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Abstract

A time-sharing terminal for use by blind people has been constructed utilizing the OPTACON optical-to-tactile converter developed by Telesensory Systems Inc. This terminal emulates a standard CRT terminal and presents the output data on the OPTACON's array.

A major problem that confronts a blind person who wishes to interact with a computer is how to obtain the computer output. The two primary methods used in obtaining computer output are hard copy (or CRT), or batch input and high speed line printer output. These methods are very well suited for a person who can see well enough to read the material that is presented, but one gets into problems as soon as there is a visual impairment.

Since the batch use of the computer system has been prevalent until recently, the first consideration for a blind person was how to read the line printer output. Experimentation was done using the period character ('.') on the line printer paper. This worked fairly well if special modifications were made to the line printer. If a blind person wanted to utilize the line printer for braille output, special arrangements had to

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be made with the computer operator so that the necessary modifications could be made to the line printer for that particular output run. A second problem with braille is that if all the words are spelled out letter by letter as they are in print, then reading the text in braille actually becomes a handicap because of the time it takes to read the page. The conventional braille system is composed of many contractions. It is not uncommon for one braille symbol to stand for an entire word. Thus, if braille is to be made efficient, a computer program must be written to translate the regular printed material into the contracted braille form. This programming task has been accomplished. A third problem with using braille output is that it is very bulky. It takes about three braille pages to hold the same amount of text as one printed page. Also the braille dots on the pages create gaps between the pages which means that a braille listing will become much thicker than the comparable print listing that has the same number of pages. Braille is an important form of output; however, I also think that some study as to alternate methods of braille production must be done to make it more efficient.

With the advent of modern electronics and chemical technology it has been possible to design machines that will convert a standard printed letter that exists on a page to a form that can be interpreted tactilely. The most common of these devices is the 'Optical-to-Tactile Converter' (OPTACON) which was developed by Stanford University and Telesensory Systems Incorporated of Palo Alto, California. The OPTACON is a device consisting of a small camera similar to a TV camera which can be maneuvered across a printed page. The image that this camera sees is that of the print letter the camera is positioned over. This image is then transferred to an array of very small vibrating rods that one can feel with one's hand. These rods pop up through holes that are configured in a small tray that is specially designed to conform to the first finger of the left hand. The rods are fitted in such a manner that when the device is at rest they do not protrude through the holes situated above them in the tray. The rods are affixed to piezoelectric crystals whose function is to expand when an electrical current is applied to them. When these crystals expand, they force the attached rods up through its corresponding hole in the tray. Thus, if one's finger is placed in the tray, one will feel the point of that rod as soon as it protrudes through the hole. There are one hundred and forty-four rods placed in twenty-four rows of six within the confines of the fingerwidth tray. Thus, when the camera receives an image of a letter, it transfers that image to the rods which then raise to form the exact shape of that letter which then can be felt by the reader. The OPTACON can translate the printed letter into an image that can be felt and interpreted.

This makes it possible for a blind computer user to obtain and read directly the printed output from a line printer. There are still some disadvantages that one comes across when using the OPTACON, the primary one being the speed of the device. The OPTACON is a one-letter-at-a-time device which means that the camera is only designed to look at one letter at a time, and the array of rods is only capable of producing the image of one letter at a time. Thus the user is restricted to a slow speed because of the amount of time required to decipher groups of letters. The reading speed of an OPTACON user is somewhere between thirty and fifty words per minute, depending on the proficiency of the OPTACON user as well as the complexity of the material that is being read. The speed at which many blind people can read braille is two to four times faster than that which has been attained with the OPTACON, so this still makes the braille medium a very important one.

There are other problems that one experiences when using the OPTACON which have to do with the problem of tracking the camera on the printed page as well as the clarity and uniformity of the characters being read. I, as a computer programmer and computer user, began to wonder if there might be a better way of obtaining the image of the character and displaying it on the OPTACON rather than using the camera. Another important consideration when thinking about this problem is that the interactive use of the computer via some sort of terminal is becoming more prevalent. With this mode of interaction one has available at the terminal the display data code that is being sent by the computer. Consideration was given to translating that character display code directly into an electronic image that could be sent to the OPTACON. This would require a process that is very similar to a character generator that is used in a CRT terminal. The character generator in a CRT terminal takes the binary codes which the computer sends and converts them into the shapes of the characters that are seen on the CRT's screen. Thus it seemed that it would be possible to take the images that are produced by a character generator and send them to the OPTACON which would in turn display them on the piezoelectro-mechanical array. When first designing the hardware logic to accomplish this it was found that the problem was more complex than originally thought. The decision was made to use a microcomputer system which would handle all of the logical functions. The advantage of using a microcomputer is that most of the logic would be handled in easily alterable software. This meant that the problem of making a hardware logic mistake was almost eliminated. The microprocessor that was chosen is the INTEL 8080 microprocessor which is a very popular model used by industry. There are other microprocessors which I am sure would have worked just as well but the decision to use the INTEL 8080 was made because Tom Jacobson (a student at the University of Minnesota and the person who would be responsible for the hardware construction and design of the project) had a familiarity with the INTEL 8080.

In the summer of 1976 a mechanical engineering student named Dean Johnson did the major design work towards the construction and implementation of a one printed circuit board microcomputer which uses the INTEL 8080 CPU as well as some INTEL peripheral chips which are configured as a very small one board microcomputer. This microcomputer has 2K of 'random access memory' (RAM) as well as 2K of 'read only memory' (ROM). This microcomputer also has communication interfacing which makes it very easy to connect up to a modem or CRT terminal. This microcomputer also has I/O ports available that can be easily interfaced to the OPTACON through an already existing connector located on the OPTACON's rear panel. This connector gives one access to both the array and camera connections of the OPTACON.

The only part of the whole project that was really original was the software program that performs all of the logical functions necessary to display characters on the OPTACON. It was also decided to emulate a CRT terminal by using the microcomputer to simulate a CRT screen composed of sixteen lines with a maximum of eighty characters per line. A cursor has been defined which can be moved anywhere within the confines of the screen buffer. The program is designed so that the character which is at the cursor position is displayed on the OPTACON. For development purposes the microcomputer was interfaced to a Control Data CDC 713 CRT terminal. Thus the cursor control keys on this terminal were used to alter the position of the simulated cursor as well as the cursor on the 713's screen. In the first version of the 'OPTACON driver program' the cursor control keys were used to move from one character to the next. As the cursor was incremented the appropriate characters would be formed on the OPTACON. The microcomputer extracts the appropriate shape from a character set in memory and displays it on the OPTACON.

There were some psychological considerations that had to be built into the software. The most important of these considerations was the way in which the transition from one character shape to the next was handled. I found that if the transition from one character to the next was immediate, it was difficult to attain much of a reading speed. The decision was made to simulate the sliding motion that is inherent when one uses the OPTACON's camera for reading. This means that when the cursor moves from one character to the next, the character shapes slide across the finger in small increments instead of instantly moving from one character to the next. Some of the function keys were defined on the 713 terminal to perform special tasks. The two most useful tasks were a new line key which moves the cursor and thus the position at which the reader was reading to the beginning of a new line. A horizontal non-blank tab key was also defined which moves the cursur to the next character that is non-blank. The implementation of the simulated shifting motion, as well as the special function keys, increased the efficiency of reading greatly. The character shapes that were programmed into the microcomputer's memory are quite distinct and easy to interpret. Thus when the 713 terminal was logged into our University time-sharing system the data that was sent from the computer was also displayed on the OPTACON. It is not possible to read as fast as the data was sent, which is thirty characters per second, and therefore it was necessary to rely on the ability to move back through the screen after the listing had stopped and read the characters at an optimum pace. After using the terminal in this configuration for a while, it was decided to add one more input device to the microcomputer. This device consisted of a rotating wheel that sends pulses to the microcomputer. The microcomputer can determine both the speed and direction of motion of this wheel. Thus we have a very flexible input device which can transfer a lot of information just by its motion. The purpose of this wheel is to simulate the motion that is used when an OPTACON user slides the camera across the page. When the wheel is rotated to the right the 'OPTACON driver program' moves the cursor to the right. The reverse happens if the wheel is rotated to the left. The speed at which the wheel is turned affects the speed at which the characters are sent to the OPTACON. This simulates quite well the motion of the OPTACON's camera and therefore makes it feel more natural to read in this manner. The final improvement to the terminal was to take away the 713 CRT and install a self-contained keyboard on the microcomputer. Thus, now I have a completely self-contained terminal which allows me to interact with most time-sharing computers. I feel this direct method of transferring characters to the OPTACON is much better than using the OPTACON's camera because of the lack of tracking problems, and the clarity of the character set. Due to the flexibility of the microcomputer design of this terminal it is very easy to alter the software at any time. The character shapes can be altered if one wishes to use a different character set.

I feel that this prototype has worked out quite well. There are many improvements that I envision will further enhance computer terminals for the blind. I also feel that it will help any blind person who can use the OPTACON to be able to use a computer more efficiently.

At the Lawrence Berkeley Laboratory development is currently proceeding on an improved version of a terminal for use by blind people. This suit-case size terminal has self-contained within it the piezoelectric array made by Telesensory Systems, rotating wheel input device, acoustic coupler, keyboard, two Telesensory speed output devices, as well as a Votrax speech module. These devices are interfaced to a microcomputer which utilized the MOS Technology Inc. 6502 CPU. This microcomputer is not encumbered by the memory restrictions that existed on the first prototype OPTACON interface terminal. Engineering-wise the interface between the piezoelec-tric array and the microcomputer has been designed in such a way that much less processing is required to control it. This means that the microcomputer is free to perform other operations. Since this terminal is still being developed, its full potential has not yet been realized. I feel that with the addition of the speech output devices, as well as the utilization of the piezoelectric array, a very flexible and efficient computer terminal will be developed.

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