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The

Faculty of the Mathematics Program California State University Channel Islands

In (Partial) Fulfillment of the Requirements for the Degree

Masters
of
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by

Shawn
Richard-
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April,
2014

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~~Committee Member's name, Thesis Committee Date~~

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~~Dr. Gary A. Berg, AVP Extended University Date~~

To my parents, name and name, in gratitude for their encouragement and support.

Acknowledgements

Abstract

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Contents

1. Introduction

In an attempt to match fingerprints sampled at different resolutions and taken at different angles, triangles were generated from the minutia points. These triangles were initially compared based on the angles between the points without regard to the length of the sides. This was done to abstract the fingerprints from the res- o- lu- tion of the orig- i- nal im- age as well as the an- gle at which the print was scanned.

2. Related Work

3. Methodology

3.1. **Initial Hypothesis.** After extracting the coordinates of the minutia points, a triangle can be generated for each unique set of 3 minutia. Each of these triangles can be stored in a database as a pair of numbers, one for each of the 2 largest angles. The third angle is not required as the sum of the angles must equal 180 degrees. By storing only the two angles, resolution, orientation, and inversion of the image are abstracted. Fingerprints could then be compared by the number of triangles in each image that match.

4. Results

800 fingerprints in database. 17639 end points and 13015 bifurcation points.

5. Discussion and Future Work

5.1. **Notation and Terminology.**

(As needed...)

6. Hypothesis

6.1. Initial Hypothesis Results.

Using the [Insert Database Name] fingerprint database, experimental results show that fingerprint images with more minutia scored significantly higher than those with fewer minutia points, even if the images were not of the same fingerprint. [Add test result data and methodology]

6.2. **Revision 1.**

In order to

reduce false positives, several revisions were made. The length of the longest side was added.

6.3. **Revision 2.**

Using the largest angle as a starting point, the next angle in a clockwise rotation was selected, regardless of size. The direction of the minutia was then added to the data set for each of the 3 minutia points.

7. Data Used for Analysis

7.1. FVC2002: Fingerprint Verification Competition.

Of the four databased made available for the 2002 Fingerprint

Verification Competition, the images in set A of DB1 were chosen for this analysis. The images in this database were optically scanned using an

Identix TouchView II. The resulting images are 388 x 374 pixels with a resolution of 500 dots per inch. A total of 90 volunteers with an average age of 20, were used to gen- er- ate the im- ages with 30 of the 90 se- lected at ran- dom used for DB1. The fore- fin- ger and mid- dle fin- ger of each hand was sam- pled for each of the 30 vol- un- teers. A to- tal of 12 sam- ples of each fin- ger were tak- ing dur- ing three dis- tinct ses- sions with at least two weeks sep- a- rat- ing each ses- sion. Ef- forts were made to increase finger placement, displacement, rotation (not to exceed 35 degrees), and moisture diversity. The sensors were not systematically cleaned, nor were

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110 fingers, 100 were designated as set A and 10 as set B, with 8 of the 12 sampled impressions included **?**,]]maio$_{f}vc$2002 :? ???.$Myresearchutilizedthe800imagesmadeavailableassetAofDB1.$

8. Minutiae Extraction

8.1. Image Preparation. The images used are optical scans of fingers at 500 dots per inch in 8 bit gray scale ash shown in Figure **??**. Utilizing the DIPimage toolbox within MATLAB, the images were enhanced to reduce misclassification of ridge endings and bifrication points. Each fingerprint image was divided into blocks of 16$\times$ 16 pixels for which the variance of each block was computed. The variance was then compared with the threshold value. If the variance of a block was less than the threshold value, then the block was deleted from the original figure. This process was carried out for the entire image. The resulting image was then normalized to get the desired variance of the given image. The blocks were then filtered along the direction of the orientation angle using the value of the frequency obtained for each block. A binary mask was used to remove points around the edges as well as internal points with a low reliability index as generated by the image enhancement process. Filtering was done for each block using the local orientation angle and frequency.

8.2. **Skeletonization.** A binary image was generated from the age

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of pixels until a single pixel wide line remained. End pixels were then identified as those pixels with exactly pixel within the 8 possible surrounding pixels. A mask was applied to these results to eliminate the areas around the edge which would otherwise generate false end points, as well as areas of low confidence where the age

image was not sufficiently clear.

8.3. **Identify Minutiae.** Each of the end points remaining after the masking process was determined to be an end point.

8.4. Minutiae Properties.

9. Analysis

9.1. Triangles.

9.2. Principal Component Analysis.

9.3. Matching.

10. Stuff to Include

10.1. Fingerprint Matching.

Reliably matching images of fingerprints is extremely difficult, mainly due to large variations in images of the same finger. The main factors responsible for these large intra-class variations are: displacement, rotation, partial overlap, nonlinear distortion, variable pressure, changing skin conditions, noise, and feature extraction errors?,]31]maltoni$_h andbook_2$003.

10.2. Data Collected.

For each image processed, the minutia points are determined. Then for each minutia point, the location, direction, and type are determined. The location is extracted as the xy-coordinate in the image and the direction is the angle relative to a line running from the origin, increasing along the x axis. The type is classified as either an end or bifurcation point.

10.3. **Triangulation.** The minutia are then grouped into sets of 3, forming a triangle. Using the xy-coordinates of each point, the angles and lengths of each side can be calculated. For each triangle, the largest angle was first determined, then taking a clockwise rotation, the second angle is determined. Along with the distance between minutia at the veracities of these two angles, the triangle can be be fully represented. Hypnosis: Using the center point of the triangle as a reference would minimize the impact of errors caused either by distortion or errors in the extraction process. The direction of the minutia point is then calculated relative to the direction to the center of the tri- an- gle. This point was cho- sen to re- duce the im- pact of er- rors in the lo- ca- tions of the minu- tia, ei- ther by dis- tor- tion or er- rors in the ex- trac- tion process.

Proof. Let A, B and C be arbitrary minutia points. Let a be the distance be-

tween

points

B

and

C,

then

$a =$

$\sqrt{(B_x - C_x)^2 + (B_y - C_y)^2}$

$b =$

$\sqrt{(A_x - C_x)^2 + (A_y - C_y)^2}$

$c =$

$\sqrt{(A_x - B_x)^2 + (A_y - B_y)^2}$

$\square$

$\theta =$
$\arctan(\frac{opposite}{adjacent}) =$
$\arctan(\frac{\Delta x}{\Delta y})$
$\cot\theta =$
$(\frac{adjacent}{opposite}) =$
$(\frac{\Delta y}{\Delta x})$
If
$\Delta y <$
0,
$\theta =$

$\theta +$
π
If
$\Delta x =$
$0, \theta =$
$\frac{\pi}{2}$

10.4. **Training Data.** The database used consistent of 8 different images of 100 unique fingers for a total of 800 fingerprint images. One image of finger was chosen, using the random function within MySQL, and reserved for the testing set. The remaining 700 images were used as a training set. Statistic for the training data are shown in

Table **??**. Angle α, being the largest angle of a triangle was expected to have a minimum value of 60 degrees and a maximum value of less than 180 degrees. The values shown for α in Table **??** when translated from radians to degrees show the sampled minimum value to be approximately 60.0685 degrees and the sampled maximum value of approximately 179.9667 degrees. Angle β being arbitrarily one of the remaining angles is expected to be greater than 0 degrees and less than 90 de- grees. The ex- per- i- men- tal data con- firms this with re- sults of ap- prox- i- mately 0.0064 and 88.5559 de- grees. The re- main- ing com- po- nents are sim- i- larly

Component	Minimum	Maximum	Average	σ
Angle α	1.0483928950	3.1410122706	1.7797521977	0.4721377805
Angle β	0.0001109755	1.5455915815	0.6718969221	0.3484298449
Direction a	-3.1415926535	3.1415926536	0.0167706757	1.8339501956
Direction b	-3.1415926535	3.1415926536	-0.0314165278	1.8484983038
Direction c	-3.1415926535	3.1411944932	-0.0277245946	1.8392294858
Length	2.2360679775	335.6262802583	58.0791589147	31.5340026405

Dataset

consistent with their expected values.

10.5. **Principle Component Analysis.** After calculating the statistical

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deviation following data: (data types). Principle component analysis was then used to reduce the number of criteria to be compared.