ISSUES IN MAN-MACHINE INTERACTIONS FOR THE VISUALLY HANDICAPPED

T. Radhakrishnan and C. Labrador

Computer Science Department
Concordia University, Montreal

ABSTRACT

It is estimated that there are more than 1.2 million blind or visually handicapped individuals in North America; of these only ten percent are working full time. Thanks to developments in computer and electronics technology, such as the speech synthesizers, personal computers and Braille terminals, there is a dramatic increase in employment opportunities for the blind in the field of information processing.

In this paper, we discuss the issues and problems in man-machine communication for information processing by the visually handicapped. They are presented under three headings: data entry and read-out, presentation of data structures to the visually handicapped, and abstractions of programs and data for communication with the blind. Solutions are suggested to some of the problems discussed and a few of these solutions have been incorporated into the experimental system under development at Concordia University.

RÉSUMÉ

Il est estimé qu'il y a plus de 1.2 million d'aveugles ou handicapés visuels en Amerique du Nord, dont seulement 10% travaillent à temp plein. Grâce aux developpements en technologie d'ordinateurs personnels et les appareils de Braille, il y a un accroissement considérable d'occasions d'emploi pour les aveugles dans la spécialité de traitement d'information.

Dans cet article nous discutons des issues et problèmes en communication homme-machine pour traitement d'information par les handicapés visuels. Ils sont présentés sous trois titres: d'entrée-sortie de les données, présentation des "data-structures" aux handicapés visuels, et abstraction des programmes et données pour communication avec les aveugles. Nous offrons des solutions à quelques problèmes mentionnés. Quelques unes de ces solutions ont été incorporés au système expérimental en cours de developpement à l'Université Concordia.

I. INTRODUCTION

In humans, there are three types of channels for the input of information: (a) video channel or sight, (b) audio channel or hearing, (c) sensory channels associated with touching, feeling, smelling, and the like. The video channel is impaired or totally lost in the case of the visually handicapped which hopefully leaves the other two channels for communication. Some of the visually handicapped can read a text printed in, or magnified to, a large size. Several kinds of equipment and visual aids are available to such vision-impaired people [1] which we will not discuss here.

Braille printing and reading (sensing) by the blind have been in use for a long time. Today, Braille terminals and Braille printers are available for interfacing to a computer [2]. The Braille characters are a matrix of dots, two columns by three rows. Presence of a dot in this matrix is represented by a small raised portion on the paper that can be sensed by running a finger over it. Combinations of dots denote the letters of the alphabet or coded words.

Another device based on the sensory channel is OPTICON [3]. This device consists of an optical scanner and presents a tactile image of each scanned charater to the reader's finger through a matrix of vibrating reeds. It requires considerable training and a high level of dedication to learn and become proficient with this device [4].

Thanks to many technological developments, the audio channel has become a viable means for man-machine communication. Today, speech synthesizers based on phonemes or on LPC (linear predictor coefficient) paramaters are available as LSI chips [5]. Algorithms have been developed by several researchers for synthesizing speech from written texts [6,7]. Personal computers that can support the necessary software for text-to-speech translation are readily available [8]. It is our contention that the audio output and tactile output from computers can be combined suitably for effective man-machine communication with the visually handicapped.

It is estimated that of the approximately 4 million visually handicapped individuals in North America (1.2 million as per 1967 statistics), only ten percent are employed full-time. Of course, sight is important to most jobs but if suitable accomodations are made and man-machine communication is available, the visually handicapped can be employed fruitfully in many types of jobs. When there is database support, the following areas have been quoted as possible avenues of employment [9]: word processing operations, data entry, computer programming, air-line ticket reservations, radio broadcasting, and information services. When more blind people are employed, it is a lesser burden on the welfare department and more income to the state. Above all, it means a lot to an individual to work, earn, and interact than to depend completely on others. To this feeling, certainly no measurable value can be attached.

II. DATA ENTRY AND READ OUT

Input to the computer is not a major problem when keyboard devices are used because most of the visually handicapped can learn to type. Although data entry through voice input and speech recognition is possible in a limited context, it has not yet become a main source of input. Optical scanning and recognition of handprinted characters provide a feasible but expensive alternative [10].

Computer input falls into two categories: data or program input and command input for editing or invoking system functions. Sometimes it becomes convenient to use a set of functional keys, in addition to the standard keyboard, for command input. Each functional key may be associated with a pre-determined command function that can be invoked just by pressing a key.

Video and audio channels have their own merits and demerits as output channels from a computer. For instance, video output on a CRT stays permanently until it is changed and the user can refer to it any number of times without asking for a re-display. However, in order to read the displayed output, the user must stay close to the terminal. On the other hand, consider audio output from a computer, physical nearness of the users to the actual device is not essential. The output can be directed to several users simultaneously but it is temporary and has to be replayed for review unless the user has the capacity to remember the complete output.

In interactive processing, menus are used to assist a casual user [11] for specifying a response to a system command. A menu is an ordered sequence of "M" alternatives displayed by the computer, that are numbered 1 to M. The user studies the M alternatives and selects the one which suits his needs. Once the menus are displayed, they are on the screen and a sighted user can refer to them any number of times. Suppose the audio channel is used for communicating with a visually handicapped user for this purpose. If M is small, the user can hear and keep all the alternatives in his mind for study. When the user wants to hear any or all of the alternatives again, he may ask for a replay by pressing suitable functional keys. If M is large or the alternatives are too complex to comprehend when heard for the first time, it is worthwhile to assign short mnemonics as labels to alternatives. Also, these short mnemonics can be printed out using a Braille terminal and the user can study them and select to hear only those alternatives relevant to his present needs. Yet another approach would be to decompose the M alternatives into several manageable sized groups and assist the user in sequential decision making instead of a single step selection.

Editing of programs, data, or texts that are stored in computer files is often required. For this purpose, the following visual aids are available to a sighted user:

(a) A cursor that indicates the position of the object (line or character) being edited.

(b) Commands or functional keys to move the cursor and position it at the desired place.

(c) Echo check: A sighted user can immediately verify the corrections made using the edited output displayed by the editor and the typed corrections that are automatically displayed.

(d) Context searching: Through suitable edit commands, the user can command automatic positioning of the cursor at the object that contains a user specified phrase.

(e) A prompt from the system to indicate that a user response is awaited. In some cases there are two or more different types of prompts to indicate different data entry modes. For example, the ">?" and "-?" are two types of prompts generated by the editor TXED [12].

Of these visual aids, the effect of stationary prompts, reading the cursor position, and echo checking can not be replaced perfectly by the audio channel. A visually handicapped user has to compromise. While editing, a sighted person makes considerable use of the context of the cursor position with respect to its neighbouring characters, words, sentences, or other syntactical units. If audio channels are used, the user has to specify what contextual details he wants to hear and by interrogating repeatedly at different contextual levels he may obtain the position of the cursor. We found that understanding a cursor position is not a difficult issue if the user has a good knowledge of the object being edited. However, this will not always be the case when he works as a member of a programming team or when he develops a large program.

In an experimental system developed at Concordia University for communicating with blind programmers, we have included an audio prompt facility [13]. Suppose the user has failed to notice the prompt when it was given, or the user went away from the terminal for a brief period, returning later. By pressing a special function key, he can interrogate and find out if the system is waiting for a user's response.

Most of our present-day formatting conventions are oriented to the visual appearence of a printed page. Blank lines, indentations, and beginning on a new page are but some examples. It is possible to use acoustical parameters such as pitch, stress, pause, and intonation contours as cues in audio communication. Another facility that exists in the voice channel is the ability to repeat a spoken unit for emphasis.

With regard to echo checking, the following facilities are worthwhile for a visually handicapped user working at an interactive terminal:

(a) Automatic correction of spelling, transversal errors in typing, or spelling errors in system commands [14].

(b) Ability to restore the copy that existed before the lattest edit by pressing a special key. This would be very useful to recover from the effects of the mistakes made while editing.

III. PRESENTATION OF DATA STRUCTURES

Linear strings of numeric or alphanumeric characters are by far the most commonly used among the different data structures. We organize them into numbers as in telephone numbers, into ordered sequences as in dates or addresses, or into records. In the case of texts, we group the linear strings into words, phrases, sentences, paragraphs, etc. Classification or grouping is a well known technique used for organizing a large volume of data. Indexes and directories that are used with such data organizations are also collections of linear strings. Teletypes, serial printers, and voice output units of computers are well suited for the output of linear strings.

Two dimensional arrays or tables are frequently used by sighted persons, particularly to show a correlation between two variables. For example, consider a table showing the correlation between height and weight of a certain group of people. A sighted person could easily browse through such a table, read it row-wise or column-wise, and select a row, column, or an element that is significant to him. The related visual effects and the ease of interpretation are difficult to achieve simply by reading the table to a visually handicapped user. Suitably designed man-machine interactions could improve the communication, but the ease and speed of the video channel can not be achieved through the audio channel. Small tables with a fewer number of rows and/or columns (e.g. two, three, four) are better than large tables for audio communication. When considered from this point of view, the size of the tables interpreted by a sighted person can not also be unlimited.

Graphs, bar charts, histograms, and scatter diagrams are used as tools for data analysis, especially in making management decisions. For presentation of these data structures to the blind, tactile output is more suitable than voice output. The tactile output may be generated either by a Braille terminal or by specially designed devices that may produce a Braille-like output on a matrix of points. In one such device, the matrix points have been conceived to be electronically controlled heat-source/heat-sink elements that can be sensed comfortably by a visually handicapped reader. Such an electronically controlled softcopy output, as opposed to Braille-type hardcopy output, is well suited for interactive data processing.

Trees and networks are two complex data structures used in the modelling and understanding of large programs or databases. The different modules of a structured program written in a block structured language can be depicted as a tree structure [15]. The following are some of the operations used in the application of such tree structures:

(a) Traverse the tree to find a specific node (module).

(b) Find the ancestors, siblings, or descendants of a given node (e.g. to examine the control and parameter interactions between different modules).

(c) Find the set of all nodes (modules) that satisfy a condition specified by the user (for debugging or understanding purposes).

(d) Insert, delete, or modify an existing node or an arc between two nodes (to reflect the editing of the program that corresponds to the tree structure).

(e) Visit all the nodes in a depth-first manner or breadth-first manner.

From an interactive terminal, some of these operations can be performed with equal ease, even by a visually handicapped programmer. The great difference is that a sighted user can refer to a visually displayed tree and its structure as often as he needs. Theoretically, it is possible to produce a complete tactile output of a complex tree structure and the details associated with its nodes and arcs; but tactile output is slow and occupies more physical space [16] and hence it can become difficult for a blind person to read. Perhaps a compromise can be achieved by displaying a "skeleton" of the tree structure as tactile output and by supplementing, upon demand, the label information as audio output. Intelligent program editors that can make inferences or perform syntax directed error corrections [17] could be modified to become "talking program editors" for further assistance to the blind in this direction.

Today, many enterprises organize their data into databases and use the commercially available DBMS (database management systems). Network, hierarchical or tree, and relational are the three common data models supported by such DBMS [18]. An application programmer has to know how to retrieve data from a database and then use it as input to his own programs. In network models, a database is modeled by a data structure diagram that is a labeled network with directed arcs. A user has to "navigate" through different nodes and arcs of a data structure diagram for data retrieval [18, p197]. Although simple query languages are now available for casual users, an application programmer may have to navigate inorder to produce efficient programs. In this context, we feel that navigation through a network and the visual effects of seeing a network can not be achieved through the audio and tactile outputs that easily. However, the relational model of data does not suffer from this structural complexity [18].

Office information systems are an outgrowth of the technological developments in many areas of data processing. In offices, forms are used for information generation, flow, and control [19]. The filling out of forms, such as a purchase order form, and the filing and management of forms are some of the functions performed with a word processing computer [20]. Forms are the most complex type of data structure to deal with and there are wide variations among them. We can expect that a visually handicapped word-processing operator will be trained to deal with the form types specific to that office. If we want to promote employment opportunities in this area for the blind, the following factors should be considered:

(a) It should not be too difficult to train or retrain a visually handicapped operator in the use of office forms. For this purpose, special software systems for computer aided training or retraining of the blind could be developed.

(b) After the training, at his/her work, a visually handicapped operator should be able to get "help" from the computer in filling or the management of forms, if necessary. This would contribute to make him/her as independent, fast, and as reliable as a sighted person.

(c) Some types of office work are better suited for others than for the blind.

(d) Above all, the employer should be able to accomodate the handicaps of the operator and the handicapped should ask for the least amount of accomodation from the employer [4].

IV. ABSTRACTION OF PROGRAMS AND DATA

When a visually handicapped person chooses programming as a carrer, he needs to cope with the following situations:

(a) To work with other programmers, sighted or other visually handicapped programmers, in team projects.

(b) To design, develop, and document large programs.

(c) To understand programs and documentation generated by others.

We do not want to give an impression that the above tasks are easy for sighted persons. Although it is more difficult for a blind programmer to cope with (a) and (c) above, he would face (b) in his daily work. Systematic programming, stepwise refinement, good documentation, and brief annotations on the different modules would all be helpful in this task [21]. There has been interest in the generation of software systems for incremental program development and verification [22] but research is required in designing such systems to suit the needs of blind programmers.

There are several levels of abstraction of a program. At one extreme there is a verbal description of what the program does, what method(s) are used, what is the input and output of the program? At the other extreme we find the different statements of the program written in a programming language. Descriptions of the structured relationships between the modules of a program and flowchart (decision table) descriptions of the different modules are two typical levels of abstraction.

When debugging a program, the user trys to understand the "context" of the bug and then he uses this knowledge in correcting his program. Consider the segment of a PASCAL program shown below.

```
. . .
var I, K: integer;
. . .
for I := 1 to 51 do
  begin
  . . .
  { TEMPORARY ASSIGNMENT }
  J := 29 mod (K div 17);
  . . .
  end;
. . .
```

We see that the variable J is undefined. The reason for the assignment might be inorder to eliminate future calculations of the same expression within the context of the for-loop. The following statements depict the correction attempted by a blind programmer.

```
. . .
var I, K: integer;
. . .
for I := 1 to 51 do
  begin
  . . .
  { TEMPORARY ASSIGNMENT }
  I := 29 mod (K div 17);
  . . .
  end;
. . .
```

A sighted programmer, who perceives the neighbouring statements, may not correct the bug as shown above, as it would redefine the loop control variable I. However, a blind programmer has no simple way of perceiving a "local context" or the neighbouring statements. In this case a language directed program editor could detect the situation and notify the visually handicapped programmer. Such an editor can take into consideration the programming language features and assist a blind programmer whenever possible.

The term "data abstraction" has been used by different authors with different interpretations [23, p7].

Here we use it in the sense of sentential or other descriptions of data as found in a typical "data dictionary" [18, p462]. Using the descriptions about data, a user can "spiral" down to the specifics that he needs or formulate a query to retrieve the data he wants. Similarly, starting from a known data item, he may find other data items related to it, or find the characteristics of a group to which the known data item belongs.

Suppose the data is viewed as a set of hierarchical clusters and each cluster is associated with some descriptions. Clusters and their descriptions may be stored a priori in the data dictionary or derived by suitable processing. By traversing this hierarchical structure interactively, a user can find more specific or more generic data items.

In spite of many aids from a computer, a blind programmer will face situations when he needs the assistance of others. Passing messages through "mailboxes", a traditional facility popular among the users of timesharing computer systems, is quite useful for this purpose. For inter-person communication, it is desirable that a computer output be readable both by the blind and the sighted. Tactile outputs like Braille are seldom readable by a sighted person, but it is not a major problem to convert a Braille output into character form.

V. SUMMARY

In the foregoing sections we have presented some of the major technical issues in man-machine interactions with the visually handicapped. Today, talking computer terminals [24], Braille computer terminals, and personal computers with audio output are commercially available as aids to the visually handicapped. We consider them to constitute the necessary first step in finding employment for the blind. However, more research and efforts are needed to train the visually handicapped as computer programmers, word processing operators, or as information specialists and to integrate them with the rest of society, wherever possible.

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