UNITED STATES
DEPARTMENT OF
COMMERCE
PUBLICATION

NBS TECHNICAL NOTE 730

Manual and Automated Fingerprint Registration

U.S.
DEPARTMENT
OF
COMMERCE
National
Bureau
of
Standards

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards[1] was established by an act of Congress March 3, 1901. The Bureau's overall goal is to strengthen and advance the Nation's science and technology and facilitate their effective application for public benefit. To this end, the Bureau conducts research and provides: (1) a basis for the Nation's physical measurement system, (2) scientific and technological services for industry and government, (3) a technical basis for equity in trade, and (4) technical services to promote public safety. The Bureau consists of the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Center for Computer Sciences and Technology, and the Office for Information Programs.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of a Center for Radiation Research, an Office of Measurement Services and the following divisions:

> Applied Mathematics—Electricity—Heat—Mechanics—Optical Physics—Linac Radiation[2]—Nuclear Radiation[2]—Applied Radiation[2]—Quantum Electronics[3]—Electromagnetics[3]—Time and Frequency[3]—Laboratory Astrophysics[3]—Cryogenics[3].

THE INSTITUTE FOR MATERIALS RESEARCH conducts materials research leading to improved methods of measurement, standards, and data on the properties of well-characterized materials needed by industry, commerce, educational institutions, and Government; provides advisory and research services to other Government agencies; and develops, produces, and distributes standard reference materials. The Institute consists of the Office of Standard Reference Materials and the following divisions:

> Analytical Chemistry—Polymers—Metallurgy—Inorganic Materials—Reactor Radiation—Physical Chemistry.

THE INSTITUTE FOR APPLIED TECHNOLOGY provides technical services to promote the use of available technology and to facilitate technological innovation in industry and Government; cooperates with public and private organizations leading to the development of technological standards (including mandatory safety standards), codes and methods of test; and provides technical advice and services to Government agencies upon request. The Institute also monitors NBS engineering standards activities and provides liaison between NBS and national and international engineering standards bodies. The Institute consists of the following divisions and offices:

> Engineering Standards Services—Weights and Measures—Invention and Innovation—Product Evaluation Technology—Building Research—Electronic Technology—Technical Analysis—Measurement Engineering—Office of Fire Programs.

THE CENTER FOR COMPUTER SCIENCES AND TECHNOLOGY conducts research and provides technical services designed to aid Government agencies in improving cost effectiveness in the conduct of their programs through the selection, acquisition, and effective utilization of automatic data processing equipment; and serves as the principal focus within the executive branch for the development of Federal standards for automatic data processing equipment, techniques, and computer languages. The Center consists of the following offices and divisions:

> Information Processing Standards—Computer Information—Computer Services—Systems Development—Information Processing Technology.

THE OFFICE FOR INFORMATION PROGRAMS promotes optimum dissemination and accessibility of scientific information generated within NBS and other agencies of the Federal Government; promotes the development of the National Standard Reference Data System and a system of information analysis centers dealing with the broader aspects of the National Measurement System; provides appropriate services to ensure that the NBS staff has optimum accessibility to the scientific information of the world, and directs the public information activities of the Bureau. The Office consists of the following organizational units:

> Office of Standard Reference Data—Office of Technical Information and Publications—Library—Office of International Relations.

---

[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Part of the Center for Radiation Research.
[3] Located at Boulder, Colorado 80302.

Manual and Automated Fingerprint Registration

J. H. Wegstein

Center for Computer Sciences and Technology
U. S. National Bureau of Standards
Washington, D.C. 20234

U.S. DEPARTMENT OF COMMERCE, Peter G. Peterson, *Secretary*
NATIONAL BUREAU OF STANDARDS, Lawrence M. Kushner, *Acting Director*,

Issued June 1972

National Bureau of Standards Technical Note 730

Nat. Bur. Stand. (U.S.), Tech. Note 730, 26 pages (June 1972)
CODEN: NBTNAE

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
(Order by SD Catalog No. C13.46:730). Price 35 cents.

Manual and Automated Fingerprint Registration

by J.H. Wegstein

A method is described for manually positioning a fingerprint so that manually read minutiae data can be searched by computer against a file of fingerprint data that has been previously read by machine. A procedure is also described whereby a computer can utilize machine-read ridge-direction data in manipulating minutiae data to effect a registration of the fingerprint prior to filing its minutiae data.

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

1. Introduction

The identification of a fingerprint can be automated by utilizing data associated with two types of minute details in the fingerprint. These minutiae are ridge endings and bifurcations or forks in the ridges. With the fingerprint in the first quadrant of an X-Y coordinate system, data is obtained by reading the abscissa X, the ordinate Y, and the angle θ which the minutia direction makes with the X axis for each minutia in the print. In Figure 1, if the areas marked B are considered as ridges, then point P is the location of a ridge ending and the line GP defines the direction of this minutia. If the areas marked A are considered as ridges, then point P is the location of a bifurcation and the line GP defines the direction associated with this minutia. Once the data is recorded, no distinction is made between ridge endings and bifurcations because, due to variations in inking, a minutia in one impression of the print may appear as a ridge ending, but the same minutia in a different impression of the print may appear as a bifurcation.

From studies of the requirements[1] and the problems[2] related to automated fingerprint identification using digital data, one can define four major tasks that must be performed:

1. Reading the minutiae data.

2. The registration or placing of the print in some standard position.

3. Classification of the print to determine where its data should be placed in a file.

4. Comparing minutiae data from two prints to determine whether they came from the same finger.

Because (1) reading and (4) matching were the most critical tasks, these were attacked first, and both of these problems have been solved to a degree that makes the automation of a large fingerprint identification system appear feasible.

For matching fingerprints, a procedure[3] has been developed at the National Bureau of Standards under the sponsorship of the Federal Bureau of Investigation that can employ either a high speed digital computer or a specially-built integrated-circuit device in determining whether two fingerprints came from the same finger. This procedure can utilize minutiae data that have either been read manually (in a semi-automated system) or read by machine (in a fully automated system).

Under sponsorship of the Federal Bureau of Investigation the Cornell Aeronautical Laboratory has developed a minutiae and ridge direction data reader called FINDER[4] for installation in a fully automated system at the FBI. Under sponsorship of the New York State Identification and Intelligence System (NYSIIS) the Electro Dynamic Division of General Dynamics is developing a closed-circuit television system[5] as an aid in manually recording minutiae data.

The problem of automatically classifying single fingerprints appears to be solvable in the near future. However, automated systems may continue to use some manual classification based on techniques drawn from existing or proposed fingerprint identification systems[6-11].

The remainder of this paper is devoted to methods of positioning fingerprints manually when minutiae data are read manually, and registering fingerprints automatically when minutiae data are read by machine.

2. Manual Fingerprint Registration

When minutiae data are to be read manually it is necessary to place the fingerprint in some standard position prior to reading data in order to minimize the amount of computation that a computer must perform when it searches a file in quest of a match. One method of manually obtaining minutiae data is to project the fingerprint on a ground glass screen using a precision ten-power opaque projector. Upon this ground glass screen is drawn the reticle shown in Figure 2.

The fingerprint is shifted about until the point marked C is on the lowest full ridge that is smoothly convex upward, that is just above the highest core. See examples in Figure 3. At the same time, the print is set at whatever angle causes the slanting lines of the reticle to best coincide with the ridge directions. Figure 4 shows how the reticle will appear on a fingerprint.

A different procedure is used with a plain arch where no core pattern occurs. Here the ridge directions are made to best coincide with the slanting lines of the reticle and at the same time the print must be slid up and down in the Y direction until the slope of the ridges is a maximum along the X axis. Coincident with this, the print must be slid back and forth in the X direction so that the Y axis cuts the highest part of recurving ridges near point 0.

After the fingerprint has been positioned (registered), the minutiae are marked as shown in Figure 1. Instead of marking them on the ground glass, it is convenient to superimpose a piece of transparent plastic and mark both the X-Y coordinates and the minutiae on the plastic. Next, with point 0 of the reticle located at an arbitrary position (200,200), the X, Y, and θ values for each minuta are measured and recorded. The data will appear as shown in Figure 5. With a 10 fold magnification, X and Y are measured in millimeters and θ is measured in degrees. The time required to do this work could be greatly reduced by using a televised fingerprint displayed on a calibrated cathode ray tube. The operator could locate minutiae and automatically record their data with the aid of a stylus controlling an X-Y digitizer[5].

This manual method of positioning a fingerprint achieves a registration approximating that of the fully automated technique described later in this paper. Accordingly, minutiae data read by hand can be used to search a file generated by the fully automated system.

It is anticipated that even with a fully automated fingerprint identification system it will be desirable to record some minutiae data manually. This will be convenient for training personnel intending to manage the automated systems, for encoding poor quality prints, and most important of all, for encoding latent fingerprints found at the scene of a crime. Figure 6 shows latent prints found at the scene of a crime. Such prints are often faint, blurred, and overprinted by other prints. A considerable portion of the print may also be missing. Nevertheless, a skilled operator can often locate and encode enough minutiae for a computerized file search. The encircled print in Figure 6 produced data for 23 minutiae. As a preliminary experiment, this print along with 9 other latent prints were manually encoded. They were then searched by computer against a file of data read by machine from 35 inked fingerprint cards that included 10 prints corresponding to the 10 latent prints. The computer successfully identified all of the latent prints. This experiment makes the feasibility of searching latent prints against a computerized file appear very promising for the future.

3. Automatic Fingerprint Registration

A block diagram for a fully automated fingerprint identification system is shown in Figure 7. Here, where minutiae data are to be read by machine, the registration technique is different from that used when minutiae data are read manually. Instead of positioning on the fingerprint itself, the Cornell FINDER positions on the boxes of the fingerprint card. It reads data from each of the ten boxes for rolled prints on a standard fingerprint card. Plotted minutiae data read by an early version of FINDER are shown in Figure 8. A more recent version of the reader eliminates duplicate minutiae and corrects certain errors in angles. In addition to reading minutiae data, FINDER also produces ridge direction data at equally spaced grid-points over the entire print. See Figure 9. A sample of ridge direction data is shown in Figure 11.

As indicated in Box 2 of Figure 7, this ridge direction data is then used to compute a "center point" (XX, YY) of the print and an angle ψ through which the print must be rotated about the point (XX, YY) in order to bring the print into a standard position. These registration parameters (XX, YY, ψ) are then used to translate and rotate both ridge direction data and minutiae data into a standard position (Boxes 3 and 4). A yet-to-be-developed procedure will then use the registered ridge-direction data to compute a classification of the print (Box 5). The ridge direction data is then discarded and the classification is used to locate the registered minutiae data in the file.

4. Registration Procedure

A detailed computer procedure called R25 for computing the registration parameters XX, YY and ψ is given in the flow diagrams, pages 22 and 23 . This is a laboratory model of the procedure that includes numerous parameters for tuning and adjusting to get optimum performance. It contains inefficiencies that can be readily removed after the best values for the various parameters have been determined from processing an adequate set of experimental data. In addition to the standard Fortran integers and reals it contains the declared integers SW, CLU, RR, RX and the declared reals K1, LLX, LMW, LOX, LOY, LY, MLW, MW, MXW, and MYW. Each of the arrays LX, PX, PY, RX, TX, TY, and YW need provision for 50 entries. The data array A_{ij} is interpreted as follows:

$$A_{i2} = X_i \text{ and } A_{i3} = Y_i$$

The largest value of i, called IMS, is the total number of points in an array for a particular print. Values of IMX as large as 680 have been found in large fingerprints. $-90 \leq \psi_i \leq 90$ are the ridge directions measured in degrees.

In searching for the center of a print, the computer works with the ridge directions in a box whose size is determined by parameters DDX and DDY. Although larger boxes would normally be used, box A in the upper left hand corner of Figure 10 will be used in the following explanation. For each row, going from the top of the print downward, the box is slid across the print from left to right. When the average ψ for the leftmost three points (MLW) is positive and the average ψ for the rightmost three points (MXW) is negative, the box stops sliding. At this point the average value of the $|\psi|$ in box A (called LMW) is subtracted from the average value of $|\psi|$ (called MW) of the four points immediately below box A. This difference $TY\kappa$ = MW -LMW is computed for each row, κ, and saved. In all prints except plain arches there will be a sharp peak in the value of $TY\kappa$ near the core of the print. The location where this occurs is shown near the center of Figure 10. Data for this area is given in Figure 11 and the situation is tabulated as follows:

ROW κ	$Y\kappa$	MLW	MXW	MW	LMW	$TY\kappa$
10	148.78	23.00	-1.00	36.25	24.50	11.75 = Z3
11	136.94	15.00	-18.00	73.25	32.50	40.75 = Z2
12	125.09	30.33	-13.33	71.50	73.25	-1.75 = Z1

Once the computer has found this maximum value of TYκ at row κ = 11, it performs a linear interpolation to get XX

$$XX = X_{146} + \frac{MXW\ (X_{146} - X_{145})}{MLW - MXW}$$

$$XX = 151.74 + \frac{-18(151.74 - 139.90)}{15 + 18} = 145.28$$

This computation of XX is shown graphically in Figure 12. YY is computed by fitting a parabola to the peak values of TYκ.

$$YY = Y_{11} - \frac{(Y_{10} - Y_{11})\ (Z3 - Z1)}{2\ (Z3 - 2 \cdot Z2 + Z1)}$$

$$YY = 136.94 - \frac{11.84\ (11.74 + 1.75)}{2\ (11.75 - 2 \cdot 40.75 - 1.75)} = 138.06$$

This is shown graphically in Figure 13.

In the event that the maximum value of TYκ is less than some parametric value SKK (=12), the print is taken to be a plain arch and each value of TYκ is replaced by YWκ. YWκ is the average value of $|\psi_i|$ for the κth row and here again there is a peak value at the center of the print. (By setting SKK to some large value, YWκ can be used as an alternate method for finding YY on all types of prints, but this method has been found to be less accurate than the method using TYκ.)

The angle ν through which print data are to be rotated is computed using ridge direction data from a horizontal band whose location is determined by the values of XX and YY. Such a band is shown by the broken line in Figure 10. The distribution density of the $|\psi_i|$ to the left of XX is compared with that to the right of XX. Figure 14 gives the distribution density tables corresponding to the data in Figure 11. For example $LX_{18} = 2$ indicates that there are two grid points to the left of XX where the angle ψ = 72°. (In practice a larger band is used and there are many more entries in the table.) The curves representing tables LX_j and RX_j are smoothed out by computing auxiliary tables LL_j and RR_j as follows. The scoring weights shown in the box at the left of Figure 14 are moved down the table and applied to table LX_j to get table LL_j and to table RX_j to get table RR_j. For example,

$$RR_5 = 1 \times RX_3 + 2 \times RX_4 + 3 \times RX_5 + 2 \times RX_6 + 1 \times RX_7$$

$$+ \quad 0 \quad + \quad 2 \quad + \quad 6 \quad + \quad 2 \quad + \quad 0 = 10$$

The peak value of LL occurs at JL = $|\psi|$ = 71° and JR = $|\psi|$ = 59°. Then

$$\psi = \frac{JR - JL}{2} = -6°$$

An auxiliary parameter

$$K1 = \frac{JR + JL}{2} = 65°$$

is also computed for possible use in print classification.

Registration of the ridge direction data can be completed by first translating all coordinates so that point (XX, YY) is moved to point (200,200). Thus a point formerly at (145.28, 138.06) will now be located at (200, 200). Next, the coordinates of all data points are recalculated to represent a 6° clockwise rotation about the point (200,200). The directions of the new coordinate axes are shown in Figure 10. The same calculations are performed on the minutiae data and this data is then ready to be filed or searched against the file.

5. Performance Measurements

Pairs of fingerprints representing a range of patterns were read by FINDER at Cornell Aeronautical Laboratory to provide data for developing, tuning, and testing the R25 registration procedure. FINDER produces angle data in degrees and coordinate data in units of approximately .002 inch. It will read a print in about 0.5 seconds. In order to make the coordinate data compatible with previous work at NBS, the Cornell English units were converted to NBS metric units of 0.1 millimeter by multiplying each coordinate value by 0.4849. Precision was retained by using real numbers instead of integers.

In one test, the R25 procedure was used to compute XX, YY and ν for 13 pairs of assorted prints. (Each pair of prints were two different impressions from the same finger read from fingerprint cards.) Each computed center point (XX, YY) was plotted on the plot of the minutiae and the new axes were drawn at the computed angle ν for each of the 26 prints. Corresponding minutiae plots were then superimposed so that corresponding minutiae coincided as closely as possible. The distance between computed centers was then measured and recorded along with the angular difference in the directions of the coordinate axes. The results are shown in Figure 15. The average angular difference of 2 degrees and the average distance between computed centers of 5.5 units indicate rather good registration. (The average distance between ridges on a fingerprint is about 5 units.)

As a further test of reader, registration, and matcher performance, the thirteen machine registered sets of minutiae data were searched against the corresponding thirteen sets of minutiae data as file prints using the M19 matcher[3]. The resulting RS score matrix is shown in Figure 16. The diagonal scores indicate correct matches. The column at the right labeled AS is the average off-diagonal score times 100 divided by the diagonal score. Column CS indicates the highest off-diagonal score times 100 divided by the diagonal score (the "closed search" score). Of the summary scores at the bottom of Figure 16, WCS (for worst CS score) is the largest of the CS scores. ACS.is the average CS score, and AAS is the average AS score. AA is the average off-diagonal scores times 100 divided by the average diagonal score. OS (the "open search" score) is the highest off-diagonal score times 100 divided by the lowest diagonal score.

As more data becomes available and numerous tuning runs are made, the lowest summary scores will indicate the best performance of the system. In the meantime, the low summary scores in Figure 16 indicate very promising possibilities for the future of automated fingerprint identification.

The computer programs used in this work were written and managed by J.F. Rafferty of the National Bureau of Standards. The author is indebted to Special Agent Conrad Banner of the Federal Bureau of Investigation for his encouragement and assistance. The work was financially supported by the FBI.

6. References

1. Voelker, C.S., "Future Requirements for Automated Fingerprint Identification," Law Enforcement Science and Technology I, Thompson Book Company, Washington, D.C., 1967.

2. Kingston, C.R., "Problems in Semi-automated Fingerprint Classification," Law Enforcement Science and Technology I, Thompson Book Company, Washington, D.C., 1967.

3. Wegstein, J.H., Automated Fingerprint Identification, National Bureau of Standards Technical Note 538, U.S. Government Printing Office, Washington, D.C., 1970.

4. Stock, R.M., "Automatic Fingerprint Reading," Proceedings, 1972 Carnahan Conference on Electronic Crime Countermeasures, University of Kentucky, Lexington, Kentucky, 1972.

5. Thornburg, D.D., and Madrazo, F.G., "Semi-automated Latent Fingerprint Processing System," Proceedings, 1972 Carnahan Conference on Electronic Crime Countermeasures, University of Kentucky, Lexington, Kentucky, 1972.

6. The Federal Bureau of Investigation, The Science of Fingerprints, U.S. Government Printing Office, Washington, D.C., 1963.

7. Cherrill, F.R., The Fingerprint System at Scotland Yard, Her Majesty's Stationery Office, London, 1954.

8. Cummins, H. and Midlo, C., Finger Prints, Palms and Soles, Dover Publications, Inc., New York, 1961.

9. Jorgensen, Hakon, Distant Identification and One-finger Registration, Publications of International Police Conference, Police Department, New York, 1923.

10. Collins, C.S., A Telegraphic Code for Fingerprint Formulae, Scotland Yard, London, 1921.

11. Battley, H., Single Fingerprints, H.M. Stationery Office, London, 1930.

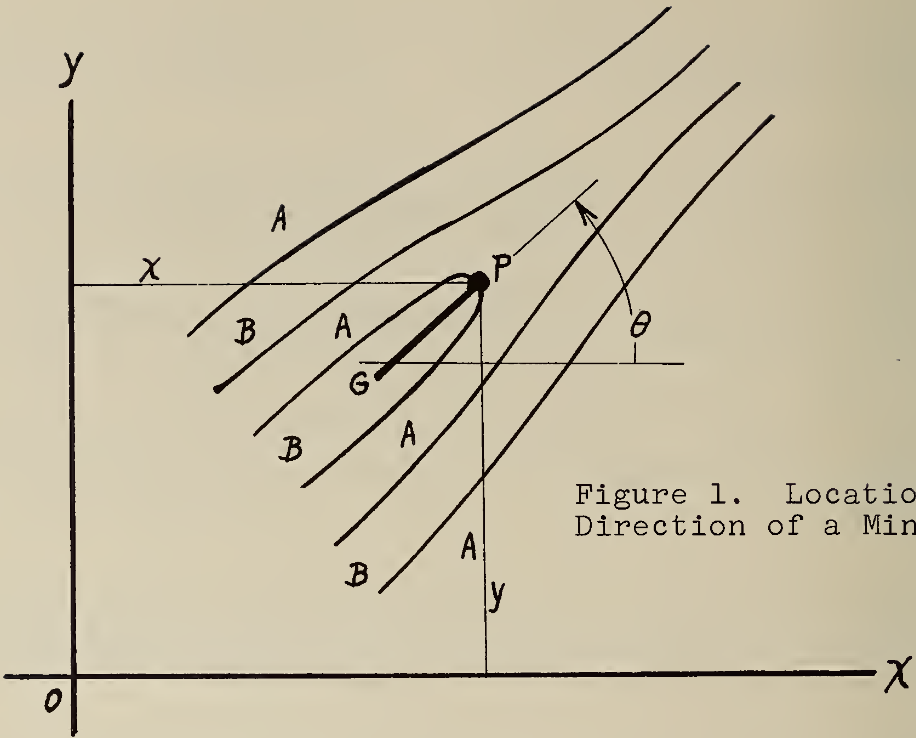
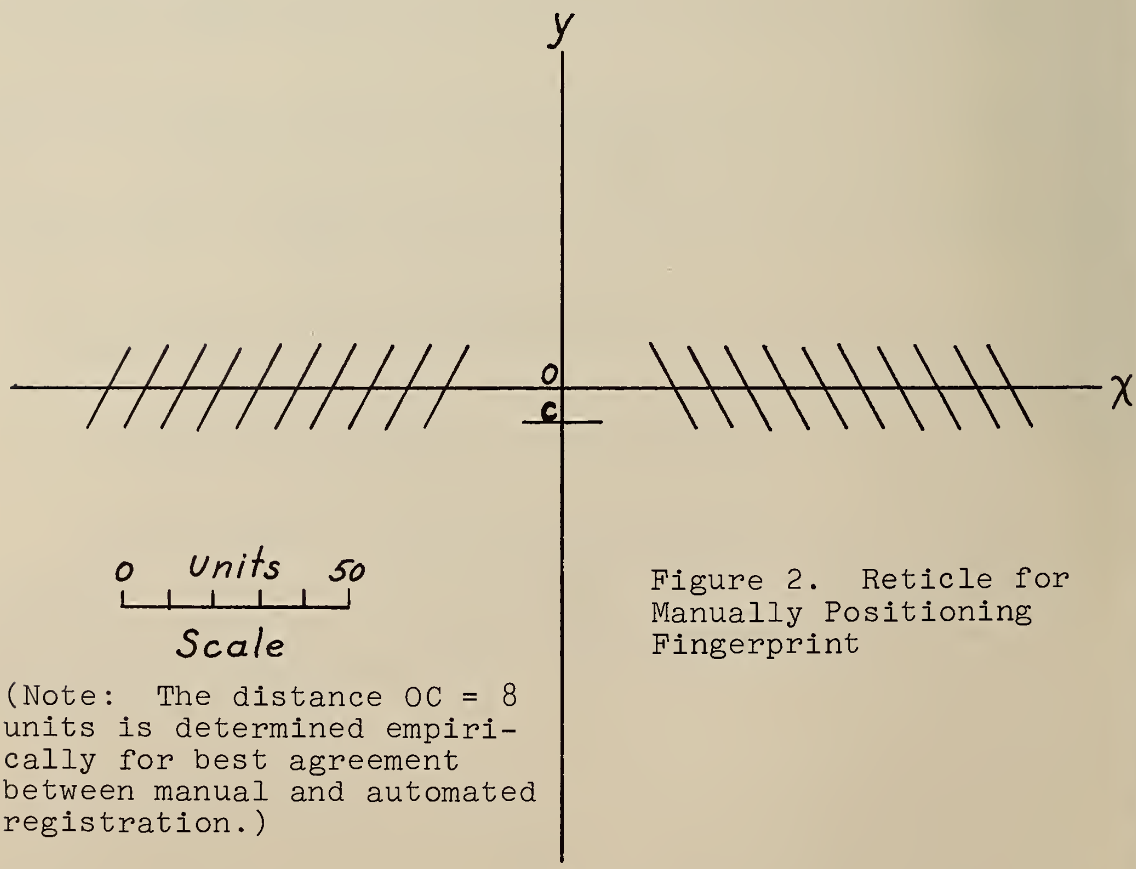


Figure 1. Location and Direction of a Minutia



(Note: The distance OC = 8 units is determined empirically for best agreement between manual and automated registration.)

Figure 2. Reticle for Manually Positioning Fingerprint

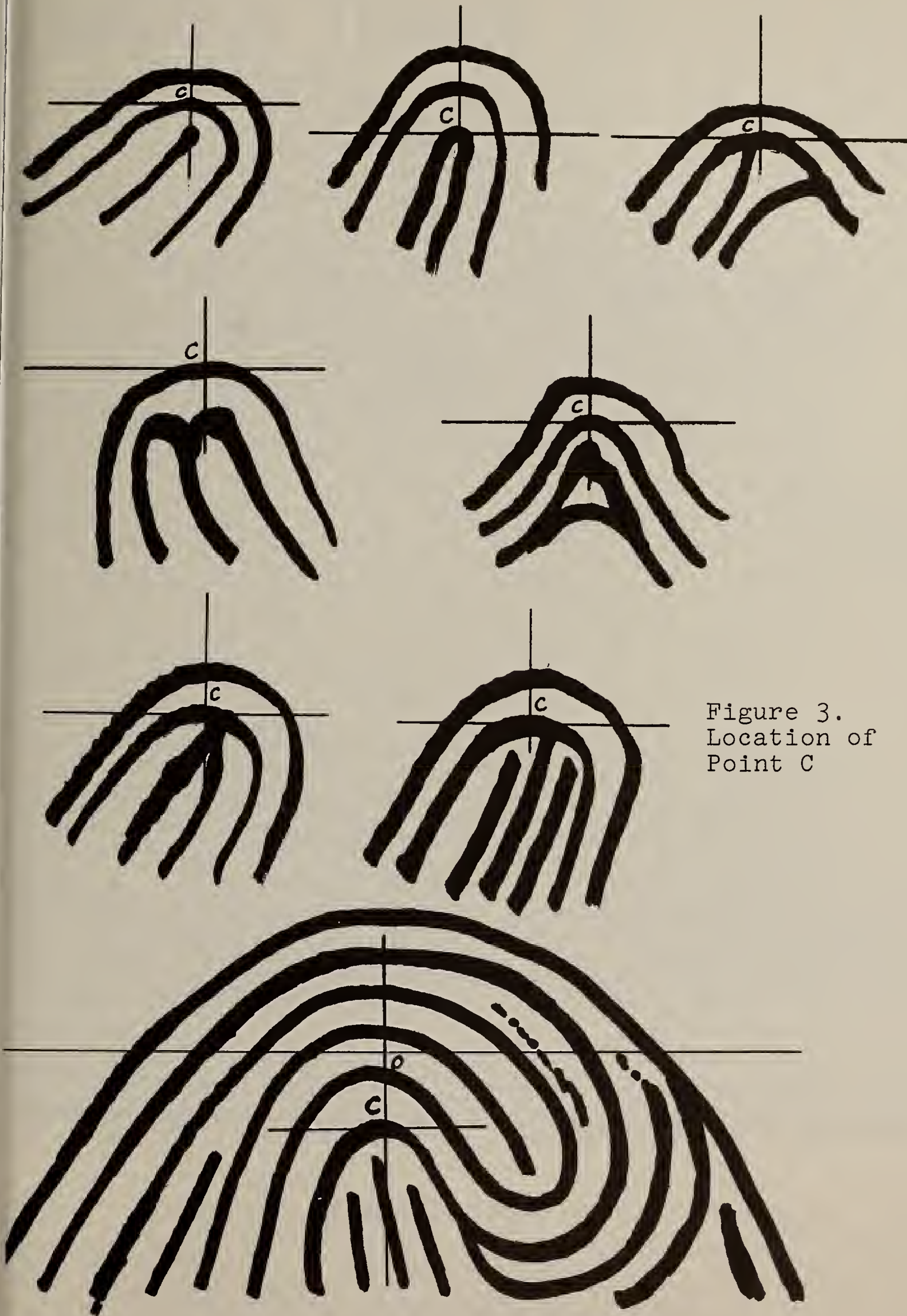


Figure 3.
Location of
Point C

Figure 4. Manual Registration of Fingerprint

X	Y	θ
179	243	327
90	223	48
246	197	121
77	181	61
127	178	20
138	82	207
---	---	---

Figure 5. A Portion of Minutiae Data Read from Fingerprint

Figure 6. Latent Fingerprint from the Scene of a Crime

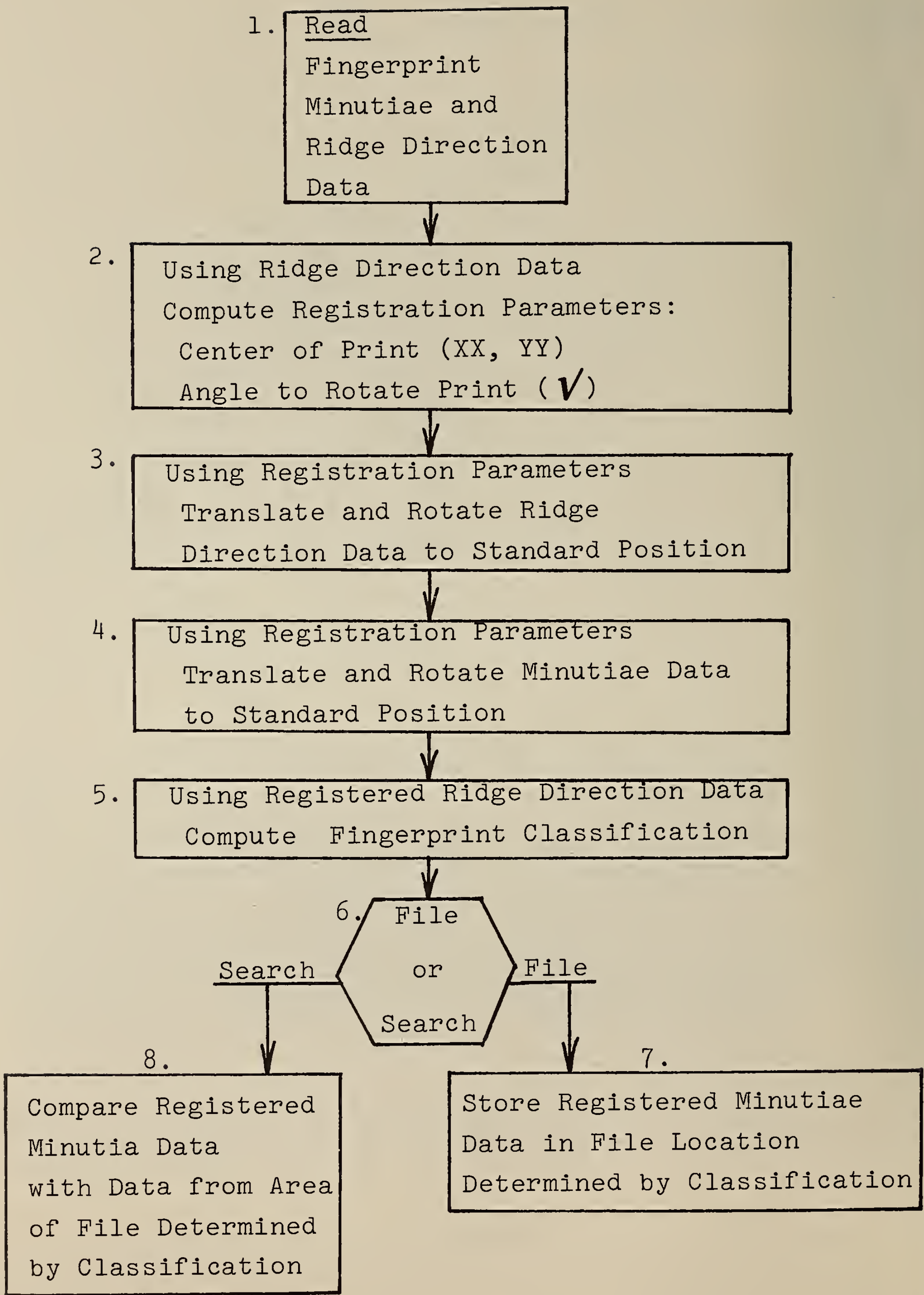


Figure 7. Fully Automated Fingerprint Identification System

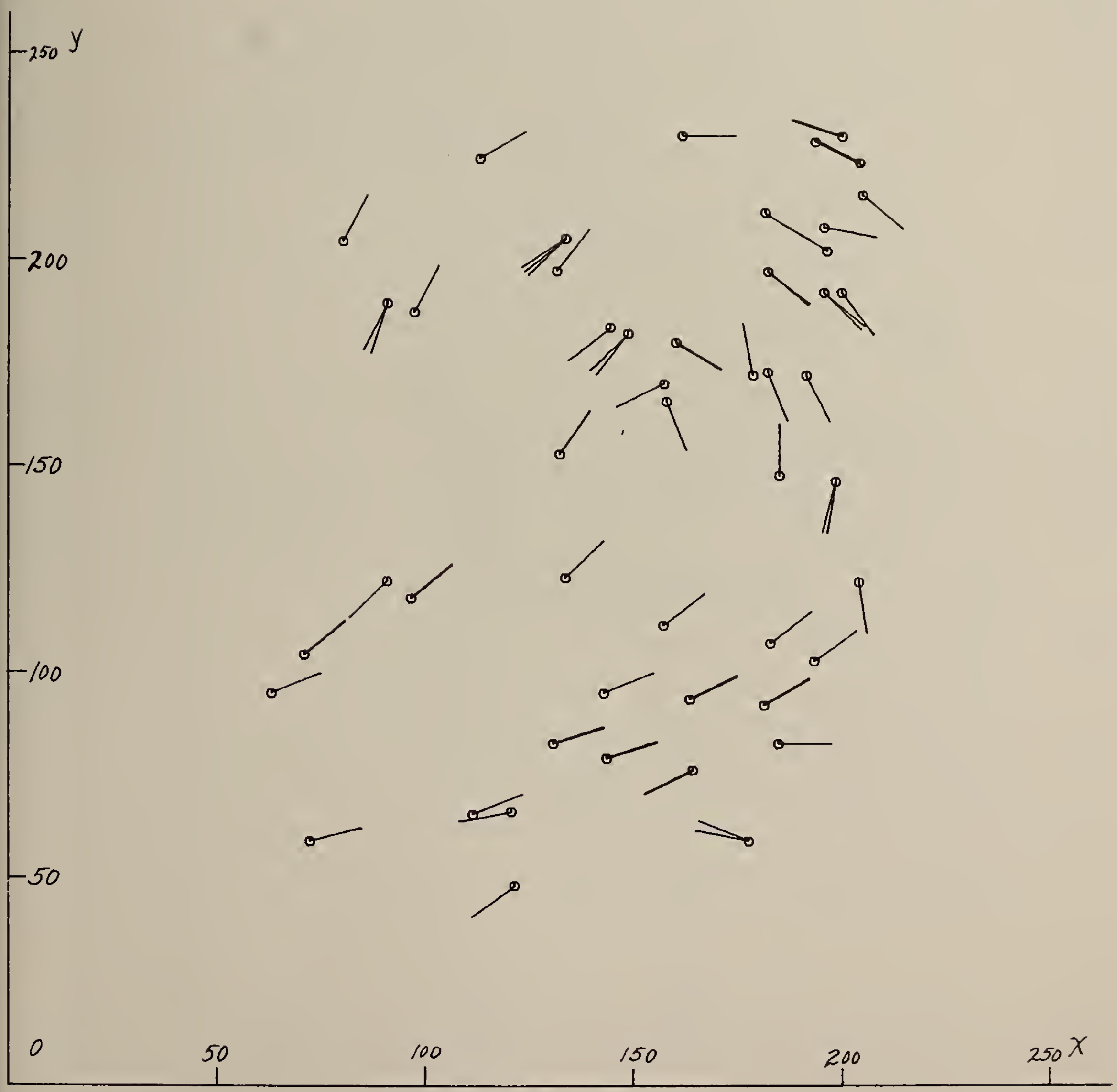


Figure 8. Plot of Minutiae Read by FINDER

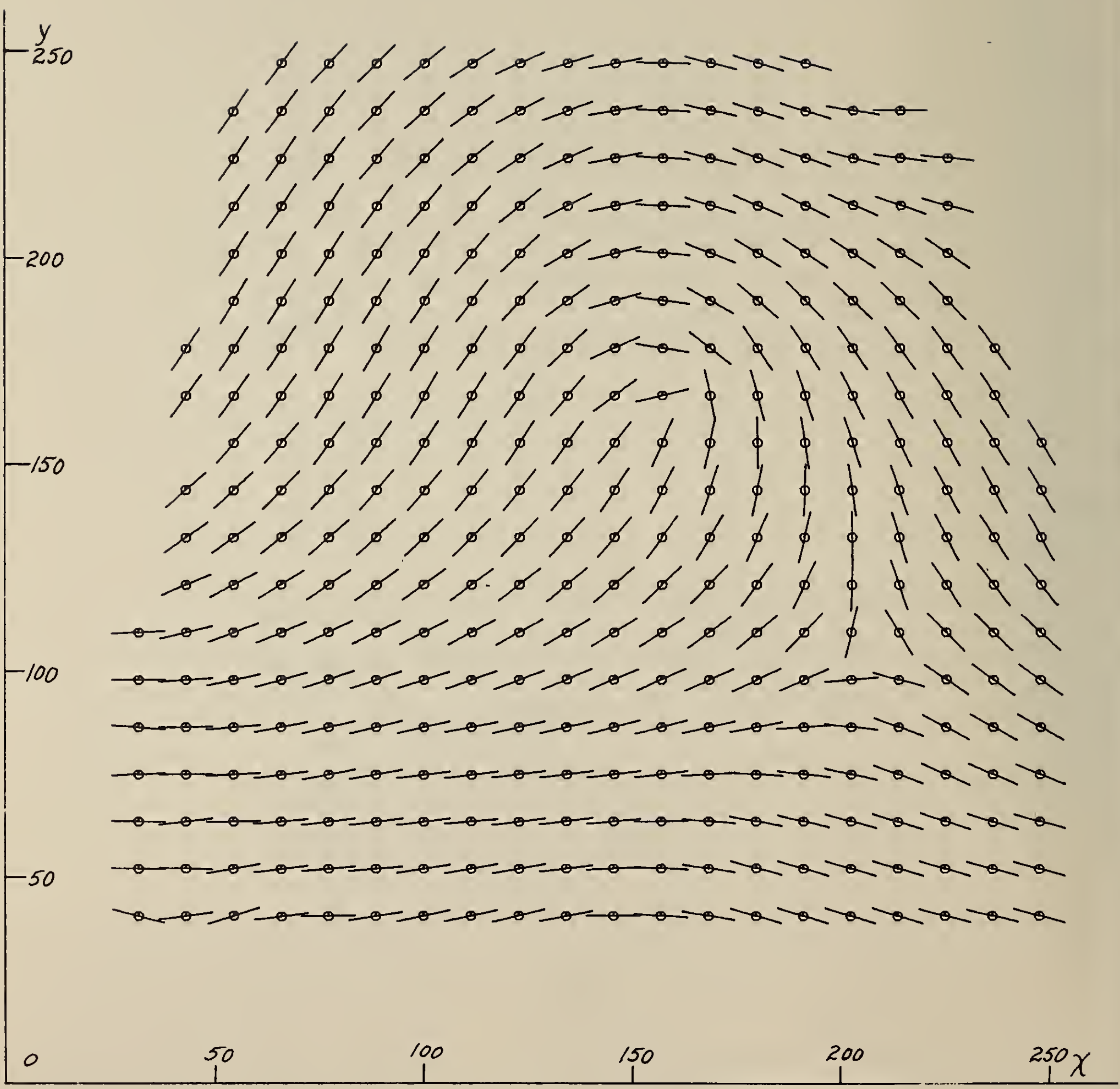


Figure 9. Plot of Ridge Directions Read by FINDER

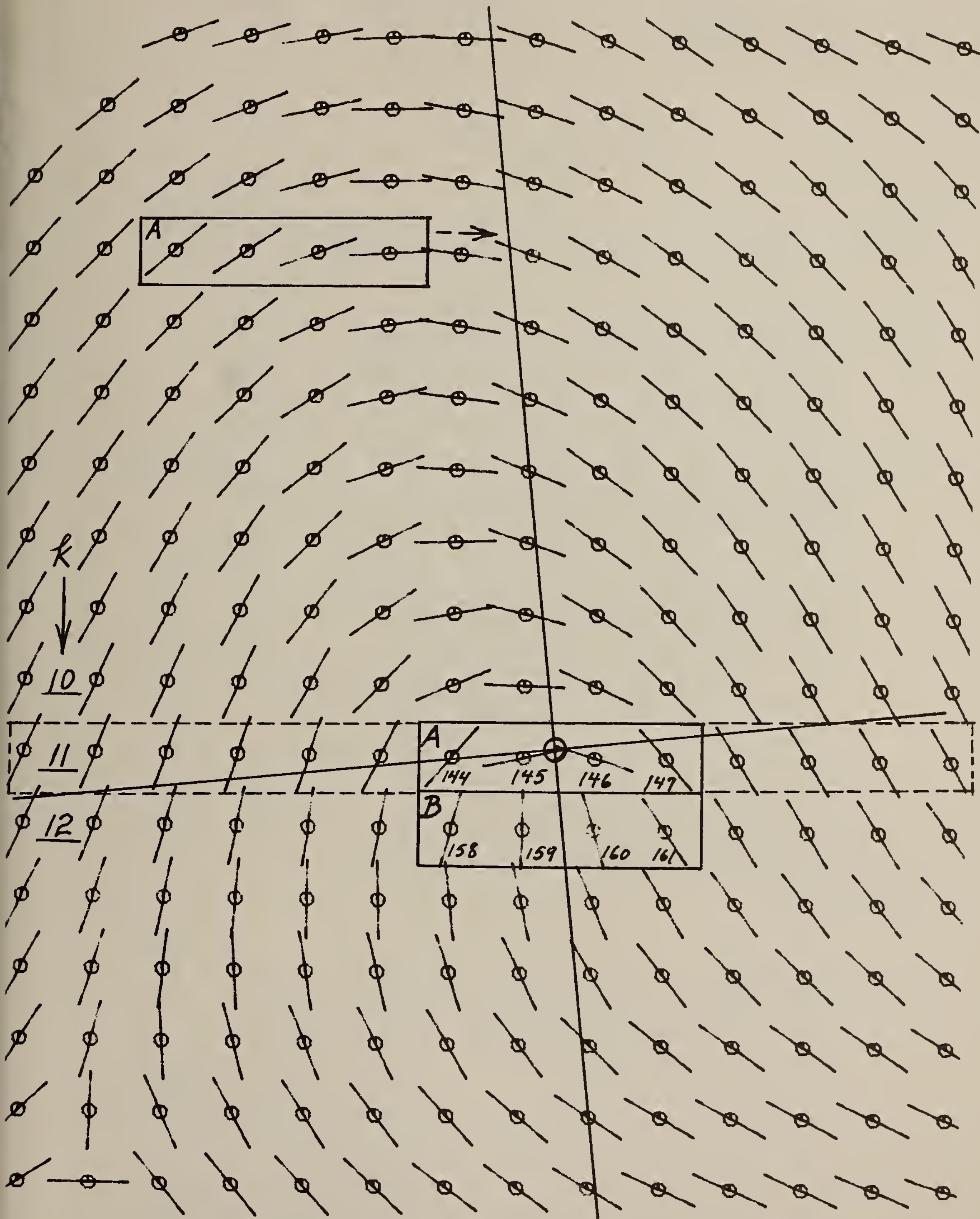


Figure 10. Automated Fingerprint Registration

i	x	y	ψ	
138	57.00	136.94	66	Left Side Row k=11
139	68.84	136.94	69	
140	80.68	136.94	71	
141	92.52	136.94	72	
142	104.37	136.94	72	
143	116.21	136.94	64	
144	128.05	136.94	50	Box A
145	139.90	136.94	13	
146	151.74	136.94	-18	
147	163.58	136.94	-49	
148	175.43	136.94	-58	Right Side Row k=11
149	187.27	136.94	-59	
150	199.11	136.94	-59	
151	210.96	136.94	-60	
---	---	---	---	
158	128.05	125.09	75	Box B
159	139.90	125.09	89	
160	151.74	125.09	-73	
161	163.58	125.09	-56	

Figure 11. X Y ψ Ridge Direction Data Corresponding to Figure 10

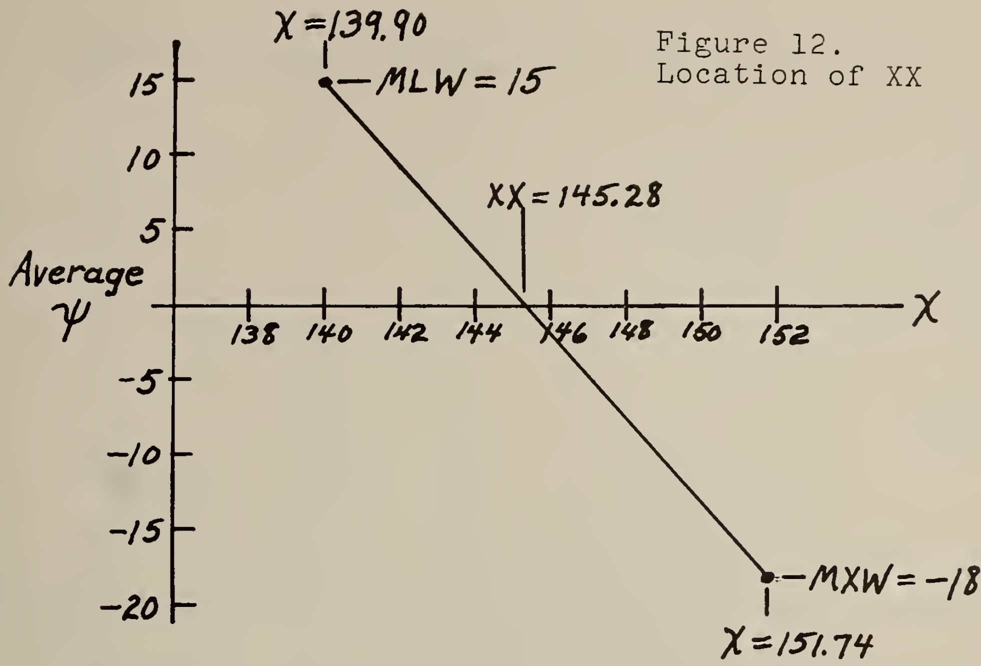


Figure 12.
Location of XX

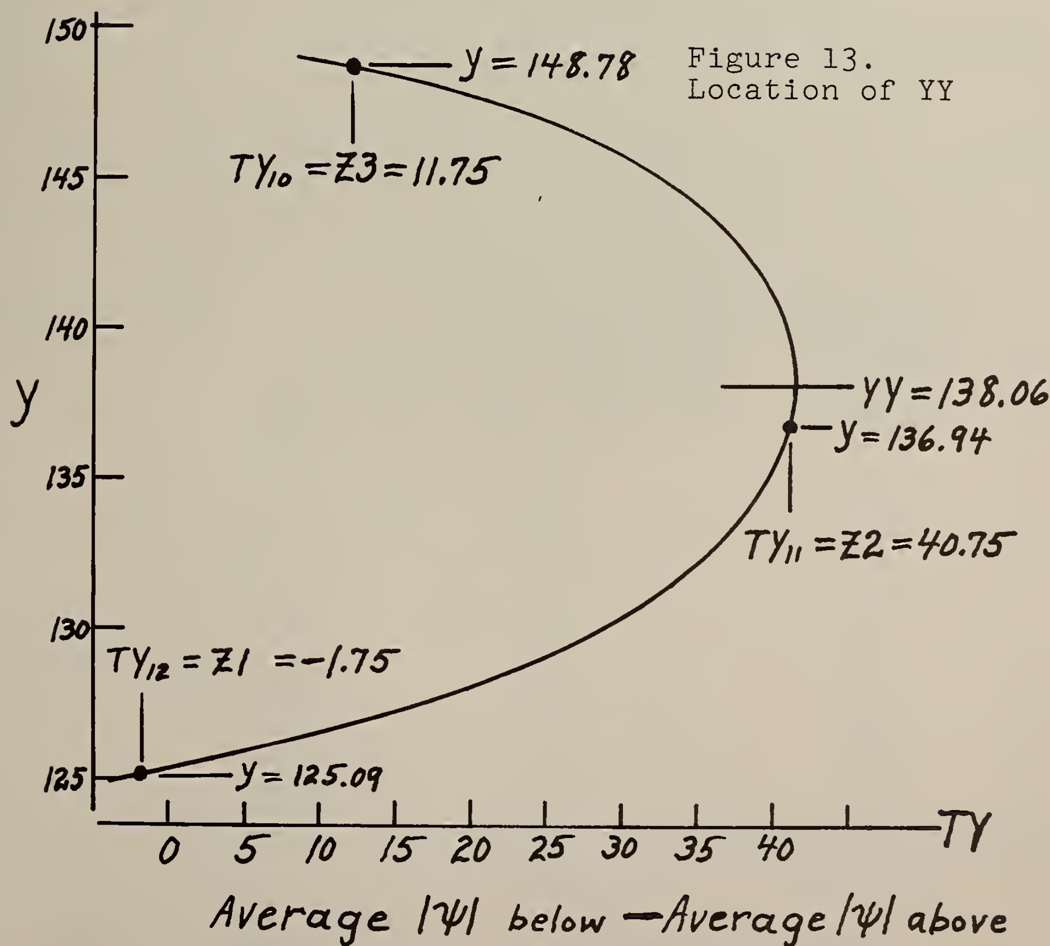
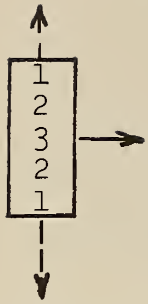


Figure 13.
Location of YY



scoring weights

j	$\lvert\psi\rvert$	LX_j	RX_j	LL_j	RR_j	
1	55					
2	56				1	
3	57				4	
4	58		1		8	
5	59		2		10	← JR=59
6	60		1		8	
7	61				4	
8	62			1	1	
9	63			2		
10	64	1		4		
11	65			4		
12	66	1		4		
13	67			3		
14	68			3		
15	69	1		4		
16	70			6		
17	71	1		8		← JL=71
18	72	2		7		
19	73			5		
20	74			2		
21	75					

$$\gamma = \frac{JR - JL}{2} = -6°$$

$$K1 = \frac{JR + JL}{2} = 65°$$

Figure 14. Calculation of γ

Print Pair	Distance Between Computed Centers	Angular Difference Between Computed Coordinate Positions	Print Pattern
1	2.2	0.5	Loop
2	3.9	0.8	Plain Arch
3	4.4	1.0	Tented Arch
4	9.2	0.5	Central Pocket Loop
5	1.7	4.0	Plain Whorl
6	3.5	6.6	Loop
7	6.2	1.1	Central Pocket Loop
8	1.6	2.5	Loop (High Delta)
9	9.2	1.5	Loop (Low Delta)
10	11.1	0.5	Plain Arch
11	0.8	2.2	Loop
12	7.8	1.3	Loop
13	10.0	4.0	Double Loop
Average	5.5 NBS Units	2.0 Degrees	

Figure 15. Registration Performance

M19 Parameters

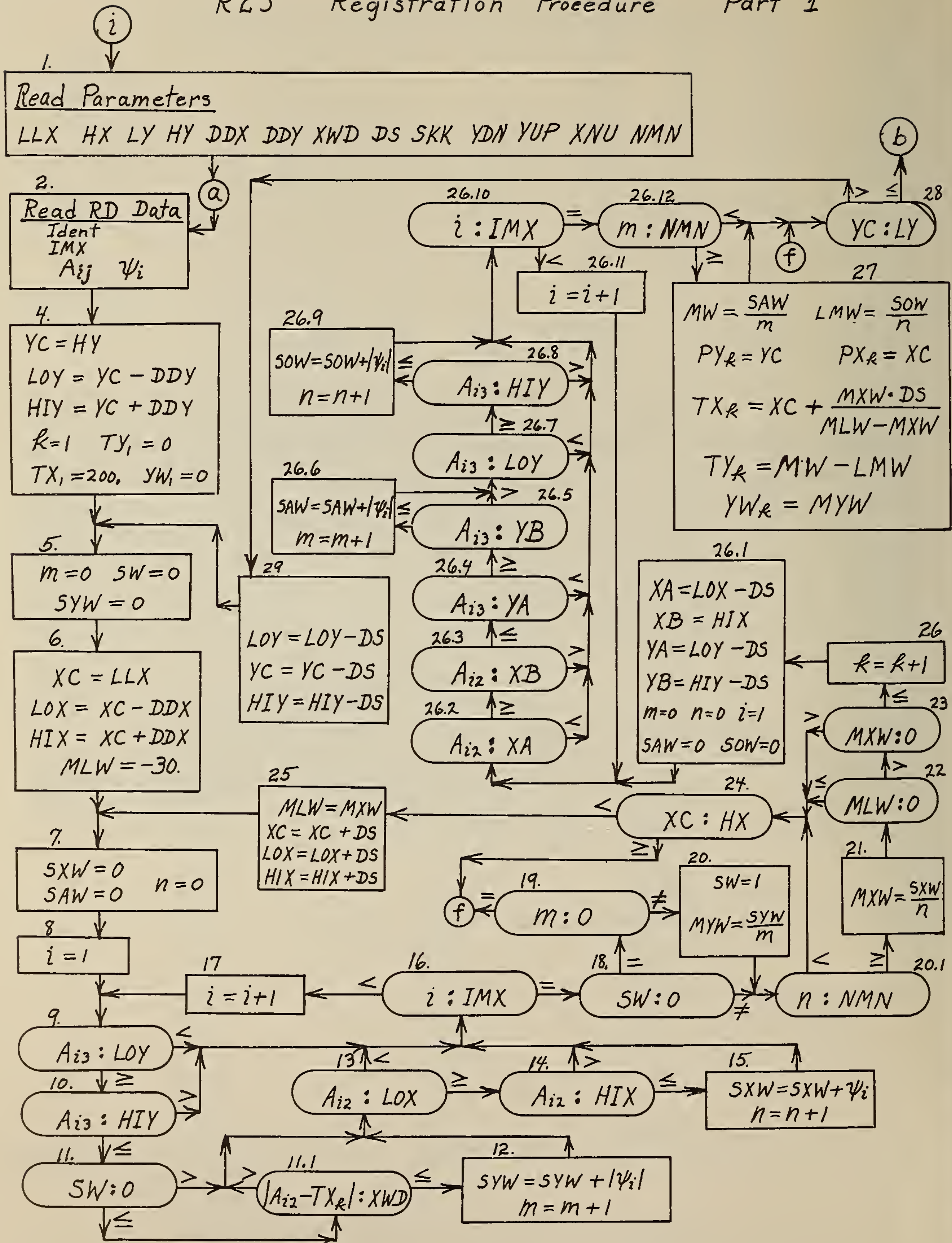
LTHETA	LS	SM	KR
10.	10.	0	10.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	AS	CS
1.	127	23	21	3	1	28	3	16	2	14	22	14	10	10	22
2.	17	150	12	3	9	8	10	23	7	33	21	12	7	9	22
3.	15	19	126	11	0	18	15	16	9	26	16	8	0	10	21
4.	12	0	13	59	23	24	17	15	9	1	7	38	20	25	65
5.	3	3	0	11	112	12	9	2	9	5	16	18	11	7	16
6.	32	7	23	20	7	78	17	20	13	6	29	10	12	21	41
7.	5	13	24	16	23	22	139	6	10	2	7	34	2	10	24
8.	14	8	19	4	12	19	0	85	2	13	10	15	5	12	23
9.	3	5	3	5	3	11	13	2	87	2	10	3	0	6	16
10.	16	23	13	4	4	8	3	6	16	121	21	6	12	9	19
11.	33	35	22	9	13	30	12	12	21	15	205	18	18	10	17
12.	16	20	9	9	13	18	21	19	9	10	24	151	4	9	16
13.	17	9	8	11	10	9	2	5	0	9	9	17	65	14	26

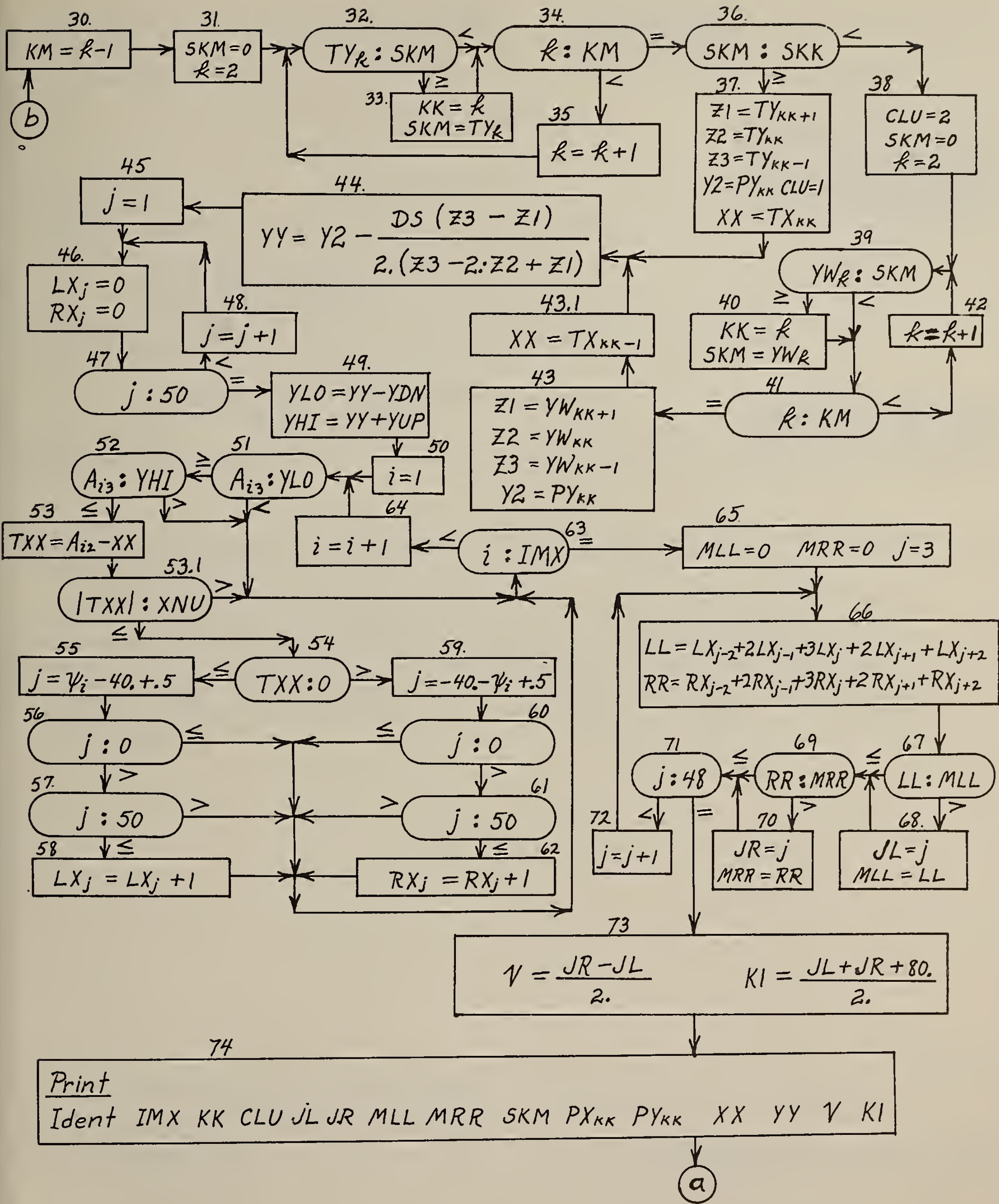
Summary	WCS	OS	AA	ACS	AAS
Scores	65	65	11	25	12

Figure 16. Score Matrix

R25 Registration Procedure Part 1



Part 2


30. KM = k−1
31. SKM=0 k=2
32. TYk : SKM
33. KK = k SKM=TYk
34. k : KM
35 k = k+1
36. SKM : SKK
37. Z1 = TYKK+1 Z2 = TYKK Z3 = TYKK−1 Y2 = PYKK CLU=1 XX = TXKK
38 CLU=2 SKM=0 k=2
39 YWk : SKM
40 KK = k SKM = YWk
41 k : KM
42 k=k+1
43 Z1 = YWKK+1 Z2 = YWKK Z3 = YWKK−1 Y2 = PYKK
43.1 XX = TXKK−1
44. YY = Y2 − DS (Z3 − Z1) / 2.(Z3 − 2.Z2 + Z1)
45 j = 1
46. LXj = 0 RXj = 0
47 j : 50
48. j = j+1
49. YLO = YY−YDN YHI = YY+YUP
50 i = 1
51 Ai3 : YLO
52 Ai3 : YHI
53 TXX = Ai2 − XX
53.1 |TXX| : XNU
54 TXX : 0
55 j = ψi − 40.+.5
56 j : 0
57 j : 50
58 LXj = LXj + 1
59. j = −40.−ψi +.5
60 j : 0
61 j : 50
62 RXj = RXj + 1
63 i : IMX
64 i = i+1
65 MLL=0 MRR=0 j=3
66 LL = LXj−2+2LXj−1+3LXj+2LXj+1+LXj+2
RR = RXj−2+2RXj−1+3RXj+2RXj+1+RXj+2
67 LL : MLL
68. JL=j MLL = LL
69 RR : MRR
70 JR=j MRR=RR
71 j : 48
72 j=j+1
73 ψ = (JR − JL)/2. KI = (JL + JR + 80.)/2.
74 Print
Ident IMX KK CLU JL JR MLL MRR SKM PXKK PYKK XX YY ψ KI
a
b

FORM NBS-114A (1-71)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS TN-730	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

Manual and Automated Fingerprint Registration

5. Publication Date: June 1972

6. Performing Organization Code

7. AUTHOR(S)

J.H. Wegstein

8. Performing Organization

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No. 6004400

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

Federal Bureau of Investigation
Washington, D.C. 20537

13. Type of Report & Period Covered: Final

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

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 method is described for manually positioning a fingerprint so that manually read minutiae data can be searched by computer against a file of fingerprint data that has been previously read by machine. A procedure is also described whereby a computer can utilize machine-read ridge-direction data in manipulating minutiae data to effect a registration of the fingerprint prior to filing its minutiae data.

17. KEY WORDS (Alphabetical order, separated by semicolons)

Computerized-fingerprint-identification; fingerprint; pattern-recognition.

18. AVAILABILITY STATEMENT

[X] UNLIMITED.

[ ] FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NTIS.

19. SECURITY CLASS (THIS REPORT): UNCLASSIFIED

20. SECURITY CLASS (THIS PAGE): UNCLASSIFIED

21. NO. OF PAGES: 26

22. Price: $.35

USCOMM-DC 66244-P71

NBS TECHNICAL PUBLICATIONS

PERIODICALS

JOURNAL OF RESEARCH reports National Bureau of Standards research and development in physics, mathematics, and chemistry. Comprehensive scientific papers give complete details of the work, including laboratory data, experimental procedures, and theoretical and mathematical analyses. Illustrated with photographs, drawings, and charts. Includes listings of other NBS papers as issued.

Published in two sections, available separately:

- **Physics and Chemistry**

Papers of interest primarily to scientists working in these fields. This section covers a broad range of physical and chemical research, with major emphasis on standards of physical measurement, fundamental constants, and properties of matter. Issued six times a year. Annual subscription: Domestic, $9.50; $2.25 additional for foreign mailing.

- **Mathematical Sciences**

Studies and compilations designed mainly for the mathematician and theoretical physicist. Topics in mathematical statistics, theory of experiment design, numerical analysis, theoretical physics and chemistry, logical design and programming of computers and computer systems. Short numerical tables. Issued quarterly. Annual subscription: Domestic, $5.00; $1.25 additional for foreign mailing.

TECHNICAL NEWS BULLETIN

The best single source of information concerning the Bureau's measurement, research, developmental, cooperative, and publication activities, this monthly publication is designed for the industry-oriented individual whose daily work involves intimate contact with science and technology—*for engineers, chemists, physicists, research managers, product-development managers, and company executives.* Includes listing of all NBS papers as issued. Annual subscription: Domestic, $3.00; $1.00 additional for foreign mailing.

Bibliographic Subscription Services

The following current-awareness and literature-survey bibliographies are issued periodically by the Bureau: Cryogenic Data Center Current Awareness Service (weekly), Liquefied Natural Gas (quarterly), Superconducting Devices and Materials (quarterly), and Electromagnetic Metrology Current Awareness Service (monthly). Available only from NBS Boulder Laboratories. Ordering and cost information may be obtained from the Program Information Office, National Bureau of Standards, Boulder, Colorado 80302.

NONPERIODICALS

Applied Mathematics Series. Mathematical tables, manuals, and studies.

Building Science Series. Research results, test methods, and performance criteria of building materials, components, systems, and structures.

Handbooks. Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

Special Publications. Proceedings of NBS conferences, bibliographies, annual reports, wall charts, pamphlets, etc.

Monographs. Major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities.

National Standard Reference Data Series. NSRDS provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated.

Product Standards. Provide requirements for sizes, types, quality, and methods for testing various industrial products. These standards are developed cooperatively with interested Government and industry groups and provide the basis for common understanding of product characteristics for both buyers and sellers. Their use is voluntary.

Technical Notes. This series consists of communications and reports (covering both other-agency and NBS-sponsored work) of limited or transitory interest.

Federal Information Processing Standards Publications. This series is the official publication within the Federal Government for information on standards adopted and promulgated under the Public Law 89–306, and Bureau of the Budget Circular A–86 entitled, Standardization of Data Elements and Codes in Data Systems.

Consumer Information Series. Practical information, based on NBS research and experience, covering areas of interest to the consumer. Easily understandable language and illustrations provide useful background knowledge for shopping in today's technological marketplace.

CATALOGS OF NBS PUBLICATIONS

NBS Special Publication 305, Publications of the NBS. 1966-1967. When ordering, include Catalog No. C13.10:305. Price $2.00; 50 cents additional for foreign mailing.

NBS Special Publication 305, Supplement 1, Publications of the NBS, 1968-1969. When ordering, include Catalog No. C13.10:305/Suppl. 1. Price $4.50; $1.25 additional for foreign mailing.

NBS Special Publication 305, Supplement 2, Publications of the NBS, 1970. When ordering, include Catalog No. C13.10:305/Suppl. 2. Price $3.25; 85 cents additional for foreign mailing.

Order NBS publications (except Bibliographic Subscription Services) from: Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

, DEPARTMENT OF COMMERCE
ional Bureau of Standards
ington, D.C. 20234

IAL BUSINESS

ty for Private Use, $300

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
215

U.S.MAIL