# Use of Exterior Contours and Shape Features in Off-line Signature Verification

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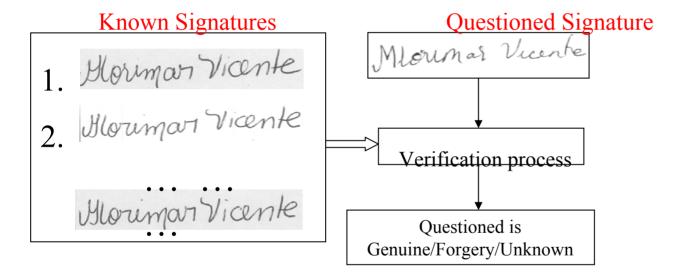
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### **Overview**

#### **Motivation:**

Off-line signature verification is a task of relevance to complex document processing, forensics, biometrics

#### Task:



#### Philosophy:

- 1. Use linear trace-- similar to on-line approach (contour-based)
- 2. Use topology-based approach-- similar to OCR (shape-based)
- 3. Combine methods

#### Overview of Rest of Presentation

- 1. Image Pre-processing
- 2. Algorithm 1: Contour-based

Overview of algorithm

Combining contours of signature

Matching contours of signature

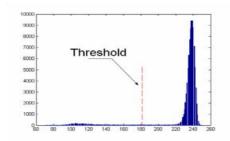
Feature extraction

- 3. Algorithm 2: Shape-based
- 4. Classifier Combination
- 5. Performance
- 6. Conclusion

## Image Preprocessing

(common to both methods)

A. Binarization (Otsu's method)



Grey scale image

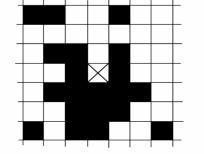
Bloringer Vicente

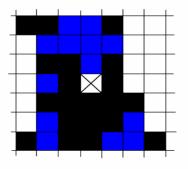
Binary image

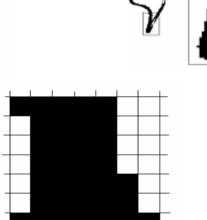
Hloringer Vicente

B. Broken Stroke connection

Hlorman Vicente





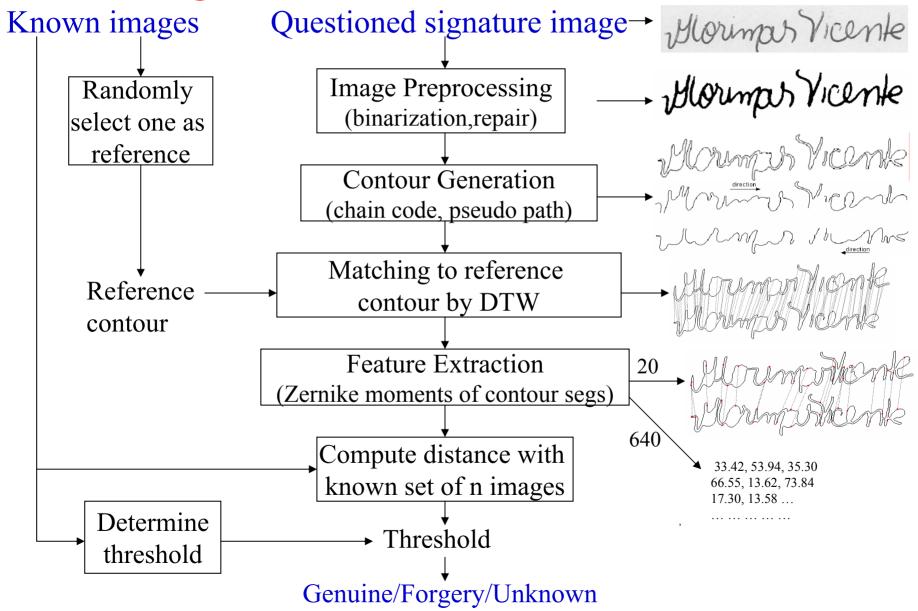


before after





## Algorithm 1: Contour-based



## Exterior Contours (upper/lower)

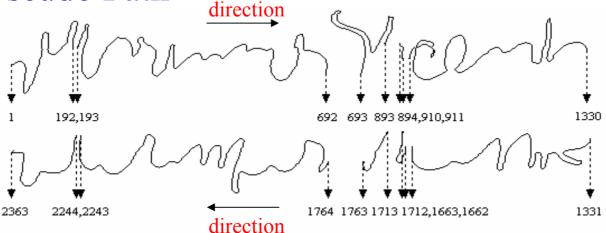
#### Chain code generation

#### **Exterior Contours**



Contour (1)	Contour (2)	Contour (3)	Contour (4)	Contour (5)
X: 9 10 11	X: 68 68 68	X: 297 298 299	X: 351 352 353	X: 365 365 365
Y: 104 104 104	Y: 91 90 89	Y: 53 52 51	Y: 108 107 106	Y: 96 95 94
Slope: 2 2 3	Slope: 2 2 2	Slope: 3 3 3	Slope: 2 3 3	Slope: 2 2 2
Curvature: 0 0 1	Curvature: 7 0 0	Curvature: 0 0 0	Curvature: 7 1 0	Curvature: 7 0 0

#### Pseudo Path

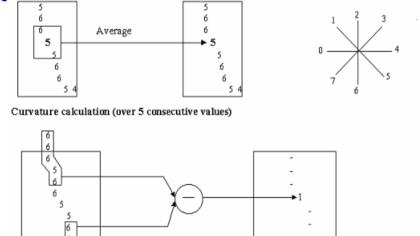


## Matching Contours of Signature



1. □Determine slope and curvature of contour points (from

chain (Average slope calculation (over 3 consecutive values)



2. Use dynamic time warping to obtain corresponding points

## Contour matching

#### **Dynamic Time Warping (DTW)**

• Initialization:



$$D(0,0) = d(0,0)$$
, where

$$d(i_x, i_y) = \left[f_s^2(slope(i_x) - slope(i_y)) + f_c^2(curvature(i_x), curvature(i_y))\right]^{\frac{1}{2}}$$

• Recursion:

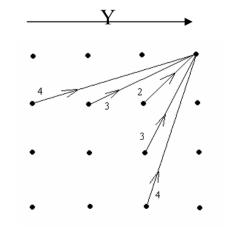
$$D(i_x, i_y) = \min_{i'x, i'y} \left[ D(i_x', i_y') + \xi((i_x', i_y'), (i_x, i_y)) \right]$$

$$\xi((i_x', i_y'), (i_x, i_y)) = \sum_{l=0}^{L_x} d(\phi_x(T'-l), \phi_y(T'-l)) \times m(T'-l) \uparrow \qquad \bullet \bullet \bullet$$

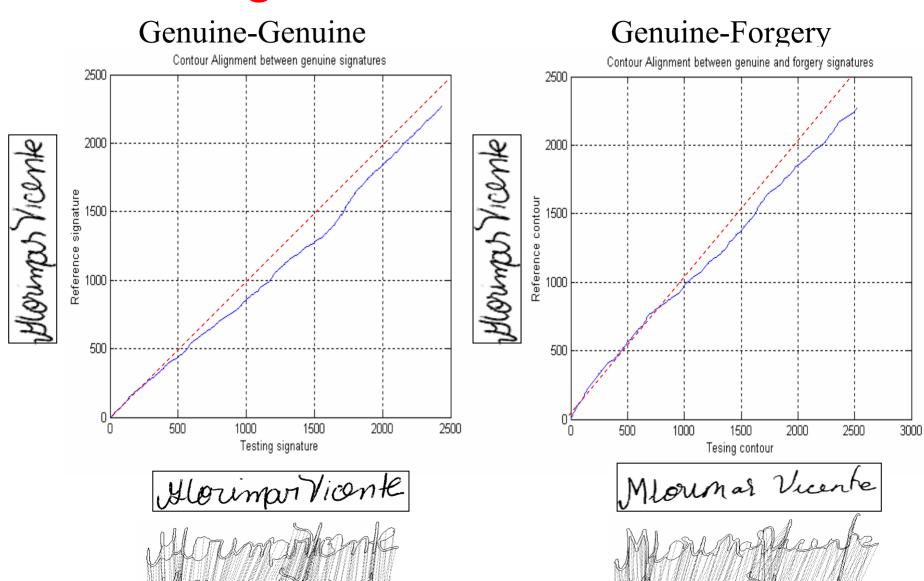
• Termination:

$$d(X,Y) = \frac{D_A(T_x - 1, T_y - 1)}{T_x + T_y}$$

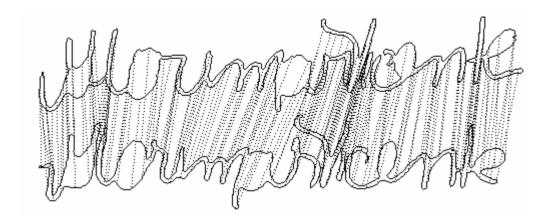
DTW: local constraints and slope weights



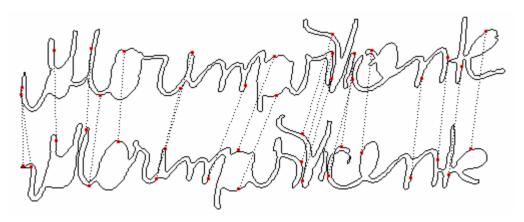
## Alignment of Contour Points



#### Alignment and Contour Segmentation

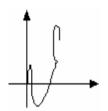


Contour segmentation (20 equal length segments in reference)

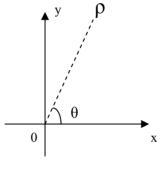


## Contour Segment Feature Extraction

#### Moments of contour segment form feature vector



#### Zernike moments



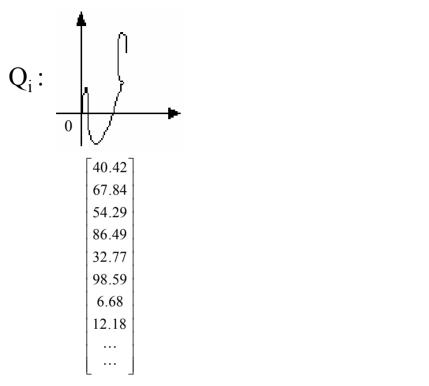
$$V_{nm}(x, y) = V_{nm}(\rho, \theta) = R_{nm}(\rho)e^{jm\theta}$$

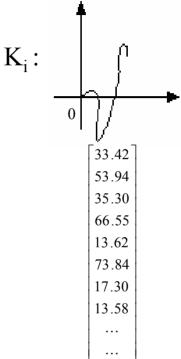
$$R_{nm}(\rho) = \sum_{s=0}^{(n-|m|)/2} (-1)^s \frac{(n-s)!}{s!(\frac{n+|m|}{2}-s)!(\frac{n-|m|}{2}-s)!} \rho^{n-2s}$$

$$A_{nm} = \frac{n+1}{\pi} \sum_{x} \sum_{y} f(x, y) V_{nm}^*(\rho, \theta) \quad x^2 + y^2 \le 1$$

Order	Zernike	No.
	Moments	
0	$A_{00}$	1
1	A <sub>11</sub>	1
2	A <sub>20</sub> , A <sub>22</sub>	2
3	$A_{31}, A_{33}$	2
4	A <sub>40</sub> ,A <sub>42</sub> , A <sub>44</sub>	3
5	$A_{51}, A_{53}, A_{55},$	3
6	A <sub>60</sub> , A <sub>62</sub> , A <sub>64</sub> , A <sub>66</sub> ,	4
-	Total (complex)	16
-	Total (value)	32

## Segment Distance Computation





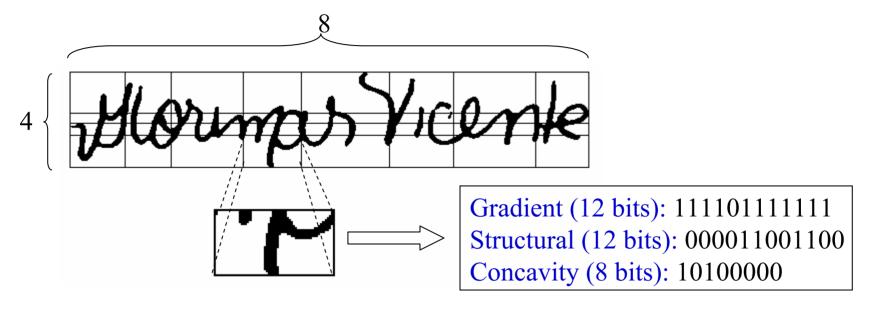
a 32 length feature vector  $q_i$ 

a 32 length feature vector  $k_i$ 

Harmonic distance between questioned and known signatures :  $D(Q, K) = \frac{1}{\sum_{i=1}^{20} \frac{1}{d_i}}$ 

Where  $d_i$  is the Euclidean distance between the ith segment of signatures  $d_i = \sqrt{\sum_{j=1}^{32} (q_{ij} - k_{ij})^2}$ 

## Algorithm 2: Word-shape based\*



Total bits = 
$$(12+12+8) \times 4 \times 8 = 1024$$
 bits

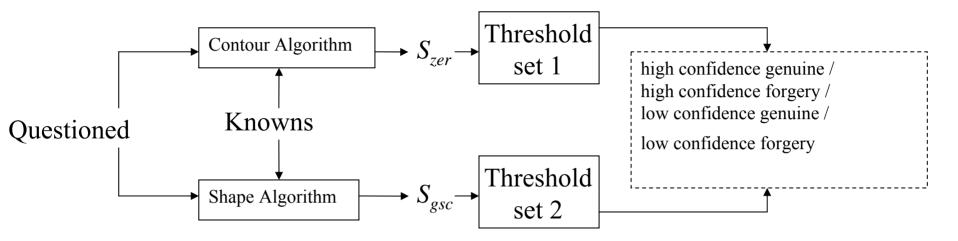
Similarity score = 
$$\frac{0.5 \times C_{00} + C_{11}}{1024}$$

 $C_{00}$  is the number of bits where both vectors have "0"s

 $C_{11}$  is the number of bits where both vectors have "1"s

\*Described in paper at IWFHR, Tokyo, Nov. 2004

#### Combination of Two Methods



high confidence genuine vs. low confidence forgery or high confidence genuine vs. high confidence genuine or high confidence genuine vs. low confidence genuine

#### → Genuine

high confidence forgery vs. low confidence genuine or high confidence forgery vs. high confidence forgery or high confidence forgery vs. high confidence forgery

#### → Forgery

high confidence genuine vs. high confidence forgery

→ Unknown

## Test Bed: Training / Testing Data

Genuine signatures (1320): 55 individuals, 24 signatures each

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MS	A STORY OF THE STO	Hydra	Delia A. Moren	Pillip
File P. tomy	_			
Melissa D. Dunkl.				

Forgery signatures (1320): 55 individuals, 24 signatures each

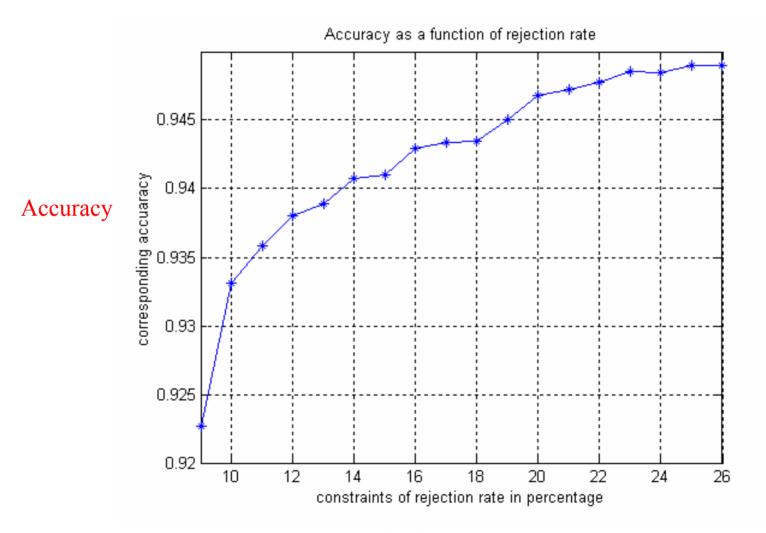
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truf Potrosf				
Melissa N. Dundle	, ,	V		

## Signature Verification Performance

Accuracy(55 writers/24 signatures each)

ALGORITHM	1-FAR	1-FRR	ACCURACY
1. Contour Method (with rejection)	87.1	86.8	86.9
	(11.6)	(9.6)	(10.6)
2. Word Shape Method (with rejection)	83.2	81.5	82.4
	(13.2)	(8.2)	(10.6)
Combined method (with rejection)	94.1	93.5	93.8
	(10.9)	(8.6)	(10.2)

## Accuracy-Rejection Trade-off Combined Method



Rejection Rate

#### **Conclusion**

- 1. Linear trace based on exterior contour (pseudo path) has value in off-line signature verification
- 2. Zernike moments are appropriate shape features for handwriting images
- 3. Contour based and shape based methods are complementary leading to improved combination performance