

METHOD OF STORING CHARACTERS AND
PHOTO-TYPESETTING APPARATUS

5 The present invention relates to a method of
storing characters (which term includes letters and
figures), and to a photo-typesetting apparatus which
projects characters on to a sensitive material using a
cathode-ray tube (CRT), laser/scanner or other flying
10 spot character imaging device.

 In recent years, photo-typesetting machines
employing a CRT and photo-typesetting machines
employing a laser/scanner have been developed and have
been widely used due to the application of advanced
15 electronics technology. The technical assignment,
resulting in the present invention, is to cheaply
reproduce the characters and yet maintain a high
quality. Generally, however, the system for storing
characters consists of digitising a character to store
20 it, as described in detail in due course with reference
to Figure 2. To obtain characters of high quality,
therefore, they must be digitised or divided into a
great many dots, which contradicts the requirement for
cheaply reproducing characters (with reduced memory
25 capacity). From the standpoint of quality,
furthermore, there is imposed a limitation on the size
of the character that is to be reproduced relying upon

a predetermined number of dots. When characters of various sizes are required, characters with different numbers of dots must be prepared. In the Japanese language, furthermore, there exists up to ten thousand characters in a single size, and characters are often used in several sizes. Therefore, to store the characters which are digitised is not practicable and various systems for compressing the data have been proposed to cope with the inconvenience. In most of these systems, however, the characters are divided into a predetermined number of dots, and the dots are compressed. Therefore, different data must be stored depending upon the size of the character, which contradicts the requirement for reducing the memory capacity.

Another system consists of storing the characters in the form of their outline or contour. In this system, however, curves are approximated to straight lines. When the data is prepared based upon characters of a predetermined size, connection points (bending points) of straight lines appear on an enlarged scale when characters of a larger size are being treated, and the quality deteriorates. Conversely, when an attempt is made to obtain large characters while maintaining high quality, the amount of data to be stored increases proportionately to offset the meaning of data compression.

An object of the present invention is to solve the above-mentioned problems and to provide a method of storing characters based upon reduced amounts of data without a deterioration in the quality, irrespective of a change in magnification factor.

5 According to one aspect of the present invention, a method of storing characters comprising the steps of dividing the contours of a character at suitable positions to form contour elements, employing at least a start point, an end point and a reference point suited for reproducing a contour element, as contour element data
10 for each contour element, which points dictate a curve of n-th degree suited for approximating said contour element to a curve, and the number of points depends on the degree of the function, and successively storing said contour element data to store contours of characters.

15 According to a second aspect of the present invention, a photo-typesetting apparatus comprising a character memory which stores characters relying upon the sets of contour element data consisting of at least start point, end point and a reference point suited for reproducing contour elements that are obtained by
20 dividing contours of characters at suitable positions, which points dictate a curve of n-th degree suited for approximating said contour element to a curve, and the number of points depends on the degree of the function; an operation circuit which calculates desired coordinates on the contour elements relying upon the contour element
25 data read from the character memory; and a circuit for controlling the turning on and off of an electron beam or light beam and for

controlling a deflecting quantity based upon the results operated by the operation circuit.

In order that the invention may be more readily understood, it will now be described, by way of example only, with
5 reference to the accompanying drawings, in which:-

Figure 1 is a diagram illustrating a method of interpolating a curve;

Figure 2 is a diagram illustrating a normalised X-Y grid with the contour of a Chinese character "K" [ei] superimposed
10 thereon;

Figure 3 is a block diagram showing major portions of an apparatus for storing characters which is equipped with a buffer memory for one scanning line according to an embodiment of the present invention;

15 Figure 4 is a block diagram which illustrates a method of gaining coincidence with a counter; and

Figure 5 is a block diagram of the apparatus equipped with a contour data memory for one character (or more characters).

The invention will be described below in detail with
20 reference to an embodiment shown in the drawings.

First, the principle of the invention will be illustrated below in conjunction with Figure 1.

In the present invention, the character is stored in the form of data relating to the contour or _____

outline of the character. Unlike the prior art, however, curved contours are not approximated by straight lines, but curves are approximated by curves. Namely, from the stored data a curve is obtained which approximates to the curve of the contour. Curves approximating to contours of characters can then be reproduced based upon the stored data. Curved contours are given by curves irrespective of the magnification. Therefore, the quality of the characters is not deteriorated and the characters can be reproduced relying upon a single kind of data irrespective of the magnification. Further, even contours having a large radius of curvature are approximated by curves. As compared with the prior art, in which approximation is by straight lines, the data need be stored in greatly reduced amounts.

Here, it is assumed that a part (hereinafter referred to as a contour element) of the contour of a character is a curve which is denoted by reference 1 in Figure 1 and which is given by a function $f(x)$. If the function $f(x)$ is a quadratic function, it ($f(x)$) can be specified provided co-ordinates of at least three points on the contour element 1 are clarified, and the contour element 1 can be determined by calculation. Further, with the three points on the contour element 1 being clarified, values on the contour element 1 can be calculated in the same manner by the interpolation

method. Namely, when the contour element is given by the function $f(x)$ of an n -th degree, the function $f(x)$ can be found or co-ordinates on the contour element can be calculated by the interpolation method, provided co-ordinates of $(n + 1)$ points on the contour element are clarified.

Relying upon the above-mentioned principle, a curved contour of a character is transformed into a function of the n -th degree, which function represents the curve or another curve that approximates to the curve. Further, as the data which represents the function, there are specified a co-ordinate of the start point of the curve, a co-ordinate of the end point of the curve and $(n - 1)$ reference points corresponding to the degree of the functions, and these co-ordinates and reference points are stored as the data of a contour element. In the example of Figure 1, in which the function $f(x)$ representing the contour element 1 is assumed to be a quadratic function, the contour element 1 can be reproduced by simply storing three co-ordinates, i.e. by storing a co-ordinate of the start point $(x_0, f(x_0))$, a co-ordinate of the end point $(x_2, f(x_2))$, and an intermediate reference point $(x_1, f(x_1))$.

As mentioned above, the contour element can be calculated from the data of the contour element by either finding functions of curves that represent

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contour elements, or by the interpolation method. With the method in which the functions are found and the calculations are effected, however, the extended periods of time are required for finding the functions.

5 So, this method is not advantageous when high speed outputs are required. Even in the interpolation method, operation must be carried out responsive to the degree, which, however, is not so cumbersome as finding the functions. Examples of interpolation methods for
10 calculating the contours can be divided into interpolation method by Aitken, interpolation method by Lagrange, etc. Among them, however, the interpolation method of Aitken can be relatively simply handled. According to this method, the equation of high degree
15 is not prepared, but the interpolation (linear interpolation) using a linear equation is carried out repetitively. First, a value interpolated by a straight line that passes through two points x_0 and x_i ($i = 1, 2, 3, \dots n$), is found according to the
20 following formula:

$$f(x/x_0, x_i) = \frac{1}{(x_i - x_0)} = \left| \begin{array}{cc} f(x_0) & x_0 - x \\ f(x_i) & x_i - x \end{array} \right|$$

$$i = 1, 2, \dots n.$$

Then, a value interpolated by a quadratic function which passes through three points x_0, x_1, x_i ($i = 2, 3, \dots n$) is found according to the following formula:

$$f(x/x_0, x_1, x_i) = \frac{1}{(x_2 - x_1)} = \left| \begin{array}{cc} f(x/x_0, x_1) & x_1 - x \\ f(x/x_0, x_i) & x_i - x \end{array} \right|$$

$$i = 2, 3, \dots n.$$

When the function $f(x)$ has a higher degree, the value of degree is increased like a value interpolated by a cubic equation which passes through points x_0, x_1, x_2, x_i ($i = 3, 4, \dots n$), like a value interpolated by a biquadratic equation which passes through points x_0, x_1, x_2, x_3, x_i ($i = 4, 5, \dots n$), etc.

In the foregoing was mentioned the principle of the method of storing and reproducing characters according to the present invention. Precisely speaking, however, the contours of characters can be encoded according to the procedure mentioned below.

First, a character is scanned by a flying spot or taken into picture by a vidicon to digitise it into a set of dots of a suitable number. The digitised result is then corrected from the standpoint of design to form a correct shape. Contours of the digitised character are extracted and divided into contour elements. Where the contour is divided into contour elements will be determined depending upon a point of inflection where a straight line changes into a curve or where a curve changes into a straight line, depending upon a position where the increment in the scanning direction is inverted, depending upon the

degree of a function that represents a curve to which the contour element should be approximated, or depending upon the degree to which the contour elements should be approximated. However, when the degree of a function is too great, or when the start point and the end point of the contour element are too close to each other, attention should be given to the fact that an increased amount of data must be stored. Therefore, the best method consists of, first, arbitrarily dividing the contour, and finding values on the contour using suitable reference points to find a correlation relative to the practical contour.

The data determined for every contour element is then stored. The order of storing the data has a close relation to the method of producing output or to the setup of hardware of an output device. Namely, in a CRT or a laser scanner, in general, the characters are reproduced by turning the electron beam or laser beam on and off while performing the raster scanning. In this case, the electron beam or the laser beam can be turned on and off relying upon the following three methods:

A. A co-ordinate which has been calculated beforehand to turn on and turn off the beam is compared at all times with the present position of the scanning beam. When they are in agreement, the beam is turned on or off.

B. A shift register for one scanning line or a line buffer is provided to write signals at positions for turning the beam on and off, and the shift register is shifted or the content of the line buffer is read out in synchronism with the scanning of the scanning line to form video signals.

C. A buffer memory having a capacity of one character is prepared, contours reproducing the character are written on to the buffer memory, and the content is read out in synchronism with the scanning of scanning line, as in B above, to form video signals.

To put the method A into practice, the contour elements must be stored according to the scanning order of scanning lines. In the method B, the contour elements which intersect a scanning line must all be reproduced irrespective of the scanning order. In the case of the method C, the contour elements may be stored in any order provided the contours of one character are produced. Therefore, if the contours are decoded according to the method A, the contours of a character digitised as shown in Figure 2 are stored according to the order mentioned below.

Namely, Figure 2 shows, by way of example, a greatly enlarged version of Chinese "永" superimposed on a grid or matrix of horizontal and vertical lines. Each character that is recorded is located on such a grid. Horizontal and vertical resolutions are

indicated to be the same in Figure 2, but this is not necessary. The character may be of any kind (alphabetical characters, numerals, Japanese characters, character width, etc., in addition to Chinese characters). Each character is also considered to include a "white space" about the character.

The line in the grid shown in Figure 2 may be represented, (numbered) by the X and Y co-ordinates of a Cartesian co-ordinate set. Any point within the grid may be designated by the co-ordinates (X,Y) of the nearest intersection of a horizontal and vertical line. The left-most vertical edge of the character zone is designated $X = 0$ and the horizontal edge is designated $Y = 0$.

When a character, such as the Chinese character "永" shown in Figure 2, is to be digitally encoded, it must first be plotted on to the grid in such a way that all values of X and Y are represented as integers. As shown in Figure 2, the outlines of the character "永" are plotted by choosing the closest intersection points on the grid. Each of these points may thus be represented by its X,Y co-ordinates, where X and Y are integers. It is, therefore, possible to completely define - i.e. digitally encode - the character by listing all of these co-ordinates, preferably in some ordered sequence.

In Figure 2, the character is divided into

100 x 100 dots. Here, let it be assumed that the
aforementioned data has been corrected (design has been
corrected), contour elements have been determined, data
has been determined for each contour element, and the
5 scanning is effected from the left toward the right,
and from the upper direction toward the lower
direction. In this case, "˘" in the upper portion of
the character "𐀀" is scanned, first, in Figure 2.
Therefore, contour elements 20, 21, 22, 23 of "˘" are
10 stored in the order of 20, 21, 22 and 23 according to
the scanning order of scanning lines. Namely, the
scanning line which crosses the contour at an end of
the character necessarily crosses the contour element
on the opposite side which corresponds to the above-
15 mentioned contour element, so that the contour
elements are stored in the form of pairs. However,
when the contour elements of the first pair are short
as denoted by 20, the end point of the contour element
20 and the contour element 22 are stored
20 simultaneously.

In the foregoing, the method of storing
characters according to the present invention has been
described. Below, in conjunction with Figures 3, 4 and
5, an example of a photo-typesetting apparatus, which
25 has a memory device to store characters that have been
encoded by the above-mentioned storing method, and
which decodes the contents to print them, will be

described.

Figures 3, 4 and 5 illustrate photo-
typesetting apparatus which is constructed to be
adapted to the aforementioned methods of A, B and C of
turning the electron beam or laser beam on and off. In
these figures, the common elements are denoted by the
same reference numerals. That is, reference numeral 31
denotes an input device which indicates a character
that is to be printed, 32 denotes a first decoder which
decodes the data such as the address storing the data
of the character as instructed by the input device 31,
magnification of character, and position of character
to be printed, 33 denotes a character memory which
stores the data of characters relying upon the
aforementioned storing method, 34 denotes a second
decoder which decodes the data of a desired character
read from the character memory 33 into co-ordinates of
a start point, an end point and a reference point of
contour element, 35 denotes a magnification memory
which stores the magnification (contraction) of
character decoded by the first decoder 32, 36 denotes a
first operation circuit which multiplies values of
contour co-ordinates decoded by the second decoder 34
by the magnification stored in the magnification memory
35, 37 denotes a contour data memory which stores the
operation results of the first operation circuit 36, 38
denotes a scanning line counter which counts the

number of scanning lines produced by the CRT or laser scanner, 39 denotes a second operation circuit which reads the data of the contour running over a position of a scanning line number indicated by the scanning line counter 38 from the counter data memory 37 to calculate the position of contour co-ordinates on the scanning line, 40 denotes a contour co-ordinate memory which stores positions of contour co-ordinates on the scanning lines calculated by the second operation circuit 39 according to the order of scanning, 41 denotes a scanning position counter which counts the present position of the scanning beam, 42 denotes a coincidence circuit which compares the con of the contour co-ordinate memory 40 with the content of the scanning position counter 41 and which produces the output when the two contents are in agreement, 43 denotes an unblanking (or modulation) circuit which controls the blank or unblank of the CRT or the laser scanner, 44 denotes a display position operation (control) circuit which calculates a position where the character is to be displayed upon receipt of a signal from the first decoder 32, 45 denotes a deflecting circuit which controls the CRT or the deflection of laser scanner, or which detects the quantity of deflection, and 46 denotes a CRT or a laser typesetting device.

In Figure 4, reference numeral 47 denotes a

one-line buffer made up of a buffer memory or a shift register having a capacity of one scanning line. In Figure 5, reference numeral 48 denotes an operation circuit having the functions of the first operation circuit 36 and the second operation circuit 39 of Figures 3 and 4. The operation circuit 48 works to multiply the contour data decoded by the second decoder 34 by the magnification, and to calculate co-ordinates in which the contours cross the scanning lines.

Reference numeral 49 denotes a one-character memory having a capacity of one or more characters. Contours calculated by the operation circuit 48 are written into the memory circuit where the original character is reproduced.

In the above description, position for displaying character, magnification of character, and contour co-ordinates were all calculated using separate operation circuits. The above calculations, however, may be performed using a single operation circuit.

In the thus constructed photo-typesetting apparatus, the data of character, size of character, and display position, are introduced through the input device 31, and are decoded in the first decoder 32 where address storing the character is sent to the character memory 33, data related to the size of character is sent to the magnification memory 35, and the data related to the display position is sent to the

display position operation (control) circuit 44. Then, the data of character is read responsive to the address signal sent to the character memory 33, and is sent to the first operation circuit 36 via decoder 34. The

5 first operation circuit 36 multiplies the data by a magnification (contraction) of character stored in the magnification memory 35, and the result is sent to the contour data memory 37. On the other hand, the data sent to the display position operation (control)

10 circuit 44 and to the magnification memory 35 are further sent to the deflecting circuit 45 and are so deflected that the character will be displayed at a desired position. The scanning line counter 38 counts the number of scanning lines responsive to the signals

15 from the deflecting circuit 45, and the scanning position counter 41 counts the present position of the beam. Therefore, the contour data memory 37 reads the data of contour element which crosses the scanning line that corresponds to a counted value of the scanning

20 line counter 38 according to the order of scanning after every count, and the second operation circuit 39 calculates the co-ordinate in which the contour element crosses the scanning line by the interpolation method, and sends the co-ordinate to the contour co-ordinate

25 memory 40. Thereafter, the comparison-coincidence circuit 42 compares the content of contour co-ordinate memory 40 with the content of scanning position counter

41, and sends a signal to the unblanking circuit 43 when the two contents are in agreement, thereby to control the brightness of the electron beam of the CRT or of the laser scanner. Thus, as the first contour position is brought into agreement, the co-ordinate in which the scanning line crosses another contour element of the pair of contour elements is calculated. In the same manner, another contour element, and contour element that crosses the next scanning line, are calculated. The above-mentioned operation is repeated successively.

In the foregoing was mentioned a decoding method relying upon the above-mentioned method A, in which the co-ordinate where a contour element crosses a scanning line was compared with the present position of the scanning beam, and the coincidence signal was utilised as a video signal. In the case of Figure 4 equipped with the one-line buffer 47 having a capacity of one scanning line, the co-ordinate in which the contour crosses the scanning line that is calculated by the second operation circuit 39, should be written on to the line buffer 47, and should thereafter be read out in synchronism with the scanning of the scanning lines to form video signals. In the case of Figure 5 equipped with the one-character memory 49 having a capacity of one or more characters, the result of calculation should be written on to the one-character

memory 49, and a video signal should be obtained when the contours of one character are all written. In the cases of Figures 4 and 5, there is no definite order for storing the contour elements.

5 Although the foregoing embodiment has dealt with "kanji" (Chinese character), it will be obvious that the present invention is applicable to characters of any other language.

10 According to the present invention as described above, the characters and figures are stored in the form of contours approximated to curves. Therefore, the quality is not deteriorated at any magnification, and the data of a single kind only are required at any magnification. Further, since curves are approximated by curves, reduced amounts of data are
15 required as compared with when curves are approximated by straight lines.

CLAIMS:

1. A method of storing characters comprising the steps of dividing the contours of a character at suitable positions to form contour elements, employing at least a start point, an end point and
5 a reference point suited for reproducing a contour element, as contour element data for each contour element, which points dictate a curve of n-th degree suited for approximating said contour element to a curve, and the number of points depends on the degree of the function, and successively storing said contour element data to
10 store contours of characters.

2. A method of storing characters according to claim 1, wherein the contours of a character are divided at suitable positions to form parts of a curve of the n-th degree for serving as
15 contour elements.

3. A method of storing characters according to claim 1, wherein said contour elements of said contours are stored in accordance with such an order that contour elements can appear in
20 the order to be reproduced.

4. A method of reproducing characters stored in accordance with claim 1, wherein points on the contour elements are calculated based upon the contour element data that consist of the data of
25 start point, end point and reference point of contour elements formed by dividing the contours of character at suitable positions,



and thereby the contours being reproduced to obtain the original character or figure.

5. A photo-typesetting apparatus comprising a character
5 memory which stores characters relying upon the sets of contour
element data consisting of at least start point, end point and a
reference point suited for reproducing contour elements that are
obtained by dividing contours of characters at suitable positions,
which points dictate a curve of n-th degree suited for approximating
10 said contour element to a curve, and the number of points depends on
the degree of the function; an operation circuit which calculates
desired co-ordinates on the contour elements relying upon the
contour element data read from the character memory; and a circuit
for controlling the turning on and off of an electron beam or light
15 beam and for controlling a deflecting quantity based upon the
results operated by the operation circuit.

6. A photo-typesetting apparatus according to claim 5,
wherein provision is made of an operation circuit which calculates a
20 co-ordinate in which the contour element crosses the scanning line
formed by the electron beam or by the light beam, and provision is
made of a one-line buffer which has a capacity of one scanning line
formed by the electron beam or by the light beam and which stores
the results operated by said operation circuit.

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7. A photo-typesetting apparatus according to claim 5,



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wherein provision is made of an operation circuit which calculates a co-ordinate in which the contour element crosses the scanning line formed by the deflected electron beam or the light beam, according to the order of scanning.

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8. A photo-typesetting apparatus according to claim 5, wherein provision is made of a memory which has a capacity of one or more characters, which writes contour elements calculated by said operation circuit, and which reproduces the state of the original character.

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9. A photo-typesetting apparatus according to claim 5, wherein provision is made of an operation circuit which derives an equation of n-th degree that represent contour element relying upon said contour element data, and which calculates a co-ordinate on the corresponding contour element relying upon said equation of n-th degree.

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10. A photo-typesetting apparatus according to claim 5, wherein provision is made of an operation circuit which finds a co-ordinate on a contour element by interpolation method, relying upon said contour element data.

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11. A photo-typesetting apparatus substantially as hereinbefore described with reference to Figures 3, 4 or 5 of the accompanying drawings.

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