Three Fonts of Computer Drawn Letters

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Detailed descriptions are given for three fonts of letters. Letter shapes are entirely described by numbers. The basic vectors are in a general form so the fonts may be easily drawn on a variety of computers and cathode-ray tubes. The fonts include both upper and lower case Roman letters, mathematical signs, and upper and lower case Greek letters. Design of the fonts is described. However, the principal contribution of this paper concerns the fonts themselves.

Introduction

Three fonts of letters are described which are useful as a computer output medium for many applications. The fonts include both lower and upper case Roman letters in three sizes, lower and upper case Greek letters in two sizes, digits in three sizes, and an assortment of mathematical symbols in three sizes.

The letters are formed by a number of vectors (short straight lines) drawn on a computer controlled cathode-ray tube. The characters are photographed from the tube. An average of 25 vectors per character is used; hence quite detailed control of character shape is achieved.

The shape is specified by a numerical vector table stored in the computer memory; thus great flexibility in changing or adding characters is inherent. The numerical table of vectors may be obtained in machine readable form for use in other computers.

The fonts were originally designed to be produced on a Stromberg-Carlson 4020 microfilm printer. This device has a 1024 raster of computer addressable points. A vector can be drawn between any two points. The resolution is limited by the width of the vector which is about 2.3 raster points. Normally the middle sized font would be used for standard text, the small size for footnotes and subscripts, and the large size for titles. There is, of course, no limitation to these uses.

The quality of the Stromberg-Carlson 4020 is just acceptable for $8\frac{1}{2} \times 11$ in. pages. The fonts should be useful on any other cathode-ray device having this good or better a raster and resolution. In particular, current announced devices which have 4096×4096 rasters and correspondingly improved resolutions should produce excellent $8\frac{1}{2} \times 11$ quality.

The main contribution of the paper is the fonts. However, this creation led to a new skill—digital type design. Some of the art of this design is discussed. In particular it is possible to greatly increase the quality of the images by properly placing the vectors and characters with respect to the raster of the cathode-ray tube. The advantage thus gained has not been quantitatively measured, but we estimate it to be equivalent to doubling the resolution.

Digital Type Design

Digital type design consists in determining the coordinates of the vectors which form the image of a letter. Selection of vectors to best fit a raster requires judgment and practice. The process is best illustrated by a few example characters from our digital approximation to a font in the Baskerville style of type.

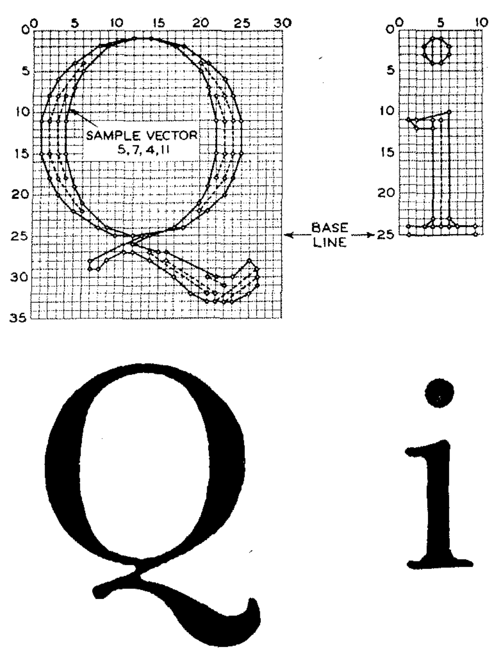

FIG. 1. Upper case "Q" and lower case "i" of Font 3. Above are the actual vectors used to design the characters. Open dots are the coordinates of the vectors. Dotted lines are "fillers" which shade in the characters. Below are the photographic enlargements of characters of Baskerville type style.

Figure 1 shows a completed design for the "Q" and "j" of Font 3, the largest of the fonts. An enlargement of a letter is placed on a suitably scaled raster, and the appropriate vectors chosen visually. The outline vectors closely match the contours of the letter outline except that both ends of each vector must lie on a raster point. The outline vectors are shown as solid lines with small circles indicating beginnings and ends. Other vectors shown as dashed lines fill the interior of the letter. These also must end on raster points.

Each character was designed on a grid with the origin of the vector coordinates [point (0, 0)] at the upper left-hand corner of the grid. All vectors for a given character are relative to this origin. Thus, the sample vector in Fig. 1 is described by the four numbers 5, 7, 4, 11 giving, respectively the horizontal and vertical components of one endpoint of the vector and then the other. In the course of typesetting, any character can be translated to any origin on microfilm by means of simple additions. The base line for Font 3 is at vertical coordinate 25. The base line is the imaginary line upon which most alphabetic characters sit, except those such as "p," which have descenders. These characters sit on the descender line, which is at vertical coordinate 33 for Font 3. All measurements are in units of raster spaces The width of the character is defined such that it is actually larger than the minimum number of raster spaces occupied by the character. The additional empty space assures that the next character in a horizontal line of type will be correctly placed relative to the current character when the width of the current character is added to its origin on the microfilm.

TABLE I. Format of Computer Cards Specifying Characters

COLUMN

2	3	6	8	16	24	32	40	48	56	64	72
3		72	29	12 114 1	14 118 2	18 221 4	21 423 6	23 624 8	24 82511	25112515	25152418
3		72	29	24182320	23202122	21221824	18241225	12251025	1025 824	824 522	522 320
3		72	29	320 218	218 115	115 111	111 2 8	2 8 3 6	3 6 5 4	5 4 8 2	8 212 1
3		72	29	12 1 9 2	9 2 6 5	6 5 5 7	5 7 411	411 415	415 519	519 621	621 924
3		72	29	9241225	6 4 3 8	3 8 211	211 215	215 318	318 622	418 315	315 311
3		72	29	311 4 8	14 117 2	17 220 5	20 521 7	21 72211	22112215	22152119	21192021
3		72	29	20211724	17241425	20 423 8	23 82411	24112415	24152318	23182022	22 82311
3		72	29	23112315	23152218	1325 728	728 729	729 829	829 928	9281127	11271227
3		72	29	12271428	14281730	17301932	19322133	21332433	24332632	26322731	27312729
3		72	29	27292628	26282430	24302230	22301627	16271527	15271226	12261425	14272132
3		72	29	16282232	21302331	22332729	23332730				

The eleven computer cards above give all the information necessary to draw the "Q" illustrated in Figure 1. The quantities in all fields are right-adjusted. Each card has the following format:

Field	Column(s)	Description
1	1–2	The font number: 1, 2, or 3.
2	3	Blank or E (See description of field 3 below.)
3	4–6	Numerical character code number.
4	7–8	Width of the character.
5–36	9–72	The remainder of the card is divided into thirty-two fields of two columns each. Each of eight successive groups of four fields describes one vector. In the example above, the first vector is drawn between coordinate points (12, 1) and (14, 1); the second between (14, 1) and (18, 2); etc.

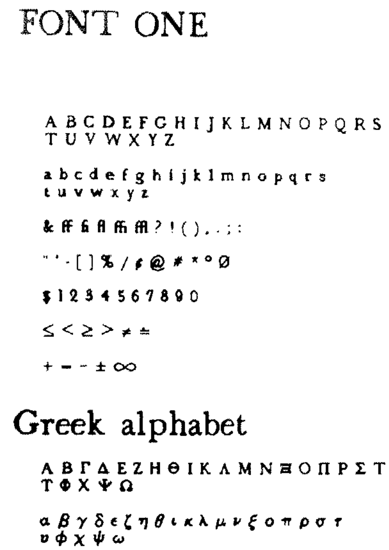

Fig. 2. Font One

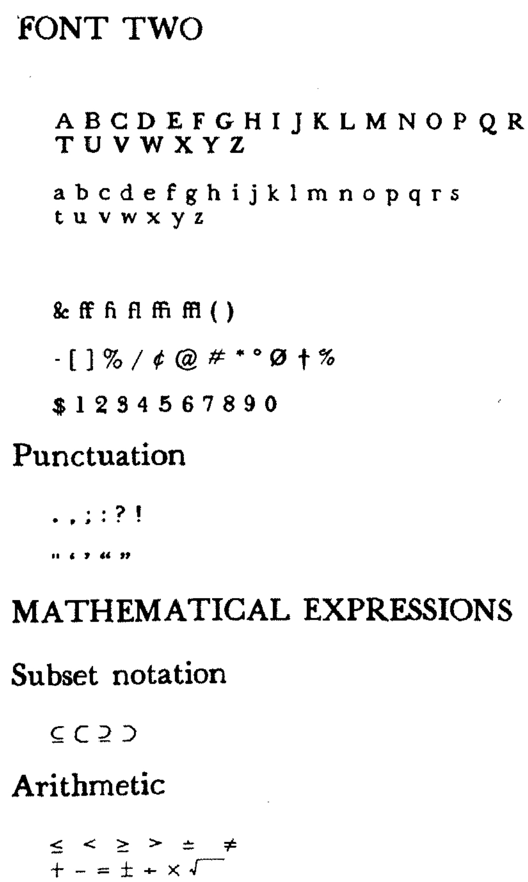

Fig. 3. Font Two

A listing of the cards which describe the letter "Q" is given in Table I. The card decks for the complete fonts are too long to include here.[1] Samples showing all the characters available in the three fonts are given in Figures 2 through 5.

Calculus

∫ ∂ Δ ∞

Geometry

∡ ⊥ ≡ ∥

Logic

↔ →

Absolute value

|a| = a if a ≥ 0
|a| = −a if a < 0

Small parentheses for functional notation

f(x) = x

Greek alphabet

Α Β Γ Δ Ε Ζ Η Θ Ι Κ Λ Μ Ν Ξ Ο Π Ρ Σ Τ
Τ Φ Χ Ψ Ω

α β γ δ ε ζ η θ ι κ λ μ ν ξ ο π ρ σ τ
υ φ χ ψ ω

Fig. 4. Font Two, continued

FONT THREE

A B C D E F G H I J K L M N O P
Q R S T U V W X Y Z

a b c d e f g h i j k l m n o p q r s
t u v w x y z

ff fi fl ffi ffl

1 2 3 4 5 6 7 8 9 0

. , ; : " ‘ ’ “ ”

[ ] ( ) - / ? !

Fig. 5. Font Three

[1] Requests for this material may be directed to the authors.

The vectors as drawn by the cathode-ray tube have a substantial width which must be considered in designing the letters. Figure 6 gives some idea of width on the Stromberg-Carlson 4020. The single vector shown in Figure 6A will be drawn as a line about two raster spaces thick surrounding the vector as indicated in Figure 6B. A double vector will produce two shades of grey as shown in Figures 6C and 6D. Although these line widths are specific to the Stromberg-Carlson 4020, other equivalent widths would apply to other cathode-ray tubes.

A useful method of producing intermediate line widths is illustrated in Figure 7. In some cases the double vectors in Figure 7A produce too thick letters and the single vectors in Figure 7B produce too thin letters. The interlaced vectors in Figure 7C may yield a more desirable thickness.

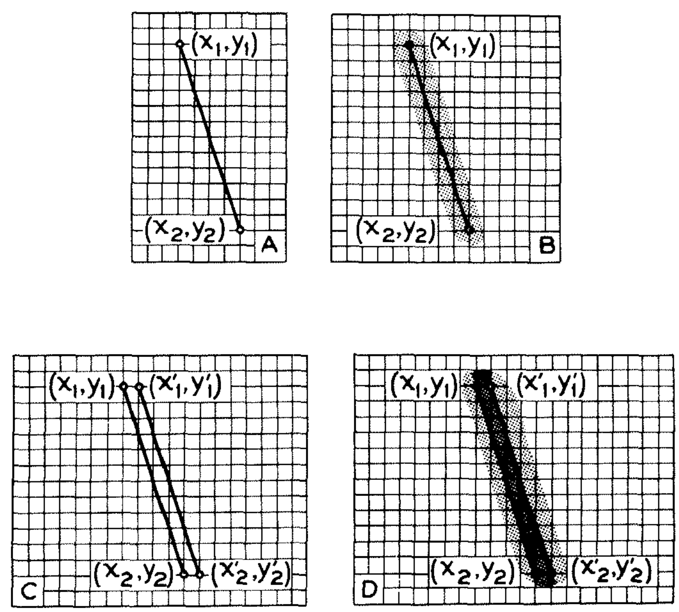

Fig. 6. In Fig. 6A, the single vector drawn between (x_1, y_1) and (x_2, y_2) is presented on the cathode-ray tube as in 6B, a line the thickness of two raster spaces with rounded ends. The double vector of 6C is presented as a line the thickness of three raster spaces with some overlap in the center, as in 6D.

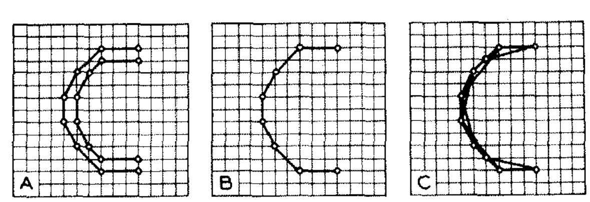

Fig. 7. The double row of vectors of Fig. 7A produces a shape which is too thick, while the single row of 7B gives a shape which is too thin. The disarrangement of vectors in 7C gives an intermediate thickness.

Cathode-Ray Tube

The letters we have generated were drawn on a specific machine, the Stromberg-Carlson 4020 microfilm printer. A brief description of the SC 4020 will assist in using the vector letters with other machines. The SC 4020 has two modes of operation. First, it can draw vectors, which can start at any raster point on its 1024 × 1024 grid and extend up to 64 grid spaces in either or both x and y directions. Secondly, it can produce a total of 64 different characters by shaping the electron beam with an appropriate mask in the cathode-ray tube. One character is a dot. This mode allows one to construct shapes using closely spaced dots, or any other available character, as building blocks. In the type fonts described here, only the vector mode of operation was used. Measurement of the width of the vector indicates that it is equal to 2.3 grid spaces. This means that a character which is 23 grid spaces high has a resolution of only 10 vector widths.

Conclusions

The three fonts of letters presented here are the beginning of a great variety of possible fonts and characters which will be numerically described and computer drawn. The generality of the representation is clear from the ease with which the vectors can be adapted to other computers and other cathode-ray tubes. We believe the fonts will have great utility.

A Grammar Base Question-Answering Procedure

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The subject of this paper is a procedure for the automatic retrieval of certain segments of stored information, either explicitly or implicitly represented, through questions posed in natural language sentences. This procedure makes use of a sentence recognition device for the class of grammars which will correctly decide between the grammatical and ungrammatical sentences of a natural language. It is possible to make use of a recognition device of this sort for the following reason: Much data is fully expressible as a set of sentences in a natural language, a set which can be exhaustively and exclusively generated by a grammar. Based upon the rules of this grammar, a sentence recognizer will evaluate sentences, questions in the normal situation. Since the recognition function succeeds just in case the posed question is drawn from the set of sentences expressing the data, or, more correctly, is grammatical in terms of the grammar for this set of sentences, sentence recognition itself is a procedure for retrieving information. When the recognition function succeeds, its value represents the requested information.

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1. Introduction

> Does the train which leaves from Croton at 4:10 for New York stop at Yonkers?

According to the Hudson Division Timetable of the New York Central Railroad, the answer to this question is "yes." Establishing this timetable as the definitive data base, we may find it of interest to determine whether the answer to this question can be computed directly or indirectly from the input question itself. An initial assumption is made here that the syntactic analysis component of such a question-answering procedure (a component which is generally agreed to be a necessary ingredient of question-answering systems of more than marginal sophistication) is transformational in nature. This assumption requires that sentences are assigned semantically interpretable deep structures which are mapped onto surface structures through transformational processes. Since, of the grammatical descriptions of English proposed and developed to date, only transformational grammars display even a partial capability of providing synonymous variants of sentences with canonical representations (i.e., common deep structures), the adoption of a transformational syntactic component seems justified. To illustrate synonymous variants, one might cite the sentences below, sentences which are synonymous with the original sentence above but by no means exhausting the set of possible synonymous variants.

> Does the 4:10 train which leaves Croton for New York stop at Yonkers?
> Is it the case that, leaving from Croton at 4:10, there is a train for New York which stops at Yonkers?
> Does the 4:10 from Croton to New York make a stop at Yonkers?

Most commonly, question-answering procedures have been contemplated in which the grammar and the data