NBS TECHNICAL NOTE 878

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

The M40 Fingerprint Matcher

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The M40 Fingerprint Matcher

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The M40 Fingerprint Matcher

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A procedure is described for automatically determining whether two fingerprint impressions were made by the same finger. The procedure uses the x and y coordinates and the individual directions of the minutiae (ridge endings and bifurcations). The identity of the two impressions is established by computing the density of clusters of points in Δx, Δy space where Δx and Δy are the differences in coordinates that are found in going from one of the fingerprint impressions to the other.

Key words: Computerized - fingerprint - identification, fingerprint, pattern recognition.

1. Introduction

An average rolled fingerprint impression exhibits about eighty ridge endings and forks or bifurcations in its ridge pattern. By comparing the data representing these minutiae, a computer can determine whether or not two fingerprint impressions came from the same finger. Figure 1 shows how the x and y coordinates and the direction θ are defined for a minutia. If the areas marked A are ridges then the minutia is a ridge ending, but if the areas marked B are ridges the pattern is a bifurcation. Since a ridge ending in one print may appear as a bifurcation in another print from the same finger, no distinction is made between ridge endings and bifurcations in recording data.

A portion of a fingerprint along with a plot of the corresponding minutiae are shown in Figure 2. The minutia data are read automatically from the rolled impressions on fingerprint cards [1,2,3,4] and in addition, the reader also produces ridge direction data at equally spaced grid-points over the entire print. In a fully automated identification system, this ridge-direction data is utilized in finding the core or "center" of a print as well as the angle through which the print should be rotated.[5,6] This registration information is used to translate and rotate the minutia data into a standard position. The ridge-direction data in the neighborhood of each minutia is also used to make slight corrections to the angle θ of that minutia. Those registered minutiae within a certain distance of the center are then sorted into a descending order on y and this data may then be placed in a file or used to search against minutia data in a previously established file.

The matcher, M40, described here differs from the previously reported M19 matcher[7] only in that M40 utilizes ordering in the y direction to achieve a great increase in speed, and the final matching score is computed in a slightly different manner.

2. Selecting Minutiae

Complete details for the M40 procedure are given in Flow Chart 1. The values of x,y, and θ are handled as elements in an array, A, as follows:

	x	y	θ
Search Minutiae	Ai11	Ai21	Ai31
	----	----	----
File Minutiae	Aj12	Aj22	Aj32
	----	----	----

The number of search minutiae IMX_1, is first compared with the number of file minutiae IMX_2. Whichever is smaller is identified as IMXB.

Each value of y_i (A_{i21}) in the control set 1 is then used to determine the range of values of y_j (A_{j22}) in set 2 with which comparisons are to be made. Thus $YBL \leq A_{j22} \leq YAB$, where YAB (above) and YBL (below) are determined by A_{i21}. While index i runs from 1 to IMX_1, index j is determined by this "window".

3. Difference Tables

The M40 matcher can deal with a certain amount of distortion and lack of registration between two fingerprints that are being compared. To illustrate this, the superimposed plots of minutiae from two different prints A and B, made by the same finger, are shown in Figure 3. This is typical of the appearance of superimposed minutiae from two prints that have been read by machine. There may be missing or false minutiae. Here one print is rotated about six degrees and is shifted about 35 units in the x direction with respect to the other print, but, of course, this information is unknown to the computer when it attempts to match these prints. X and Y are measured in units of one-tenth millimeter and θ is measured in degrees. The minutia data for prints A and B is shown in Figure 4.

Since print A has 5 minutiae and print B has 6 minutiae, IMXB = 5. The procedure begins by comparing:

$$DX = X_i - X_j$$

$$DY = Y_i - Y_j$$

$$D\theta = \theta_i - \theta_j$$

where i runs from 1 to IMX_1 and j is determined by the previously described window. Only those pairs of minutiae that satisfy the following conditions simultaneously are used.

$$|DX| \leq LS$$

$$|DY| \leq LS$$

$$|D\theta| \leq L\theta$$

If the matcher parameters have the values

$$LS = 60$$

$$L\theta = 25$$

then the resulting differences can be plotted as points in a Δx, Δy coordinate system as shown in Figure 5. If the prints are from the same finger then many points will tend to be in a cluster, but if the prints are from different fingers the points tend to be randomly located over the entire area. Figure 6 is an enlargement of the cluster area from Figure 5 and Figure 7 gives the difference table for prints A and B. For example, point 1, 1 in Figure 6 indicates the distance from minutia B1 to A1 in Figure 3.

4. The Matching Score

The task of the matcher is to compute a matching score that increases as the density of the cluster increases. The M40 matcher accomplishes this by starting from each point in the graph in Figure 6 and counting the number of steps in the Δx and Δy directions to each of the other points. (See boxes 23 through 36 in the Flow Chart.) If this number of steps, TR, is less than a matcher parameter KR, then the quantity KR - TR is added to an accumulating sum R. $D\theta$ can also be made to contribute to the R score by selecting a suitable value for a parameter $K\theta$. To see how this works, let KR = 10 and refer to Figure 6 and the difference table in Figure 7. The column S in Figure 7 determines the order in which steps are counted. One goes from S = 2 to S = 1, S = 3 to S = 1, S = 3 to S = 2, S = 4 to S = 1, etc. The number of steps from point 2,2 to point 1,1 exceeds 10 so that nothing is added to R. The distance from 2,3 to 1,1 is just 10 so again, nothing is added to R. In fact nothing is added to R until one goes from S = 4 to S = 2. Here, in going from point 3,4 to point 2,2 one steps down 5 steps and to the left 3 steps, or a total of 8 steps. Thus TR = 8, and the score R is increased by KR - TR = 10 - 8 = 2. Referring to Box 25 in the Flow Chart, the computer computes

$$TR = |DX_4 - DX_2| + |DY_4 - DY_2|$$

$$\text{or} \quad TR = |-35 + 38| + |9 - 4| = 3 + 5 = 8$$

In Box 29, R which was previously set to 0 is increased to 2.

The next contribution to the score R occurs when one steps from point 4,5 to 2,2. Two steps to the right and two steps down gives TR = 4. Then R = 2 + (10 - 4) = 8. The history of the development of the R score is shown in Figure 8 where the final value of R is found to be 12. The matching score actually used is

$$RS = \frac{KRR \times R}{IMYB}$$

where KRR is a scaling parameter. In this illustration let KRR = 2. Then

$$RS = \frac{2 \times 12}{5} = 4.8$$

5. Conclusion

Matching runs have been made with a Univac 1108 computer on data read by the FBI's prototype fingerprint reader from somewhat better than average quality fingerprint cards. The parameter values most frequently used were:

$L\theta$	LS	$K\theta$	KR	$KH\theta$	KHR	KRR
10.	10.	0.	8.	8.	8.	2.

The average matching time per pair of prints was about 20 milliseconds. Eight prints from each card were used (little fingers excluded). For the most frequently used reference data set, the average matching score for prints from the same finger was 26.04. The highest mating print score observed was 165. The average score for non-mating prints (false matches) was 0.97. The highest false matching score observed was 17. It appears that a threshold score can be established such that when a pair of prints exceeds this threshold, a positive identification is achieved.

The computer programs used in this work were written by J.F. Rafferty of the National Bureau of Standards. The author is also indebted for advice and assistance to R.T. Moore of NBS, and R.M. Stock of the FBI. The work was financially supported by the FBI.

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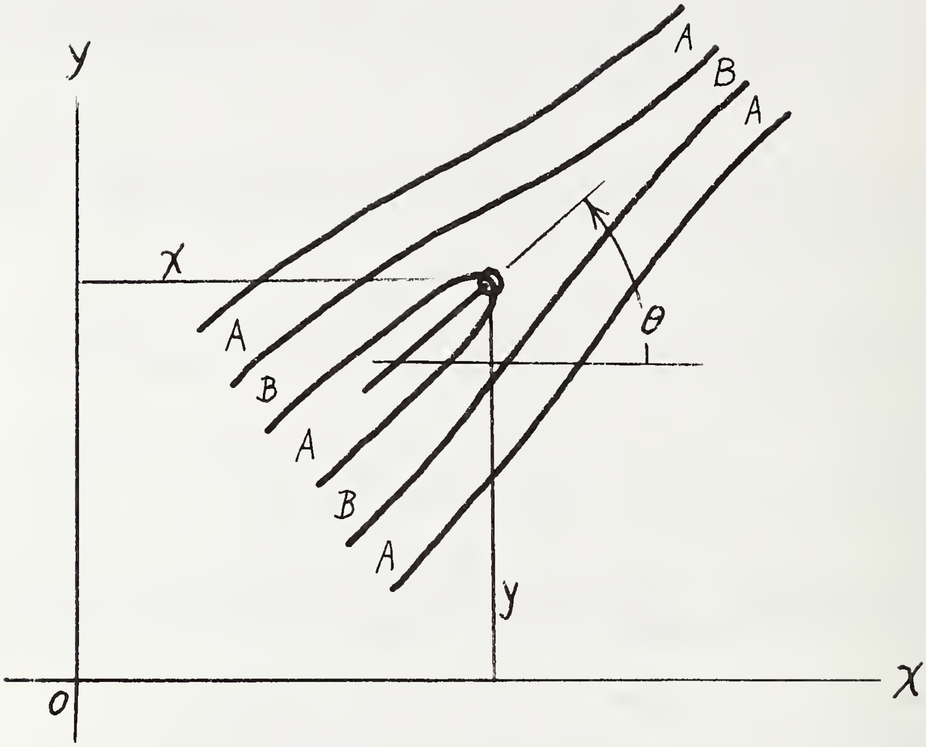


Figure 1. Definition of Minutia Data

Figure 2. A Portion of a Fingerprint with
a Plot of Corresponding Minutiae

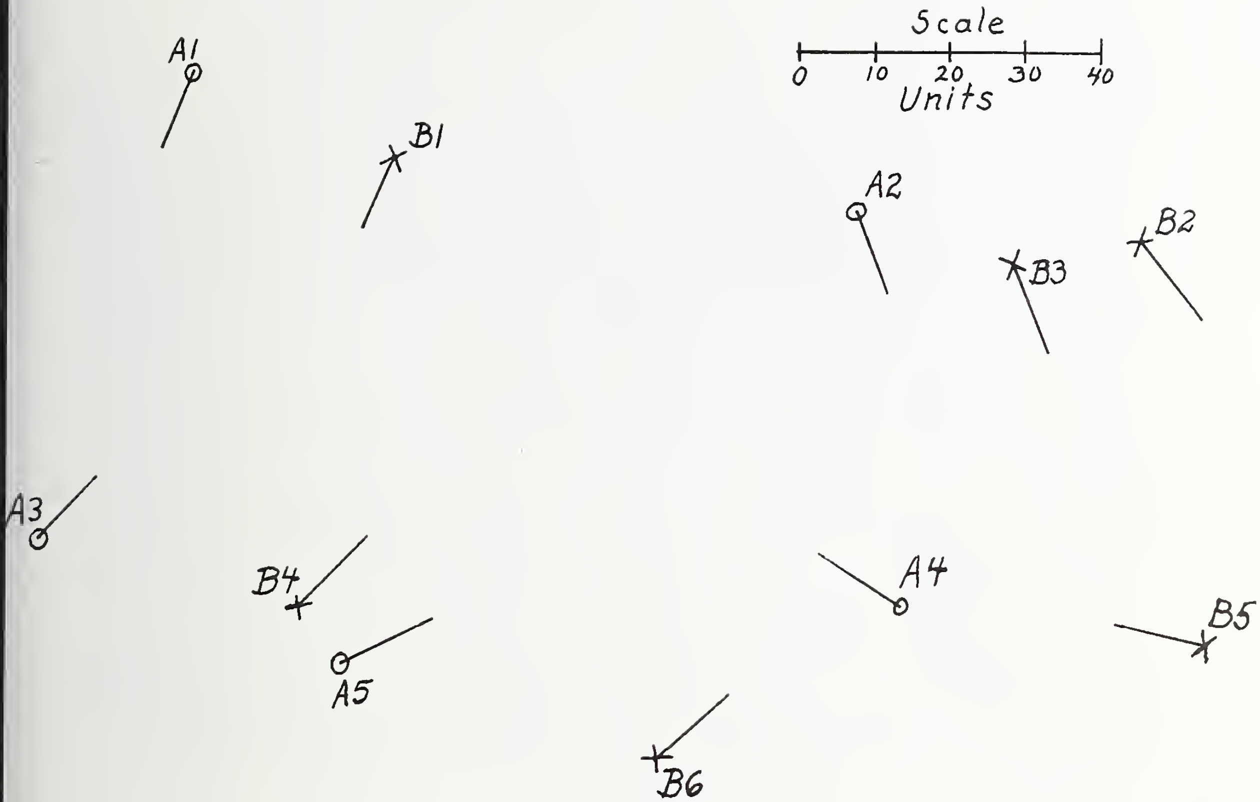


Figure 3. Superimposed Machine-Read Minutiae from Prints of the Same Finger

Minutiae from Print A

Minutiae from Print B

Print A

i	x	y	θ
1	48	252	67
2	136	233	111
3	27	190	226
4	142	181	327
5	68	174	205

Print B

j	x	y	θ
1	75	241	65
2	174	229	128
3	157	226	111
4	62	181	225
5	182	175	346
6	109	161	222

Figure 4. Minutia Data for Prints A and B

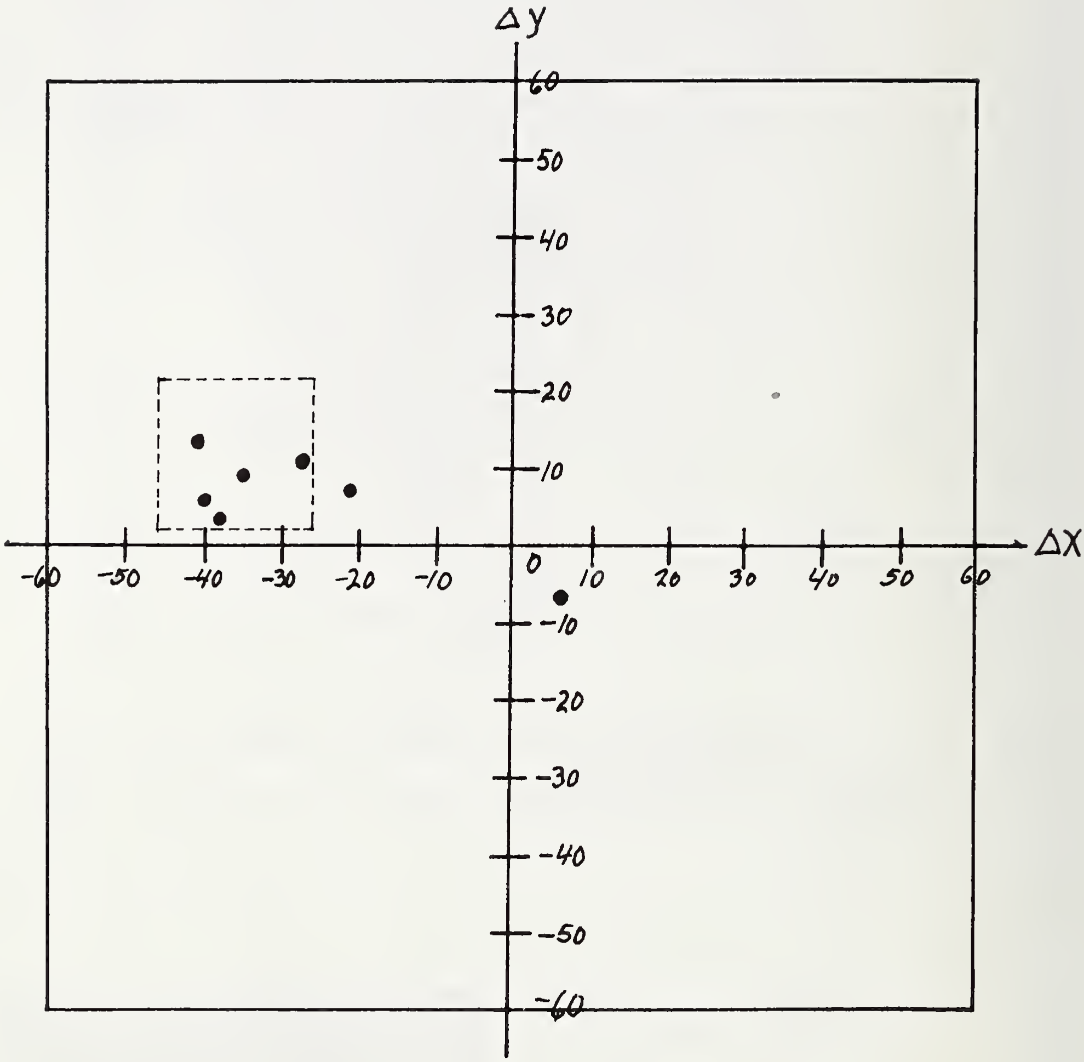


Figure 5. Difference Graph for Prints A and B

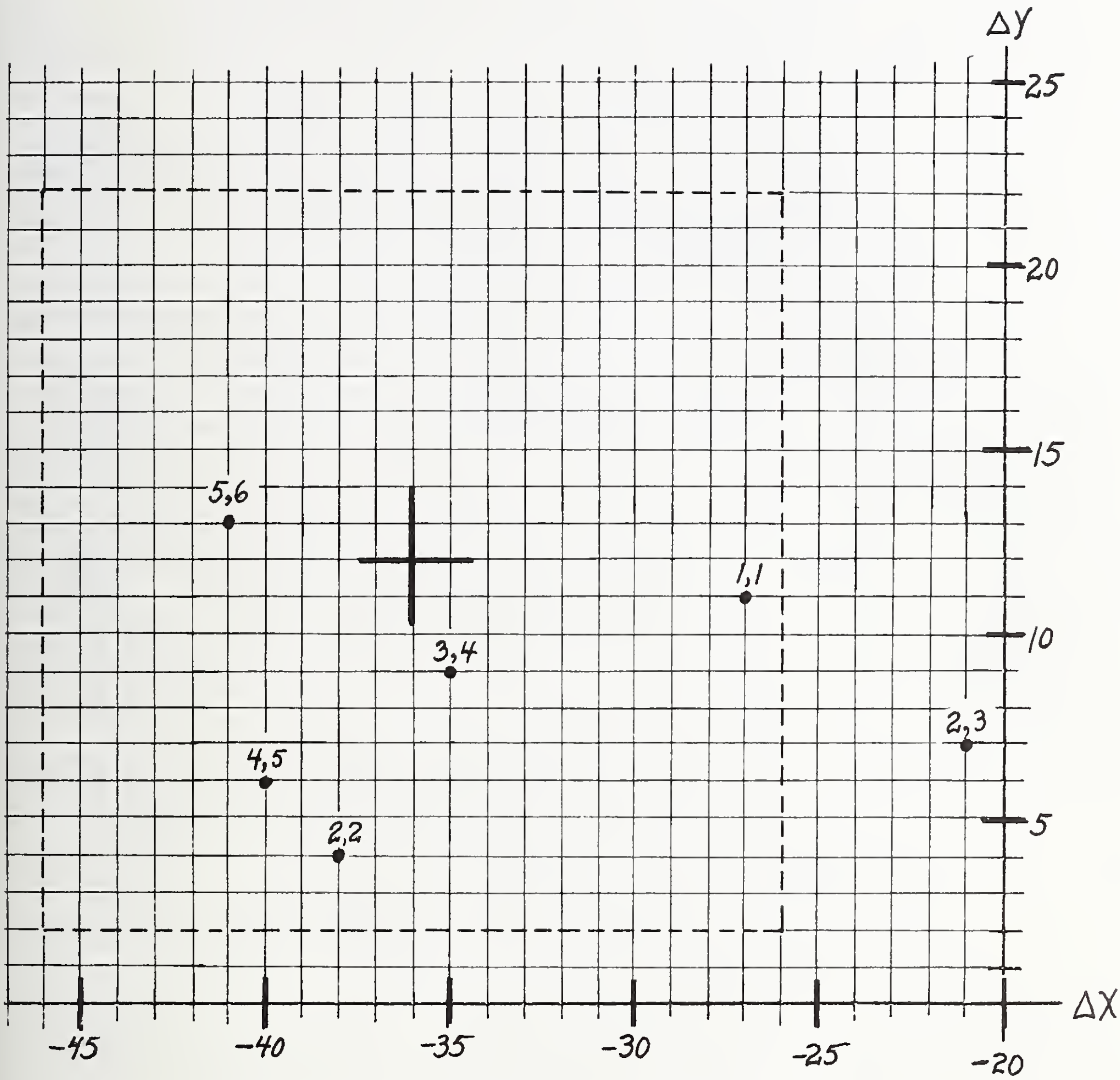


Figure 6. Enlarged Portion of Difference Graph for Prints A and B

s	i	j	DX	DY	Dθ
1	1	1	-27	11	2
2	2	2	-38	4	-17
3	2	3	-21	7	0
4	3	4	-35	9	1
5	4	5	-40	6	-19
6	5	4	6	-7	-20
7	5	6	-41	13	-17

Figure 7. Difference Table for Prints A and B

i	j	TR	TΘ	R
4	2	8	18	2
5	2	4	2	8
5	4	8	20	10
7	5	8	2	12

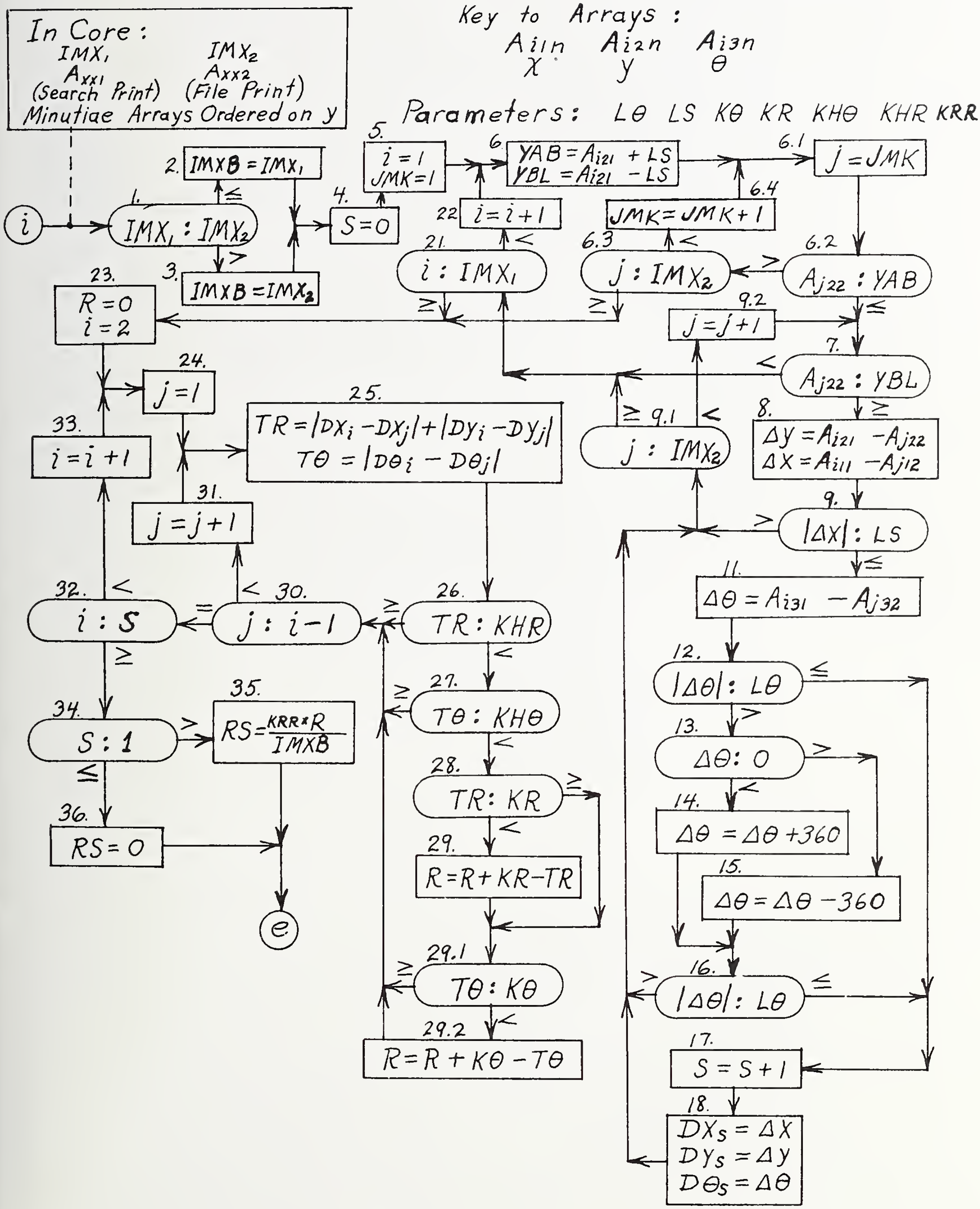
Figure 8. Matching Score Computation Using Data from Figure 7.

FLOW CHART 1 M40 (Matcher)

Key to Arrays :

A_{i1n}	A_{i2n}	A_{i3n}
x	y	θ

Parameters: $L\theta$ LS $K\theta$ KR $KH\theta$ KHR KRR



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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

A procedure is described for automatically determining whether two fingerprint impressions were made by the same finger. The procedure uses the x and y coordinates and the individual directions of the minutiae (ridge endings and bifurcations). The identity of the two impressions is established by computing the density of clusters of points in Δx, Δy space where Δx and Δy are the differences in coordinates that are found in going from one of the fingerprint impressions to the other.

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Computerized fingerprint identification, fingerprint, pattern recognition

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