.

Color

To give an alternative to the users, I decided to offer two different color schemes for the product. For the first color scheme, I chose light green (*Pantone 3255*) for the display unit and contrasting grey (*Pantone 422)* for the main unit. The textures for these two colors were also contrasted. The grey surfaces have a rough texture while the light green surfaces are smooth. A dark grey surface *(Pantone 425)* with a smooth texture was adopted for the input stylus pen to give a change from the main unit. Purple (*Pantone 257*) was chosen as an accent color to apply to the controls and to highlight key elements in the unit.

For the second color scheme, I chose the same light grey for the main unit and used sky blue *(Pantone 306)* instead of light green for the display unit. The same dark grey and purple were adopted for the input stylus pen and controls respectively.

Graphics

I decided to apply the brandname of 'Comline'. Comline was combined 'com', out of 'communication', with 'line'. To clarify the meaning of this compound word and to make 'com' and 'line' graphically interactive, I used Helvetia bold italic font and Helvetica light italic font respectively. Italic fonts were adopted because it could create more active and dynamic image. During the process of deciding the graphics, a computer was used efficiently. By using a computer, I could reproduce many variations on a idea in seconds, while if done by hand, would take hours.

I tried to be moderate in using instructions so as not to result in the confusion of meaning. Instead I adopted symbols such as o.>. For necessary instructions like input/output mode, I used Helvetica medium font (9 point).

VII. Product Components

The Electronic Interpreter for the Deaf roughly consists of three parts : a main unit, a display unit, and an input pen. The main unit contains a processor of speech recognition and synthesis, a speaker, controls, a connector, and the power supply. The display unit has a touch sensitive display, controls, and a microphone. The input pen is also an important component. It is secured to the end of the main unit when not in use.

The following is an explanation of the physical makeup of the Electronic Interpreter for the Deaf.

Microphone/Receiver

The microphone in the display unit receives the sound into this product. The microphone transduces the energy carried by sound waves into electrical energy. Electrical signal produced by the microphone is amplified.

For the Electronic Interpreter for the Deaf, I adopted a directional microphone. The directional microphone is more responsive to sound originating from the front of the microphone than from behind it. The directional microphone has two acoustic inlets or microphone openings, one on each side of the diaphragm. This directional microphone can help to eliminate or suppress unwanted background noise in order to enhance speech (sound) quality. For some cases in which it might be desirable to hear background noise, the directional mode can be switched off.

Amplifier

Another basic component of this product is the amplifier. The amplifier receives the electrical signal from the microphone, amplifies it and then transmits it to the processor for speech recognition in the main unit. Amplification is achieved through the use of a transistor.

Controls/Switch

This component has three controls/switches :

- a speaker volume control which includes the on/off function
- a microphone/receiver volume control
- an input/output mode switch

In input mode, speech is converted to text. In output mode hearing-impaired individuals can convey their message to hearing people by writing text on the touch sensitive display.

Touch Sensitive Display

The practical uses of touch sensitive displays are increasing these days. Elographics Co. is one company which develops touch sensitive display. Some of the newer touch-screen technologies such as Dura Touch, Accu Touch, and Intelli Touch are available from the company.

Dura Touch uses a resistive membrane plastic mounted on a second plastic sheet, and is designed for flat screen low-cost monitors. Accu Touch is for curved screens. Here a special film is made to fit the glass panel's curvature exactly. Intelli Touch consists of a single glass panel with piezo electric transducers placed under the display bezel.[24]

Upon touching the surface of the screen with an input pen, transducers gather the reflected waves and convert them into an energy signal that a computer can understand.

There are several reasons that I chose a touch sensitive display as an input device rather than any other input device (such as a keyboard). First of all, a touch sensitive display can be made small enough to be fit into this product. A bulky keyboard is not suitable to this design in that the product should be easy to carry. In addition, the input speed of a touch screen is much faster than a keyboard.[25]

Another important reason for choosing a touch sensitive display is the ease of learning and operating. People can use it effectively without any previous training.

The touch sensitive display could be alternately used for the output display and the input interface. In other words, users not only could see the text of the spoken words, but also input information on the same touch sensitive display. That will maximize the use of the limited space of this product.

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[24]*Computer Buyers Guide.* Fall, 1991.

[25]Mark S. Sanders and Ernest J. Mc Cormick. *Human Factors In Engineering and Design.* p.292.

Input pen

The input to the Electronic Interpreter for the Deaf is handwritten using an electronic input pen. An electronic input pen is an pen-shaped device with a cord coming out of the end, and it is attached to the main unit. The act of writing with an input pen is similar to writing with a pencil onto a paper.

Power Supply

Like many portable electronic products available today, power supplied to the Electronic Interpreter for the Deaf can be through a rechargeable battery or directly through a wall socket.

Speaker

Speech synthesized in the processor of the main unit, is amplified, then transmitted by the speaker.

Connector

The connector links the display unit with the main unit. The connector can be extended to allow for hands-free use during extended periods. For example, hearing-impaired people can use it when a lecture continues longer than expected, and they feel fatigued. And it can be used when hearing-impaired people want to take notes during a lecture. The connector is built into the back of the main unit, and it can be extended or retracted manually like an antenna.

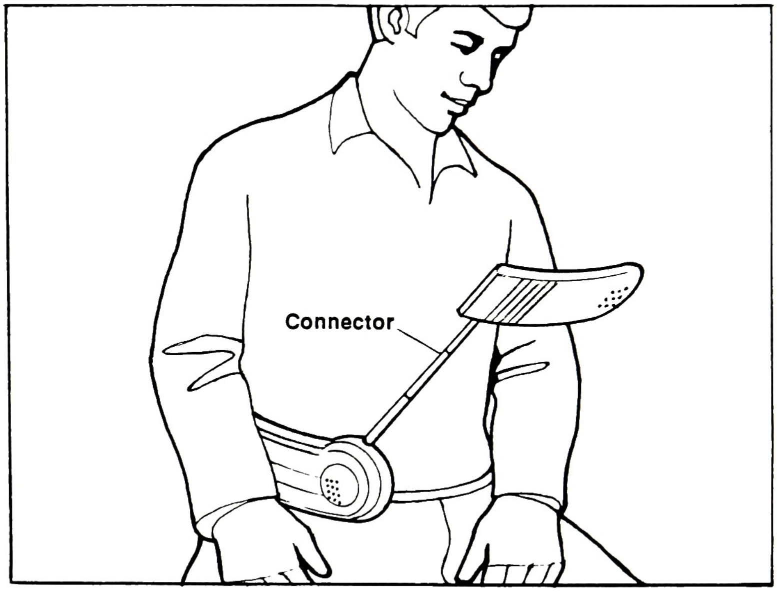


Fig 4: Connector

Cord Storage

The cord which connects the display unit to the main unit is held in the cord storage. The storage has a similar mechanism to a power measuring tape; this enables the cord to be rewound automatically when a user pushes the cord release button.

Conclusion/Evaluation

As NTID is a college within RIT, I have had many opportunities to study with deaf students. It was natural that I became interested in their communication problems and also the problems of sign language interpreters. This interest led me to design the Electronic Interpreter for the Deaf for my thesis project. Along with the experiences that I had while I was studying with deaf students, the suggestions from researchers in NTID helped me to approach the project more realistically. The response to the product by deaf students was positive.

They agreed that providing text instead of sound for deaf people would be a desirable way for communication. Many hearing devices which have been developed lately, including the closed caption decoder, are machines which provide text.

The gently curved profile of the main unit and the display unit make a favorable impression on a user. Additionally, the curved display provides a sense of privacy to the users. Making its appearance as attractive as other consumer products was a major goal for this project. I realized that a cumbersome design often aggravated the frustration and feelings of inadequacy which a handicap can cause in disabled people. Applying two different color schemes to the design was judged positively in terms of providing alternatives for its users. Graphics in this design including the logo of "Comline", I think, should have been more studied. They are somewhat featureless. Another shortcoming relating to appearance was that the round grooves, which were presented in sketches for suggesting sound waves, were not expressed in the final mock-up.

Wearing the product on a user's belt (or, carrying by a shoulder strap) was regarded as a good solution. Many products in the everyday world are carried this way. Its use does not advertise a handicap. I realized that a designer can't come up with a good design for the disabled, including deaf people, without considering their psychological concerns as well as their physical ones.

Another lesson relating to this was that applying product semantics to a product for disabled people should be selective. For example, the metaphors which might advertise their handicap should be avoided.

As I established designating a proper size of display readout as a goal of the product, a suitable size of display readout was determined. The proportion in which the width is larger than the length enables text to flow naturally without cutting it frequently.

Most people I asked to evaluate this product wondered whether the underlying technology was feasible or not, although they agreed that the product was desirable. In order to bring this product to realization, above all things, speaker independent, large-vocabulary, continuous speech is required. Although the speech recognition technology is not advanced enough to combine the above mentioned three characteristics at this time, the future prospect is bright. As I explained in chapter 5, commercial systems which combined speaker-independence with large-vocabulary were introduced in 1990. The pace of developing the technology is accelerating, and the feasibility of this design will not be long in coming.

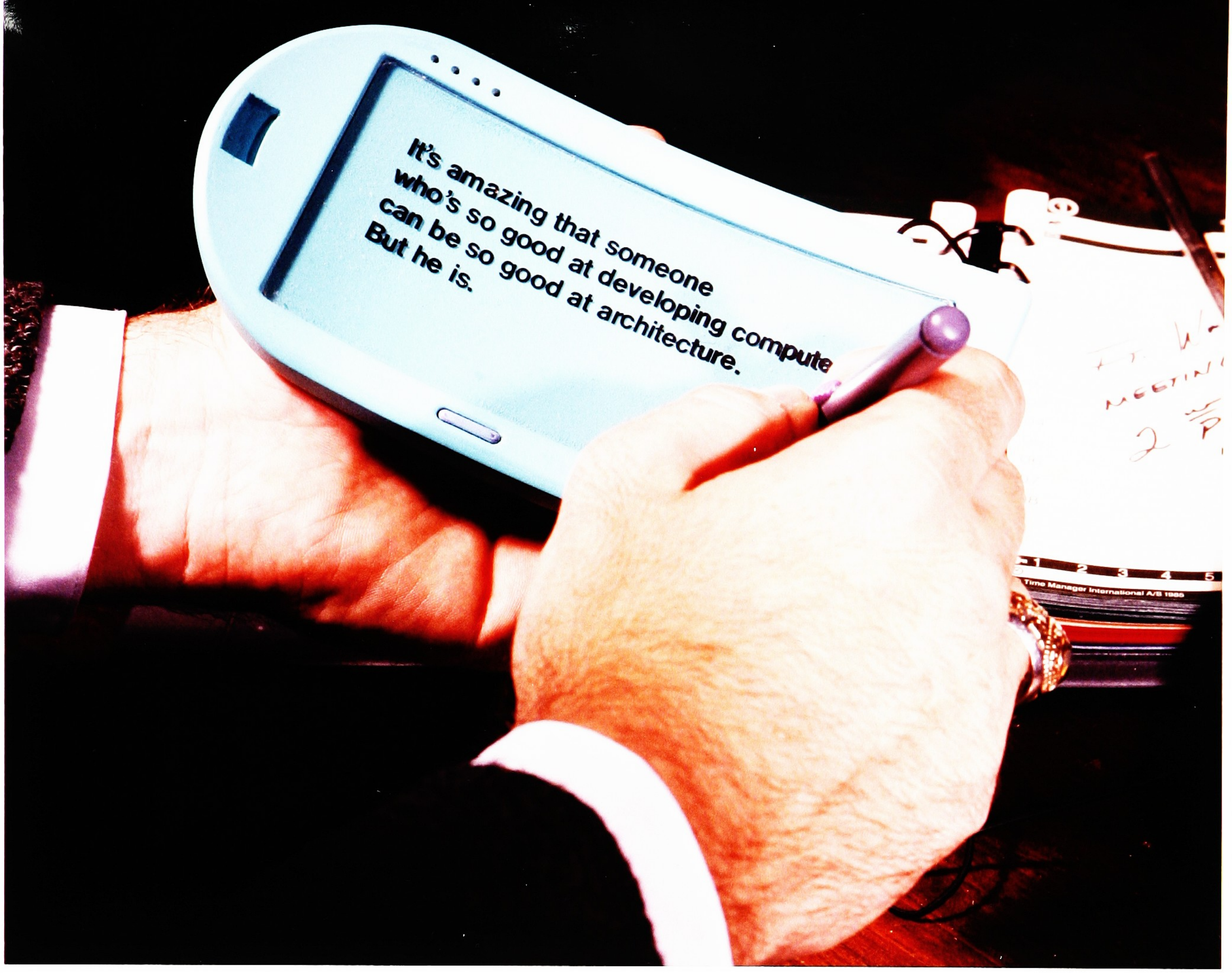
Appendix

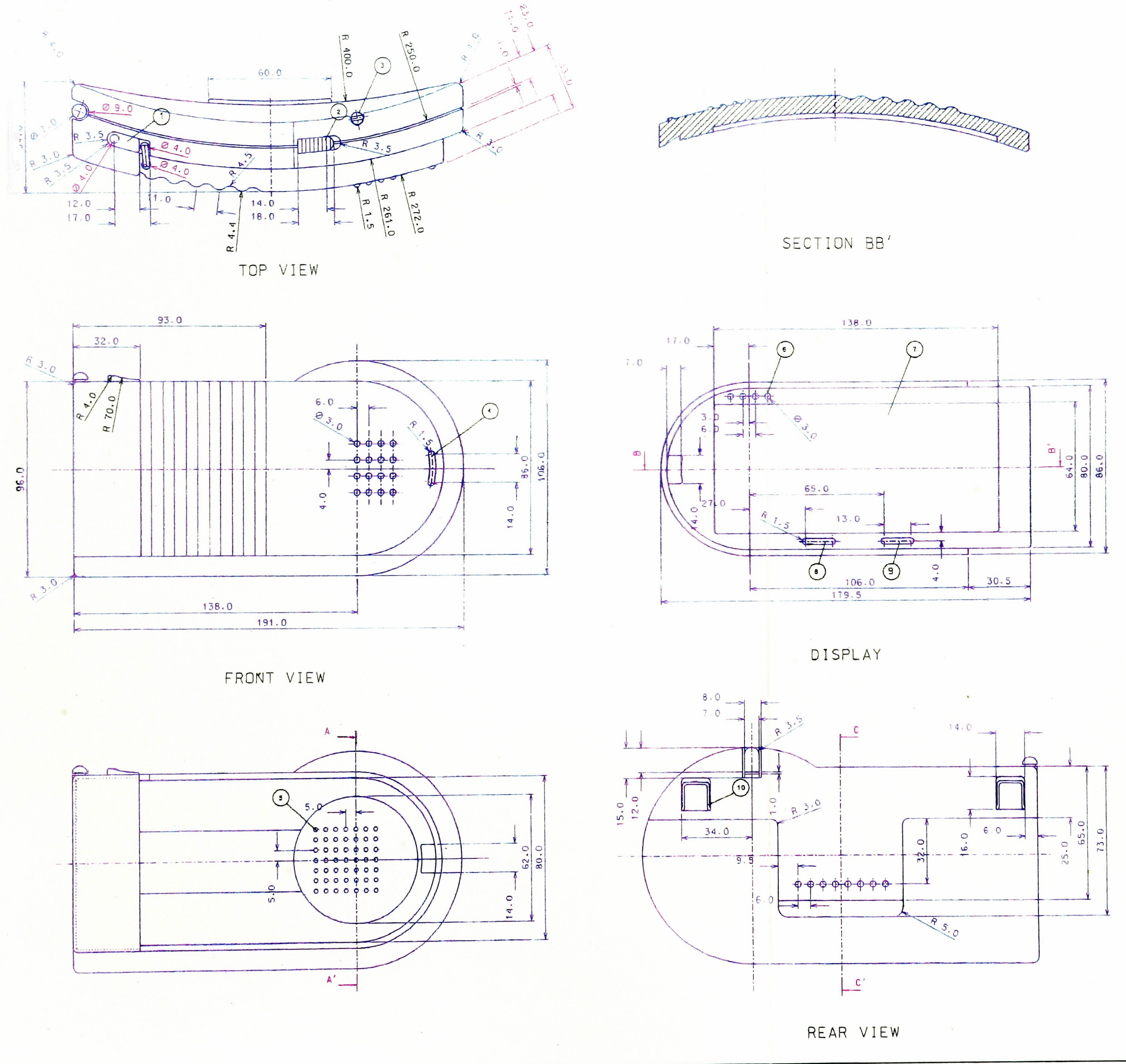

comline .....
comline .....

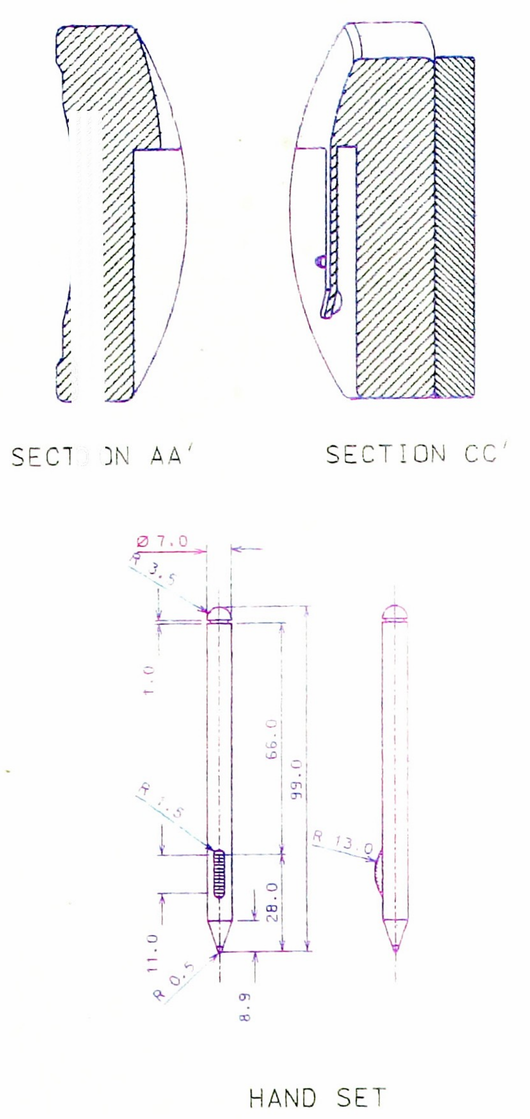
5

6


comline.....
It's amazing that someone
who's so good at developing computers
can be so good at architecture.
But he is.


It's amazing that someone
who's so good at developing compute
can be so good at architecture.
But he is.





NOTE

1. CORD RELEASE BUTTON
2. SPEAKER VOLUME CONTROL BUTTON
3. TELESCOPIC CONNECTER
4. RELEASE BUTTON
5. SPEAKER
6. MICROPHONE
7. DISPLAY
8. ON/OFF SWITCH
9. INPUT/OUTPUT MODE SWITCH
10. WIRE RING FOR STRAP Ø 1.0

ELECTRONIC INTERPRETER FOR THE DEAF
UNIT : MM
SCALE : 1:1
DATE : MAY 18, 1991

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