Vol. 39 No. 8 Transactions of Information Processing Society of Japan Aug. 1998

Regular Paper

A Method of Skew Detection and Correction in Document Images for Personal Computers

YASUO KUROSU† and HIDEFUMI MASUZAKI†

In order to normalize the skew angles of an input image using a personal computer, it becomes necessary to improve the processing rate and to divide an image into small segments adjusting a limited memory. This paper proposes a new method of an automatic skew normalization, comprising a high-speed skew detection and a distortion-free dividing rotation. We have evaluated the proposed method from the viewpoints of the processing rate and the accuracy for typed documents. As a result, the processing rate is 2.9 times faster than that of a conventional method. A practical processing rate for software processed on a personal computer can be achieved under the condition that the accuracy of a normalized angle is controlled within ±0.3 degrees. Especially, the rotation with dividing can have no error angle, even when the work memory size is reduced to 1/100.

1. Introduction

Image filing systems are now widespread in the fields handling documents as means for promoting a paperless environment. These systems store large volumes of document images in optical disks and retrieve them by user's request. Thus, the systems are expected to improve the business efficiency in sections where large volumes of documents are produced. However, the documents are scanned mechanically by a scanner, often resulting in the input images that may be skewed. The normalization thereof may requires a lot of labor power. This has specifically been called the bottleneck of an input. The automatic normalization of the skewed images will be one of the most important problems in the image filing systems.

On the other hand, the image filing systems have been expensive, because these are configured as many pieces of specialized hardware to enable high-speed processing for a document image. This reason is that the amount of image data is very large, approximately 250 times larger than that dealt with in a word processer. It has been considered that it is difficult for software to deal with the image filing on a personal computer. Today's offices are filled with various kinds of personal computers. It is desired to employ low-cost personal computers for image filing systems. Personal computers have limited computing powers and limited memory size. For software processed on personal computers, to achieve automatic skew normalization in practice, improvement of the processing rate and dividing of the image must be required.

With respect to a skew detecting process for the input images, various methods[1),2)] applying the Fourier transform and methods[4),5)] on the basis of Hough transform[3)] have been studied and good results have been reported. The former methods detect a skew angle using the fact that the intensity of a spatial frequency corresponding to the cycle of text lines forms a peak. However, the amount of the calculation is so enormous that an optical processing may be more suitable for these methods. The latter methods obtain a skew angle using the Hough transform of some parameters or black pixels of characters, because text lines are considered to be printed on horizontal base lines. The Hough transform can calculate faster than the Fourier transform. But, for software processed on personal computers, it is necessary to improve the processing rate. Various methods have been proposed to improve the processing rate for the Hough transform[6)]. By applying these concepts, it is considered that the skew detection can be made faster.

A rotation processing for an image can be broadly classified into a method[7)] which directly transforms by a rotation matrix and methods[8),9)] which transform by a combination of oblique axis transformations. The former method calculates the coordinates for each pixel of the image based on the rotation matrix. As results, the image is inputted and outputted in units of a pixel, so that it is difficult to speed up the rotation processing. To solve this problem,

† Data Storage & Retrieval Systems Division, Hitachi, Ltd.

the latter methods resolve the rotation matrix into the combination of oblique axis transformations and processes multiple pixels at the same time. This method is effective for reducing the times of input and output. However, when the image is simply divided and rotated using this method, local distortion may be caused in the vicinity of dividing points. For rotating the image on personal computers, it is thought that a distortion-free dividing rotation must be required.

In this paper, the property of the input images and normalized image with dividing will be mentioned in Section 2. The high-speed method for the skew detection and the distortion-free method for the dividing rotation will be proposed in Section 3. Some experimental results with CCITT standard documents will be described in Section 4.

2. Properties of Input and Rotated Images

2.1 Properties of Input Images

In this section, we describe the statistical properties of a skew angle, then we mention the concepts on high-speed skew detection using the properties. In the following discussion, the input images are defined as those of the typed documents from B5 to A3 size.

After an auto-feed scanner feeds a paper document into the sensor unit mechanically, it may be scanned in a skewed posture due to an unbalanced force applied to the paper. **Figure 1** shows the distribution of the skew occurrences when the papers are fed into the sensor unit. This example shows the result of the test with 101 pieces of typed documents.

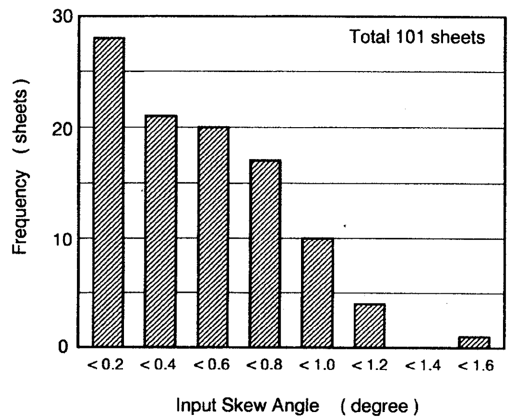


Fig. 1 Frequency of input skew angle by auto-feed scanner.

The skew angles of the input images are scattered over a wide range, but the majority are distributed within a narrow range near zero degree. A characteristic is observed that 99% of the skew angles of the fed papers are concentrated within ±1.2 degrees. However, due to the mechanism of the auto-feed scanner, the maximum skew angle is restricted to the range of ±5.0 degrees. For the proposed algorithm, it is necessary to detect the skew angle within ±5.0 degrees.

On the other hand, the text lines of an input image are considered to be printed on horizontal base lines, so the skew angle can be estimated from text lines using the Hough transform. By using some parameters of characters, it is well known that the skew angle can be obtained accurately within a certain range[4]. But, applying the Hough transform would consume much computing power. This is not practical.

In order to improve the processing rate, the statistical properties of the skew angle is utilized. In the first stage, the skew angle is searched in the narrow range in which the skew distribution is concentrated. If the skew angle is determined at the first stage, the detecting process terminates. If not, in the second stage, the skew angle is searched in the maximum range in which the skew distribution can exit. With this two-step procedure, it is possible to improve the processing rate sharply, compared to the conventional method which searches over all the ranges uniformly.

For software processed on a personal computer, the image must be divided into small segments. The above mentioned procedure does not cause any obstacle. So, to simplify the explanation hereinafter, the skew detection will be omitted to explain the dividing process.

2.2 Properties of Rotated Images with Dividing

In this section, we introduce the principle of rotating an image briefly. we describe the properties of rotated images with dividing, then we mention the concepts on rotating without marring an image quality.

Assuming that the coordinates of an original image are designated (x, y), and the coordinates after rotation are designated (X, Y), the rotation at an arbitrary angle of θ may be defined as follows:

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \quad (1)$$

In this expression, an extended transformation

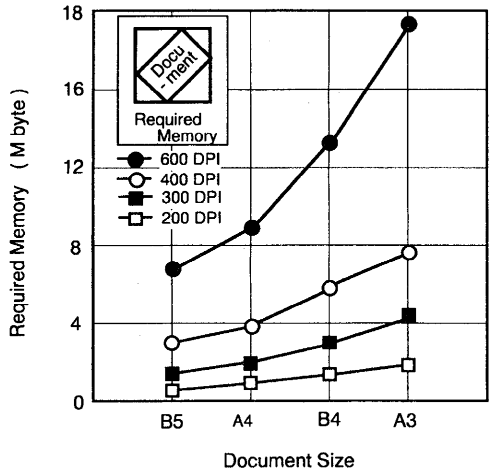


Fig. 2 Relationship between required memory and image size.

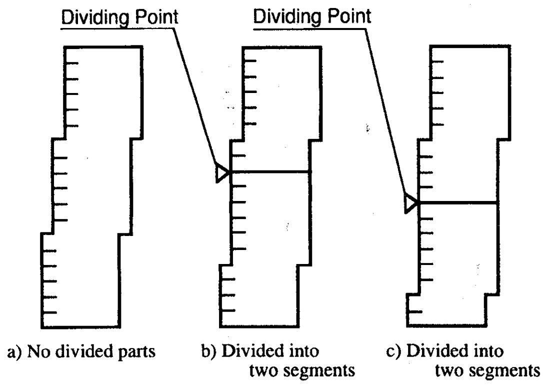


Fig. 3 Examples of distortions caused by oblique axis transformation.

time must be required to process the image, because of calculating each pixel individually. It can be also defined as follows:

$$\begin{bmatrix} X \\ Y \end{bmatrix} = T_3 \cdot T_2 \cdot T_1 \begin{bmatrix} x \\ y \end{bmatrix} \qquad (2)$$

where

$$T_1 = \begin{bmatrix} \cos\theta & 0 \\ 0 & \sec\theta \end{bmatrix} \qquad (3)$$

$$T_2 = \begin{bmatrix} 1 & -\sin\theta\cos\theta \\ 0 & 1 \end{bmatrix} \qquad (4)$$

$$T_3 = \begin{bmatrix} 1 & 0 \\ \tan\theta & 1 \end{bmatrix} \qquad (5)$$

Where in, the matrix T_1 represents a transformation for scaling, and the matrixes T_2, T_3 represent oblique axis transformations. In the oblique axis transformations, the adjacent pixels are transferred simultaneously varying the shift amount. The transformation for scaling at high speed is obtained by an established conventional technology. By applying these transformation matrix to the original image, an image rotated with the angle θ can be obtained at high speed.

In the above method, the coordinate transformation is applied to the original image three times in order to obtain the rotated image. So, a memory is required to store an intermediate image during each coordinate transformation process. **Figure 2** shows the capacity of the required memory for the various sizes of image. The maximum memory capacities of the images with the inclination of 45 degrees are plotted. It clearly shows that the capacity of the required memory for the skew normalization is very large, for example, 17.4 Mbytes in the input image of A3 size with 600 DPI (Dot Per Inch). In order to process in a limited memory size, the image must be divided into small segments.

However, in the conventional methods[8),9)] the matching of the divided images have not been fully considered. In these methods, local distortions may be generated in the vicinity of the dividing point. **Figure 3** shows examples of the oblique axis transformation for small segments divided into two. In the drawing, a) shows an oblique axis transformation without dividing, b) and c) show an oblique axis transformation with divisions into two segments. In the drawing a), the image shifts 6 dots in the Y direction for each 1 dot in the X direction. In the drawing b) and c), the two parts of the divided image are independently processed. Therefore, the image is shifted by 8 or 10 dots in the Y direction for each 1 dot in the X direction for the transformation near the dividing point. Thus, an error of 2 or 4 dots exists, respectively. Since the oblique axis transformation produce an error value between the real oblique axis and the pixel arranged in a square lattice type, the shift amount in an adjacent segment needs to be determined after the adjustment for this original error value. But, in the conventional methods, the image is transformed assuming that the error value in the dividing point is 0, resulting in the shallow inclination of the oblique axis.

In order to obtain a high quality rotated image without distortion, the error value in the dividing point of a preceding segment is utilized. The image is divided into small segments and the rotation processing is performed for each individual segment. Upon the completion of one segment , any error value between the real oblique axis at the dividing point and the shift amount of the pixel is transmitted to an adjacent segment, and the transmitted error value is used as an initial value during the rotation processing of the adjacent segment. This rotation processing is applied to the divided segments in sequence. In such a constitution, the skewed image can be normalized in a memory with small capacity without marring the image quality.

3. Skew Normalization Method Using Two-step Skew Detection

3.1 Basic Concept

In this section, we describe an automatic skew normalization method which can deal with an input image even using software processed on a personal computer. A proposed method is called "skew normalization method using two-step skew detection". In order to normalize the skewed image automatically, it is necessary to improve the processing rate and to divide an image into small segments. Therefore, in the new method, for detecting the skew angle of an input image with high speed, the statistical properties of a skew angle is utilized. For rotating the skewed image without local distortions, the error value in the dividing point of a preceding segment is also utilized.

Figure 4 is a block diagram of the proposed method. This method comprises 3 stages of an image division process, a two-step skew detection process and a dividing rotation process broadly. In the first stage, the input image is divided into small segments, so as to be stored in a memory region with a limited capacity. In the second stage, the skew angle of the divided image is detected by a stepwise operation, so as to improve the detecting rate sharply, as follows. The skew angle is searched in a narrow range on which the skew distribution of an input image is concentrated. If the skew angle is determined, this stage terminates. If not, the next step starts. The skew angle is searched in the maximum range which the skew distribution of an input image can exit. This is called "two-step skew detection method". In the third stage, according to the detected skew angle, the input image is rotated in sequence for small segments At the same time, an error value of the oblique axis transformation in the dividing point is transmitted to an adjacent segment, so as to eliminate the local distortions. This is called a "dividing rotation method".

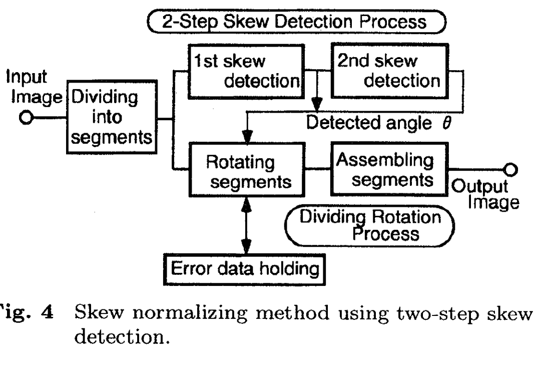


Fig. 4 Skew normalizing method using two-step skew detection.

3.2 Two-step Skew Detection Method

In this section, we describe an algorithm to detect the skew angle of an input image from text lines. Generally, in typed documents, a base line of a text is aligned on a single straight line. The skew angle of the base line may be detected by the Hough transform.

Figure 5 shows the principle of the skew detection, indicating that features are integrated in the direction of θ degrees from X axis. In the first stage, the input image is scanned and the bottom-right corners of characters are extracted as the features. In the second stage, the features are projected on several integral tables having variety of angles. The projections on the integral tables are calculated. In the third stage, an integral table which gives the sharpest projection pattern is selected and the angle perpendicular to the integrated direction of θ degrees is estimated as the skew angle. Here, using the terms of the Hough transform, the calculation of the integral tables $S(y)$ in the

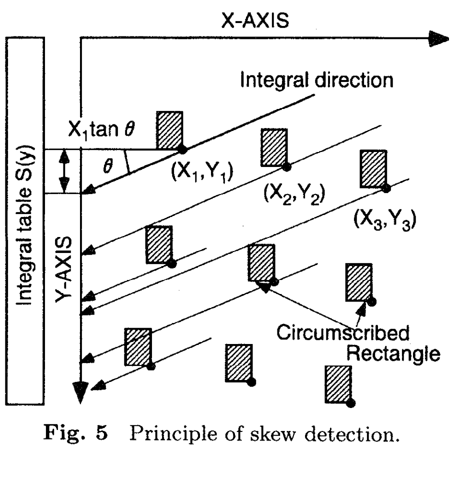


Fig. 5 Principle of skew detection.

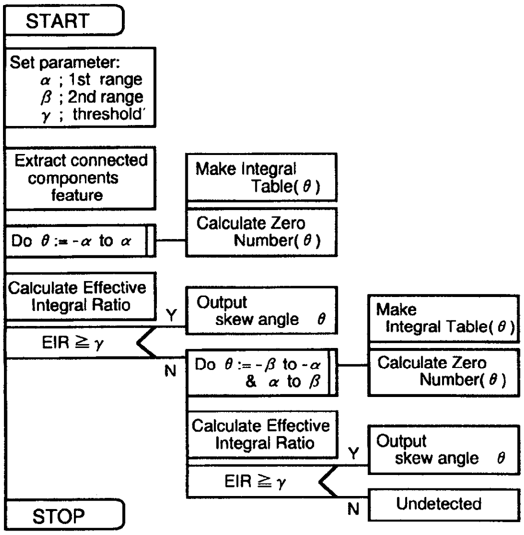


Fig. 6 Procedure of two-step skew detection.

above procedure corresponds with the so-called "voting" operation.

On the other hand, the majority of skew angles are concentrated within a narrow range. By using of this property, it is possible to shorten the processing time of the Hough transform.

The procedure of our method goes as follows. **Figure 6** shows the procedure of the two-step skew detection process. First of all, the parameters α, β and γ are set. α represents the search angle of the first step detection, β the search angle of the second step detection, and γ the threshold value for verifying the effectiveness of the first step detection. Then, the features are extracted from an input image. During a raster scanning, the target pixel is painted black when both the adjacent left and upper pixels are perceived to be black. The components satisfying a condition, which is a certain range (for example from 10 to 100 connected pixels per a raster), are selected. By this selection, small noises or large image elements such as figures, tables or photographs may be excluded. The coordinate (X_1, Y_1) of the bottom-right corner of black pixels is extracted as the features. This is called "connected components feature". Here, the optimum value of α and γ are set to 1.0 and 2.0, in accordance with the discussion in the next chapter. That of β is also set to 5.0, in accordance with the discussion in the preceding chapter.

In the first step detection, the skew angle is searched in a narrow range on which the skew distribution is concentrated. The integral table $S(y)$ are calculated for the connected component features within a range from $-\alpha$ to α degrees. This calculation can be considered as the projection of the feature (X_1, Y_1) for the integral table $S(y)$, as shown in Fig. 5. After all the features are processed, the integral table $S(y)$ for angle θ is created. According to the same procedure, the integral tables for the range from $-\alpha$ to α degrees are created.

Then, a integral table $S(y)$ which gives the sharpest projection pattern is selected and the angle of the integral table $S(y)$ is estimated as the skew of the input image. Since the sharpness of the integral table is proportional to the number of addresses having a value of zero, an angle of the integral table which has the maximum number of zeros is assumed as a skew angle. In the next, the assumed skew angle is verified. When an evaluation function of certainty is defined as an effective integral ratio (EIR), it is expressed as follows:

$$\mathrm{EIR} = \frac{\mathrm{Max}\,\{\sum u(S(y))\}}{\mathrm{Min}\,\{\sum u(S(y))\}} \tag{6}$$

$$u(v) = \begin{cases} 0 & (v \neq 0) \\ 1 & (v = 0) \end{cases} \tag{7}$$

If the EIR is larger than the threshold value γ, the angle giving the maximum sharpness a as the skew angle θ. If the ratio is smaller than the threshold value γ, the second step detection is executed.

In the second step detection, the skew angle is searched in the maximum range which the skew distribution of an input image can exist. The integral tables $S(y)$ are created within a range from $-\beta$ to β degrees. This means that the integral tables from $-\beta$ to $-\alpha$ degrees and from α to β degrees excluding the search range in the first step detection are created. The EIR is calculated in the same way and the skew angle of the image is determined based on the threshold value γ. If the ratio is larger than the threshold value γ, the skew angle is determined. If the ratio is smaller, it can not be determined and "indeterminable" is output.

With this two-step procedure, it is possible to improve the processing rate sharply, compared to the conventional method in which the skew angle is searched over all the ranges uniformly.

3.3 Dividing Rotation Method

In this section, we describe an algorithm to rotate a divided image without marring the image quality. After estimating the skew angle, the divided image must be rotated to normalized position. In order to obtain a high quality rotated image, an error value caused by the oblique axis transformation must be transmitted to an adjacent segment.

The procedure of our method goes as follows. **Figure 7** shows the procedure of the oblique axis transformation for a small segment. In the first stage, the parameters ED, XN, and YN are set. Here, ED represents the error value of the final raster in the preceding segment and XN and YN represent the coordinates of the ending point of the preceding segment. The initial coordinates of a whole image shall be X_0 and Y_0. In the second stage, in order to transform the segment into a parallelogram with an inclination of tanθ, the following process is executed for each raster from the starting point YN + 1 to the ending point $Y_{\max}$. The inclination tanθ is added to the error value e. If the error value e equal to 1.0 or larger, 1.0 is subtracted from e and 1 is added to the address on the X axis. If not, the subtraction and the addition are skipped. Then one raster of the image is moved from the starting point (X_0, y) to the starting point (x, y) and 1 is added to the address on the Y axis. This series of a process is repeated so as to complete the parallelogram. In the third stage, in order to hold the error value e of the final raster and the starting point (x, y), each value is substituted for ED, XN and YN, respectively.

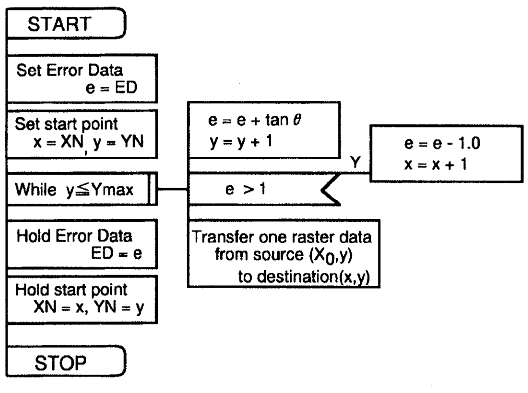


Fig. 7 Procedure of oblique axis transformation.

Figure 8 shows an example of the dividing rotation process using the aforementioned oblique axis transformations. In the figure, a) shows a original image, b) a scaling, c) the first oblique axis transformation, d) a 90-degree rotation, e) the second oblique axis transformation, and f) an inverse 90-degree rotation. Numerals I to IV enclosed with circles indicate small segments. The angle of the rotation is $-\theta$ degrees.

In a), the original image is divided into small segments from I to IV. In b), a segment is reduced and enlarged according to Eq. (3) and the processing result is stored into a work memory. The process is executed for all segments of the divided image, the results are used in the next process for the calculated segments. In c), the final error value of the preceding segment is used as an initial value and the oblique axis transformation is executed according to Eq. (4). The error value of the final raster is held. In d), the segment is rotated 90-degrees to execute the oblique axis transformation in the scanning direction. In e), the oblique axis transformation according to Eq. (5) is executed in the same procedure as that in c) and the error value of the final raster is held. In f), the 90-degree rotation in d) is calculated by an inverse 90-degree rotation. Finally, the rotated images in small segments I to IV are recombined.

With transmitting the error value in the preceding segment, the skewed image can be normalized in the memory of small limited capacity without marring the image quality.

4. Experimental Results

4.1 General Description

The procedure to detect the skew angle has

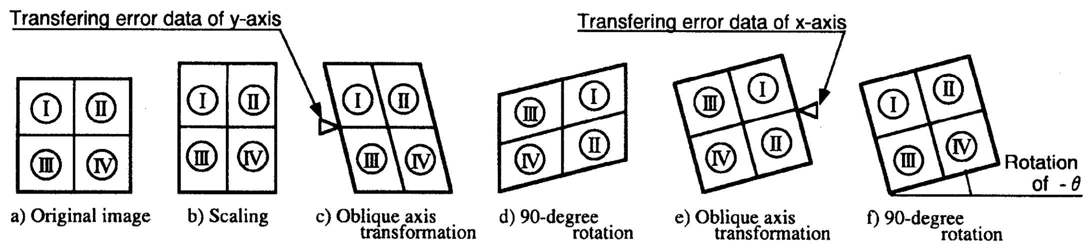


Fig. 8 Example of dividing rotation.

Table 1 Processing time of skew normalization methods.

A4/200 DPI

	Item	No.1	No.3	No.4	No.5	No.6	No.7	average
1	Number of features	918	580	3659	1387	224	2451	1537
2	Effective integral ratio	5.50	3.96	5.45	4.06	3.13	2.93	4.17
3	Two-step skew detection (sec.)	1.40	1.16	3.34	1.73	0.90	2.48	1.84
4	Conventional skew detection (sec.)	4.43	3.39	12.80	5.87	2.31	9.11	6.32
5	Rotation (sec.)	0.53	0.53	0.53	0.53	0.53	0.53	0.53
6	Proposal method (sec.)	1.93	1.69	3.87	2.26	1.43	3.01	2.37
7	Conventional method (sec.)	4.96	3.91	13.33	6.39	2.84	9.64	6.85

been implemented as a program on the Hitachi FLORA3010DV personal computer equipped with a 32 bit processer Pentium/90 MHz. The program is written in C language. Experiments using CCITT standard document database[10] are executed using this program.

The CCITT standard document database includes 8 samples whose sizes are 210×297 mm. No. 1 is an English letter, No. 2 a handwritten diagram, No. 3 a table, No. 4 a French document, No. 5 a technical article with a figure, No. 6 a graph, No. 7 a Japanese publishing printed vertically, and No. 8 a handwritten memorandum and a white-on-black advertisement. In these samples, Nos. 1, 3, 4, 5, 6 and 7 are typed documents and the others are handwritten documents.

The samples are scanned with a resolution of 200 DPI by the Hitachi image file system HITFILE Wn. To examine the ability of the proposed method, the simulated skewed documents are generated by rotating the samples. The skew angles are changed with an increment of 0.05 degrees.

4.2 Processing Rate of Normalization

The processing rate of normalization comprises that of the two-step skew detection method and the dividing rotation method.

In the two-step skew detection method, the processing rate depends on a switching angle α which is the search range of the first step detection. First of all, the optimum value of the angle α is evaluated. **Figure 9** shows the relationship between the skew detection time and the angle α. The unit of detecting angles is 0.05 degrees. The skew detection time is the sum of a feature extraction time and the Hough transform time.

The skew detection time is 6.32 seconds at the switching angle of 0.0 degrees and it is reduced to 1.84 seconds at the switching angle of 1.0 degrees. When the switching angle is larger than 1.0 degrees, the time increases again. It become to 6.32 seconds at the switching angle of 5.0 degrees. It is considered that the probability that the skew angle is detected in the second step detection increases when the switching angle is too small. This means that the total processing time increases. On the contrary, even though the number of samples for which the skew angle is detected by the second step detection is reduced for the larger switching angle, the processing time of the first step detection increases. The switching angle of the two-step skew detection is determined to 1.0 degrees.

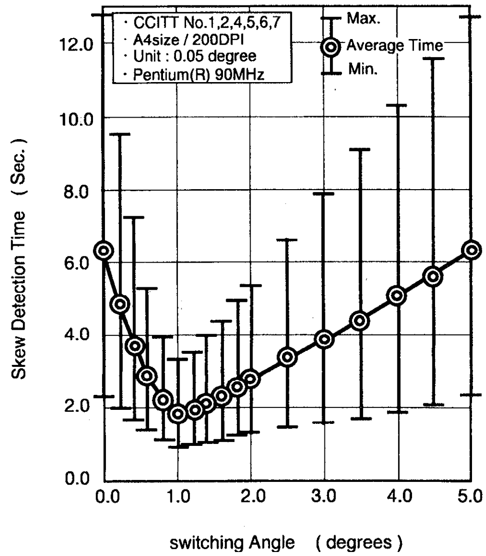


Fig. 9 Switching angle and skew detection time.

Table 1 shows the results of the proposed method using the two-step detection with the determined switching angle and a conventional method using a uniform search. Here, the threshold value γ is selected to be 2.5. The other conditions are the same as those shown in Fig. 9. Item No. 6 and No. 7 are the entire processing time of the proposed method and the conventional method, respectively. Items No. 3 to No. 5 show the details of the entire processing time. Item No. 1 is the number of features and item No. 2 is EIR. For the typed documents, the mean value of EIR is 4.17 and the minimum value is 2.93.

The processing time of the two-step skew detection method is 1.84 seconds, which shows a 3.4-fold processing rate improvement over the 6.32 seconds obtained by the conventional method. It is considered that the latter method executes the Hough transform for the whole search range uniformly, while for the former method almost all of the skew angle can be detected in the first step detection in which the skew distribution of the image is concentrated, resulting in shortening the Hough transform time. On the other hand, the processing time of the dividing rotation method is 0.53 seconds, which is independent of the samples. The time of dividing into the segments and synthesizing rotated segments can be ignored, because it is not found up to the second decimal place.

The entire processing time of the skew normalization method using two-step the skew detection is 2.37 seconds and improves 2.9-fold as compared with 6.85 seconds for the conventional method. In order to put the method into a practical use for the image, the processing time has to be less than the scanning time, which may be 1.5 or 3.0 seconds per sheet, this is to say, 20 or 40 sheet per minute. The proposed method can achieve a practical processing rate of 25 sheet per minute.

By the way comparing the processing time for each sample, the processing time for No. 6 is the shortest and No. 4 requires the longest time. The number of features is the least for No. 6 and the most for No. 4 in the same way. This processing time increases in proportion to the number of features. If the processing time had become longer time than the scanning time, it could be shortened to control the number of features. The proposed method can achieve the automatic skew normalization in practice even for software processed on a personal computer.

4.3 Accuracy of Normalization

The accuracy of the skew normalization can be specified from that of the skew detection and the rotation to a normalized position.

The accuracy of the skew detection obtained from the experiment are shown in **Fig. 10**. The ordinate represents the error between the set angle and the detected angle.

The accuracy of less than ±0.1 degrees is achieved for the typed documents consisting of typed characters only, which are Nos. 1, 4 and 7. For the typed documents including graphical elements, which are Nos. 3, 5 and 6, the skews can be detected with the accuracy of ±0.3 degrees. However, the accuracy for the handwritten documents Nos. 2 and 8 degraded to the accuracy to ±3.75 degrees, it is 12.5 times as bad as that of the typed documents. Because the proposed method detects the skew angle by the base lines of the typed text. It is found that the proposed method has sufficient accuracy for typed documents, but the accuracy is insufficient for handwritten documents.

Next, the accuracy of the rotation is evaluated. **Figure 11** shows the maximum error angles in the proposed method and the con-

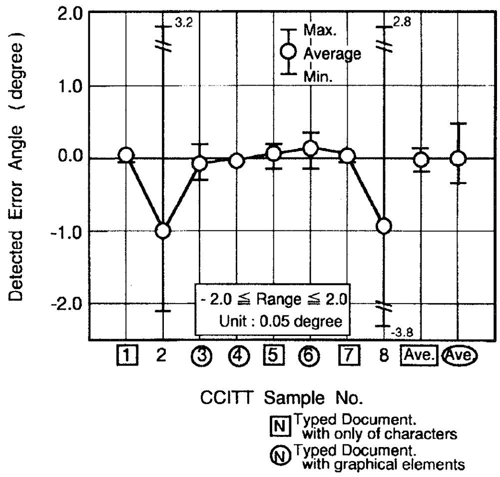


Fig. 10 Error between rotated angle and detected angle.

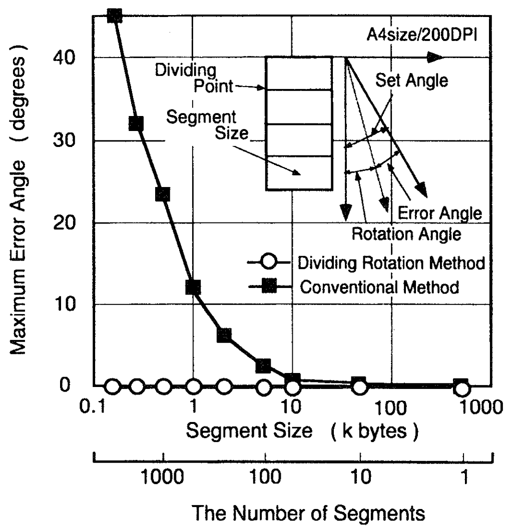
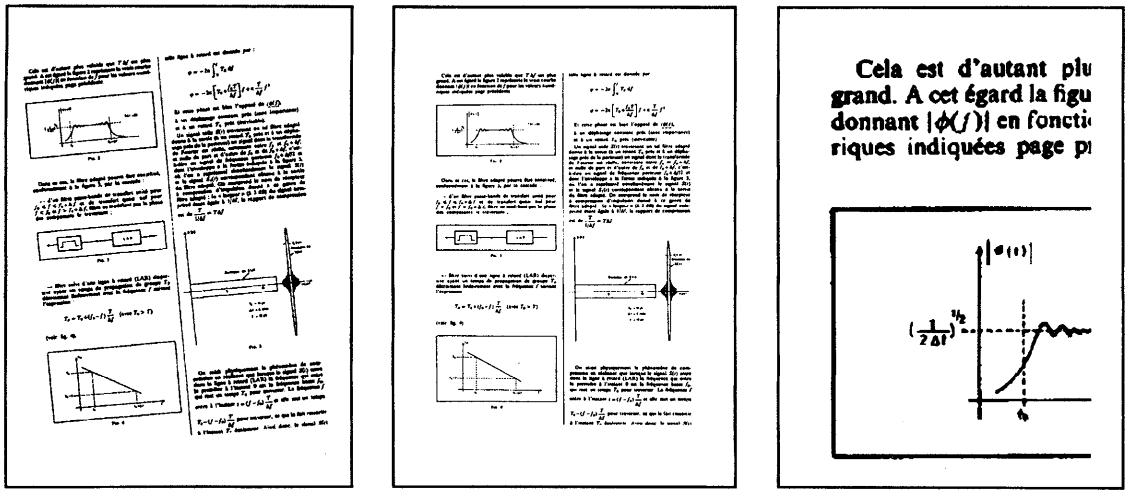


Fig. 11 Max. error angle of the dividing rotation method and the conventional method.



a) Original image b) Skew normalized image c) Skew normalized image (upper left part)

CCITT No.5 (dividing into 400 segments)

Fig. 12 Example of skew normalization of document image.

ventional method. The ordinate represents the maximum value of the error angle and the abscissa represents the segment size. The size of the image is A4, the resolution is 200 DPI, and the memory capacity is 483 Kbytes.

In the conventional method, the image is divided into small segments and rotated without transmitting the error value in the dividing points. The error angle of 0.24 degrees is generated when the image divided into 10 segments rotated. When the division number increases to 100 or 1000, the error angle increases to as 2.45 or 23.2 degrees. In the proposed method, the image is divided into small segments and rotated with transmitting the error value in the dividing points. The image is rotated without error angle. It is considered that the error value caused by the oblique axis transformations can be transmitted accurately at the dividing points. It is found that the proposed method can achieve the rotation without distortion.

The example of the skew normalization is shown in **Figure 12**. The image is divided into 400 segments forming vertically horizontal strips. In the figure, a) shows the original image, b) and c) show the skew normalized image.

4.4 Conclusions

An practical method is proposed for normalizing the skew angle of an input image for software processed on a personal computer. It has been essential in practice to improve a processing rate and to divide in a limited memory size. The input image is divided into small segments. This method detect a skew angle in a two-step process to improve the processing rate. This method also normalize the segments with transmitting the error data of dividing points to obtain at high quality.

We have evaluated the proposed method from the viewpoints of the processing rate and the accuracy for typed documents. The optimum switching angle from the first to the second step detection is ± 1.0 degrees. It is confirmed that the processing rate could be made 2.9 times faster than that of a conventional method and might be 2.37 seconds per sheet. It is also made clear that the proposed method could achieve a practical processing rate of 25 sheet per minute, which is faster than a scanning rate.

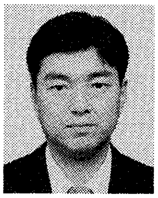
With respect to the accuracy, it is confirmed that the input image which consists of the typed documents could be normalized within ± 0.3 degrees. Especially, the dividing rotation can have no error angle, even when the input image is divided into 100 segments, whereas the conventional method cause the error angle of 2.45 degrees.

Some more effort must be made to extend the object to handwritten documents and to promote the ease of restrictions on an input document.

References

1) Hase, M. and Hoshino, Y.: Segmentation method of document images by two dimensional fourier transform, *IEICE Trans. Inf. & Syst.*, Vol.J67-D, No.9, pp.1044–1051 (1984).
2) Postl, W.: Detection of linear oblique structure and skew scan in digitized documents, *8th Int. Conf. on Pattern Recognition, Paris, France*, pp.687–689 (1986).
3) Hough, P.V.C.: Method and means for recognizing complex patterns, U.S. Patent, 3069654 (1962).
4) Nakano, Y., Shima, Y., Fujisawa, H., Higashino, J.and Fujinawa, M.: An algorithm for the skew normalization of document images, *10th Int. Conf. on Pattern Recognition, Atlantic City, USA*, pp.8–13 (1990).
5) Akiyama, T. and Masuda, I.: Document skew detection based on text line extraction, *37th Natl. Conv. Rec. IPS Japan*, 6W-1, pp.1646–1647 (1988).
6) Matsuyama, T. and Koshimizu, H.: Hough transform and pattern matching in computer vision, *Trans. IPS Japan*, Vol.30, No.9, pp.1035–1046 (1989).
7) Alexander, P.: Array processer in medical imaging, *IEEE Computer*, Vol.16, No.6, pp.17–30 (1983).
8) Tabata, K., Takeda, H. and Machida, T.: High speed rotation of digital images by raster scanning and table-lookup operations, *IEICE Trans. Inf. & Syst.*, Vol.J69-D, No.1, pp.80–90 (1986).
9) Miyazawa, A.: Performance evaluation of the T^2D^2 decomposition method, a fast image-rotation algorithm, *Trans. IPSJ SIG Notes*, 49-1, pp.1–9 (1987).
10) Hunter, R. and Robinson, A: International digital facsimile coding standard, *IEEE Trans.*, COM-28, 7, pp.854–867 (1980).

(Received December 22, 1997)
(Accepted May 8, 1998)



Yasuo Kurosu received the B.E. and M.E. degrees in mechanical engineering from Waseda University, Tokyo, Japan in 1978 and 1980, respectively. Since 1980, he has been engaged in research on character recognition, image processing and file systems at Hitachi Ltd. He is a member of IEEE, IPSJ and IEICE Japan.

Hidefumi Masuzaki received the B.E. degree in electronic engineering from the University of Tokyo, Tokyo, Japan in 1976 and the M.E. degree in electronic engineering from Stanford University, Calif., USA in 1985, respectively. Since 1976, he has been engaged in research on character recognition, image processing and file systems at Hitachi, Ltd.