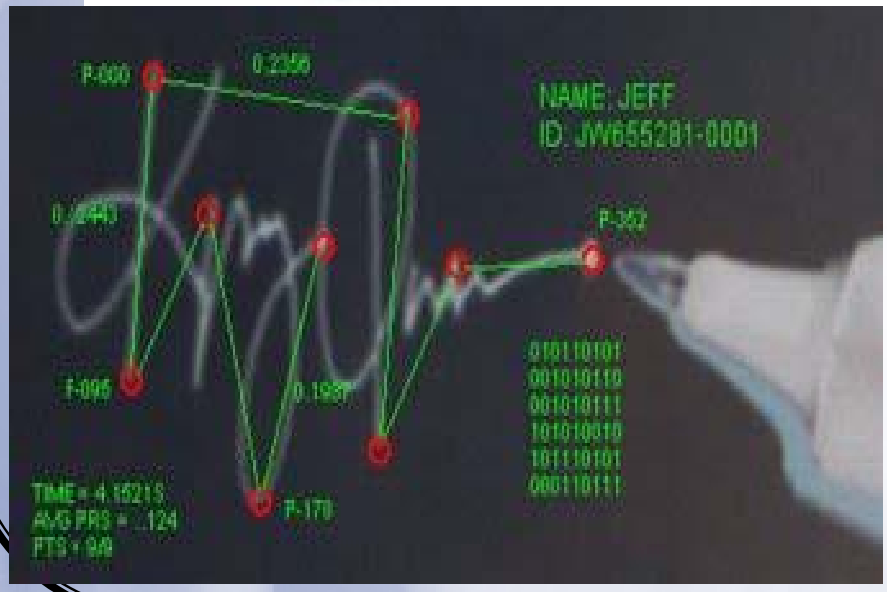
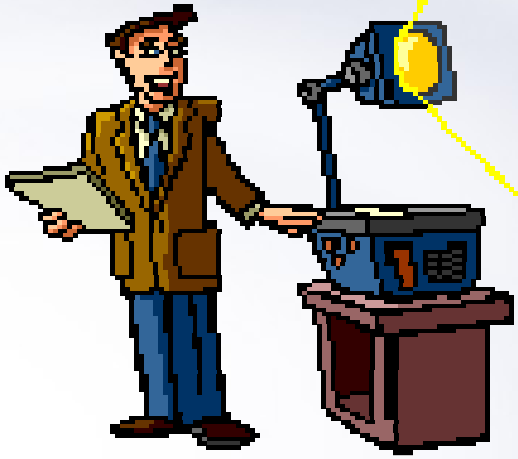
Biometric Authentication

Lecture 10

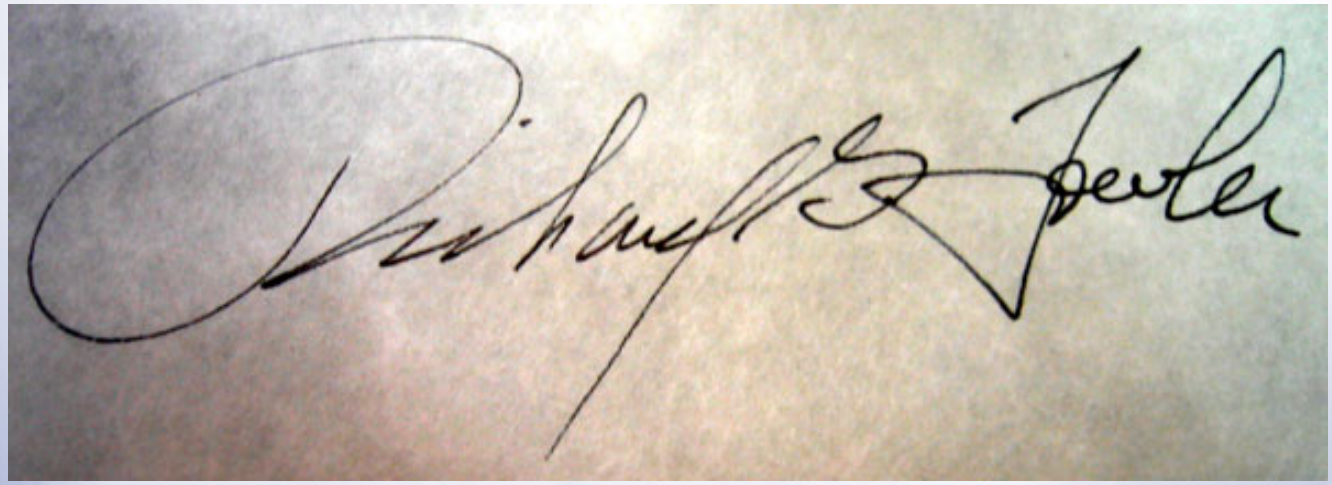


Behavioral Biometric: Signature

Outline



- Introduction
- Offline Signature
- Online Signature



Signature Recognition

Signature

Signature

❑ Current State

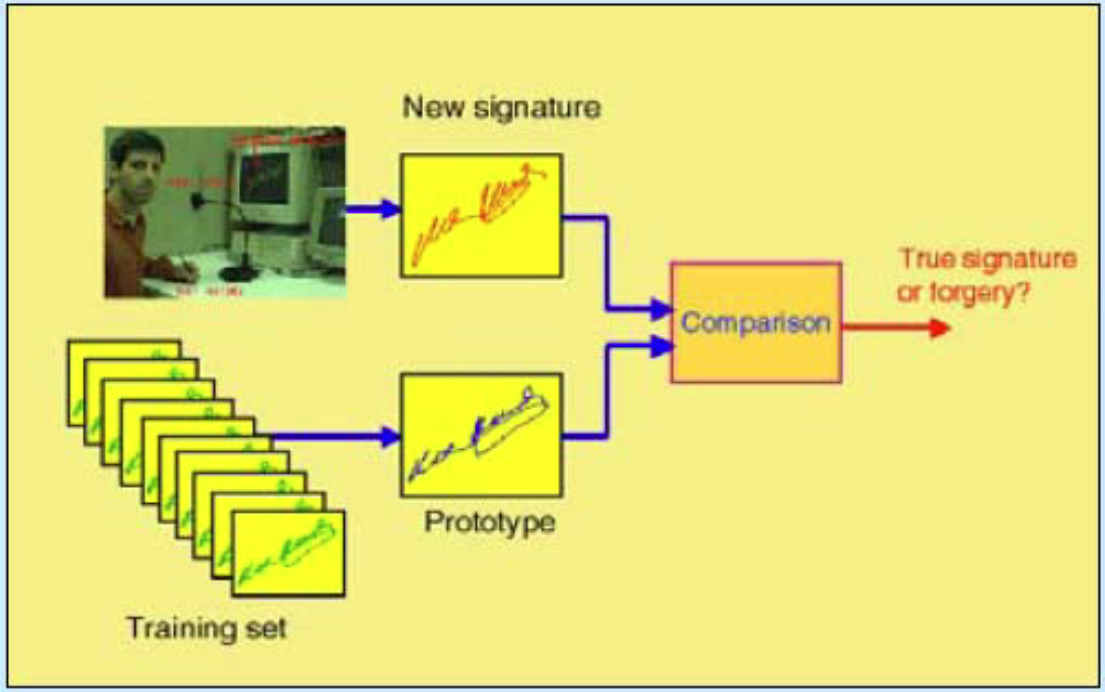
- ↖ Analyzes the way a user signs his/her name to measures the physical activity of signing.
- ↖ It should distinguish between person's habitual parts and those that vary with almost every signing.
- ↖ Two methods: **on-line** & **off-line**, where **wired pens** & **sensitive tables** are needed for on-line signature.

❑ Feature Set

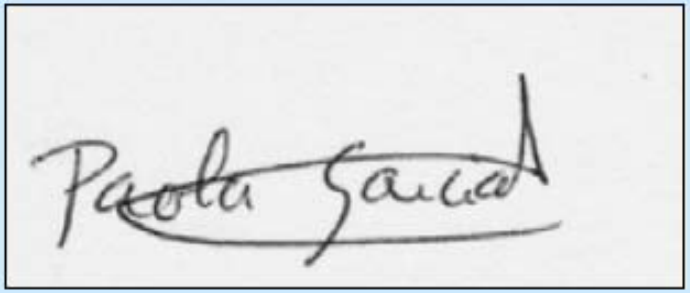
Behavioral components of the signature, such as shape, velocity, stroke order, off-tablet motion, pen pressure and timing information captured during the act of signing, etc.

Signature and Handwriting

- Different from handwriting recognition ...



Signature Recognition (Verification)

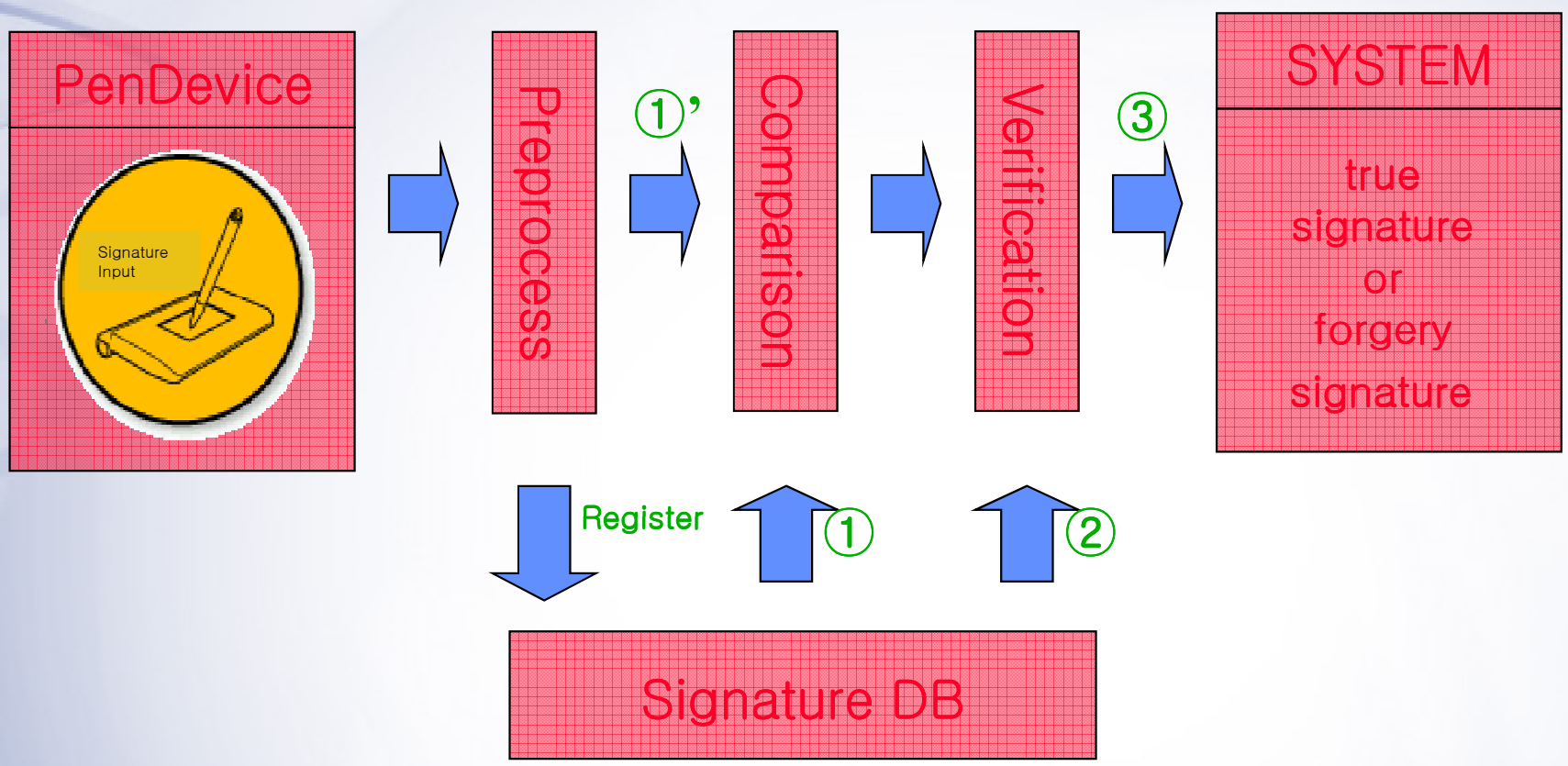


Paola Garcia

Handwriting Recognition

... but similiar features and matching techniques.

System Overview



①' Input Signature Feature

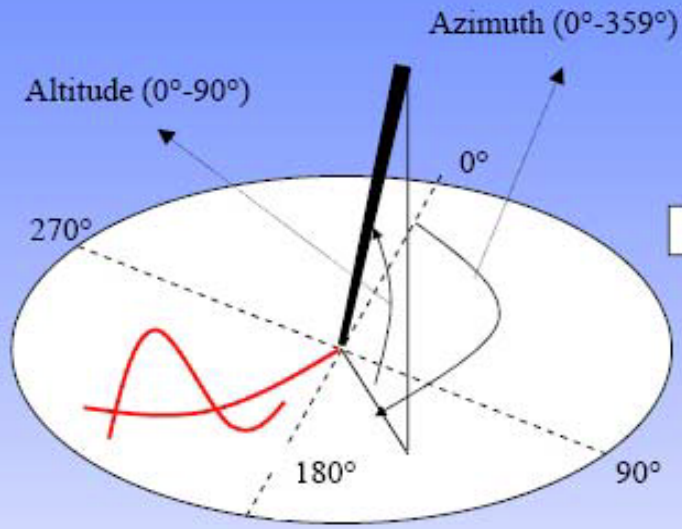
① Standard Signature Feature

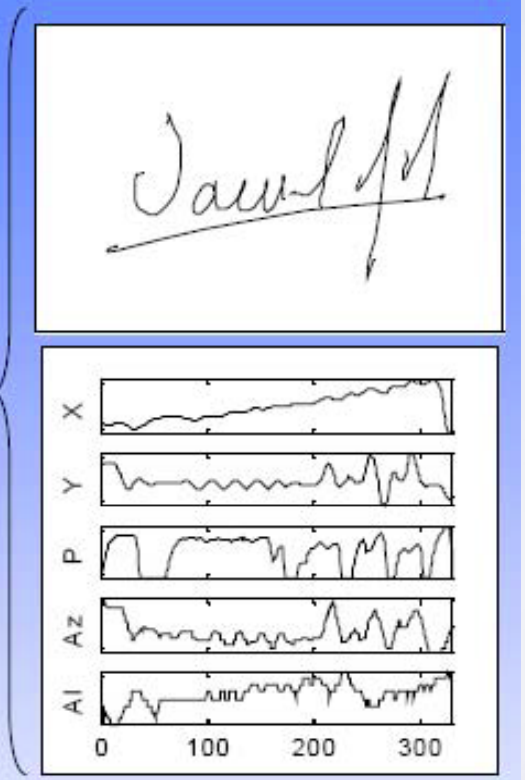
② Decision critical point of Standard Feature

③ Similarity of Input/Standard Signature

Offline & Online Signature

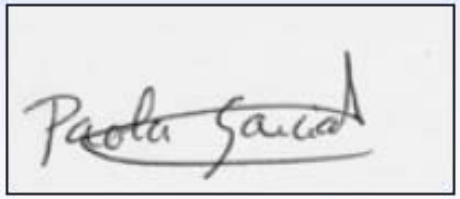
- On-Line:





- Off-Line

SCANNER

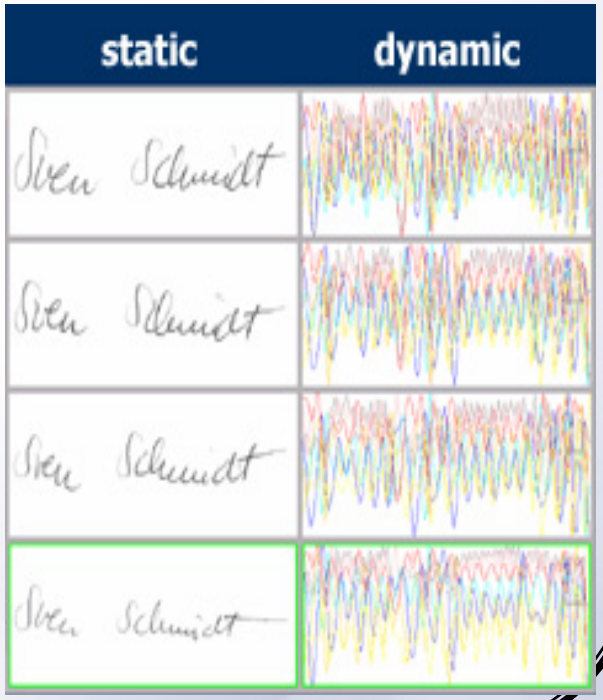


Signature Recognition

- Two approaches:
  - Offline (static)
  - Online (dynamic)

- Offline signature verification:
  - Input: image
  - Features: Shape of the signature
    - line densities, loops, upstrokes, types of arches, enclosed areas etc

- Online signature verification
  - Input: Sign on pressure-sensitive tablets
  - Features: Time element & shape
    - speed, acceleration, pressure, x/y location, pen tilt etc.



Offline Signature Verification

- System processes:
  - Data acquisition
  - Feature extraction
  - Image processing
  - Dissimilarity calculation

Stage 1: Image Acquisition

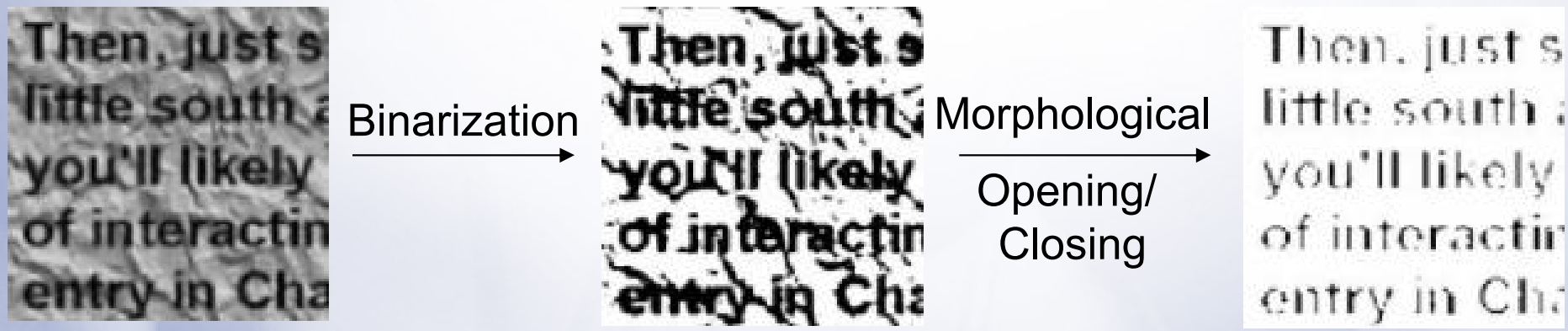
- Signature is signed on paper & input to system by scanner

Stage 2: Image Processing

- Noises are introduced during scanning, so this stage removes noise to improve system performance
  - Size normalization
  - Smoothing

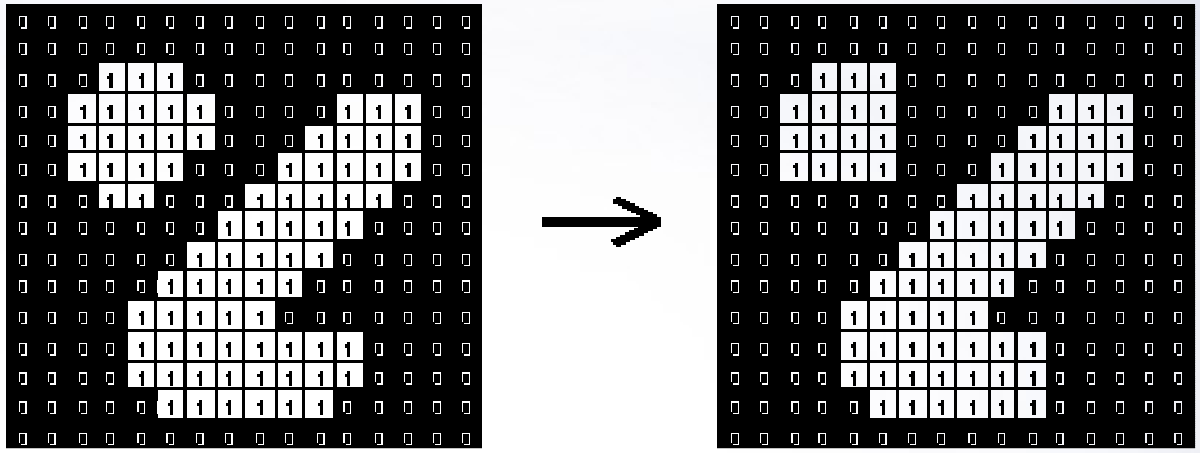
Smoothing (Image Preprocessing)

- The scanned image quality is depends on the scanner and the paper type
- Smoothing by Gaussian filter can remove normally distributed noise
- The smoothed image is then converted to B/W image
- Noises from background are created during conversion
- Morphological opening and closing operator can be used to remove these noises

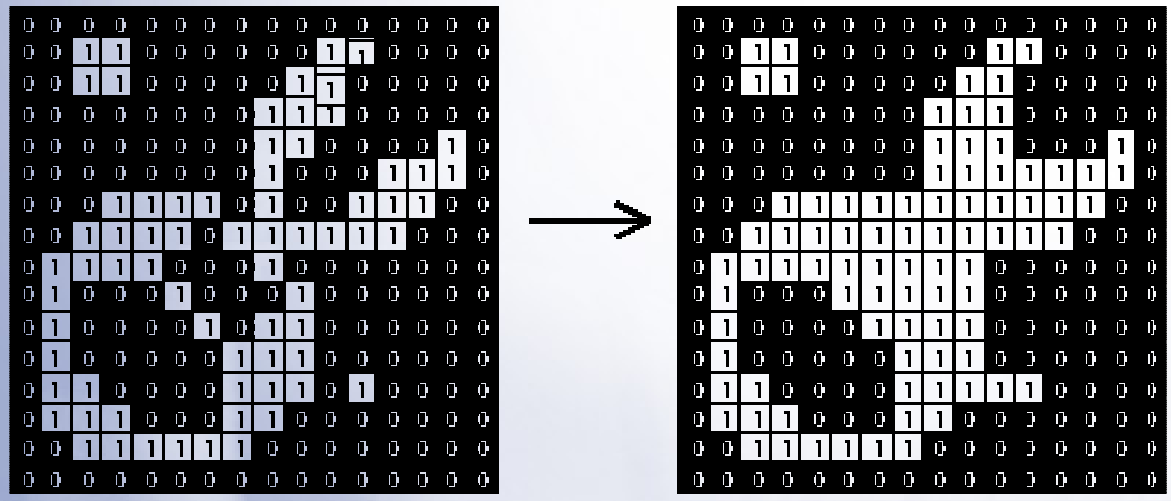


Smoothing (Image Preprocessing)

Opening operator: removes some of the foreground bright pixels from the edges of regions of foreground pixels



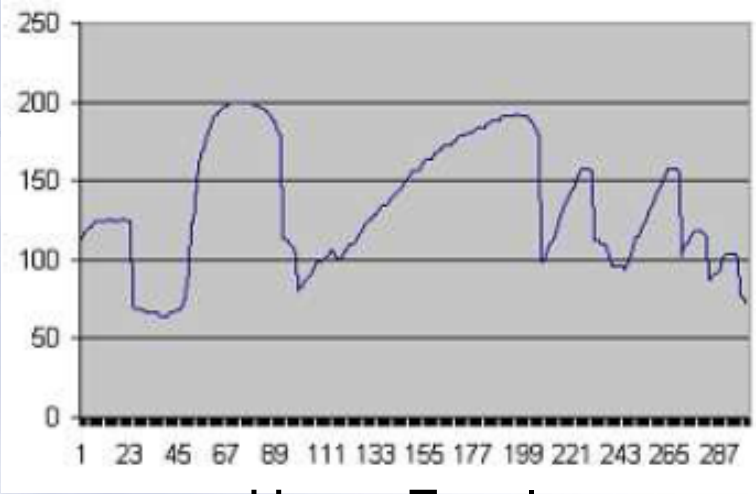
Close operator enlarge the boundaries of foreground regions in an image and shrink background color holes in such region



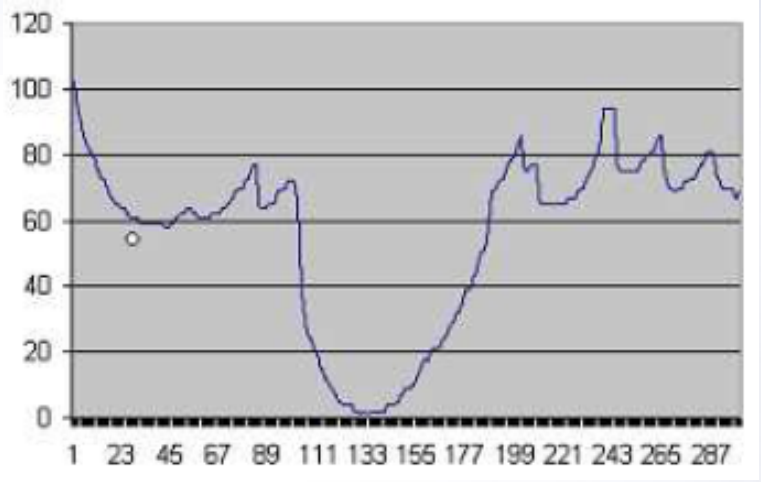
Stage 3: Feature Extraction

- The features extracted from signature image includes: the **upper** and **lower** envelop, and the vertical and horizontal projection
- Upper and lower envelop: the curve connecting the most up or low pixel of the signature trajectory
- Vertical and horizontal projection: the counting of black pixel per horizontal (or vertical) lines.

Upper and Lower Envelop

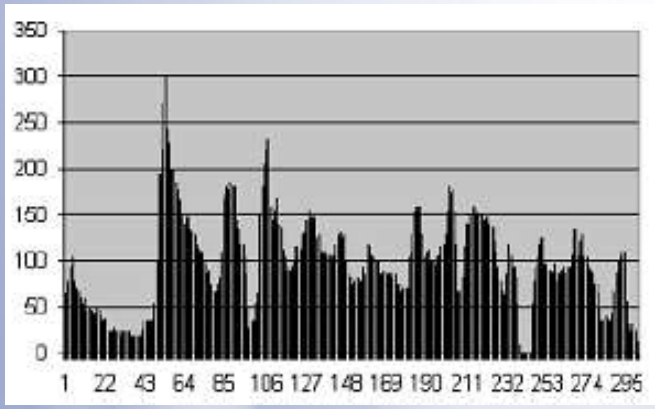


Upper Envelop

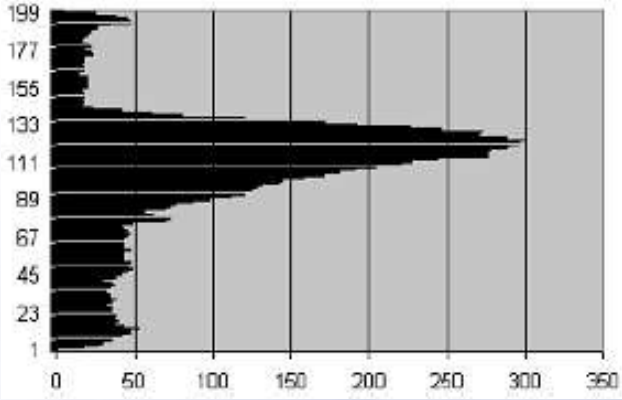


Lower Envelop

Vertical and Horizontal Projection



Horizontal Projection Profile

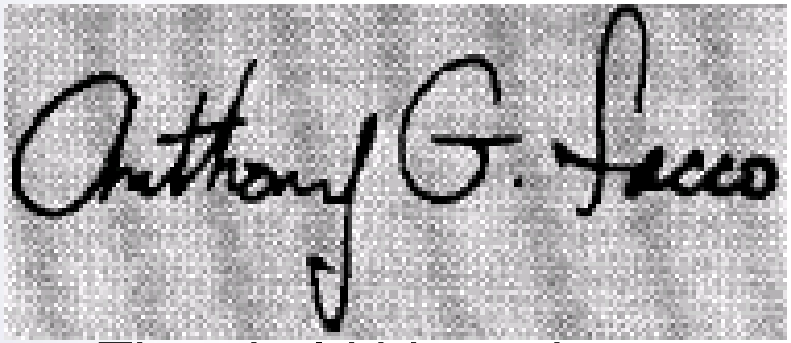


Vertical Projection Profile

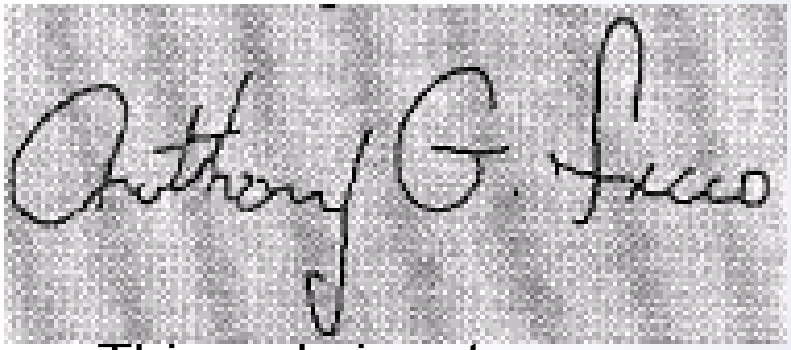
System Description

(a) A Query Image

(b) Preprocessing

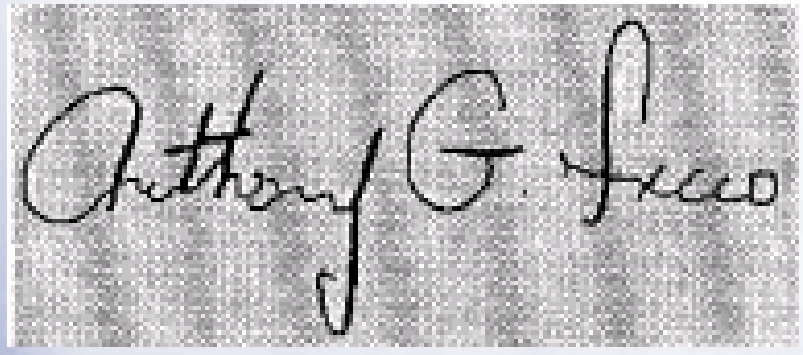


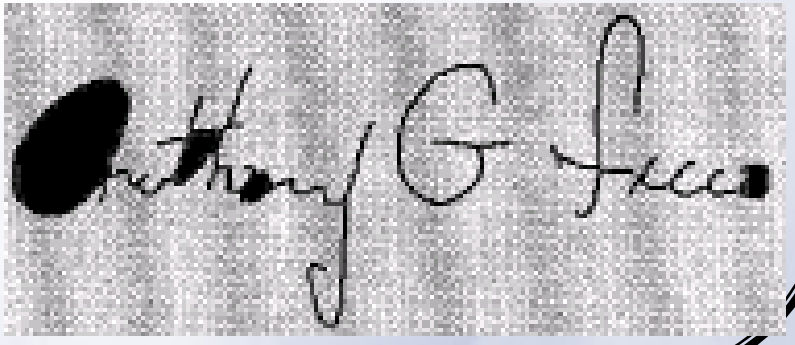
Threshold binary image



Thinned signature

(c) Geometric Features (horizontal/vertical bars and loops)

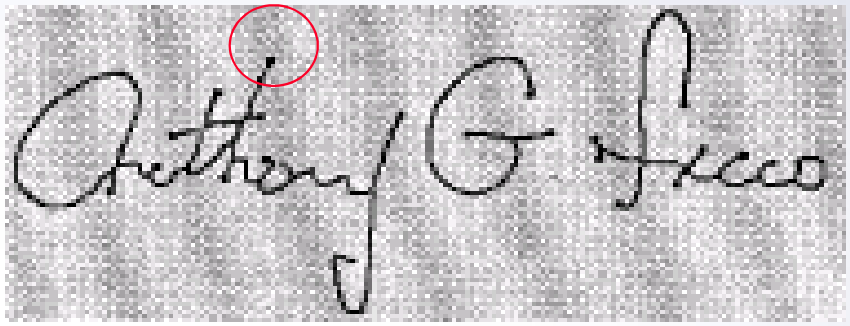


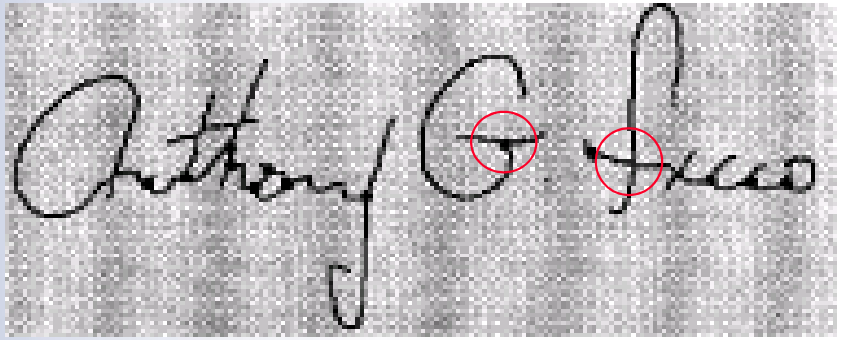


System Description (2)

(d) Topological Feature

End points

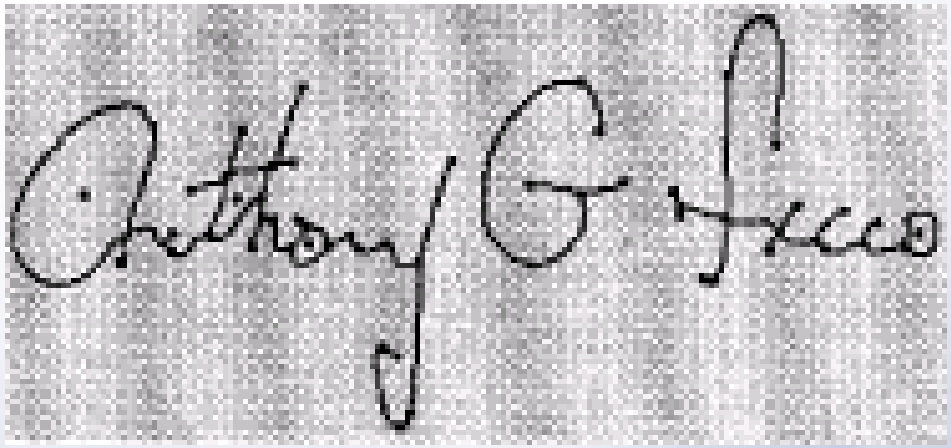




Branch points/Crossing points

Concave/Convex

(e) Features Map



Summary

Public acceptance

- Have been used as identification method for long time
- People accustomed to provide signatures during customer interaction

Difficult to forge

- Behavioral characteristics are generally difficult to forge ⇨ Low FAR
- Offline system can still be forged by skilled professionals, but online system is almost impossible

Noise affecting system performance

- Many noises introduce during data acquisition
- Preprocessing remove some important feature together with noise ⇨ affecting feature extraction

Inconsistent signature of a genuine

- Human behavioral characteristics change from time to time
- Not enough features remain in test signature to be comparable to the template ⇨ High FRR

Online Signature Verification

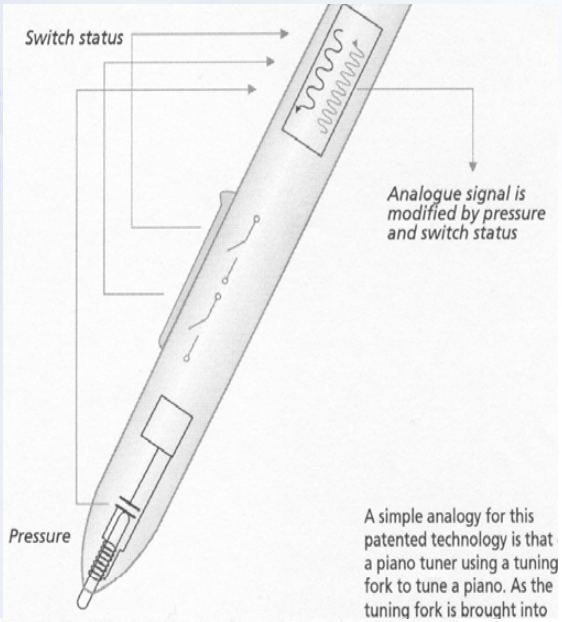
- Online signature verification take into account both *shape* and *time element* of the signature, where time elements: speed, acceleration, pressure, x/y location, pen tilt etc.
- System processes:
  - Data acquisition
  - Feature extraction
  - Image processing
  - Dissimilarity calculation

Stage 1: Data Acquisition

- Capture signature into the system.
- Hardware:
  - Digital tablet
  - Digital pens
  - Smart pens
- Device suitability:
  - Size of active area of a pad
  - Resolution
  - Pressure sensitivity level
  - Sampling rate

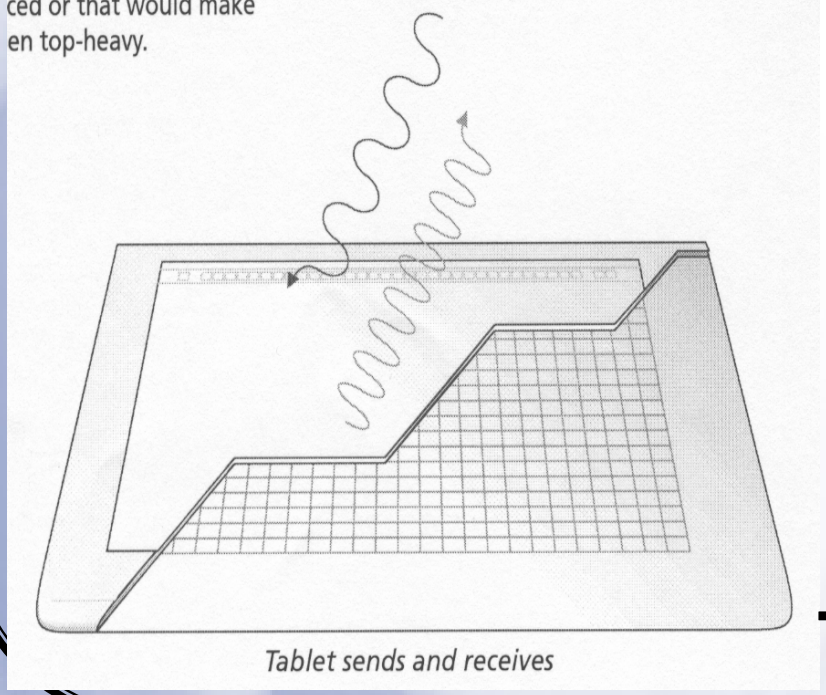
Various Signature Devices

Pen (Stylus)



A simple analogy for this patented technology is that a piano tuner using a tuning fork to tune a piano. As the tuning fork is brought into

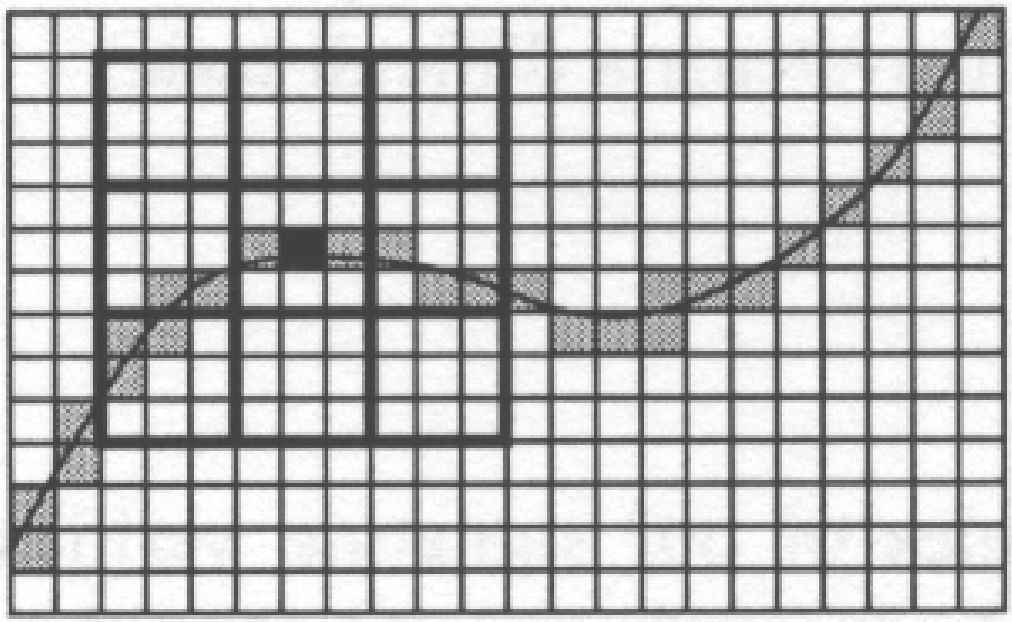
ced or that would make
en top-heavy.



Tablet

Stage 2: Image Preprocessing

- Noises are introduced during data acquisition. Image preprocessing removes these noises to improve system performance.
- Preprocessing:
  - Smoothing
  - Segmentation
  - Re-sampling



Smoothing

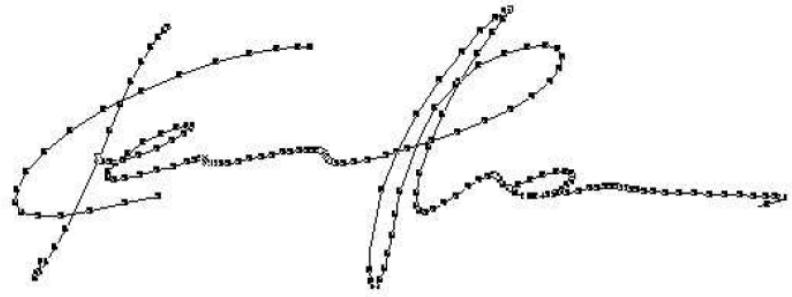
- The input signal from a digitizing pen can be very jagged.
- Jagged effect affects the feature extraction.
- Smoothing to remove the jagged effect.

Segmentation (Image preprocessing)

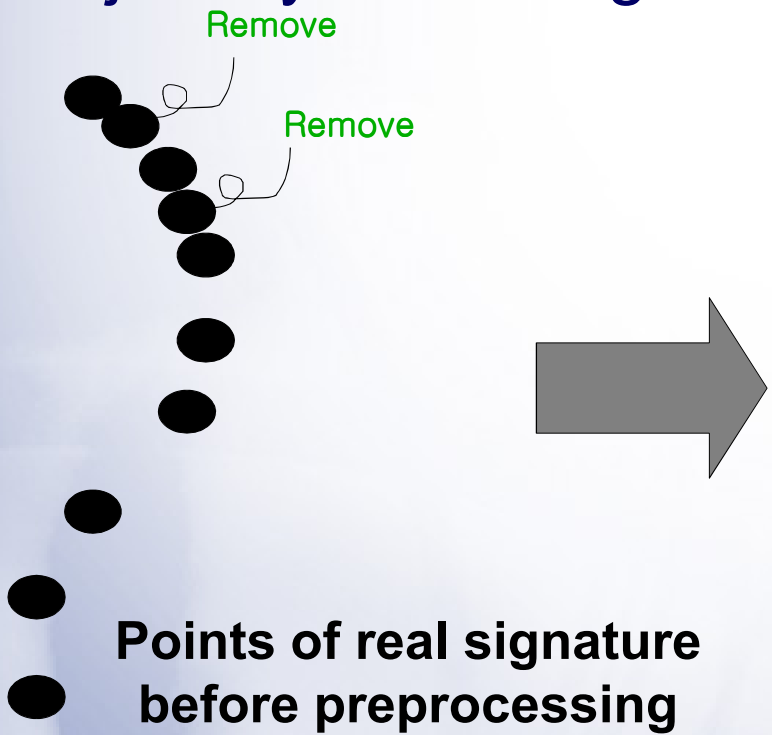
- **Segmentation:** Determination of the beginning and ending of signing.
- Signature beginning: First sample where pressure information is not null (first pen-down).
- Signature ending: Last pen-up. Because few pen-ups can be found in the signature, we have to establish a maximum pen-up duration.

Re-sampling (Image preprocessing)

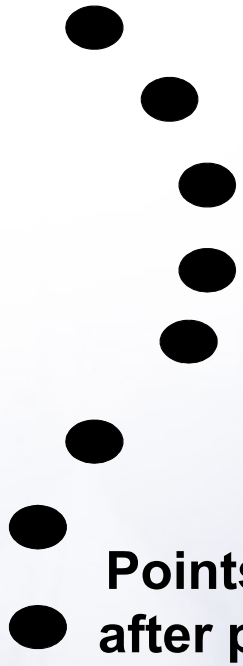
- Input device with high sampling rate ⇨ some sample points mark the same trajectory.
- Redundant point make comparisons slow ⇨ re-sample the input to obtain a trajectory consisting of equidistant points.



Sampling poinst

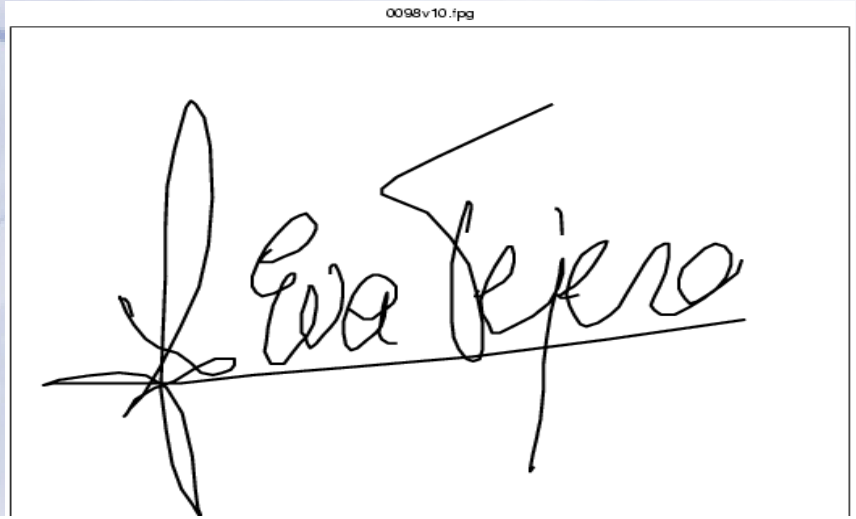


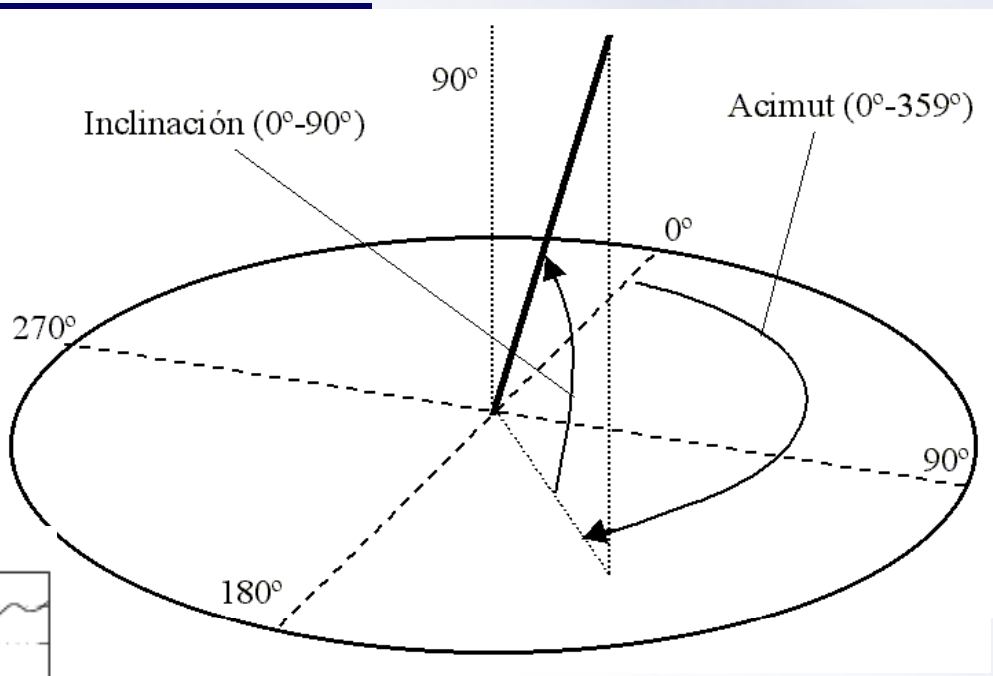
Points of real signature before preprocessing

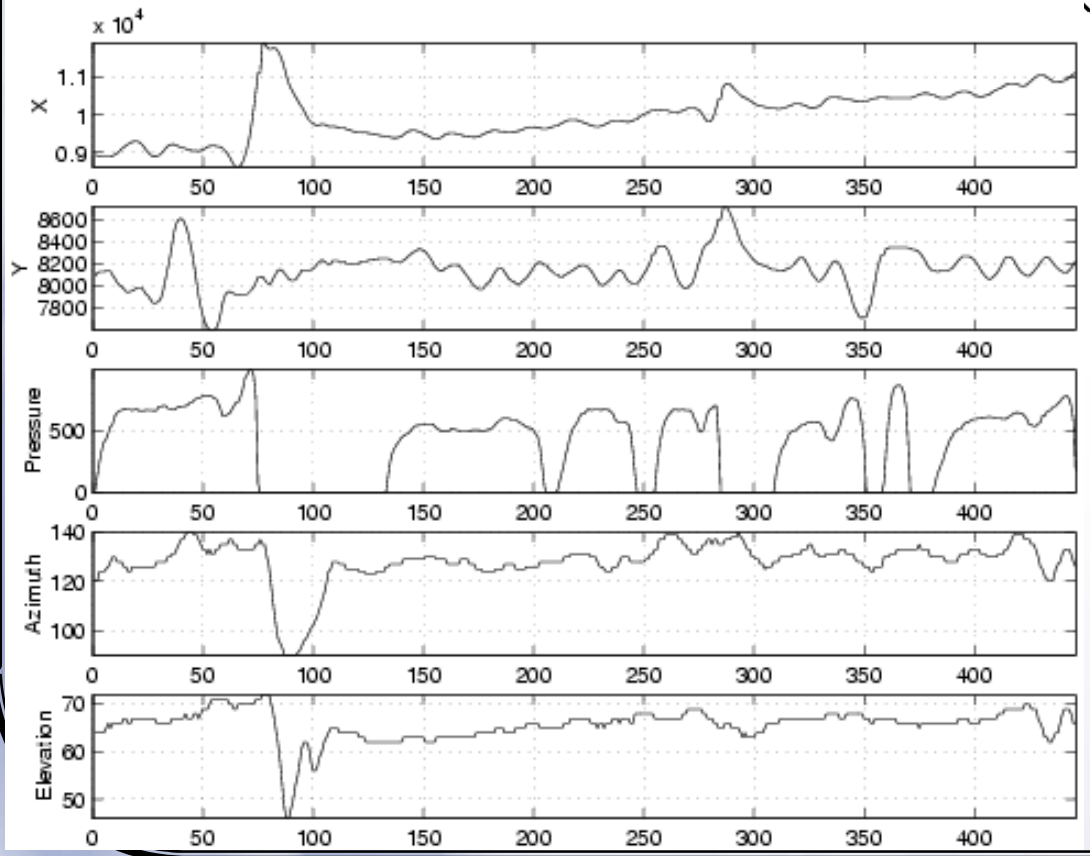


Points of signature after preprocessing

Stage 3: Feature Extraction



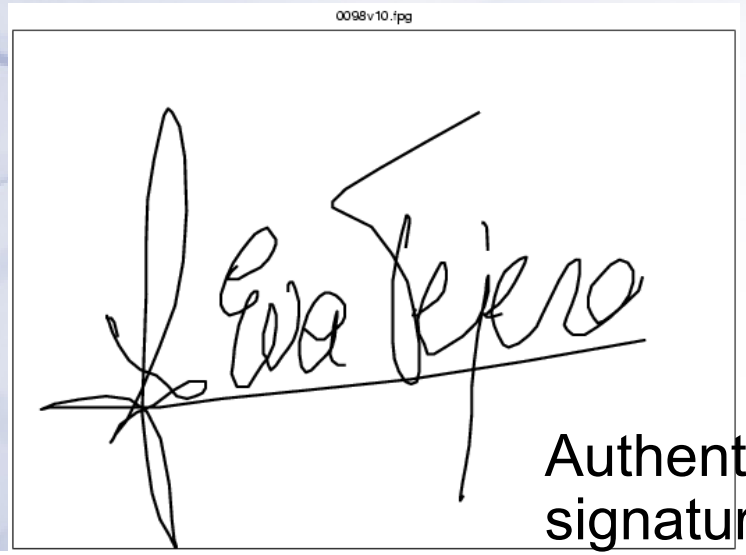




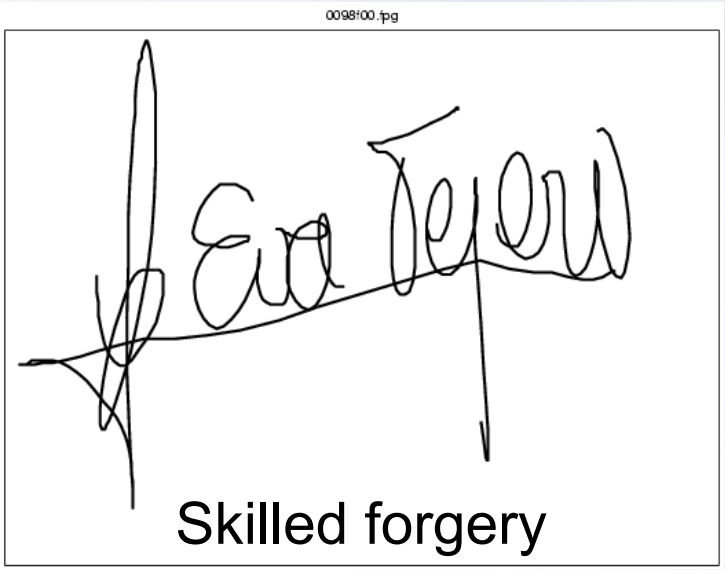
Dynamic Features:

1. Coordinate X
2. Coordinate Y
3. Pressure
4. Penazimuth(0° -359°)
5. Penaltitude (0º-90°)

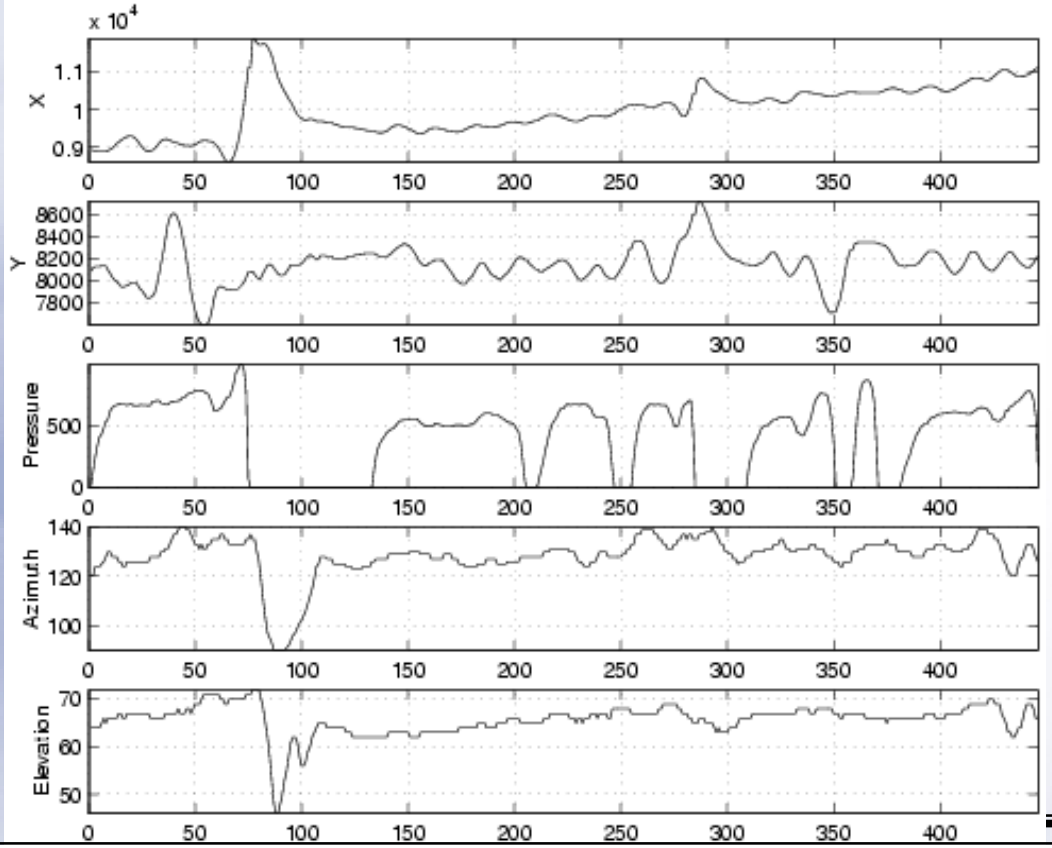
Comparison: Authentic & Skilled Forgery

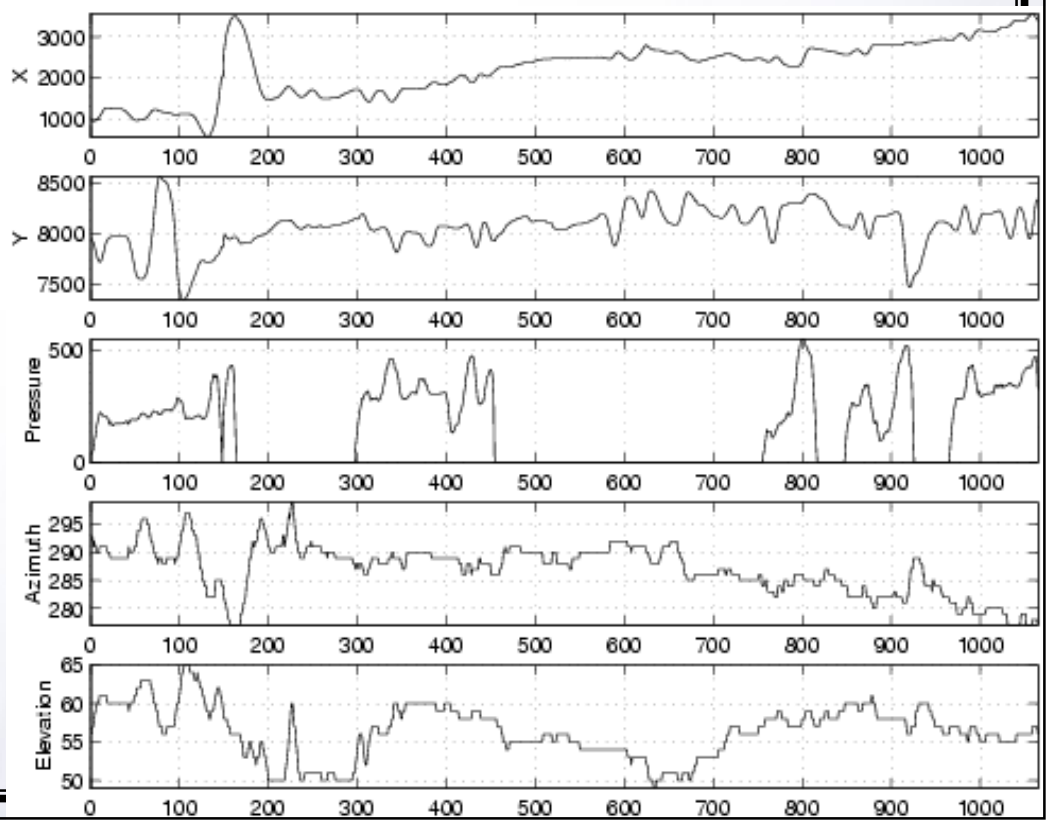


Authentic signature

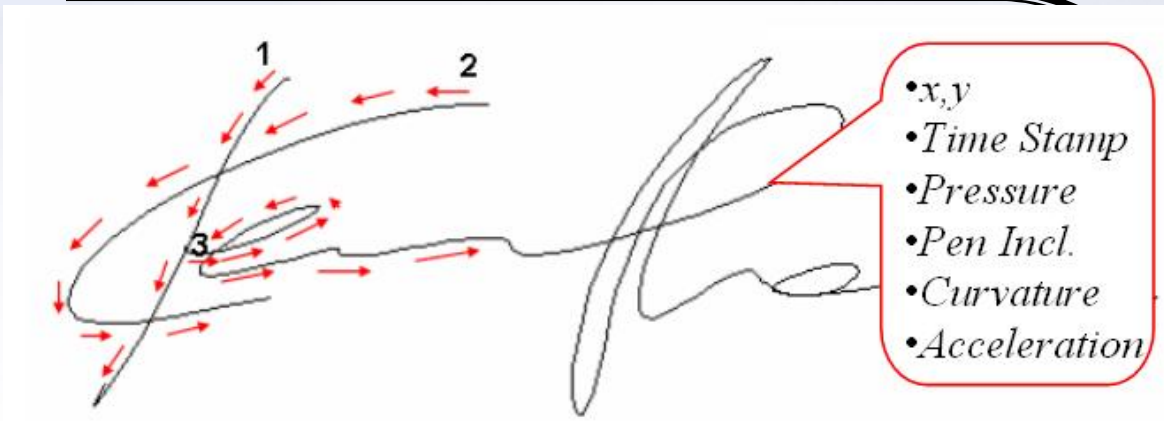


Skilled forgery





Features Analysis

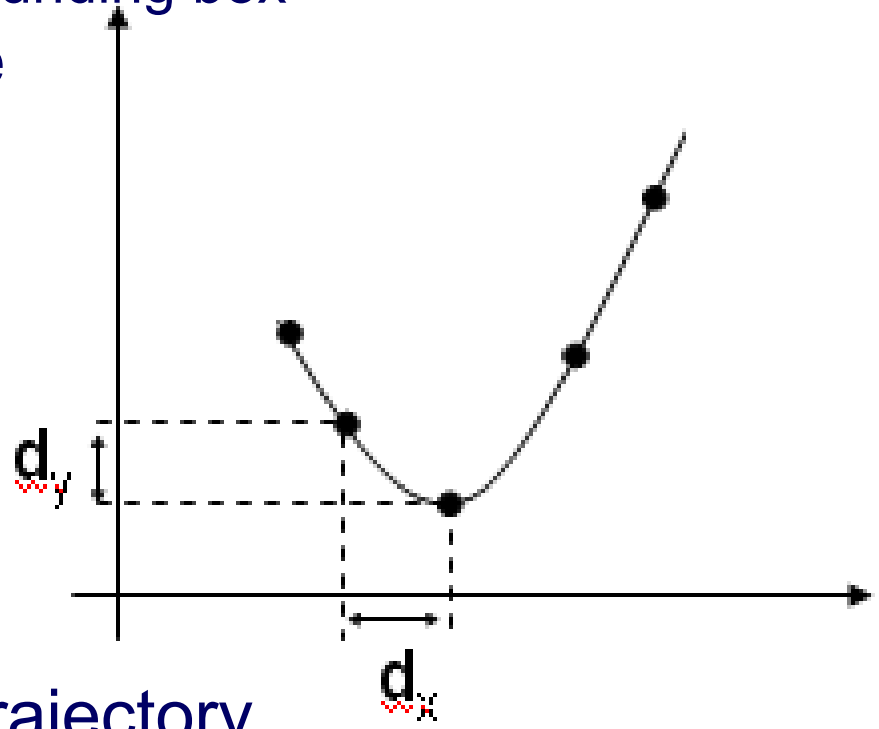


Global Feature

- Features refer to the signature as a whole
  e.g. signing speed, signature bounding box
- Easy to extract and compute
- Lack discriminative power

Local Feature

- Features refer to specific sample point along the trajectory of signature
- *x* and *y* offsets relative to the first point on the signature trajectory



- *x* and *y* coordinate difference between two points
- Curvature differences between two points

Feature Points

- Speed, velocity, pressure information
- Shape, vector, angle, skew information
- Pen up time for each strokes
- Pen down time for each strokes
- Signature size
- Pen down information
- Pen up information
- Cross points
- Total elapsed time
- Number of strokes
- Number of points

- Feature points of individual signature (Dynamic information):
  - Shape, writing speed, pressure, angle, sequence,
  - Number of stroke, pen up, pen down, etc.
- Decision ➔ True Signature, Forgery Signature

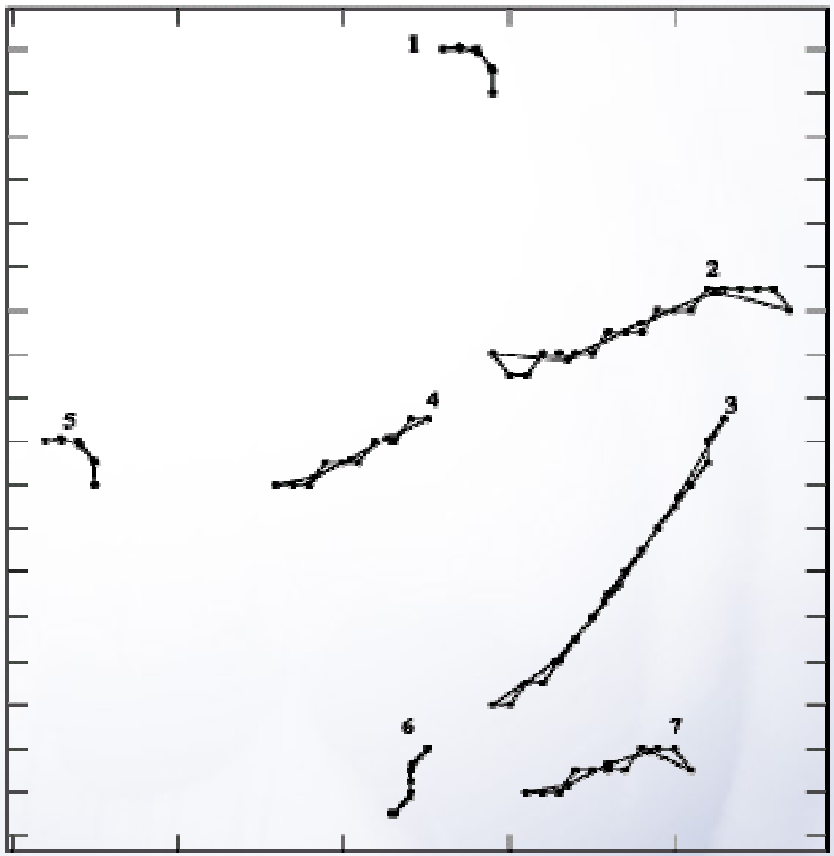
Directional Frontier Feature (DF)

- DF is a directional grouping of the contour pixels

Pixel labeling

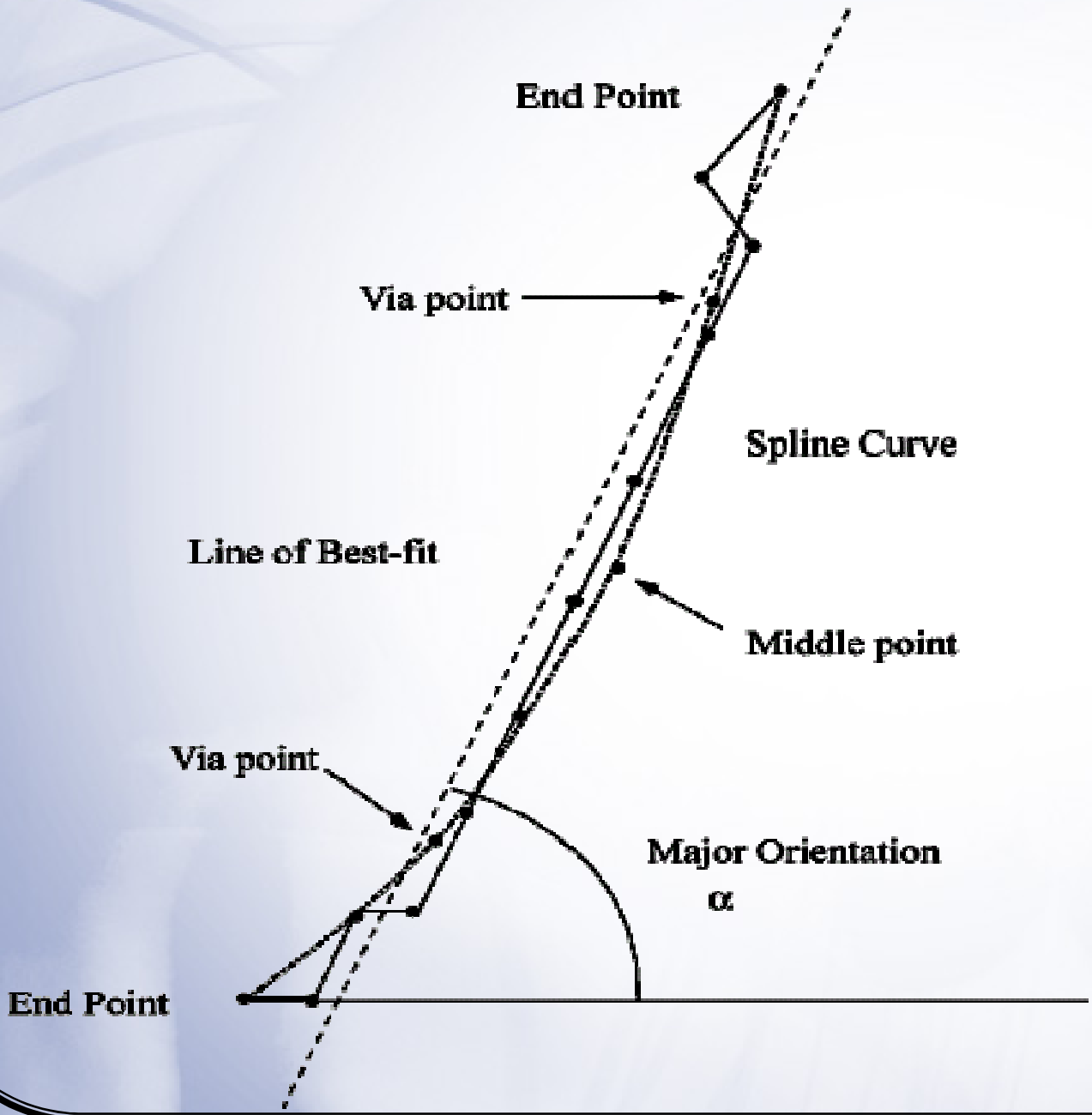
(a)

Curve tracing



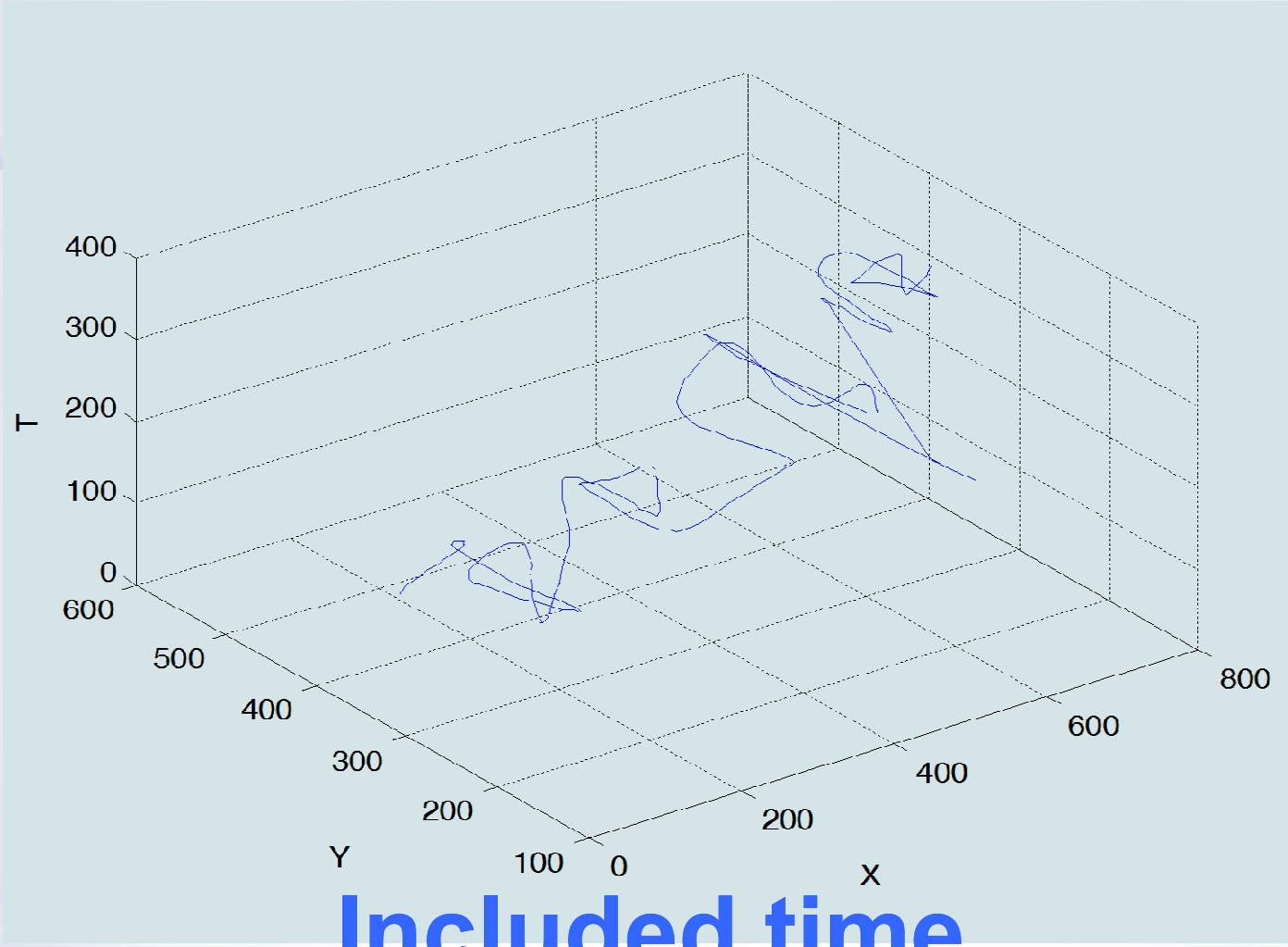
(b)

DF Curve Characterization



- End Point
- Via point
- Middle point

- Spline Curve
- Line of Best-fit
- Major Orientation



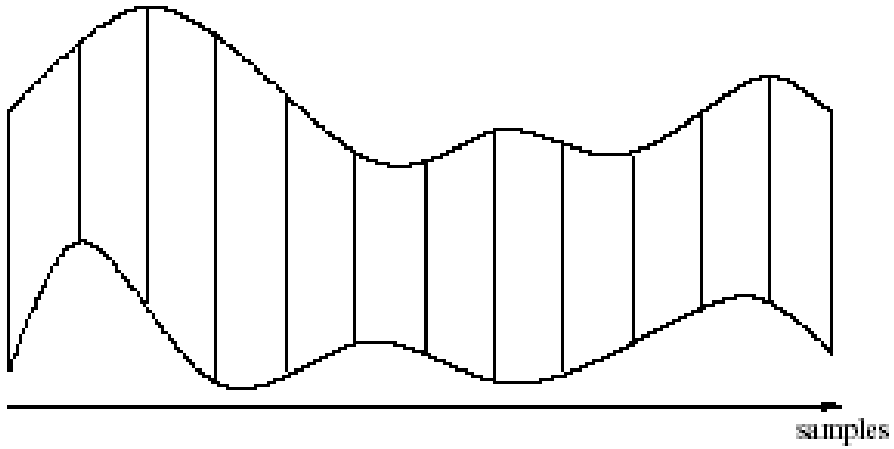
Included time information, an original signature shown in 3-D

Stage 4: Dissimilarity Calculation

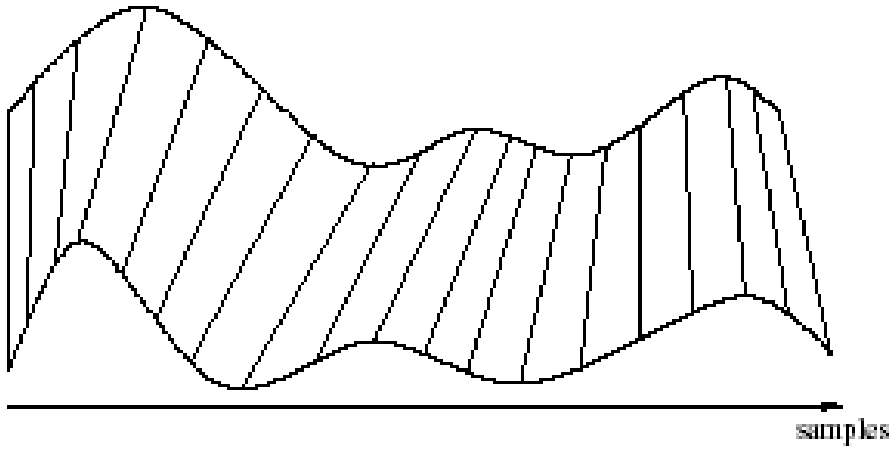
- After feature extraction, signature is represented by the feature vector.
- Signature dissimilarity is calculated by comparing two signatures based on the **vector representation**
- Feature vectors:
  - Vector may of different length due to the changing signing behavior of genuine user
  - Time dependent
- Dynamic Time Warping (DTW) Algorithm is suitable for this kind of vector calculation, which solves the discrepancy and calculated matching distance by recovering optimal alignments between sample points in the two time series.

Dynamic Time Warping (DTW) Algorithm

- Dynamic Time Warping (DTW) Algorithm: recovering optimal alignment



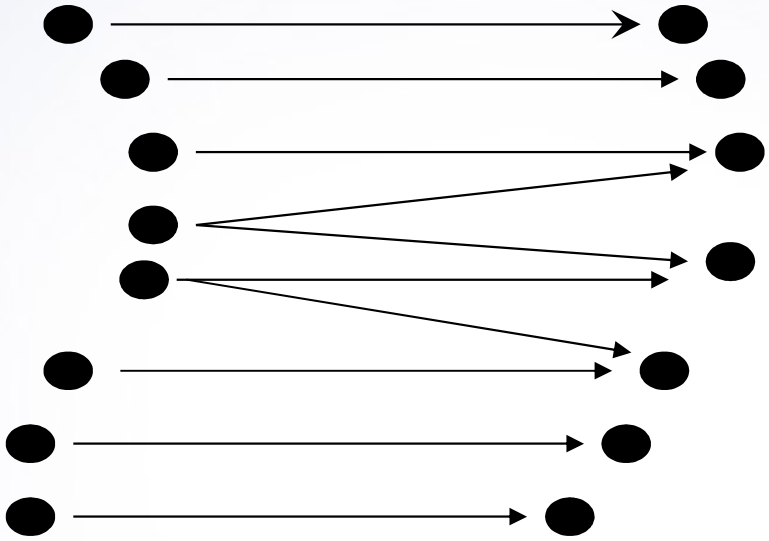
(a) naive alignment after resampling,



(b) alignment with DTW.

- After finding the most suitable alignment between the test and reference signatures, they are compared and the overall distance is calculated

Comparing with Two Signature



Signature A Signature B

Matching

Signature A = A1, A2, A3, . . ., An

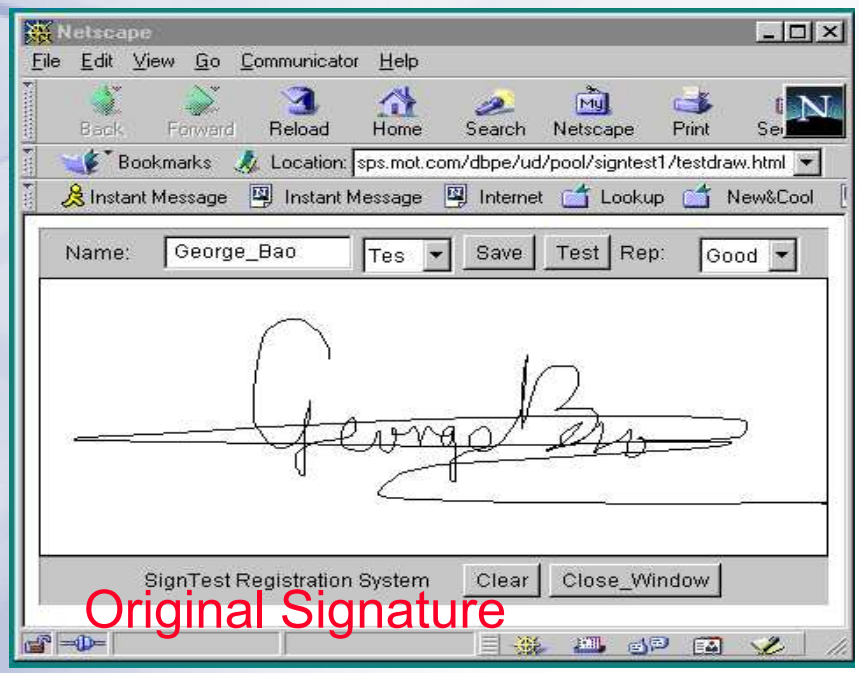
(Feature information of signature A)

Signature B = B1, B2, B3, . . ., Bm

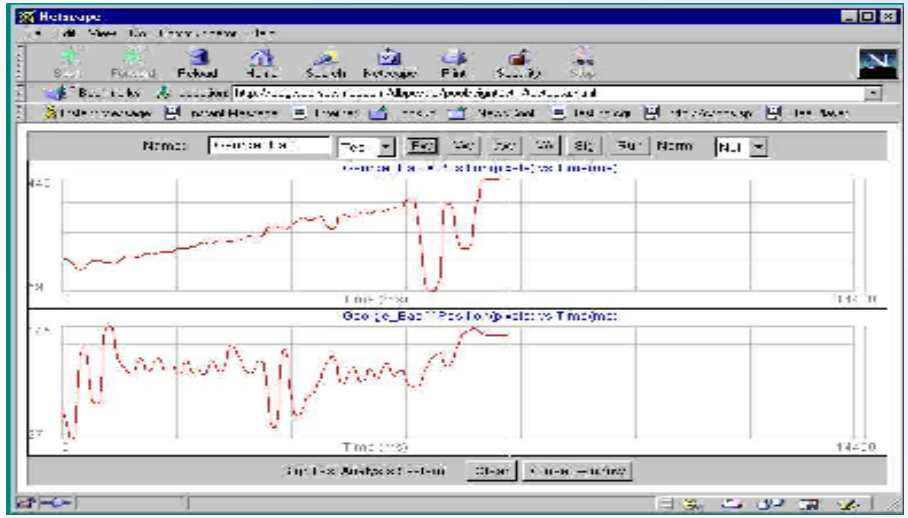
(Feature information of signature B)

On-Line Signature System

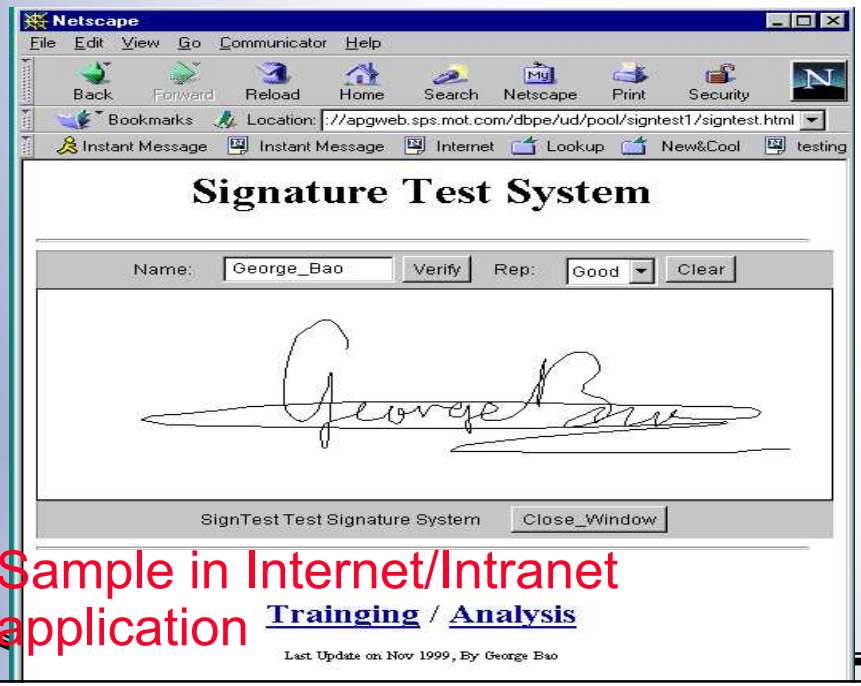
Signature



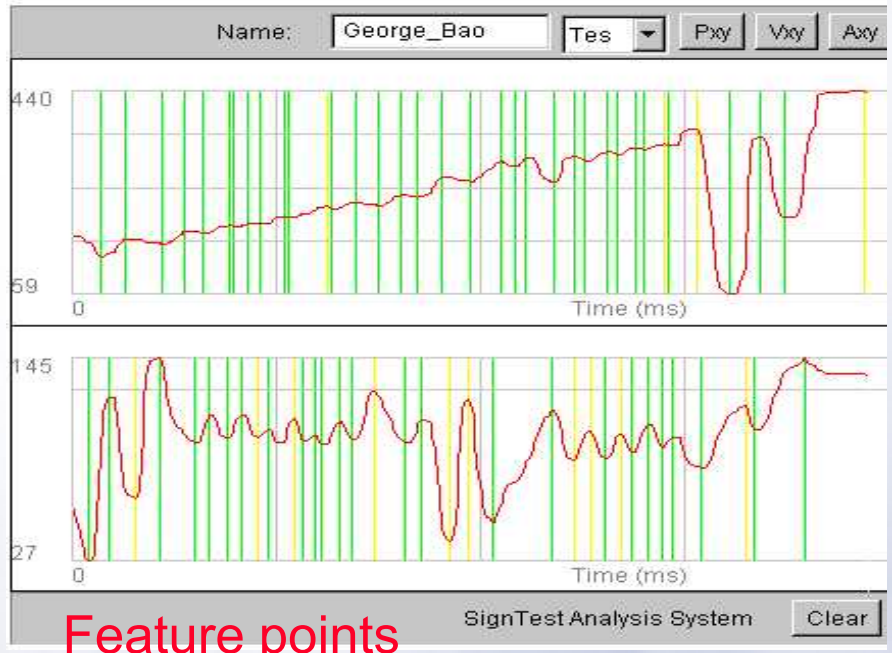
Original Signature



x, y coordinates and pen up, down status are recorded with sample period 20ms.



Sample in Internet/Intranet application

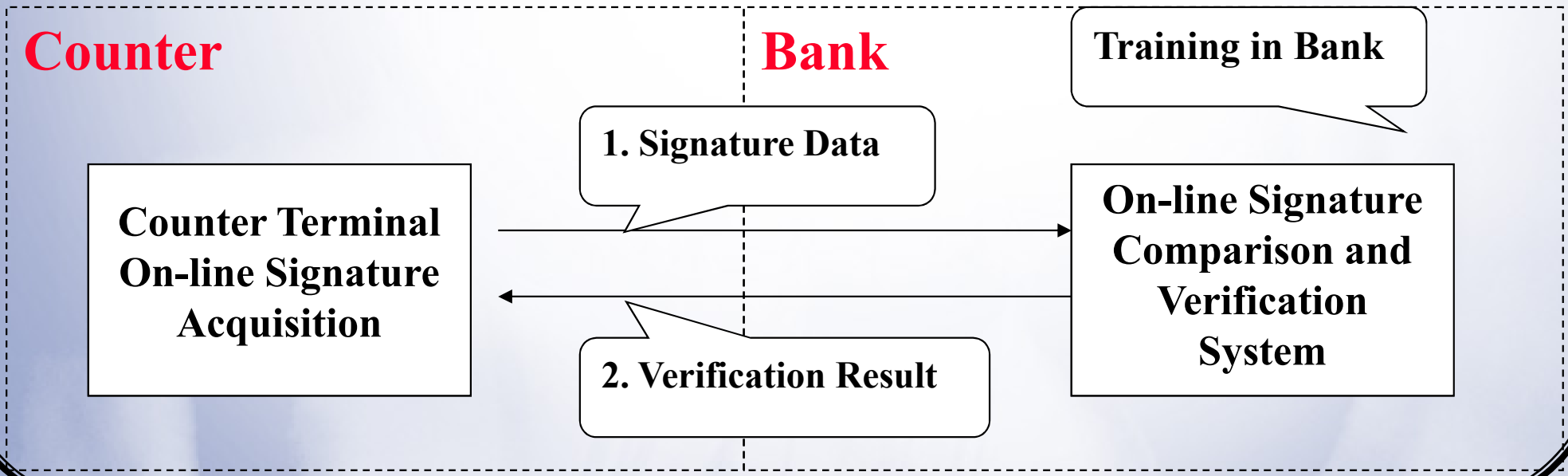


Feature points

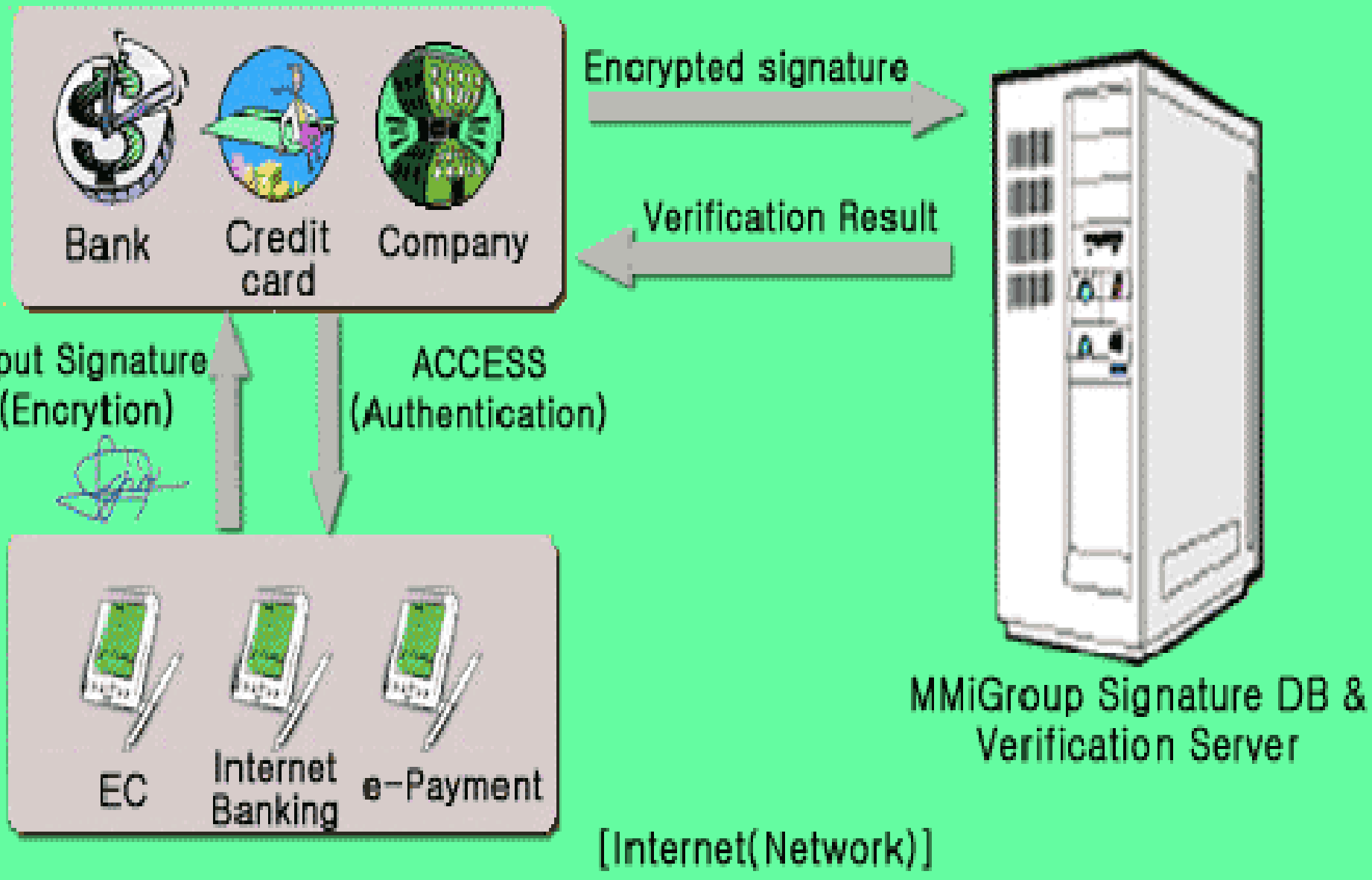
Signature Recognition: Perfect for Documents

Signature

- Sensor: Tablets utilize electromagnetic technology, digitizing tablet , etc.



Signature Application using MMigroup



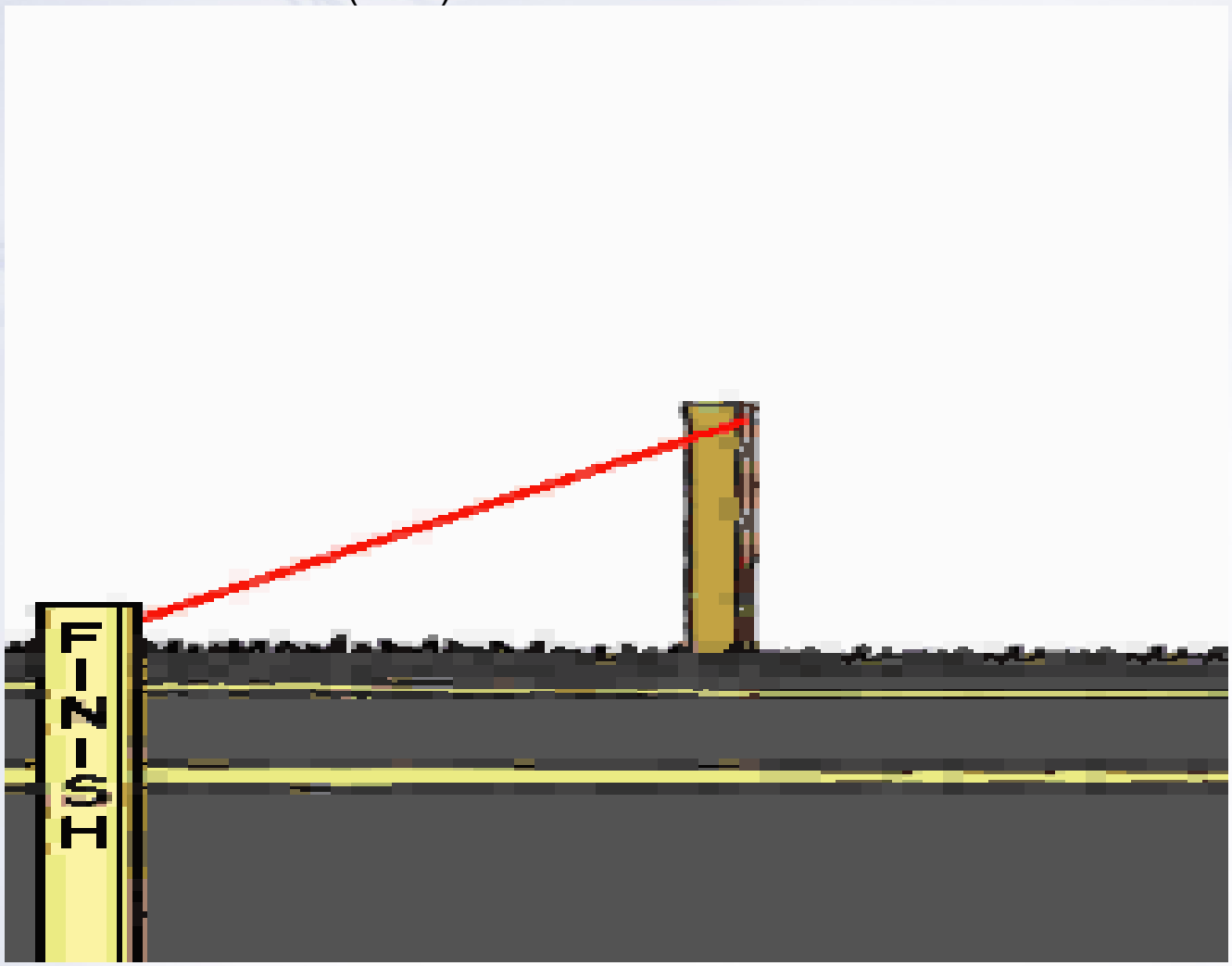
Signature Summary

Strengths

- ❑ High user acceptance since it is similar to the existing pen based signature method.
- ❑ Resistant to impostors
- ❑ Leverages existing processes
- ❑ Perceived as non-invasive
- ❑ Users can change signatures

Weaknesses

- Inconsistent signatures lead to increased error rates
- Users are unaccustomed to signing on tablets
- Has limited applications
- Change over time
- Professional forgers may be able to reproduce signatures
- Some people cannot produce stable signatures, even successive impressions



END