Hand-based biometrics and Signature Verification

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contents

Introduction Biometric Systems

- traditional, automatic, personal identification: 2 categories:
  - token-based (physical key, ID card, passport, . . .)
  - knowledge-based (password)

- biometric approach
  - verification (*)
  - identification

Hand Geometry

- size and shape of hand
  - medium cost (low resolution camera)
  - low computational cost algorithm -> fast results
  - low template size
  - very easy/attractive to users
  - lack of relation to police, justice and criminal records

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Measurement Device

- platen (highly reflective surface)
- pegs for accurate hand positioning
- CCD camera
- infrared light emitting diodes
- mirror and reflectors

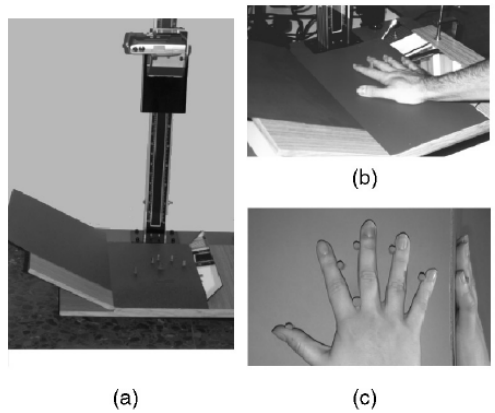

Fig. 1. Different views of the prototype designed: (a) Platform and camera, (b) placement of the user's hand, and (c) photograph taken.

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Usage – Enrollment, Verification

- enrollment session
  - personal identification number (PIN)
  - multiple placement of the hand (typ. 3x)
  - mathematical average of the templates
  - store template

- verification
  - enter PIN
  - retrieve template
  - user places hand on the scanner
  - camera takes picture
  - system generates template
  - compare to stored one
  - ACCEPT

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Enrollment – Further Discussion

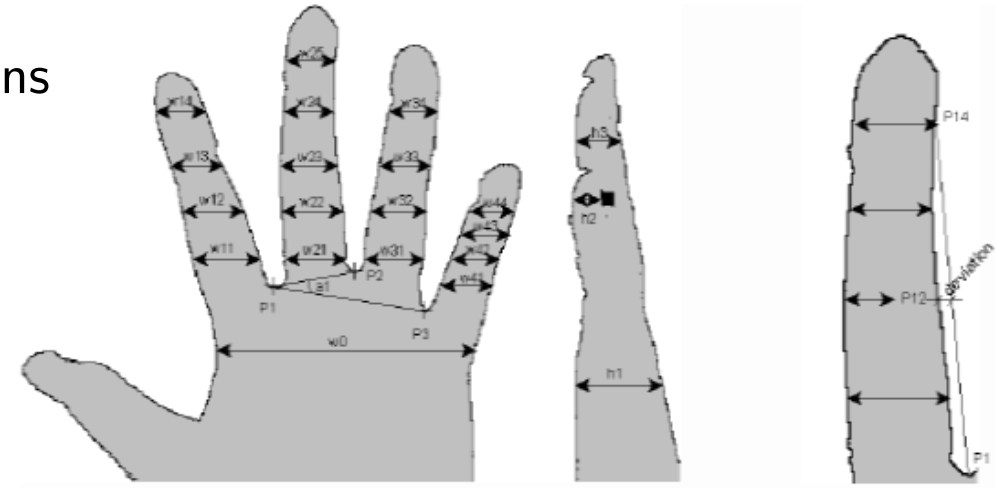
- quality of enrollment effects performance
  - platen height (enroll and verify)
  - sitting/standing position of user
  - train users during enrollment possible
  - "landing an airplane" scenario
  - training before enrollment recommended

Verification – physical changes

- long time change due to aging
- "learn" minor hand shape changes
- continually update templates as users verify
- example housing project
  - hand geometry scanners for access by tenants + children
  - age of 8 and older
  - templates grow with their users

Workflow of the system

- take a picture
  - orthographic scanning (top + side view)
- preprocessing
  - binary image
  - sobel function for contour
- measurements
  - widths, heights, deviations
  - eg. 31 features
- feature selection
  - $F_j = \frac{interclassvariability}{intraclassvariability}$
  - reduced to 25 features



Template Calculation

different ways to calculate, store and compare templates

- euclidian distance
  - distance of each sample
  - $d = \sqrt{\sum (x_i - t_i)^2}$
- hamming distance
  - each feature follows Gaussian distribution
  - # of values not within certain deviation
- Gaussian Mixture Models (GMMs)
  - approach between statistics and neural networks
  - like hamming but with weights for each Gauss model
- Radial Basis Function Neural Networks (RBF)
  - two layer neural network
  - lots of training template data needed

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Performance analysis 1

		Euclidean	Hamming	GMMs	RBF
No. enrollment vectors (25 features)	3	86 %	75 %	88 %	90 %
	4	85 %	82 %	93 %	91 %
	5	86 %	87 %	96 %	91 %
Feature vector dimension (5 enrollment vectors)	25	86 %	87 %	96 %	91 %
	21	84 %	86 %	97 %	95 %
	15	86 %	88 %	96 %	89 %
	9	77 %	75 %	91 %	82 %

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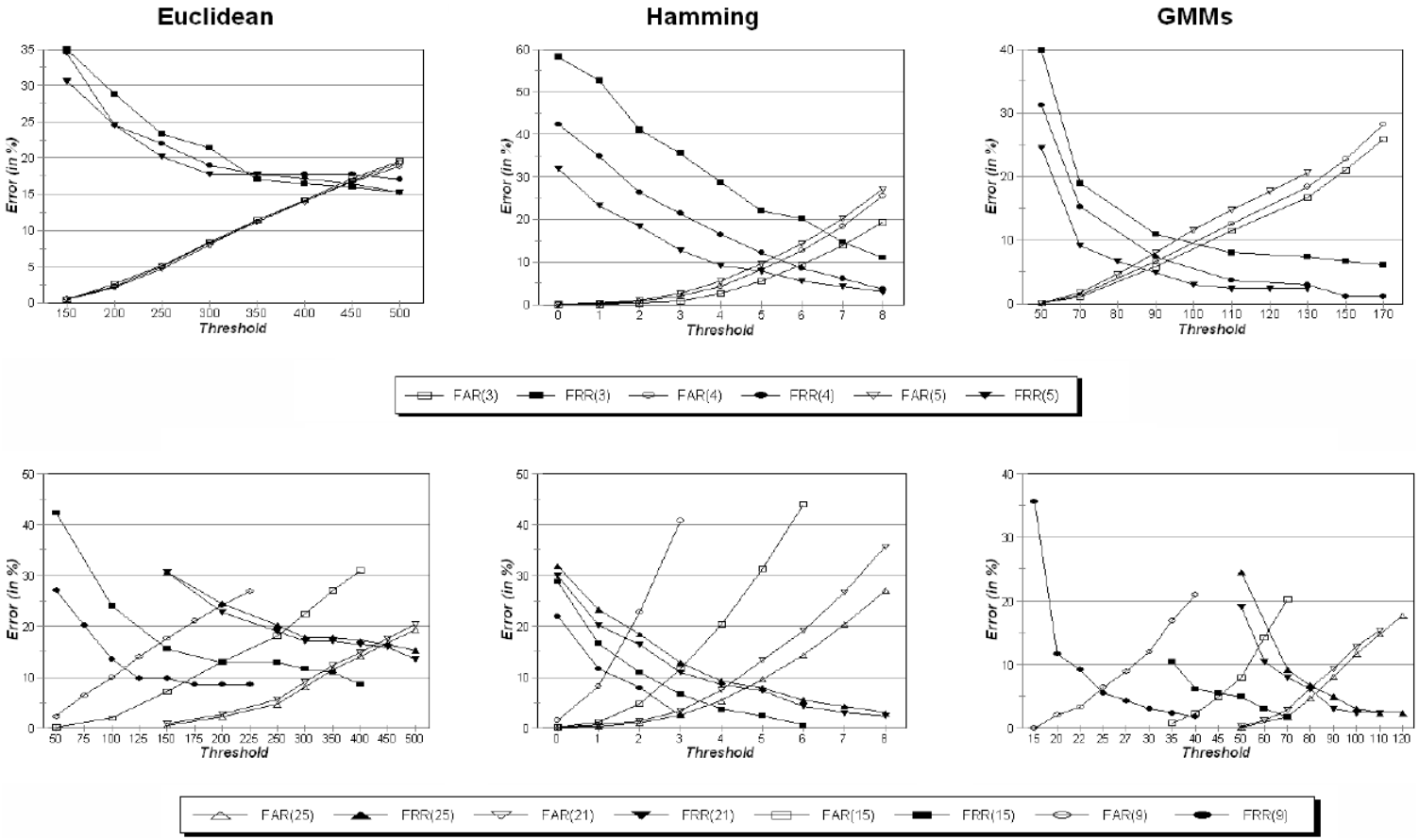
Performance analysis 2



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Applications

- INSPASS (now USPASS)
- O'Neal Steel
- McDonald's (buddy punching)
- Banks
- Hospitals
- ...

INSPASS - INS Accelerated Service System

- program of the United States Immigration and Naturalization Service (INS)
- hand geometry as a biometric identifier
- associated membership card
- pre-screened low-risk travellers (frequent fliers)
- immigration and customs at certain airports

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O'Neal Steel

- HandPunch terminals in 35 locations across the United States
- input time and attendance

We find hand geometry to be less intrusive and the best functioning biometric in a harsh environment.

– Bill Burks, Network Specialist O'Neal Steel

McDonald's

- Handpunch is lovin' it!
- over 3,400 employees at 85 McDonald's restaurants in Venezuela
- about 90 % students
- frequently punching one another in to cover for exams

HandPunch Terminals Eliminate Expensive "Buddy Punching"

Palm print

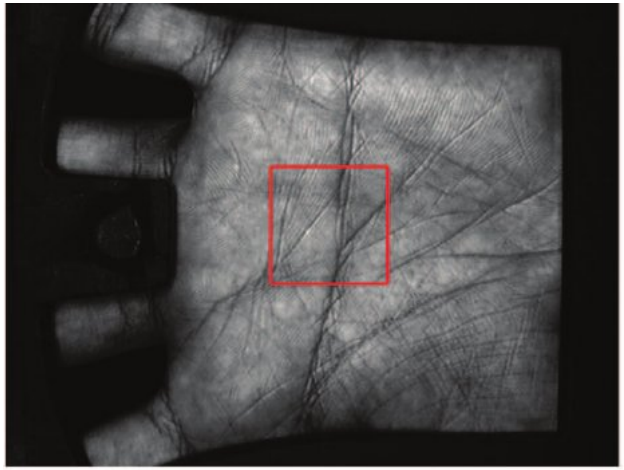
- Definition: What is palm print ?

  Verification of a person's identity by recognizing the pattern of the palm and therefore quite similar to Fingerprint systems.

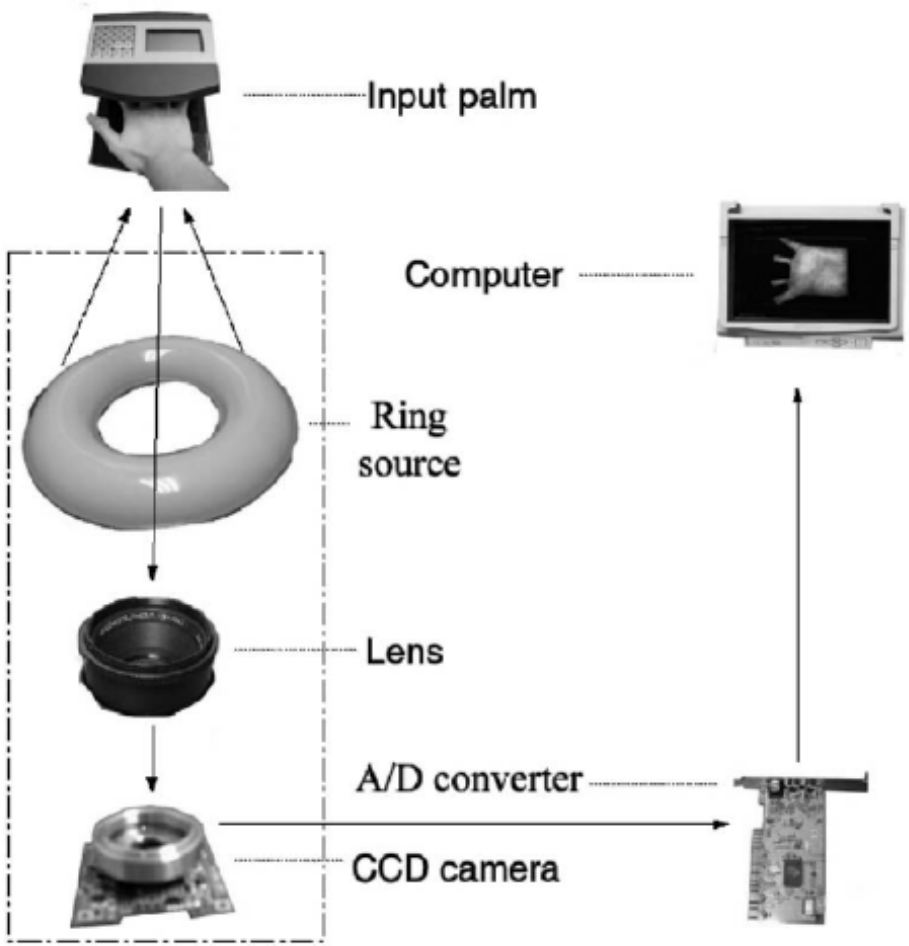
- Procedure
  - Capture picture
  - Feature extraction
  - Preprocessing
  - Palm print matching

Palm print

- measured features
  - Palm print
    - principal lines
    - wrinkels
    - minutiae and singular points
    - texture
- Purpose
  - non high security applications
  - easy, fast identification/verification



Online palmprint identification system



Goals

- Good quality image, short time interval
- types of palmprint features?
- good search properties

Applications of Palm print

- laboratory entrance access control
- British police replaces fingerprint database by an extension with palm print
- Customs
  - Biometric verification, identification
- Construction & manufacturing
  - Time & attendance, identification, shop floor data collection, access control cards and systems, asset tagging.
- Prisons
  - Visitor control, identification, workstation log-on

Palm print in use

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Vein Recognition

- Definition: What is vein recognition ?

  Verification of a person's identity by recognizing the pattern of blood veins in the palm (number of veins, their position and the points at which they cross). The pattern of blood veins in the palm is unique to every individual, and apart from size, this pattern will not vary over the course of a person's lifetime.

- Procedure
  - Infrared Light
  - Subcutaneous Veins black
  - Remaining Palm structure white

A Vein Recognition System

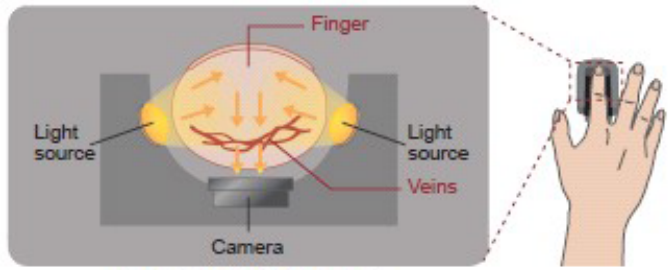
Contactless palm vein recognition unit

Infrared image

Vein and hand contour

Vein Recognition

- Measured objects
  - Palm (combined with palm print)
  - Back of the hand
  - Finger
- Comparision with Fingerprint
  - Security higher (dummy)
  - Bloodflow-Measure
  - Contactless Systems
  - you leave fingerprints everywhere
  - Opposition against fingerprints (criminal)



Cross-section view of finger

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Applications of Vein Recognition

- Japanese banks customer authenticfication at ATM's
- University of Tokyo Hospital for Room access security
- Chiba Institute of Technology (Japan) student ID system
- Hitachi Laptop with vein pattern scanner
- Cashless Catering in America (Smart Card or vein scan)
- To start a car (Hitachi Japan)

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Signature Verification

- Definition

  Signature verification is a behavioral biometric that analyses the way an end user signs his/ her name. The signing features such as speed, velocity and pressure exerted by a hand holding a pen are as important as the static shape of the finished signature.

- Field of application
  - Credit Cards (MasterCard $450 million loss each year)
  - Check Encashment
  - Parcel Services
  - ...

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A Signature Verification System

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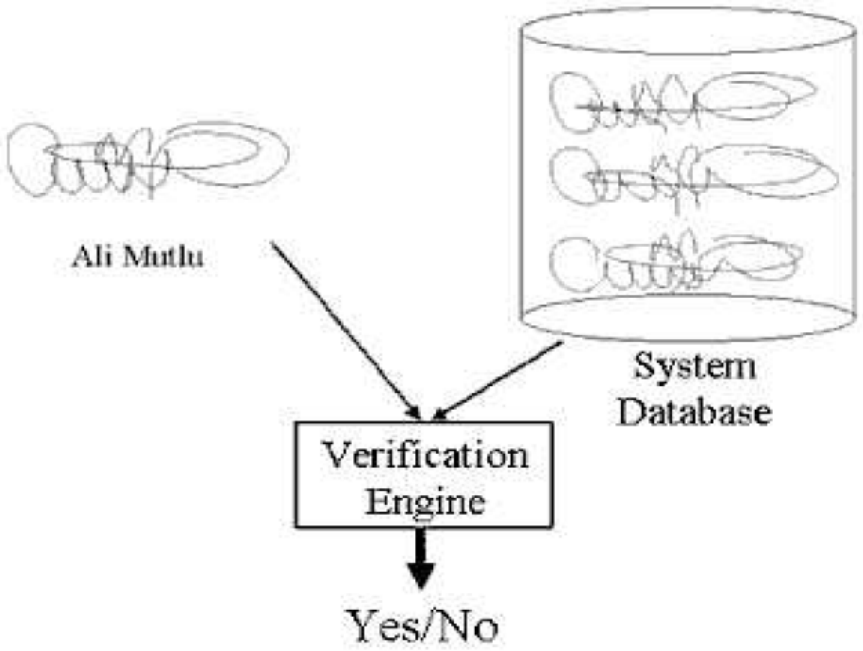
Signature Verification

- Types of Signature Verification Systems
  - Offline (static signature)
    - Hardware: Scanner or Camera
  - Online (dynamic signature)
    - Hardware: Touchpad
- Automatic Signature Verification System



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'Good' Signature Verification System

- Visually similar signatures must be accepted, even if there are
  - discrepancies in velocities
  - minor discrepancies in the shape
- It must be difficult (or better impossible) to forge the signature even if you
  - trace the signature
  - copy the signature
  - practice the signature
  - have complete knowledge of the generation
  - know the strategy used by the verification system
- You must not be able to generate a signature that is visually disperate from your signature and is accepted by the system.

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Classification

	Genuine	**Forgery**
Accepted	True Positive	False Accepted
Rejected	False Rejected	True Negative

- False Acceptance Rate is a Security attribute
- False Rejection Rate is a Comfort attribute (Second Attempt)
- Goal is a low FAR

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Offline Signature Verification

- Genuine Signatures of the same persons slightly vary
- Differences between forgery and genuine signature may be very small
- Other problems:
  - Different pen widths
  - Change in aspect ratio
  - Noise if signature is scanned
- Professional forensic examiners perform at about 70 % signature classification rate

Types of Offline Signature Verification

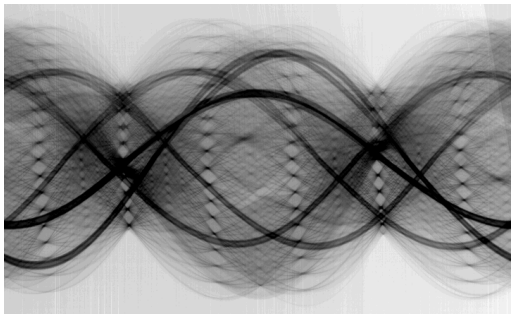
- Random Forgery Detection
  - produced without knowing the signature
  - easy to detect
- Skilled Forgery Detection
  - produced with knowledge of the genuine signature
  - harder to detect

Random Forgery Detection

- Image Based Features
  - Moment Invariants
  - Fourier Desciptors
  - Maximum Likelihood Classifier applied on Features
- Results of the different methods
  - Global image features not sufficient, even for Random Forgery Detection
  - Some systems have problems with Transformations (Scale, Rotation)

Skilled Forgery Detection

- Needs better Algorithms than Random Forgery Detection
- Example: Work with Radon Transformation (used in CT)
  - Comparison of the sinograms
  - tested on 460 genuine, 138 skilled and 138 random forgery signatures
    - 23 % error rate on skilled forgeries
    - 10 % error rate on random forgeries



- Other methods used
  - vertical and horizontal projections
  - 2D-displacement function between signatures

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System example

- System for authentificating bank checks
- Signatures are scanned and classified
- System knows three classes
  - Genuine
  - Forgery
  - Uncertain - need to be checked by a human

Offline Signature Verification System

- Preprocessing
  - Scanner (low noise level)
  - Gaussian Filter
  - Image Morphology
- Feature Extraction
- Signature Dissimilarity Calculation
- Enrollment
- Verification (PCA, Maximum Likelihood, ..)
- Performance Evaluation

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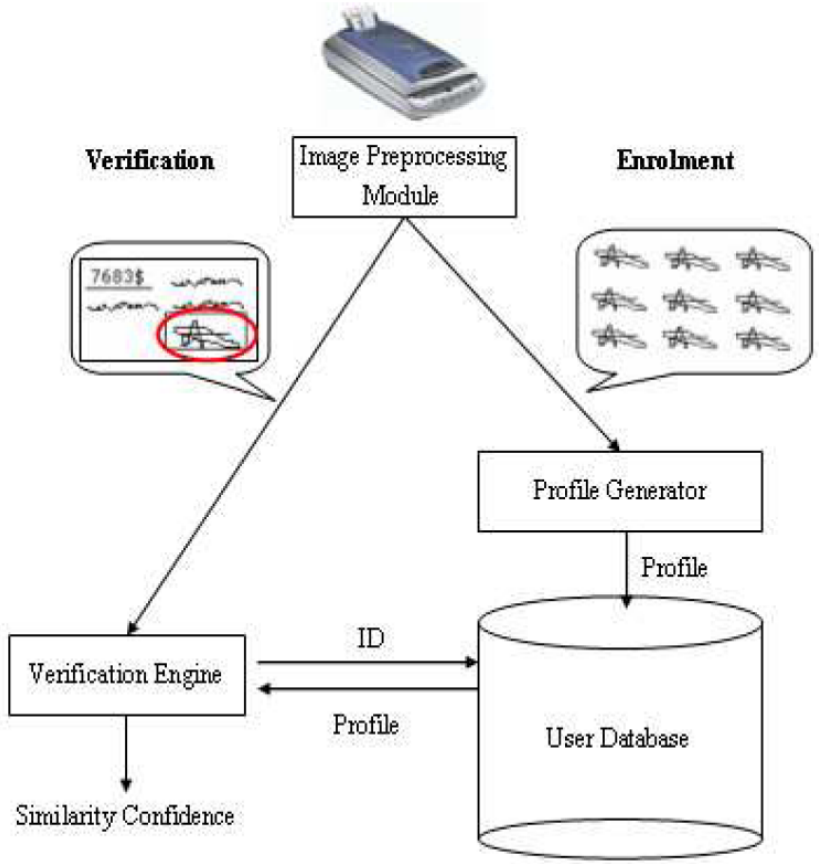
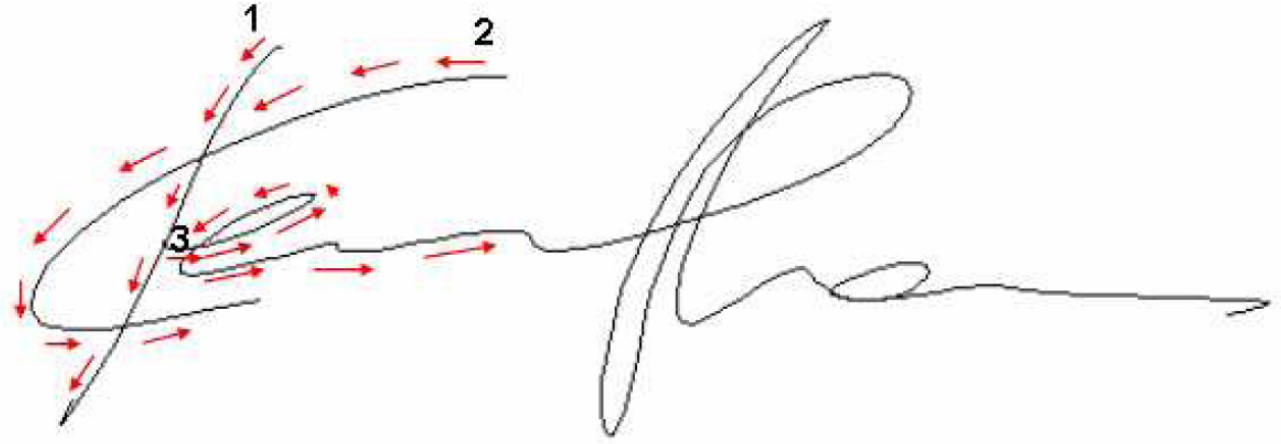
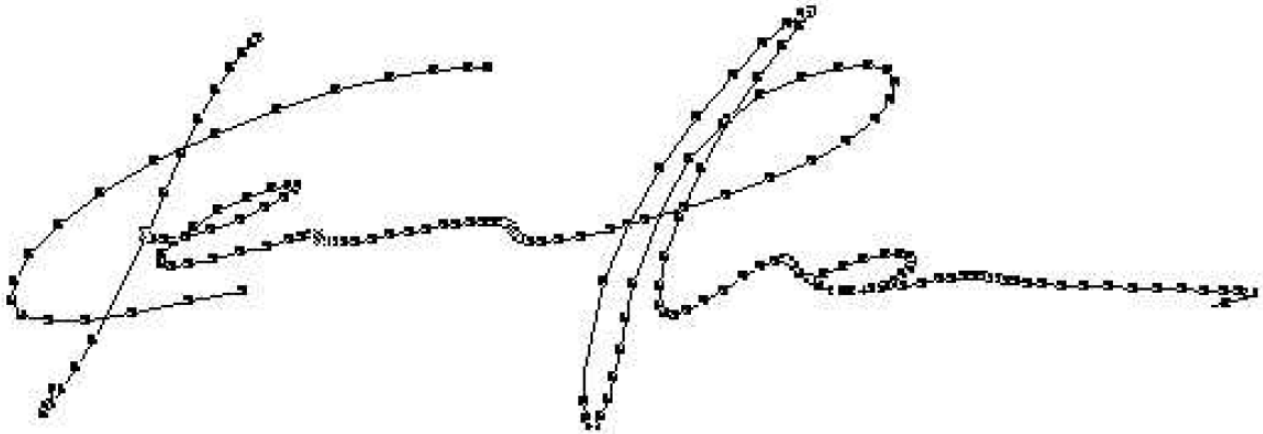
System for Offline Signature Verification



Online Signature Verification





Online Signature Verification

- Functional Approach
  - Signals (speed(t), pressure(t), x(t), y(t),..)
  - Compared point by point
  - Computationally intensive
- Parametric Approach
  - Parameters extracted
  - Comparison of the parameters (e.g. vectors in featurespace)
  - Straightforward computation

Parametric Online Signature Verification

- Seven Parameters extracted from the Signature
  - Total time
  - Number of sign changes in the x and y velocities
  - Number of sign changes in the x and y accelerations
  - Pen-up time
  - Total path length
- Parameters are stored in a matrix
- Reference matrix derivations 3-10 signatures
- Difference vector is used to compare

Results

	Number of Sample Signatures							
	3		5		7		10	
Threshold	FRR	FAR	FRR	FAR	FRR	FAR	FRR	FAR
4	64.2%	1.5%	35.9%	1.8%	22.0%	1.8%	14.3%	2.1%
6	37.8%	2.5%	11.5%	5.8%	6.9%	8.6%	3.2%	8.6%
8	23.7%	6.1%	5.6%	9.8%	3.0%	13.2%	1.0%	13.2%
10	14.0%	8.9%	3.0%	12.9%	0.6%	16.0%	0.0%	18.8%
12	9.6%	13.2%	2.0%	18.5%	0.2%	20.6%	0.0%	23.7%
14	7.4%	16.3%	1.3%	22.8%	0.2%	27.1%	0.0%	27.4%
16	5.2%	19.4%	0.8%	25.9%	0.2%	30.8%	0.0%	32.0%

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Functional Online Signature Verification

- Recommended Paper Nalwa

  The behavioral characteristics of a signature are not as consistent as the shape information.

- Three phases of the algorithm
  - Normalization
  - Desciption
  - Comparison

Normalization

- Extraction of Global Features
  - Aspect ratio
  - Jitter
  - Number of strokes
- Fitting Polygon through sample points
- Normalization of the polygon
  - Rotation
  - Aspect ratio

Description Phase

- Five characteristic functions
  - x and y coordinates relative to the center of mass
  - Torque[1]
  - Two curvature-ellipse measures derived from moments of inertia[2]
- Characteristic functions warped against prototypes
- Alignment Cost as Global Feature

[1] dt. Drehmoment
[2] dt. Massenträgheit

Comparison Phase

- Four Global Features
  - Aspect ratio
  - Jitter
  - Number of strokes
  - Alignment Cost
- Dissimililarity Measure as weighted harmonic mean
- With 6 Reference Signatures Error Rate 2-5 %

Other Methods used for Online Signature Verification

- Dynamic Time Warping DTW
- Mixtures of Offline and Online Verification
- Using Local and Global Features
  - coordinate differences between two consecutive points
  - Curvature
  - Gray values in 9x9 neighborhood
  - Absolute and relative speeds
  - Number of signature strokes

Results

- Online Signature Verification
  - Theory: very hard to forge a signature
  - Practice: hard to determine between genuine and forgery
  - Error Rates: 1-10 % (depending on random or skilled forgery)
- Offline Signature Verification
  - difficult for human specialists (30% error rate)
  - Error Rates: 5-40 % (depending on random or skilled forgery)
- Great losses caused by forgery for banks

References

- **R.Sanchez-Reillo, C.Sanchez-Avila, and A.Gonzales-Marcos:** *Biometric identification through hand geometry measurements*; IEEE 2000
- **D.Zhang, W.-K.Kong, J.You, and M.Wong**: *Online palmprint identification*; IEEE 2003
- **R.L.Zunkel**: *Hand geometry based verification*; Boston, 1999

References

- **H. Dullink et. al.** *Implementing a DSP Kernel for Online Dynamic Handwritten Signature Verification Using the TMS320 DSP Family*
- **Alisher A. Kholmatov** *Biometric Identity Verification Using On-Line & Off-Line Signature Verification*
- **Vishvjit S. Nalwa** *Automatic on-line signature verification*
- **Hao Feng** *Online signature verification using a new extreme points warping techniqueh*

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