INTERACTIVE DIGITIZATION OF SOUNDING VALUES ON CHARTS

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Abstract

An optical character recognition system has been developed by the Graphic Systems Design and Applications Group at the University of Saskatchewan in cooperation with the U.S. Naval Oceanographic Office. The system, which is primarily associated with the automatic recognition of navigational sounding numerics from existing charts and handprinted survey sheets, makes extensive use of interactive processing procedures.

The features include display and edit capabilities for the sounding values already processed and filed in the host minicomputer, an interactive real-time display digitizing facility for use with chart areas that are not amenable to automatic process and a limited adaptive capability to the character set being processed.

A prime consideration of the design has been to make the interactive operation as flexible as possible; this was facilitated by the inclusion of two display units. The first was a standard black and white television monitor for displaying the input image data, and the second a bistable storage display device. Special hardware was designed to use this last device concurrently as an input image storage display and standard input-output computer terminal.

NUMÉRISATION INTERACTIVE DES SONDES DE CARTES

Résumé

Un système de reconnaissance optique des caractères a été mis au point par le Groupe d'étude sur la conception et les applications des systèmes graphiques de l'université de la Saskatchewan, en collaboration avec le *U.S. Naval Oceanographic Office*. Le système, qui sert surtout à la reconnaissance automatique des chiffres indiquant les sondes sur les cartes marines et les feuilles de relevés notées à la main, fait un large usage de méthodes de traitement interactives.

Parmi les caractéristiques du système, mentionnons la possibilité d'afficher et d'éditer des sondes déjà traitées et fichées dans le mini-ordinateur principal, la présence d'un dispositif de numérisation interactif à affichage en temps réel utilisé pour les régions des cartes qui ne se prêtent pas au traitement automatique, ainsi que la possibilité d'une adaptation limitée au jeu de caractères traité.

Un des éléments principaux dont on s'est préoccupé au cours de la conception a été de rendre le fonctionnement interactif aussi souple que possible, ce qui a été facilité par l'inclusion de deux unités d'affichage. La première est un écran de télévision noir et blanc ordinaire permettant d'afficher les images d'entrée, tandis que le second est un dispositif d'affichage de mémoire bistable. Grâce à un matériel spécial, ce dernier dispositif peut servir aussi bien comme unité d'affichage des images d'entrée en mémoire que comme terminal ordinaire d'entrée-sortie.

INTERACTIVE DIGITIZATION OF SOUNDING VALUES ON CHARTS

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BACKGROUND

The recent decisions of both the Canadian and United States governments in favour of metrication have caused considerable activity in existing cartographic establishments. In order to effect the changeover as efficiently as possible, automatic data processing systems are being used to handle the large amounts of cartographic data which must be manipulated. The United States Naval Oceanographic Office (USNOO) recently had a need for an automatic recognition and digitization device for use with sounding values (numerics) on navigational charts (maps), and approached the Graphics System Design and Applications Group (GSDAG) at the University of Saskatchewan. GSDAG has had considerable experience in the automatic processing of cartographic data in the past nine years and it was felt that an automatic optical character recognition (OCR) system for use with navigation chart sounding numerics would be a valuable addition.

INTRODUCTION

The problem of automatic recognition and digitization of sounding values from charts is a complicated one. Due to years of preconditioning through daily experiences in recognition, the problem of recognition of numerics at first seems to be an easy one. However, due to the practical usage of the sounding data, precautions must be taken to ensure that the resulting recognition decisions are as accurate as possible (eg: liability in case of maritime disaster). The variability of the actual data (input material, character font, handwritten, etc.) also adds to the complexity of the recognition process. For the above reasons it was decided during the development of the OCR system, that certain processes or routines would be made interactive, so that the operator could use the years of experience at his/her disposal to aid the operation. In order to do this interactive processing effectively, it was found that two different types of information displays would be appropriate. The first is basically a standard black and white television (TV) monitor. This is used for displaying the real-time quantized video information produced by the vidicon camera (Sierra Scientific LV-1). The quantizer is a specially built U. of S. unit which allows for the adjustment of quantization level to compensate for differing base materials (mylar, white or colored paper, etc.). Figure 1 shows an example of the quantized video output. The lightly shaded box around the central image should be noted; this box can be used to further aid the operator in deciding on

the role he/she should assume in the processing. The second unit is a TEKTRONIX 4015 computer terminal with bistable storage display which is specially modified to display text and image information concurrently. This allows the operator to choose whichever information is most helpful in reaching decisions, while at the same time reducing the amount of head or body movement needed to acquire it. Figure 2 shows the format used for this display.

INTERACTIVE PROCESSES

The areas chosen for interactive processing are:

1) Chart information entry (digitization)
2) Multiple character set capability
3) Manual entry of sounding values
4) Manual editing of processed data

Each of the interactive processes makes use of one or both of the display devices in a way which is unique to the specific process. Each process will now be separately discussed in terms of their interactive capabilities.

1. CHART INFORMATION ENTRY (DIGITIZATION)

Chart information entry relates to the OCR digitization system for the specification of important areas or points on the map. In this mode of operation, the position of the camera head mounted on the Gerber 22 plotting table is manually controlled by the operator using a joystick control; the real time video is used as feedback for accurately positioning the reference point under the modified "cross-hairs" of the video display. The nature of the video system results in a magnification of approximately 25X from chart to TV screen and therefore the system can be used as a highly accurate x, y digitization device. The information digitized includes:

1) main chart boundaries and control points, later used in merging charts or separate chart areas.
2) problem areas in which the nature of the chart data is such that recognition would be better done by the operator directly.

The manual digitization mode is the only time during chart processing in which the operator is allowed to control the plotting table.

2. MULTIPLE CHARACTER SET CAPABILITY

In order to accomplish a recognition decision, the computer program must have some standard data with which to compare each digit acquired from the chart. It was decided early on in the project that the best results would be obtained if the program could be "trained" by the operator. This "training" consists of entering the standards from each chart into the program as the work is to be done. This is

accomplished interactively; initially the program has no standard character data with which to compare the digits coming from the chart. The operator is responsible for entering the data as each different digit is acquired from the chart. To do this it is necessary for the operator to monitor the recognition process with the 4015 display. Depending on the information acquired, the digit being processed is either classed as suitable for a standard and is entered as such, or as unsuitable and is discarded. Only one standard may be used for each digit and thus a considerable degree of operator experience with the system is needed to correctly interpret the information. An example of this information output is shown in Figure 3. If the operator decides that a digit being processed is more suitable as a standard than one entered previously, it may be used to replace the inferior digit. After characteristic examples of all digits and special symbols have been entered, the standards data may be stored in a file for later use, whenever a chart similar to the present is being processed. Such a case will arise when different charts have been created by the same cartographer or automatic symbol printing head. In this way a library may be built up for the differing fonts in use.

In a specific case analyzed by one of the authors, the increase in recognition due to this supervised adaptive capability was 7% over a non-supervised adaptive approach. This increase in recognition performance was also accompanied by a decrease in the substitution error rate; for this type of data this must be kept to the minimum possible.

3. MANUAL ENTRY OF SOUNDING VALUES

As mentioned previously, there are certain areas on the charts where it would be more efficient to process the soundings using the operator as the recognition device. These areas usually consist of crowded soundings or soundings that are tilted with respect to one another. An example of a problem area is shown in Figure 4.

In the above instances the operator, at the beginning of the recognition run, specifies these areas using the digitization capability of the OCR system. These areas are subsequently ignored during the automatic recognition run. When the main run is finished, the computer program keeps control of the table movement; but allows the operator to interactively digitize the values seen on the images from the problem areas.

This operation is accomplished using the 4015 as a display terminal and a "mouse" as a pointer. The operator points to the sounding centres and enters the numerics seen, using the keyboard, for each sounding in the image. This process is repeated until the chart has been completed. The procedure is simple and easily learned and replaces the large degree of sophistication which would otherwise necessarily have to have been included in the OCR program.

4. MANUAL EDITING OF PROCESSED DATA

Once the soundings have been digitized from the chart, it is

necessary to check the data and correct the errors. This is done using the existing sounding editing facilities in the University of Saskatchewan Computer Aided Map Compilation (CAMC) system. This facility allows:

1) The correction of the label (numeric value) of an existing sounding.
2) The correction of the coordinate of an existing soundings.
3) The addition of missing soundings.
4) The selection of various soundings to be output into a special file. This file may be a plotting file for hard copy output of processed data.

This editing is accomplished interactively using the 4015 display terminal and "mouse".

SYSTEM PERFORMANCE

The USNOO/GSDAG OCR system with the above interactive processes was implemented on a small DEC PDP 8/e minicomputer with 8K words of core and a 1.6M word disk. Coupled to this was a Gerber 22 plotting table on which was mounted a Sierra Scientific LV-1 vidicon camera together with the special interfaces needed for the high speed transfer of video data to the computer from the camera and also for the movement communications between the plotter and computer. The total system hardware cost was approximately $90,000 (CAN: 1974).

As mentioned before, the reliability of the data was paramount, and therefore three different recognition methods were implemented with the final decision reached on the basis of a weighted vote. The result of using a weighted vote was an increase in final recognition rate of 15% over any of the individual methods.

The three methods used were:

a) grid
b) template
c) characteristic waveform

The final recognition results obtained for a test chart with machine printed numerics are shown in Figure 5.

For a human operator processing the same type of chart the usual figures quoted are:

recognition rate = 96%
substitution rate = 4%

The substitution rate in this case arises mainly from errors in entering the munerics by means of the keyboard. Also of note is the time needed to process an average chart; a human operator would take approximately 55 hours versus 15 hours for the OCR system.

Unfortunately, first attempts to read hand-printed field sheets met with disappointing results:

recognition rate = 60%
substitution rate = 5%
rejection rate = 35%

which was well below that expected. As a result one of the authors considered another method of recognition more suited to this type of input and improved the recognition rate to 90%. The method requires a large number of multiplications and while the PDP 8/e is not noted for a high arithmetic operation speed, the hardware necessary for this work has recently become available; it is hoped that now more work can be done in this area.

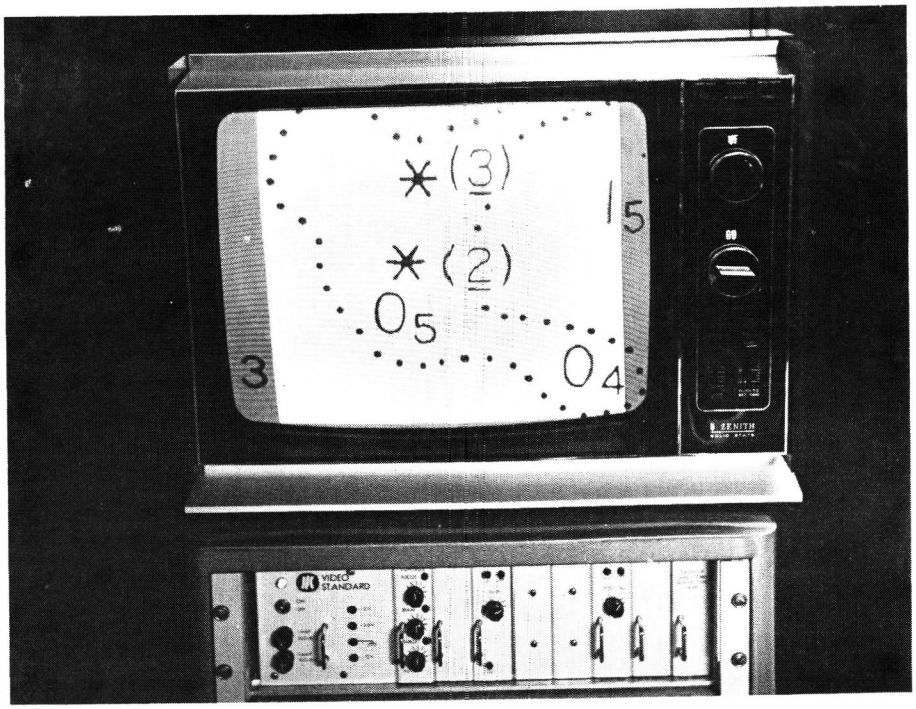
The USNOO also has implemented further refinements to the mini-computer system to increase the rate at which the images are processed by approximately 75%.

CONCLUSIONS

The resulting OCR system has proven to be both efficient and flexible. The ability to accommodate the character sets being used, along with the various interactive processes, have enabled an economical OCR system to be realized. While the interactive processes were intended to ease the sophistication necessary in the actual program, they also proved invaluable in the actual development of the OCR system. They allowed the operator to view the sequence of events in the various algorithms used in the program, and make adjustments where necessary.

Due to the nature of the data and the degree of reliability needed in the recognition decisions in the final sounding data, it was necessary to include interactive editing facilities to ensure the integrity of the data.

All of the interactive processes were made simple to use so that a cartographer using the system could easily add his/her accumulated experience to reach the optimal decisions concerning the nature of the final data.



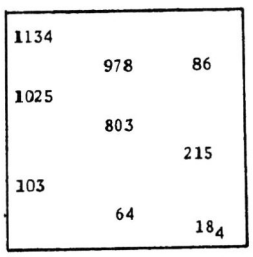
Quantized Video Output
Figure 1

#134@@@T	X = 009754	Y = 001753
978@@@@T	X = 009840	Y = 001732
86@@@@@T	X = 009900	Y = 001731
1025@@@T	X = 009747	Y = 001678
803@@@@T	X = 009839	Y = 001655
21#@@@@T	X = 009895	Y = 001640
103@@@@T	X = 009735	Y = 001580
64@@@@@T	X = 009850	Y = 001540
18.4@@@T	X = 009921	Y = 001530

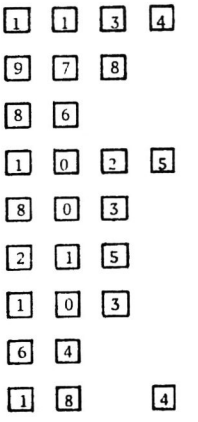
LABEL COORDINATES

A) # indicates unrecognized sounding.

(TEXT INFORMATION)



BINARY IMAGE



EXTRACTED SOUNDINGS

B) Blank in sounding format indicates a subscripted sounding

(IMAGE INFORMATION)

Tektronix 4015 Display Format
Figure 2

	NUMERICS										SPECIAL SYMBOLS						
	0	1	2	3	4	5	6	7	8	9	;	:	(	=	)	?	
GRD:	12	18	13	13	14	14	12	15	12	12	6	5	3	8	7	2	(A)
TPL:	101	143	103	97	104	96	93	115	101	94	24	32	67	73	38	110	(B)
CWF:	15	24	14	11	16	10	11	21	13	9	5	6	3	4	8	2	(C)

G: 1

T: 1 ANSWERS

C: 1 7 (D)

(A) Grid method recognition results.

(B) Template method recognition results.

(C) Characteristic waveform method recognition results.

(D) Multiple decision due to bad standard entered for 7.

OCR Program Recognition Information
Figure 3

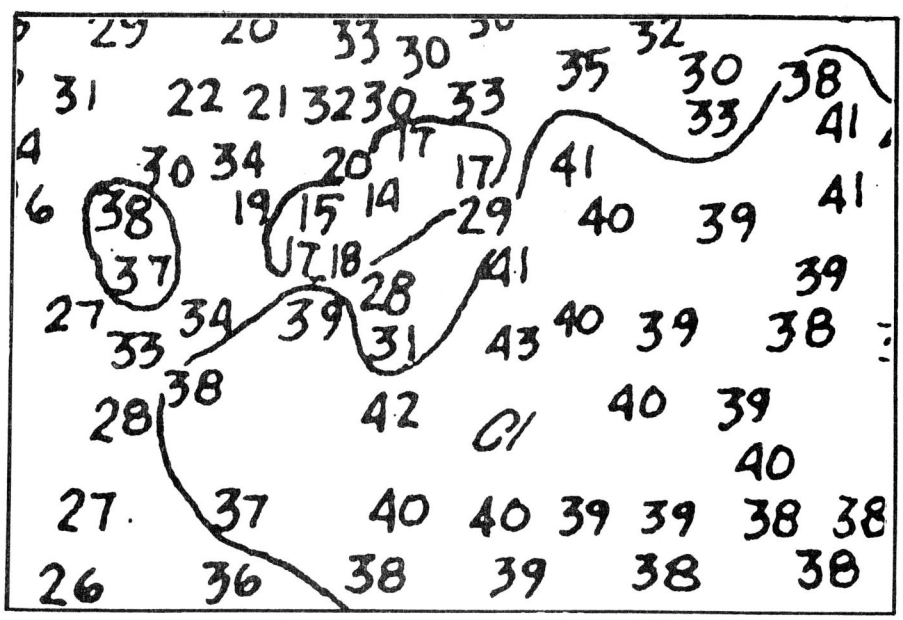
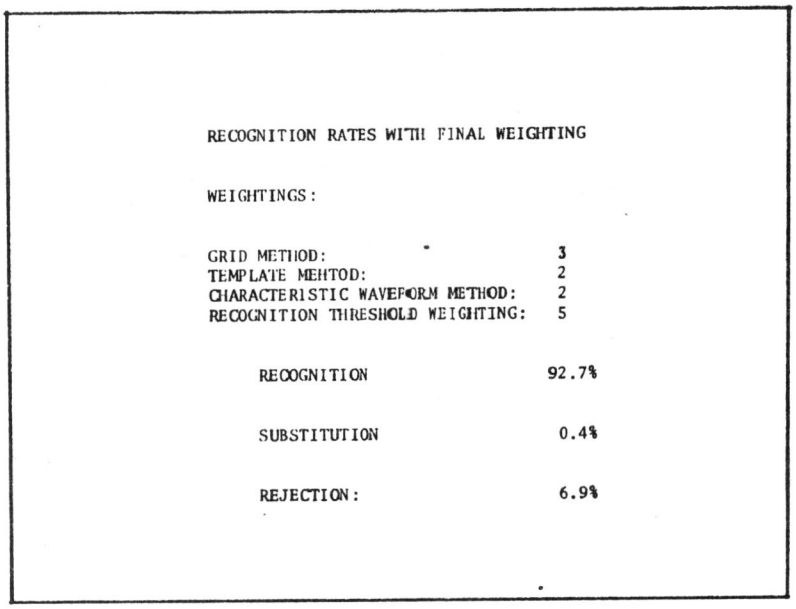


Chart Problem Area
Figure 4



Final Recognition Rates
Figure 5