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A Semi-automated Single Fingerprint Identification System

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A Semi-automated Single Fingerprint Identification System

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by J.H. Wegstein

A system is described in which a fingerprint is manually coded by tracing certain ridges and noting events such as ridge endings and ridge beginnings. This code is sent by teleprinter to a central file where a computer identifies the fingerprint by comparing the code with codes previously entered in the file. The scheme for comparing codes is given along with some preliminary test results using typical fingerprints.

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

1. Introduction

The Ninth Session of the International Police Conference held in New York in 1923 adopted a system for identifying individuals using information from single fingerprints. This system, called Distant Identification, was developed by Hakon Jorgensen[1] and utilized about fifty numerals of coded fingerprint information which could be transmitted by telephone, telegraph, or radio.

About the same time Scotland Yard began testing a similar system by C.S. Collins[2]. In both of these systems the coded information from fingerprints was obtained with a magnifying glass using a special reticle containing two parallel lines. In the Collins system the parallel lines were 6 mm apart and in the Jorgensen system the lines were 4 mm apart. In addition to information about the core of the fingerprint, the codes also included topological information from the ridges observed between the parallel lines of the reticle resting at a prescribed position on the fingerprint.

At Scotland Yard the Collins system was tested on a collection including some 40,000 single prints representing about 4,000 persons. It was found that the codes did not discriminate adequately between like and unlike prints, and it was necessary in many cases to examine not less than 75 per cent of the impressions filed under the particular type of pattern for which the search was being made. During a period of seven years only a very few identifications were made[3].

Another single fingerprint identification system was developed by Battley[4] at Scotland Yard which was intended to augment the Henry system for dealing with latent fingerprints found at the scene of a crime. The Battley system deals with coded core information along with delta positions, ridge counts, ridge traces and other peculiarities of the print. A special reticle with concentric circles is used for defining areas for scrutiny in the fingerprint.

The success of any of these single fingerprint identification systems has been limited, and several reasons for this might be identified as follows: (a) Searching files of codes manually is difficult and slow. (b) The skill required to code the fingerprints may have limited the number of users. (c) The technique may have had an insufficient ability to discriminate between like and unlike prints. (d) The system lacks an adequate scheme for ordering or classifying the codes.

Most of the fingerprint systems developed to date utilize topological techniques such as core pattern descriptions, ridge counts and ridge tracing. They also utilize geometrical techniques such as measurements on the print and determining where to count ridges. Geometrical techniques suffer from the stretching and flexing of fingerprints, and topological techniques such as core pattern descriptions suffer from the variation in the inking of fingerprint impressions as well as the amount of training required by the user. Hankley and Tou[5] have investigated purely topological coding and concluded that it should be feasible to automatically trace ridges and topologically code fingerprints.

The system described in this paper attempts to strike a good balance between the geometrical and topological techniques used. It limits its objectives by not attempting to deal with latent prints, and most important of all, it utilizes a computer for searching a fingerprint file and matching fingerprint codes. The use of the computer has permitted the code for the fingerprint to be easily written by an individual with limited fingerprint experience.

2. Objectives of the System

In this system it is assumed that a central computer will maintain a file consisting of the codes for two fingerprints from each of several thousand fugitives or persons wanted by police. At some remote location the two appropriate fingerprints can be taken from a suspected person. The codes for these fingerprints can be determined in about ten minutes using a special reticle with a regular fingerprint magnifying glass. (An opaque projector with an enlarged reticle is of course easier to use.) These codes are then sent to the central computer via a directly connected remote teleprinter or by radio or telephone to an operator at such a typewriter. The computer compares these codes with those in the file and computes a score indicating how well these codes match each of those in the appropriate section of the file. If the score is above a certain threshold value, the computer reports the probable identity of the suspect back to the inquirer.

An enlargement of the reticle used by this system is shown in Figure 0. The horizontal lines are 13 mm apart and the radial lines are 18° apart.

3. Instructions for Coding a Fingerprint

Orienting Reticle

Set the horizontal lines of the reticle parallel with the crease in the finger.

Locating Origin

The upper horizontal line of the reticle is placed on the lowest full ridge that is smoothly convex upward, that is, just above the highest core. See examples in Figure 1.

On a plain arch where no core pattern such as those shown in Figure 1 occurs, set the intersection of the vertical line and the lower horizontal line at the middle of the crease in the finger. Next, move the reticle up or down slightly so that the upper horizontal line falls on the nearest ridge.

The intersection of the vertical line and upper horizontal line should be at the highest point of the ridge.

Coding the Print

Starting with the first ridge above the (upper) horizontal line and moving upward, the successive ridges that cross the vertical line are numbered 1, 2, 3, etc. through 14.

Each ridge is traced from left to right starting at the horizontal line on the left and ending at the horizontal line on the right. As one follows the ridges from left to right, events are coded as follows:

— ridge runs all the way from the horizontal line on the left to the horizontal line on the right. See Figure 2 for such ridge patterns and their codes. Ridges that cross the vertical line are called reference ridges and are given integral line numbers.

e ridge ends before it reaches the horizontal line on the right. The position at which the ridge ends is indicated by the sector number. Thus ridge number 3 ends in sector 7 in Figure 3. If a ridge does not cross the vertical line it is given a decimal line number. See ridge 3.1 in Figure 4. A ridge that rejoins a lower ridge is also called a ridge ending. See ridge 3 in Figure 5.

s a ridge starts. See ridge 5 in Figure 5. The point where a ridge departs from a lower ridge is also called a starting ridge. Thus, ridge 7.1 starts in sector 8 in Figure 5.

i an island or short ridge whose length does not exceed a sector length. See code line 8.1 in Figure 5.

An enclosure, spur, closure between ridges, or notable lump on a ridge is also coded as i if such event does not exceed a sector length. Several examples are given in Figure 6. If one of these events falls on a sector line, such as code line 4.1 or 10.1 in Figure 6, it is given the sector number corresponding to where it starts. The line number of an event occurring between ridges is obtained by referring to the next lower ridge. Note that spurs hanging below a ridge are referred to the next lower ridge by line number. See line 7.1 in Figure 6. Enclosures and spurs projecting upward are referred to the ridge to which they are attached.

A break in a ridge that is shorter than a sector length is not coded. See ridge 5 in Figure 6. Islands separated by less than a sector length are treated as continuous ridge. Incipient ridges are ignored. When a section of ridge does not cross the horizontal line, its start and end are both given in a code line separated by a comma. For examples, see lines 7.1 and 7.2 in Figure 7.

Figures 7 through 10 demonstrate the order in which events are coded. Events are coded from a reference ridge outward as they are noted in reading from left to right. Thus in Figure 8, following ridge 5, ridge 5.1 ending in e3 is followed by ridge 5.2 starting in s7, and this is followed by 5.3 ending in e1. Ridge 5.3 may be thought of as having higher rank than 5.1 and 5.2 because it is further from the reference ridge 5.

Note that the line numbers correspond to the ridge count along the vertical line. Nothing is coded ahead of ridge 1. Coding stops when line numbers reach 14, when an indistinct area is encountered, or when full ridges fail to reach from the horizontal line on the left to the horizontal line on the right.

4. Computer Procedure for Reading and Filing Codes

When a code is to be entered into the computer the operator first indicates whether the codes is to be filed (F) or the code is to be searched against the existing file (S). An identification such as a name or police identification number is next typed in followed by the code. The line numbers are omitted to save time. As an example, the

```
__
__
e7
__
s3
__
__
s8
__
i2
__
```

code from Figure 5 would be typed as shown at the left. The computer treats this code as columns A and B in a table. Dashes are entered as 00. The line number is re-determined by the computer without the decimal and stored in column C. The code would now appear as the table shown in Figure 11. This table is next sorted on column B without otherwise changing the order of the table so that the table appears as shown in columns A B C of Figure 12. This table along with the identification is compressed in whatever manner suits the computer and is entered in the file or else it is held in readiness for comparing with other tables from the file.

5. Procedure for Comparing Codes

Assume that a match for Figure 5 is being sought from a file which already contains the table of data corresponding to Figure 10. When the computer is ready to compare Figure 5 with Figure 10, it holds the table corresponding to Figure 5 as columns A B C of Figure 13 and it brings the table corresponding to Figure 10 from the file as columns E F G of Figure 13. (When two tables corresponding to two fingerprints are being compared, the shortest table is always placed in columns A B C.)

The numbers in columns D and H are initially set equal to zero. (The details of the computer program for what follows are given in the Flow Diagram in the Appendix.)

Starting at M=1, step down the rows of table A B C D one at a time. For each row in table A B C D, sweep down the table E F G H looking for the following situation: A is identical with E; B and F differ by one or less; C and G differ by one or less, and H is not one. If this situation <u>is found</u>, set H equal to one and set D equal to one. If this situation <u>is not found</u>, do the first of the following which is appropriate: If A is 0, set D equal to -1; If A is "i" or if B is equal to 0 or 9, leave D equal to zero; otherwise, set D equal to -1.

When the steps in the previous paragraph have been applied to each row of table A B C D the matching operation is finished. The score, S, indicating how well the prints match is obtained by adding the numbers in column D. In Figure 13, S=3. This score is re-computed with G increased by one and also decreased by one. (In the computer program given in the Flow Diagram, this means using Q=0, 1, and -1.) The final score is taken as the largest of these three scores. This allows for a difference of opinion by coders as to where ridge counts should start on the fingerprint. (The matchine procedure allows for an additional difference in opinion as to ridge count as well as sector number.) A final score equal to or greater than 14 indicates that the prints probably came from the same finger, but a value for this probability has not been determined.

Figures 14 and 15 show two different impressions taken from the same finger. The reticle is superimposed and the code for each impression is shown at the right of each figure. Note that the codes do not exactly agree. For example, the ridge ending, eo, in line 1.1 of Figure 15 does not occur in the code in Figure 14. Also, the ridge ending, e3, in line 7.1 of Figure 15 is interpreted as being in code line 8.1 in Figure 14. However, these differences do not lose points in the scoring. The tables generated for comparing these two impressions are shown in Figure 16. The score, S=26, indicates a very high probability that the impressions are indeed from the same finger.

6. Preliminary Results and Discussion

As a preliminary test of this system, fourteen different fingerprint impressions labeled W1 through W14 were coded directly from cards and stored in the computer file. The types include ulnar loops LH, ulnar loops RH, whorl, and double loops. Fourteen different impressions from the same fingers respectively (taken from five months to eight years later) were then coded by a different person and labeled P1 through P14. These codes were then compared with those in the file and the resulting scores are given in Figure 17. The scores for two prints from the same finger appear along the diagonal. If a threshold were set so that any score of 14 or greater would be considered a "make", all of the second set of fingerprint impressions would be correctly identified except P5 which would claim to be either W1 or its correct match, W5.

This preliminary data suggests that a single fingerprint might be used with a suitable threshold score to locate one or more "possibilities" for an identification.

When plain arches are coded it is difficult to determine where to start counting ridges because of variation in the inking of the crease in the finger which locates the lower horizontal line of the reticle. As above, nine different arches were coded and filed as W15 through W23. Different impressions of these same fingers were coded by another coder and searched against the file. The results, shown in Figure 18, indicate that single arches are not very satisfactory for use in this system. The very low score for P18 matched with W18 was found to be caused by a difference of inking of the crease in the finger.

The scores in Figure 17 and 18 suggest that using two fingerprints from an individual instead of one print will produce a higher discrimination. To analyse this, assume that successive pairs of these prints are from the same person. Thus assume that W1 and W2 are both from the same person. P1 and P2 would therefore be two different impressions from the same fingers of this person. The scores of P1 versus W1 equal to 19 and P2 versus W2 equal to 17 are multiplied together to produce a new score for this individual, SR=323. P1 versus W3 and P2 versus W4 produce a score of 4 representing a comparison of prints from two different people. The results of this scoring technique for the loops and whorls are shown in Figure 19 and the results using arches are shown in Figure 20. With a threshold score of SR=90, every individual would be correctly identified.

7. Conclusion

From these preliminary results, it appears desirable to use two fingerprints from each person, for example the two index fingers. Arches are less reliable than other pattern types. This degradation could be minimized by systematically skipping arches and using the prints from other fingers. If this practice were followed, arches would only be used from those individuals who have no other types of prints.

Considerably more fingerprints must be processed to answer the following questions: What threshold score should be used? What is the probability that an identification is correct? Can police technicians readily learn to consistently code fingerprints using this system? When an individual's prints are to be placed in the file, what is the probability that prints can be found in existing files that are suitable for coding? (When a suspect is in custody the unsuitable prints can be re-taken.) Can a computer or specially built device search a file fast enough? This raises a question as to whether subfiles are needed based on pattern types or whether an ordering or classification scheme can be devised based on the code themselves. Finally, will the system be useful?

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This system was tested with the MOBIDIC computer in the NBS Research Computer Facility. It has been particularly helpful to demonstrate the system using a portable teletype terminal with an acoustic data coupler and a regular telephone line directly to the computer.

8. References

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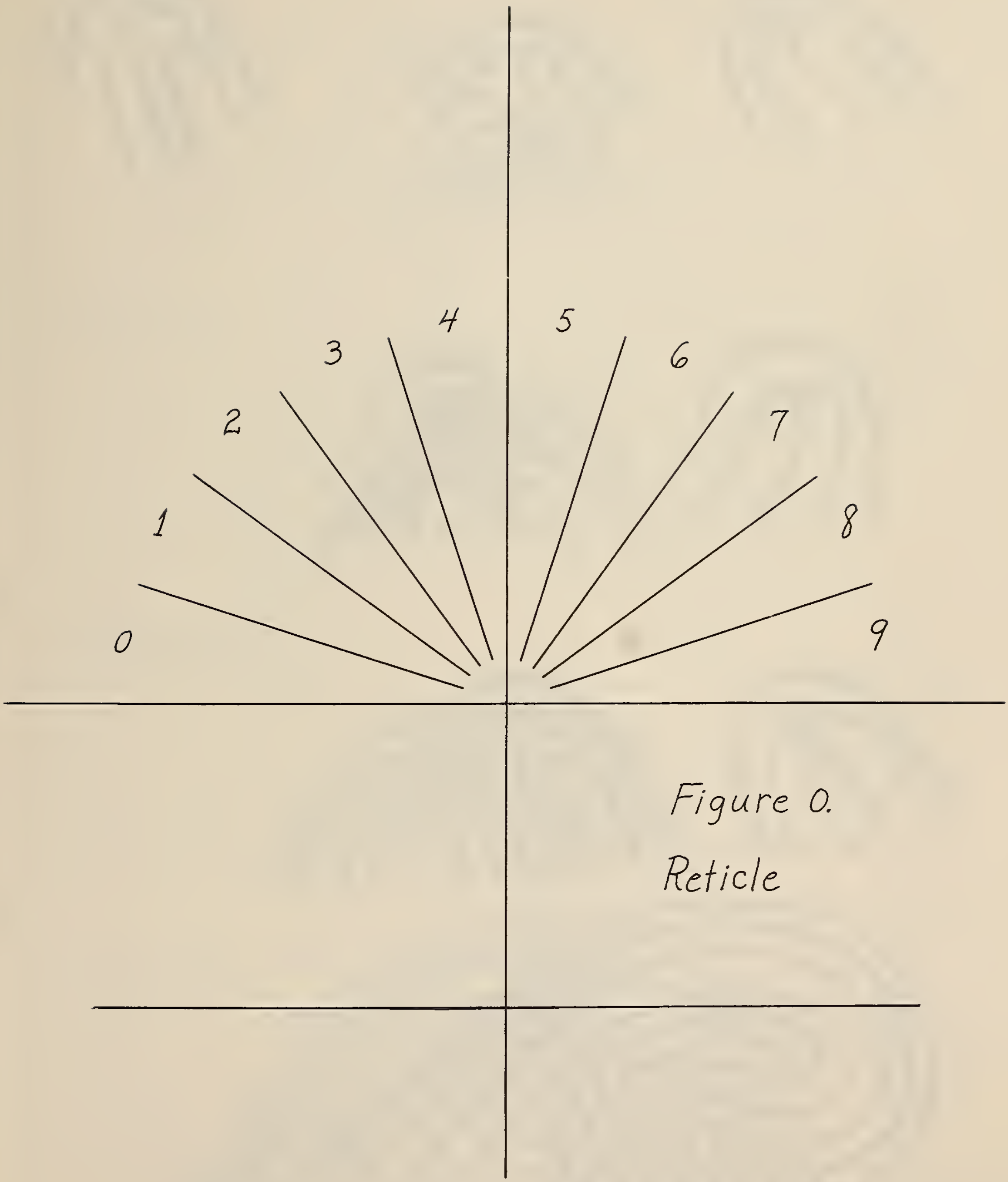


Figure 0.
Reticle

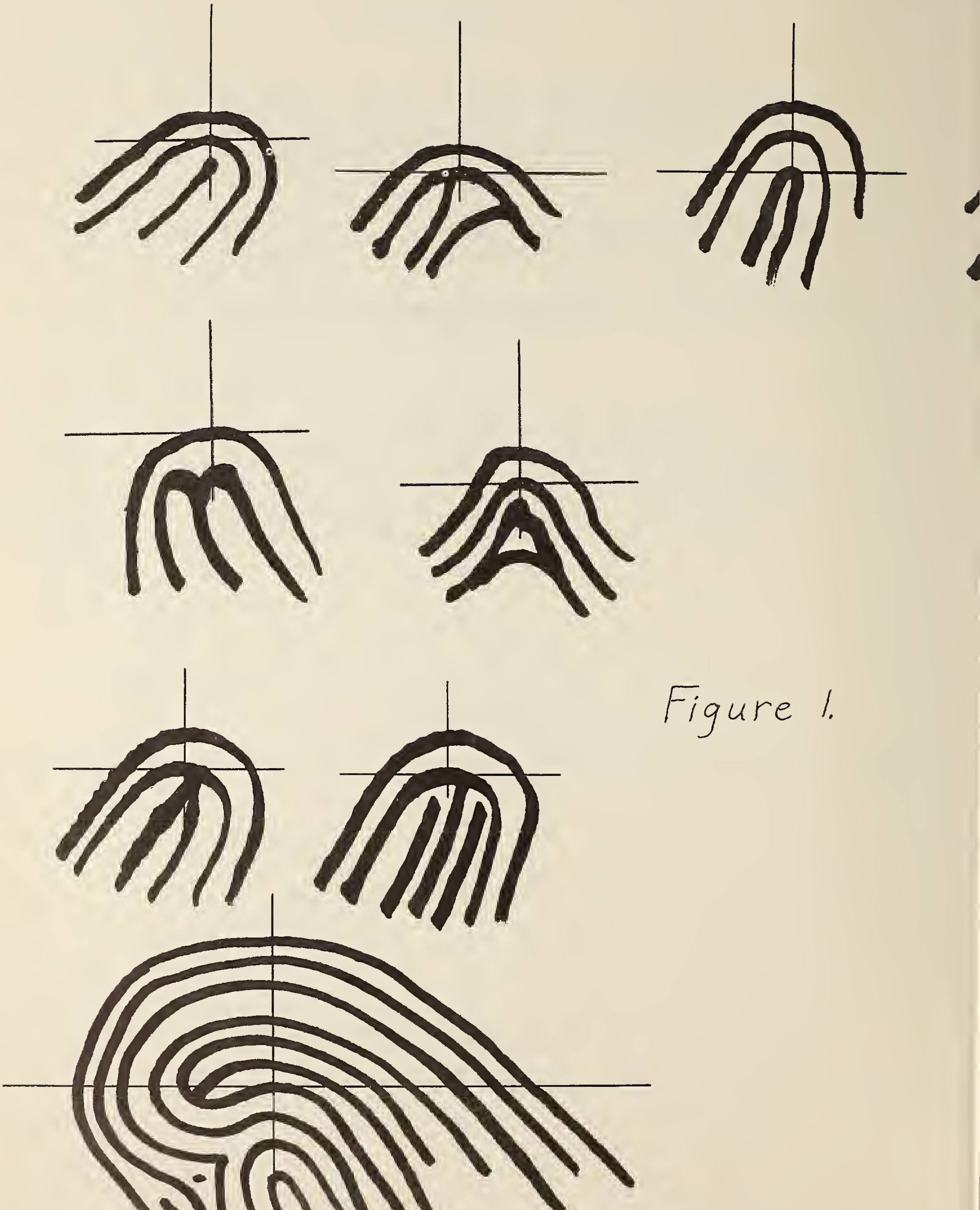


Figure 1.

Figure 2.

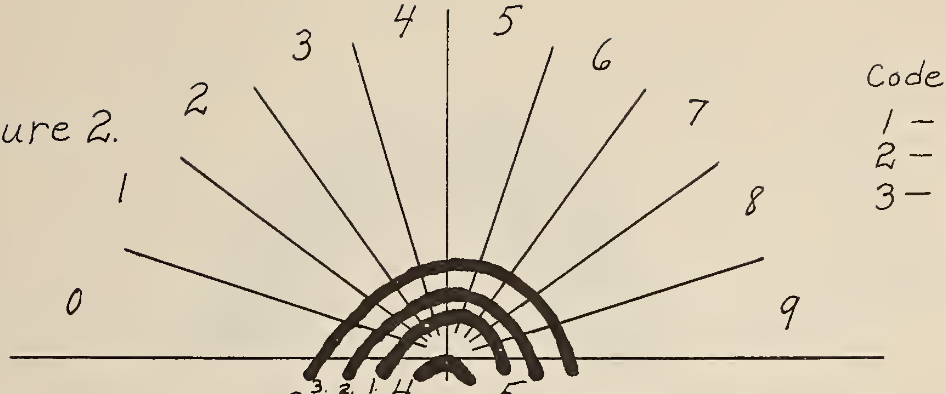


Figure 3.

Figure 4.

Figure 5.

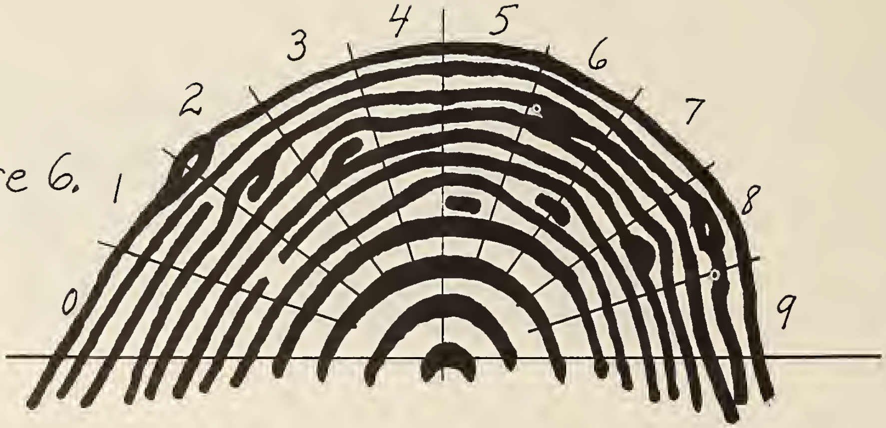


Figure 6.

1 —
2 —
3 —
3.1 i5
4 —
4.1 i6
5 —
6 —
6.1 i3
6.2 i8
7 —
7.1 i2
7.2 i6
8 —
8.1 e1
9 —
9.1 i8
10 —
10.1 i1

Figure 7.

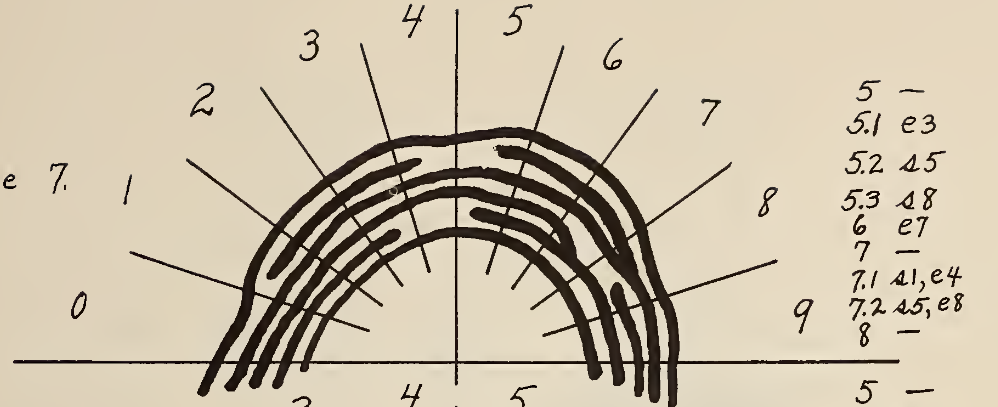


Figure 8.

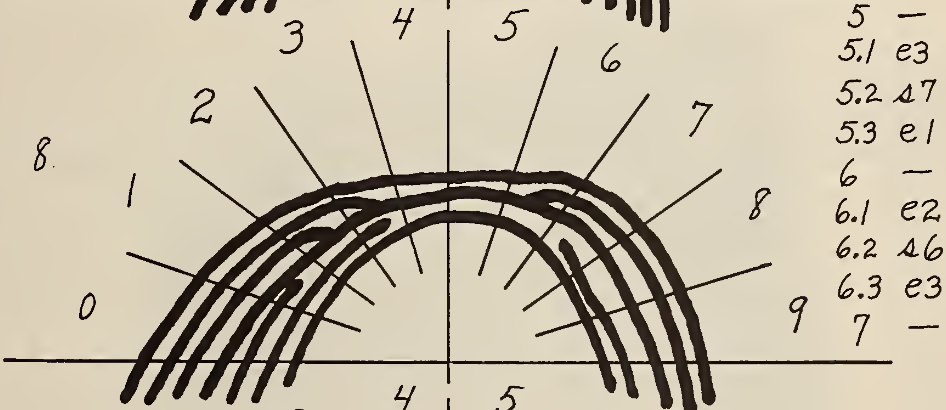


Figure 9.

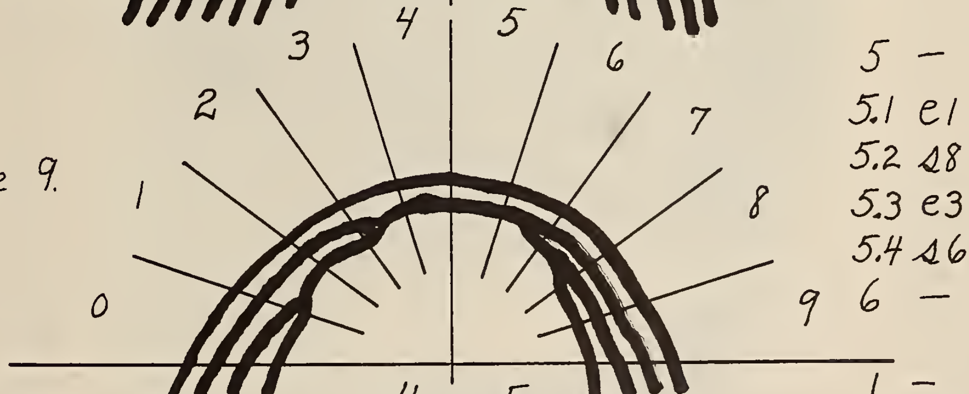
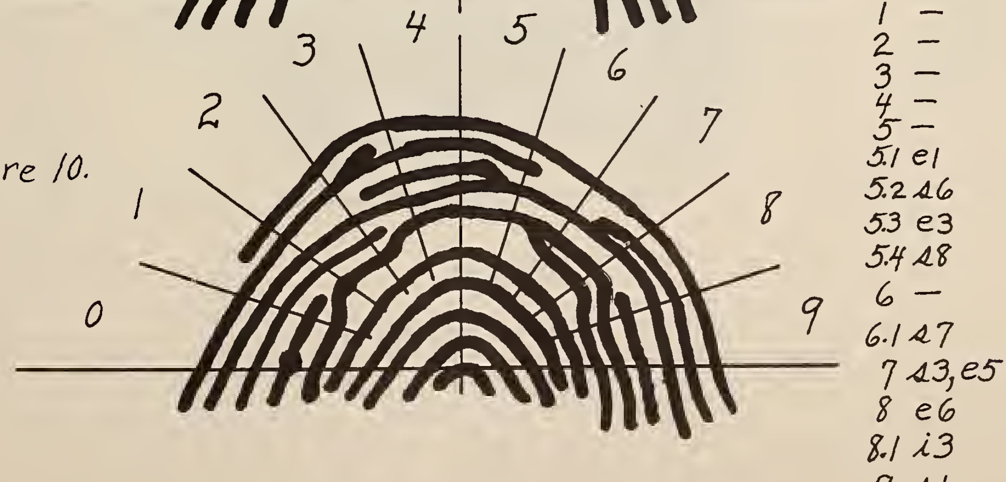


Figure 10.



A	B	C
0	0	1
0	0	2
e	7	3
0	0	4
s	3	5
0	0	6
0	0	7
s	8	7
0	0	8
i	2	8
0	0	9

Figure 11

Code for Figure 5
As Entered in
Computer

A	B	C
0	0	1
0	0	2
0	0	4
0	0	6
0	0	7
0	0	8
0	0	9
i	2	8
s	3	5
e	7	3
s	8	7

Figure 12

Code for Figure 5
As Stored in File

M	A	B	C	D
1	0	0	1	1
2	0	0	2	1
3	0	0	4	1
4	0	0	6	1
5	0	0	7	1
6	0	0	8	-1
7	0	0	9	-1
8	i	2	8	1
9	s	3	5	-1
10	e	7	3	-1
11	s	8	7	1

S = 3

N	E	F	G	H
1	0	0	1	1
2	0	0	2	1
3	0	0	3	1
4	0	0	4	0
5	0	0	5	1
6	0	0	6	1
7	e	1	5	0
8	s	1	9	0
9	e	3	5	0
10	s	3	7	0
11	i	3	8	1
12	e	5	7	0
13	s	6	5	0
14	e	6	8	0
15	s	7	6	1
16	s	8	5	0

Figure 13

Tables Used in Comparing
Code for Figure 5 with Code for Figure 10


0
1
2
3
4
5
6
7
8
9
62
1 —
1.1 e2
2 —
2.1 e1
3 —
3.1 s1,e3
4 —
5 —
6 e8
6.1 s1,e4
7 —
7.1 s8
8 —
8.1 e3
9 —
9.1 i0
9.2 e3
9.3 e1
10 —
11 s2
11.1 s8
12 —
12.1 i8
13 —

Figure 14

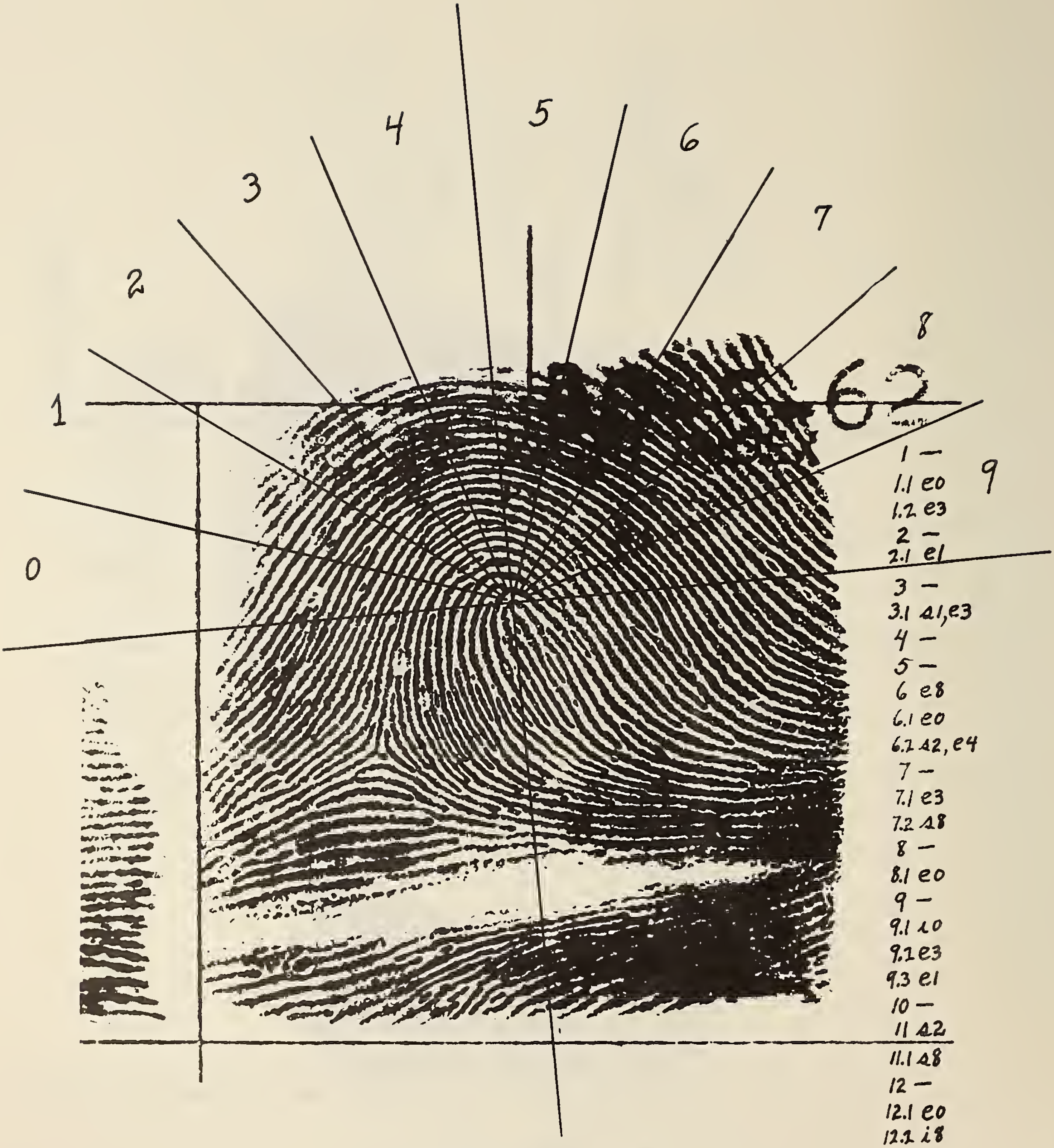

0
1
2
3
4
5
6
7
8
9
62
1 —
1.1 e0
1.2 e3
2 —
2.1 e1
3 —
3.1 Δ1,e3
4 —
5 —
6 e8
6.1 e0
6.2 Δ2, e4
7 —
7.1 e3
7.2 Δ8
8 —
8.1 e0
9 —
9.1 i0
9.2 e3
9.3 e1
10 —
11 Δ2
11.1 Δ8
12 —
12.1 e0
12.2 i8
13 —
13.1 i6
14 —

Figure 15

From Figure 14

A	B	C	D
0	0	1	1
0	0	2	1
0	0	3	1
0	0	4	1
0	0	5	1
0	0	7	1
0	0	8	1
0	0	9	1
0	0	10	1
0	0	12	1
0	0	13	1
i	0	9	1
e	1	2	1
s	1	3	1
s	1	6	1
e	1	9	1
e	2	1	1
s	2	11	1
e	3	3	1
e	3	8	1
e	3	9	1
e	4	6	1
e	8	6	1
s	8	7	1
s	8	11	1
i	8	12	1

S = 26

From Figure 15

E	F	G	H
0	0	1	1
0	0	2	1
0	0	3	1
0	0	4	1
0	0	5	1
0	0	7	1
0	0	8	1
0	0	9	1
0	0	10	1
0	0	12	1
0	0	13	1
0	0	14	0
e	0	1	1
e	0	6	0
e	0	8	1
i	0	9	1
e	0	12	0
e	1	2	1
s	1	3	1
e	1	9	0
s	2	6	1
s	2	11	1
e	3	1	0
e	3	3	1
e	3	7	1
e	3	9	1
e	4	6	1
i	6	13	0
e	8	6	1
s	8	7	1
s	8	11	1
i	8	12	1

Figure 16

Tables Used in Comparing
Code for Figure 14 with Code for Figure 15

Fingerprint Impressions Searched Against File	Fingerprint Impressions in File													
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
P1	19	6	2	0	13	-2	5	6	4	8	10	8	7	6
P2	7	17	5	2	8	2	4	6	8	8	4	6	7	6
P3	2	6	17	8	6	6	4	8	6	8	4	5	4	6
P4	0	2	6	16	6	11	8	4	4	-2	2	8	6	4
P5	17	8	4	6	24	4	13	7	9	6	12	8	7	12
P6	2	2	11	7	4	14	10	5	4	1	0	4	2	3
P7	4	6	4	8	5	6	22	3	5	5	4	10	9	5
P8	8	6	8	10	5	9	6	21	6	6	2	6	3	2
P9	2	4	4	6	8	6	6	6	19	4	2	0	5	5
P10	4	8	10	4	5	2	2	1	9	15	4	7	6	11
P11	6	12	2	2	10	3	9	2	6	4	17	10	10	12
P12	5	9	7	8	6	1	5	8	4	7	8	18	9	8
P13	4	10	4	6	4	0	8	2	4	2	8	12	20	8
P14	6	6	6	4	7	4	7	2	8	6	10	8	8	19

Figure 17

Scores Obtained from Comparing 14 Fingerprint Impressions with 14 Different Impressions from the Same Fingers. The types include loops, whorls, and double loops.

		Impressions in File								
		W15	W16	W17	W18	W19	W20	W21	W22	W23
Impressions Searched Against File	P15	17	3	6	1	2	7	5	5	5
	P16	9	14	2	3	1	3	1	5	1
	P17	3	1	14	8	7	8	7	9	9
	P18	4	1	10	7	6	8	5	10	10
	P19	1	0	8	6	10	14	9	7	4
	P20	4	0	8	7	5	13	5	7	4
	P21	4	2	6	2	6	8	8	8	8
	P22	6	4	7	2	7	4	7	15	9
	P23	3	0	14	7	3	9	9	11	14

Figure 18

Scores Obtained in Comparing 9 plain Arch Impressions with 9 Different Impressions from the Same Fingers.

		Impressions in File						
		W1 W2	W3 W4	W5 W6	W7 W8	W9 W10	W11 W12	W13 W14
Impressions Searched Against File	P1 P2	323	4	26	30	32	60	42
	P3 P4	4	272	66	16	-12	32	16
	P5 P6	34	28	336	65	9	48	21
	P7 P8	24	40	45	462	30	24	18
	P9 P10	16	16	16	6	285	14	55
	P11 P12	54	16	10	72	42	306	80
	P13 P14	24	16	16	16	24	64	380

Figure 19

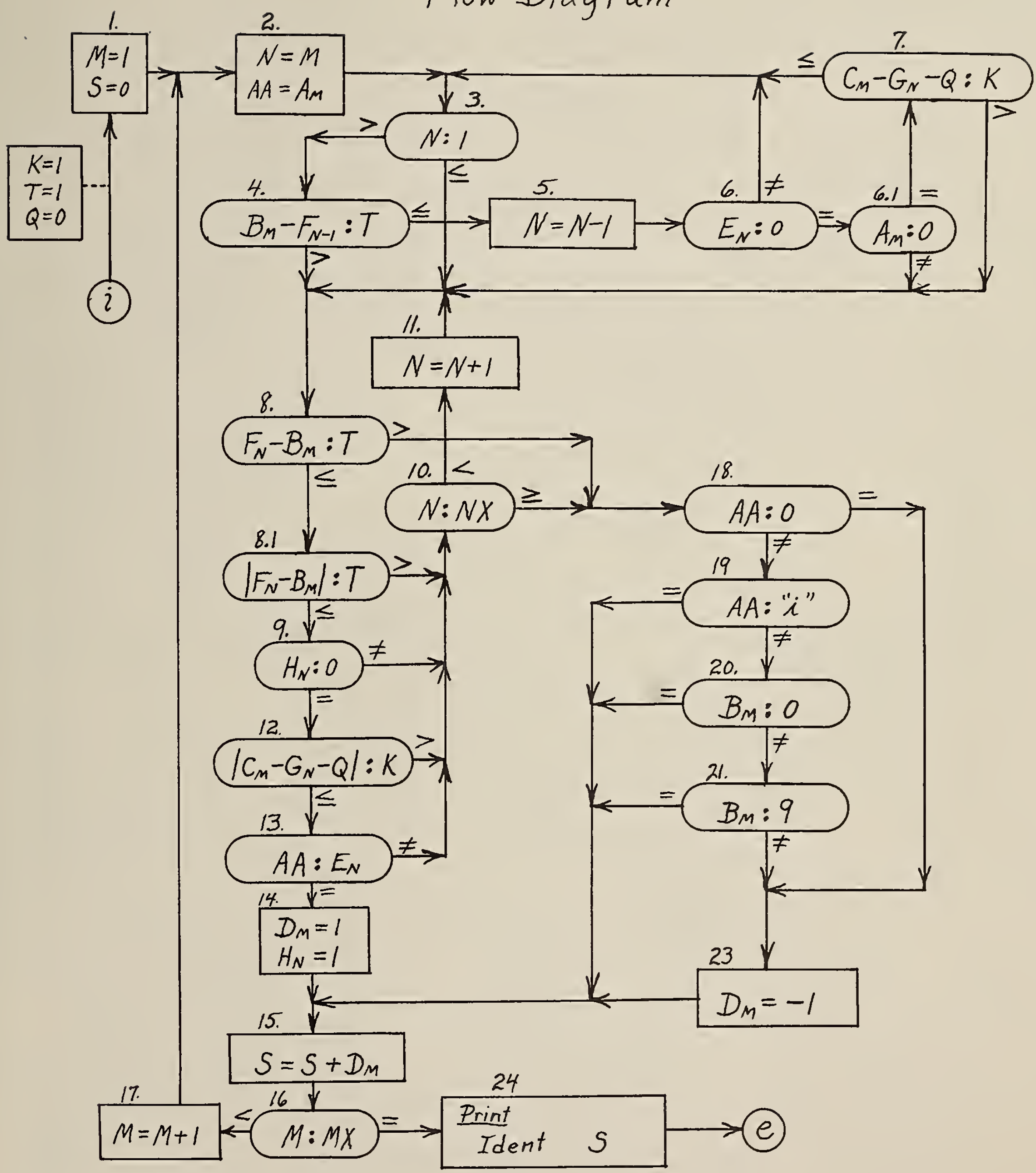
Identification of Seven Individuals
Using Two Fingerprints (Loops and Whorls)

		Impressions in File			
		W15 W16	W17 W18	W19 W20	W21 W22
Impressions Searched Against File	P15 P16	238	18	6	25
	P17 P18	3	98	56	70
	P19 P20	1	56	130	63
	P21 P22	16	12	24	120

Figure 20

Identification of Four Individuals
Using Two Fingerprints (Plain Arches)

Appendix
Flow Diagram



Computer Program for Matching Fingerprint Codes

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