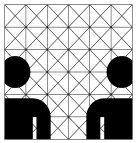
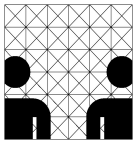


Developments in Computer-supported Palaeographic Analysis

Prof. Bernd Neumann, Ph.D.

Department of Informatics
University of Hamburg

International Workshop „Digital Support for Manuscript Analysis“
Hamburg, 23-24 July, 2010



Computer Vision, Artificial Intelligence and Palaeography

Computer Vision

Artificial Intelligence

Image Processing

Pattern Recognition

Image Understanding

Knowledge Representation

Shape Description

Handwriting Recognition

Probabilistic Models

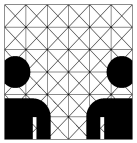
Content-Based Image Retrieval

Forensics

Datamining

Learning

Palaeographic Applications

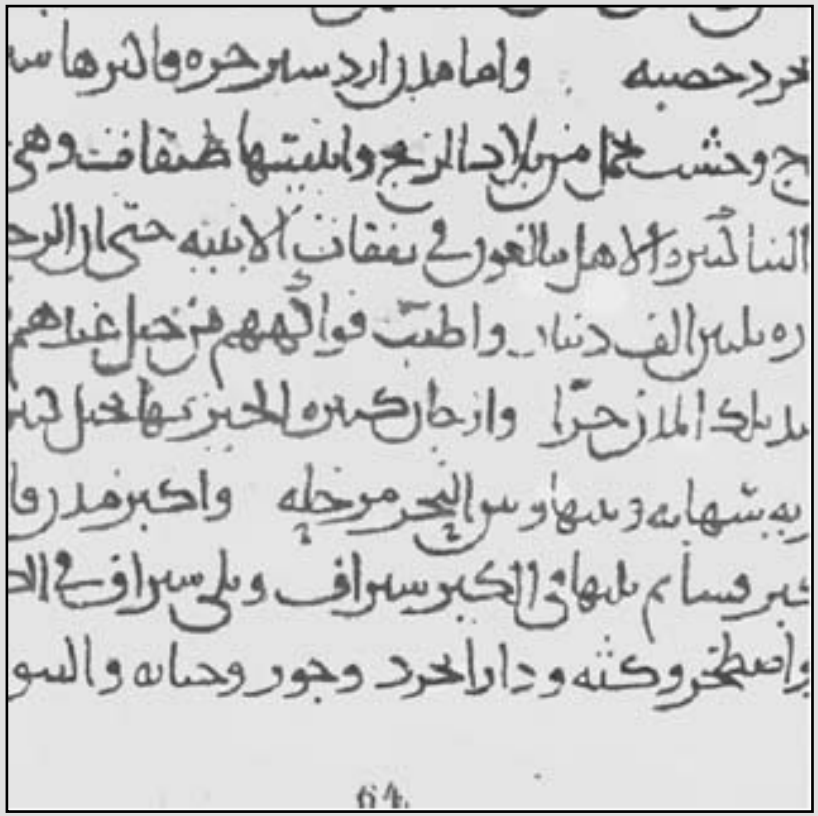


Agenda

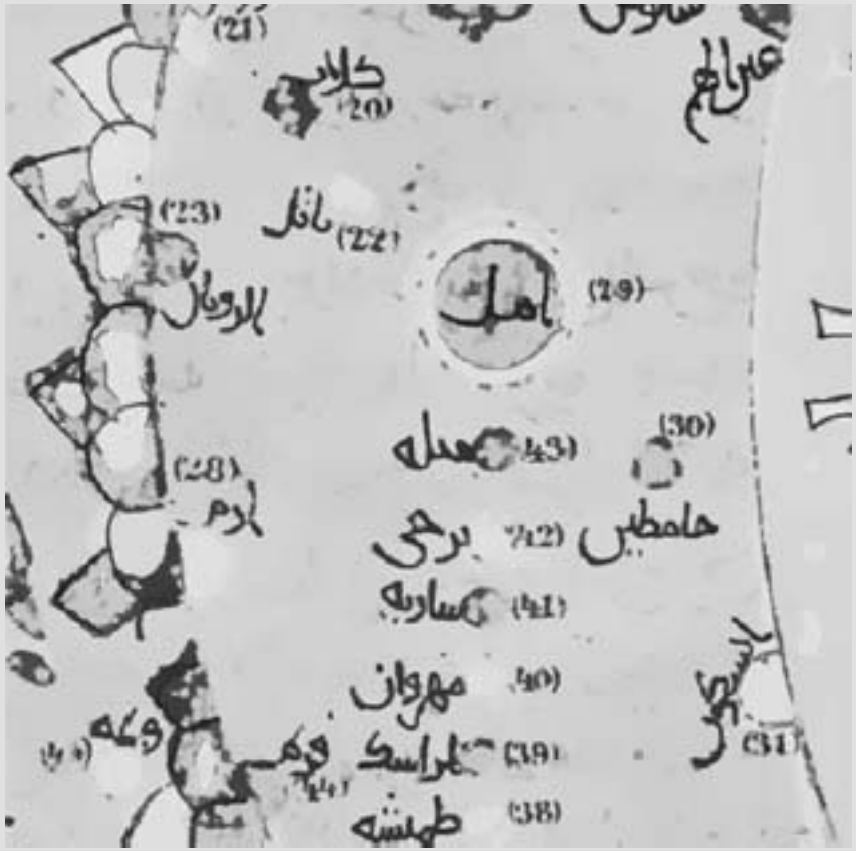
- **Image restoration and segmentation**
- **Writer identification**
- **Content-based image retrieval**
- **Computer-based manuscript analysis in Hamburg**

Restoration (1)

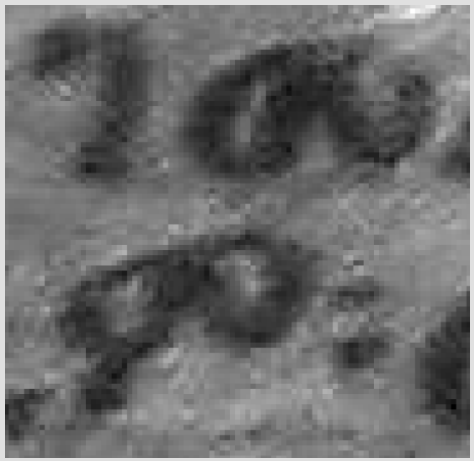
Removing background variations and noise by anisotropic diffusion (Moghaddam & Cheriet 2009)



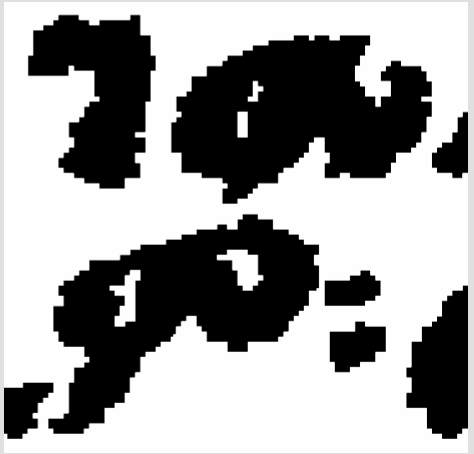
Restoration (2)



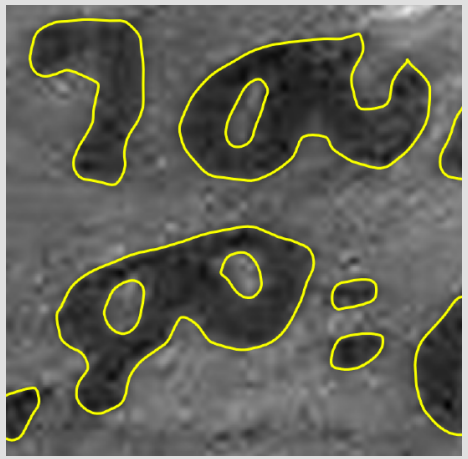
Segmentation



pixel-based



subpixel accuracy



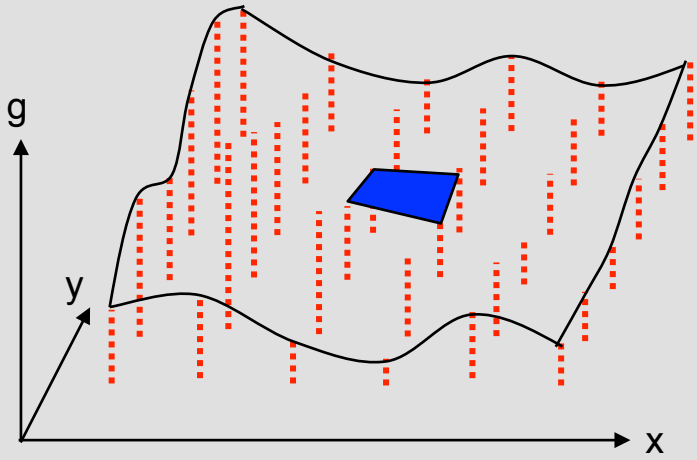
Subpixel Watershed Segmentation

A Generate continuous image by spline interpolation between pixels of original image

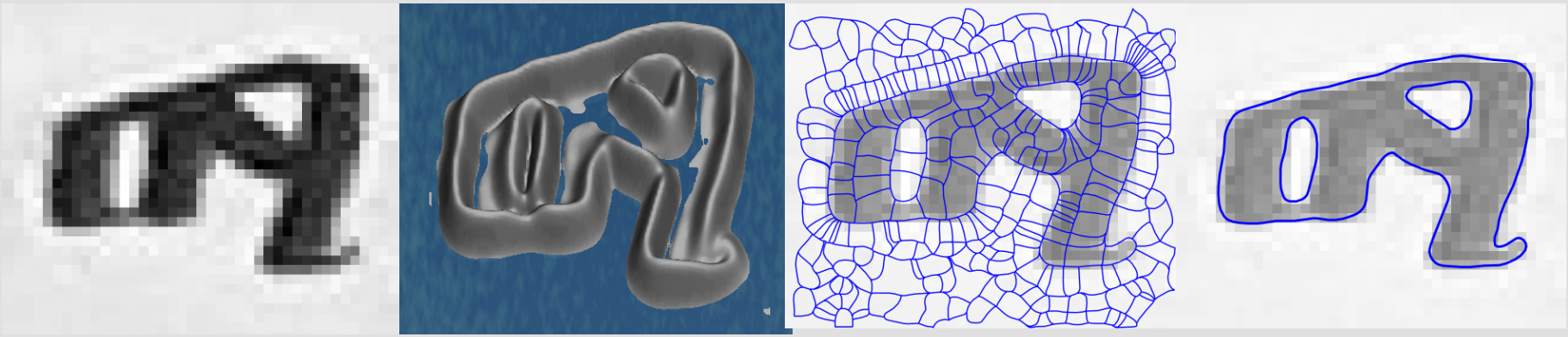
B Determine gradient image by differentiating the (analytical) continuous image

C Trace maxima in gradient image (watersheds“)

D Remove weak edges

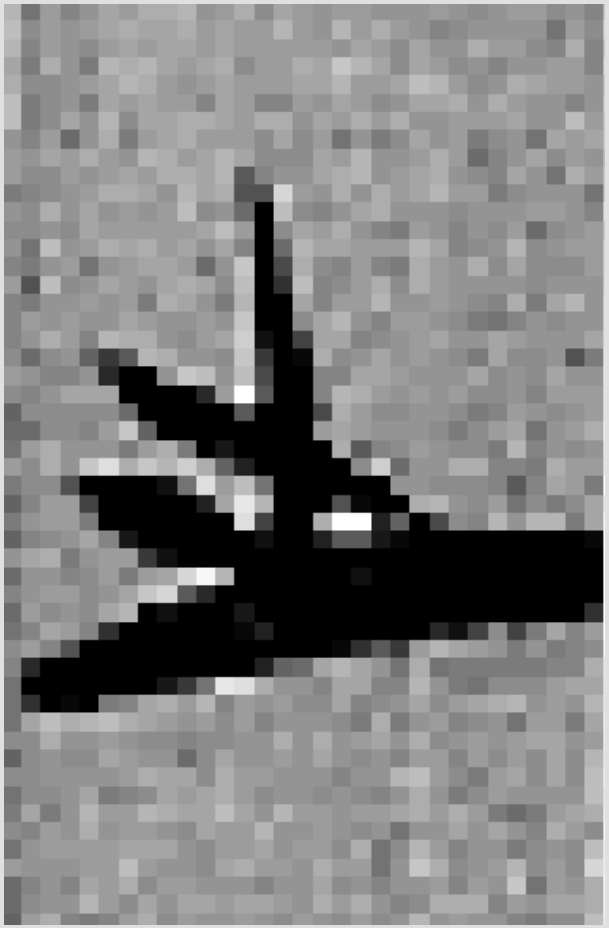


5th order spline interpolation

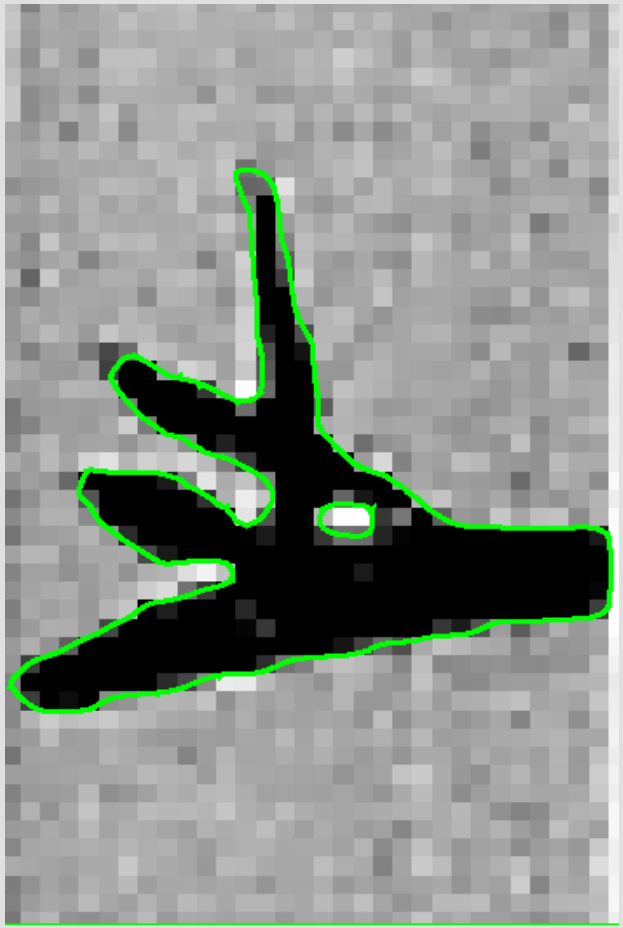


Subpixel Segmentation (2)

Original



Subpixel Watershed Contours



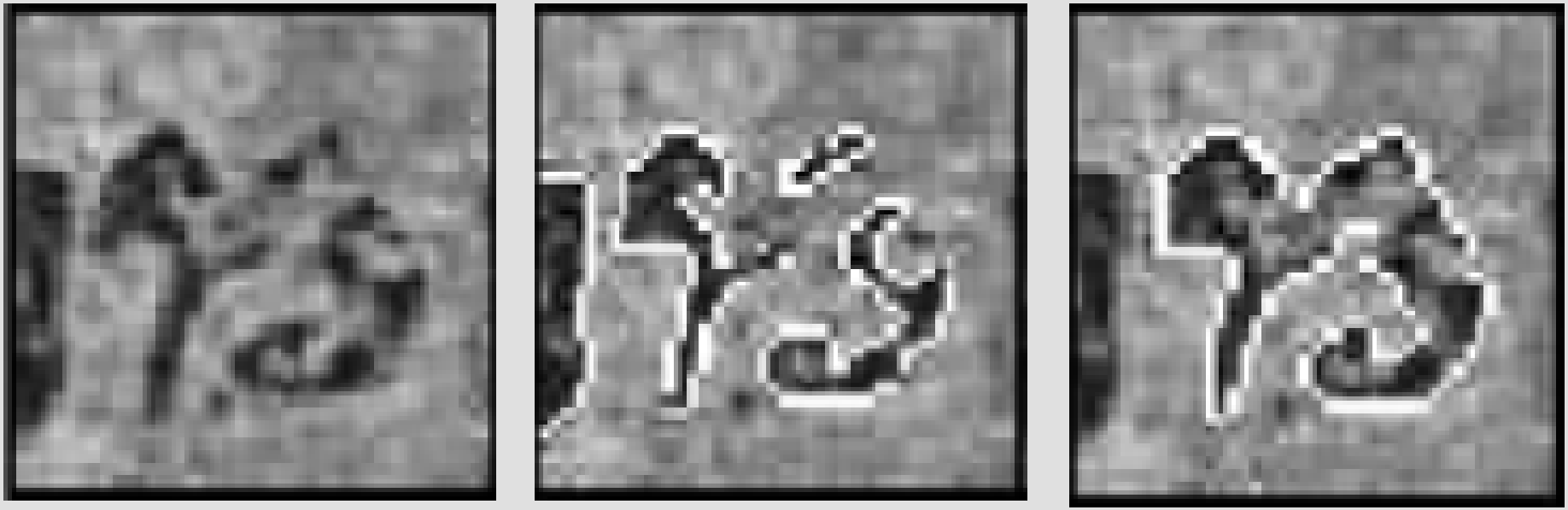
Segmentation of Degraded Text

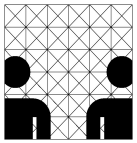
Uninformed segmentation methods will fail

Segmentation Using Shape Priors

Learnt shape models bias variational segmentation towards realistic results (Bar-Yosef et al. 2009)

original	segmentation without shape knowledge	segmentation with shape knowledge



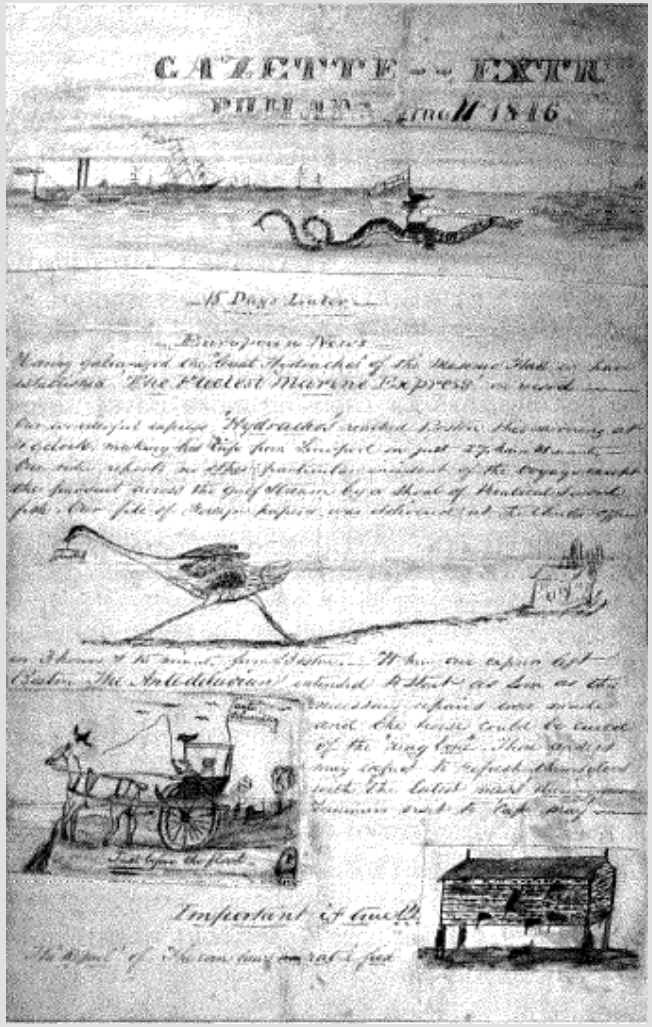


State-of-the-art in Restoration and Segmentation

- **Sophisticated mathematical models**
- **Incorporation of domain-specific knowledge**
- **Learning and statistics**
- **Advanced tools**

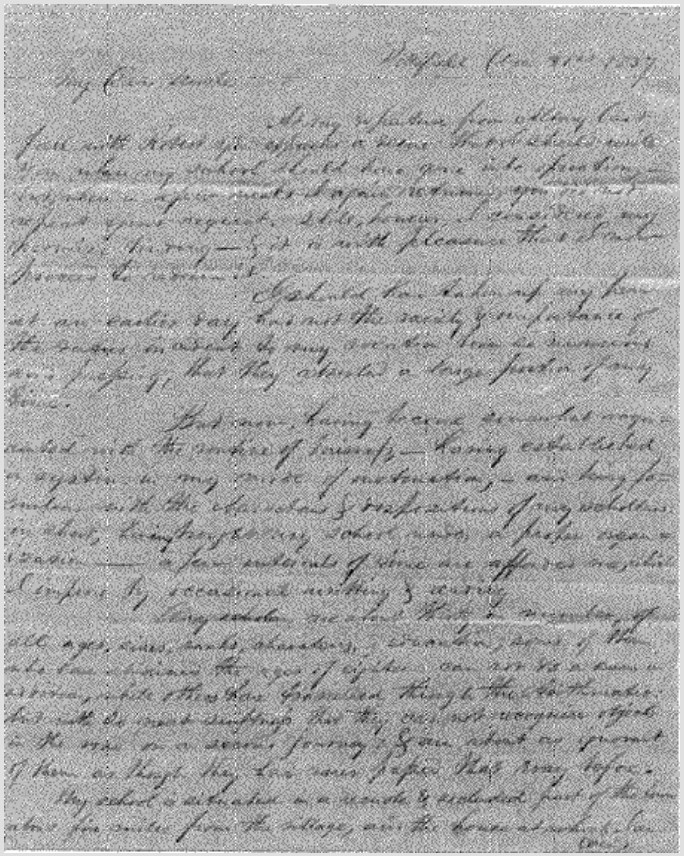
A Case of Writer Verification (1)

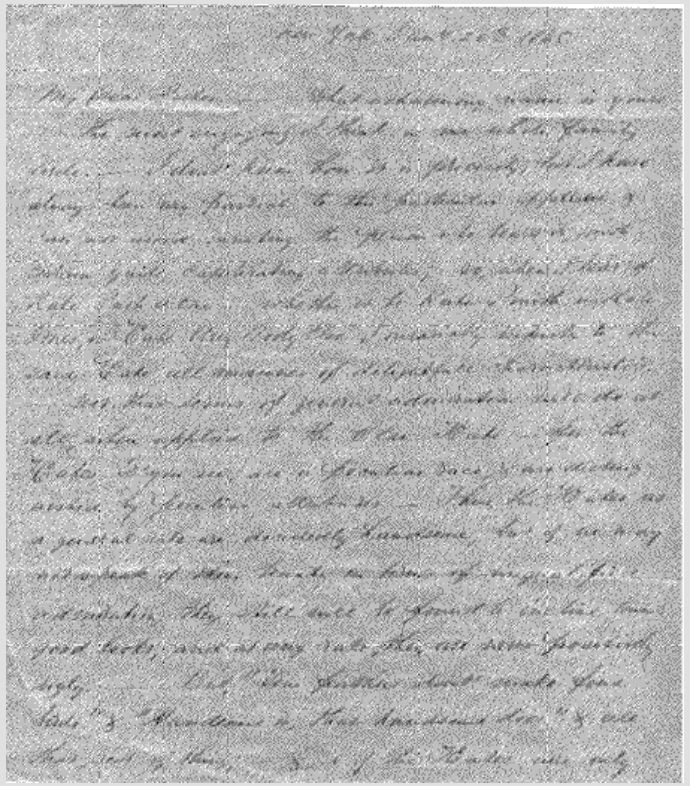
Two pages of a satiricical newspaper of 1846, allegedly handwritten by the New England author Hermann Melville



A Case of Writer Verification (2)

Documents known to be written by Melville





Writer Verification with CEDAR-FOX (1)

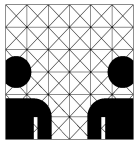
Center for Excellence in Document Analysis and Recognition
Sargur N. Srihari, University at Buffalo

Preparing a document for analysis **(Ball et al. 09)**

- **Manual processing: Remove non-text and major noise**
- **Preprocessing: Binarization, line and word segmentation, computing global document features, automatic character recognition**
- **Manual correction of word segmentations**
- **Transcript mapping to obtain correct ground truth for words**

Word images of
- known documents

- unknown documents



Writer Verification with CEDAR-FOX (2)

Comparison of corresponding characters based on GSC features:

Gradient-based:

- **A 4x4 grid is placed over the character, dividing it into 16 subfields**
- **Gradient directions are counted in each subfield for 12 directions**
- **Direction frequencies above a threshold receive 1 feature bit**

⇒ 192 bits

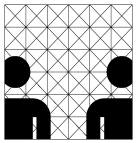
Structure-based:
Presence of corners, diagonal, vertical and horizontal lines

⇒192 bits

Concavity-based:
Major topological and geometrical features, direction of bays, presence of holes, large vertical and horizontal strokes

⇒128 bits

Similar approach extended to comparison of words

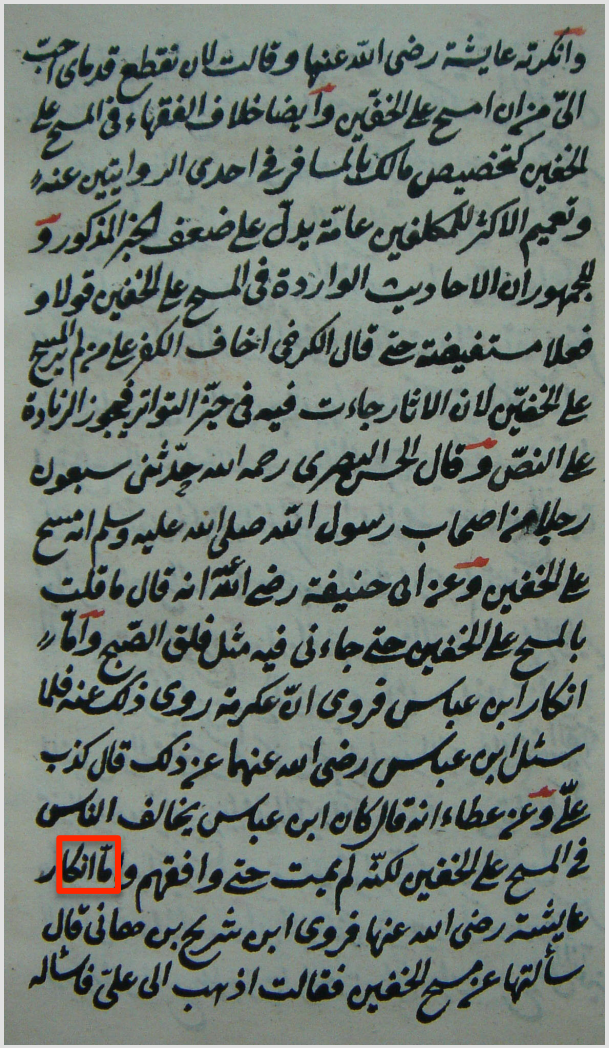


State-of-the-art in Writer Verification

- **Handwriting recognition technology adapted to requirements in forensics**
- **98% reliability for forensic writer verification tasks in USA**
- **Non-interactive black-box approach**
- **Not immediately applicable to other writing systems**
- **Incomplete prototypical systems for palaeographical applications**

Content-based Image Retrieval

Determine occurrences of example image in large database



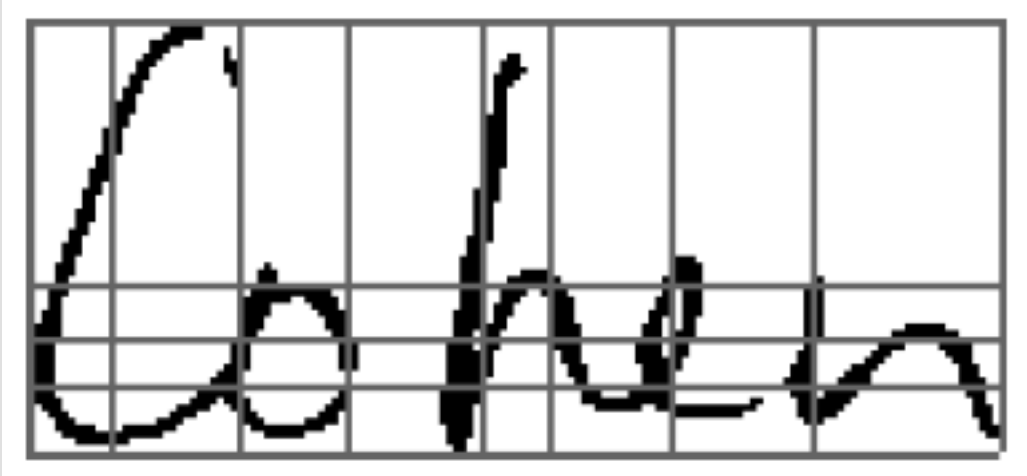
Object Recognition Using SIFT Features (1)

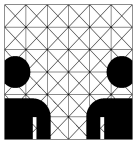
- **SIFT (Scale Invariant Feature Transform) features are gradient-based descriptors evaluated at significant image locations („interest points“)**
- **For content-based image retrieval**
  - database images are annotated with SIFT features
  - SIFT features of input image are compared with SIFT features in database

Object Recognition Using SIFT Features (2)

Word Image Retrieval Using CEDAR-FOX

1024 bits characterizing the word „Cohen“ (Zhang et al. 04)



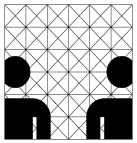


Similarity Measure for Binary Feature Vectors

Correlation of binary vectors:

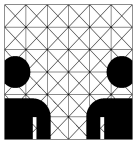
$$D^b(X,Y) = \frac{1}{2} - \frac{S_{11}S_{00} - S_{10}S_{01}}{2((S_{10}+S_{11})(S_{01}+S_{00})(S_{11}+S_{01})(S_{00}+S_{10}))^{1/2}}$$

S_{ij} counts the number of matches with i in the first and j in the second pattern at corresponding positions (i, j = 0, 1)



State-of-the-art in Content-based Image Retrieval

- Large efforts underway for web applications
- Promising solutions based on precomputed descriptors
- Special-purpose developments for manuscript analysis



Computer-based Manuscript Analysis in Hamburg

Part of the Reserach Group "Manuscript Cultures in Asia and Africa"

www.manuscript-cultures.uni-hamburg.de

9 projects for

Indology, Sinology, Iranistics, Japanology, Islamic Sciences / Arabistics, Sanskritistics, Tamilistics, Tibetology, Ethiopistics

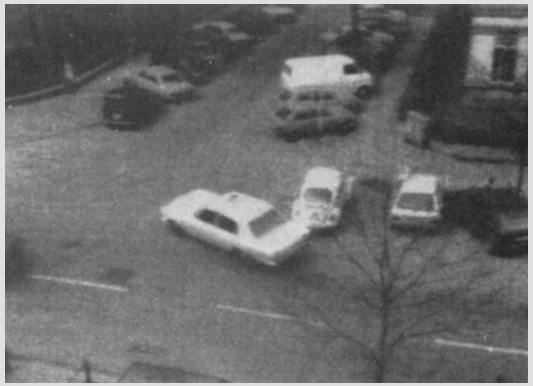
+

1 project for Informatics

Cognitive Systems Laboratory

1971

Image Sequence Analysis



1980

Natural-language Description of Image Sequences

1990

Model-based Scene Interpretation

Radiological Image Analysis

Image Registration

Aerial Image Analysis

Applications of Knowledge-based Systems

Description Logics RACER

2000

Learning for Scene Interpretation

Subpixel Segmentation

Topology-preserving Sampling

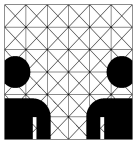
Ocean Current Analysis

Semantic Information Processing

2010

Real-time Scene Interpretation

Manuscript Analysis



Research Goals

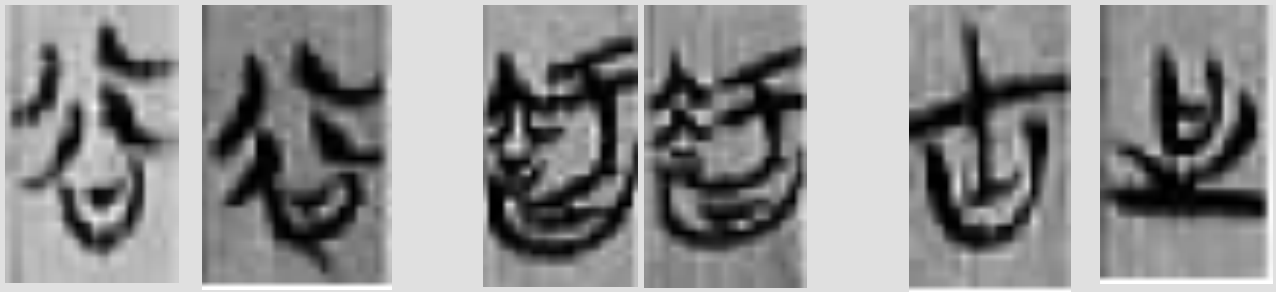
Development of innovative image processing methods for:

- **Computing layout and character features for comparative manuscript analysis**
- **Retrieving example patterns from large manuscript databases**
- **Using discriminative features to determine**
  - related cultural origins of manuscripts
  - identities of scribes
- **Contributing to a toolbox for palaeographic research**

Are Hands A and B the same?

Hand A:

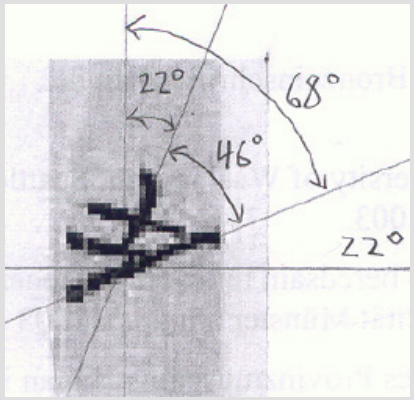
Hand B:

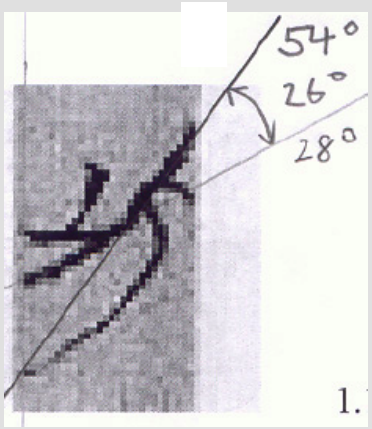


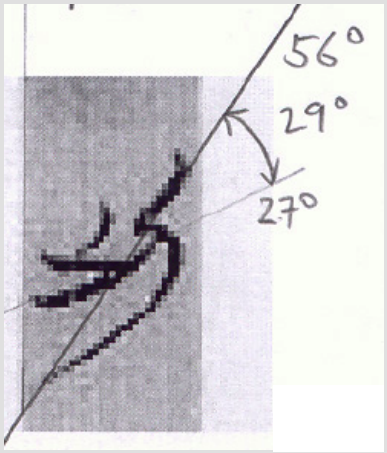
Richter 2006:
"Tentative Criteria for Discerning Individual Hands in the Guodian Manuscripts"

Comparison of Stroke Angles

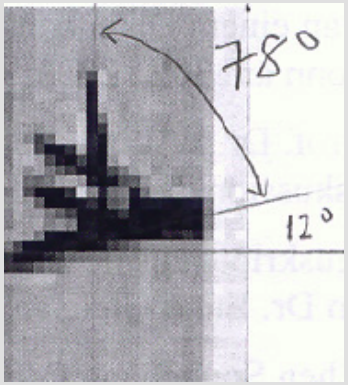
Hand A:

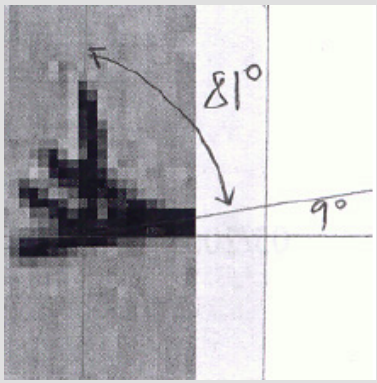


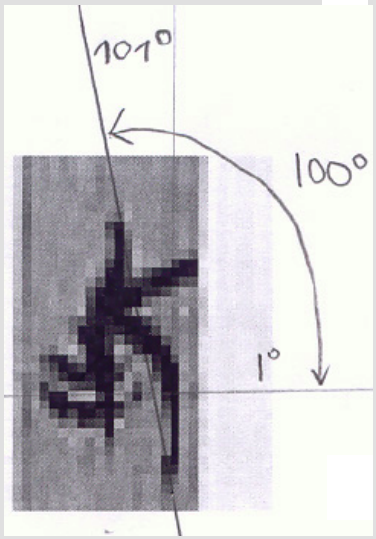




Hand B:



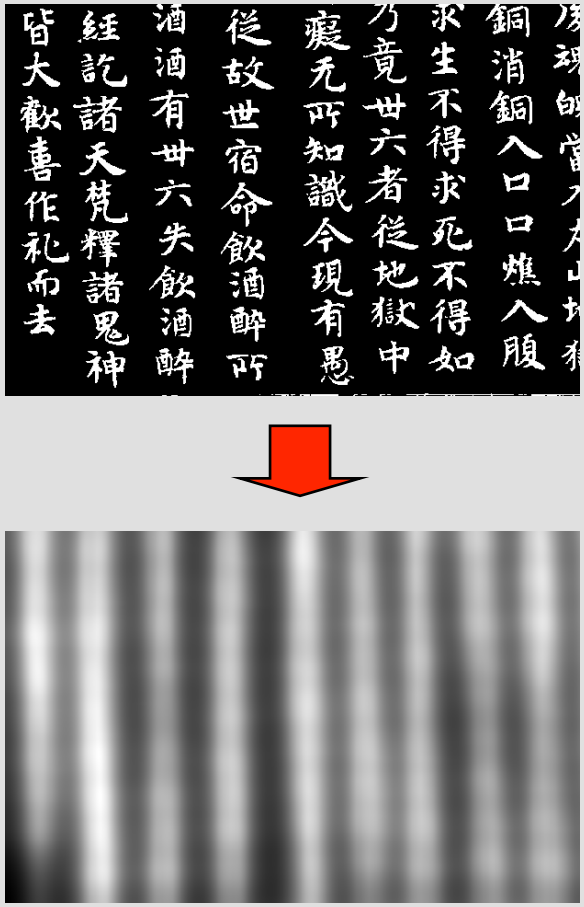




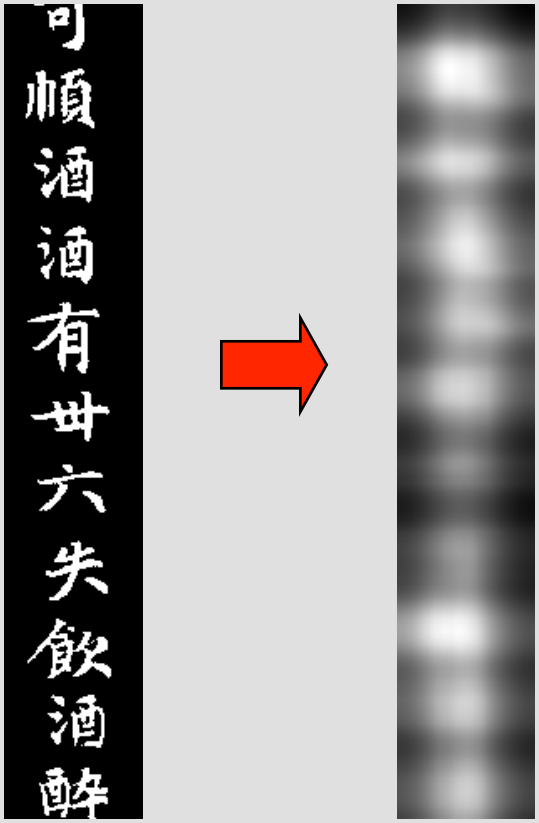
MIN Faculty
Department of Informatics

Analysis of Column and Line Structure by Anisotropic Filtering

Column structure

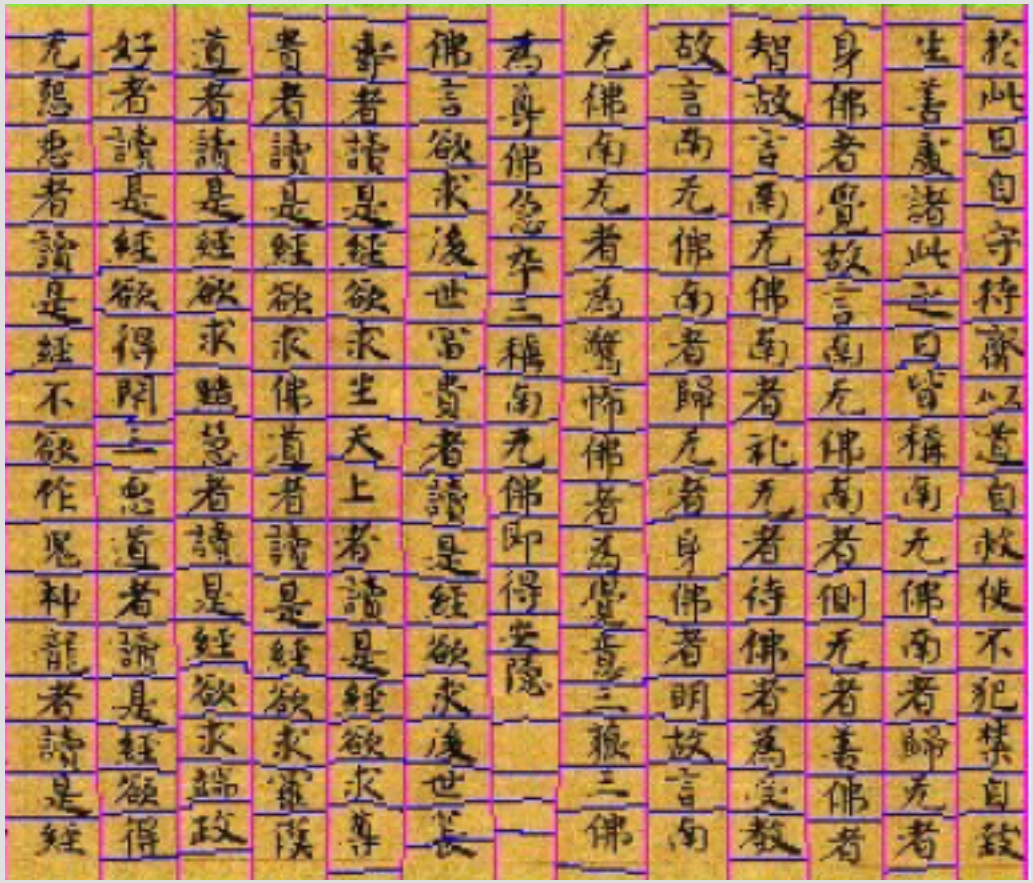


Line structure



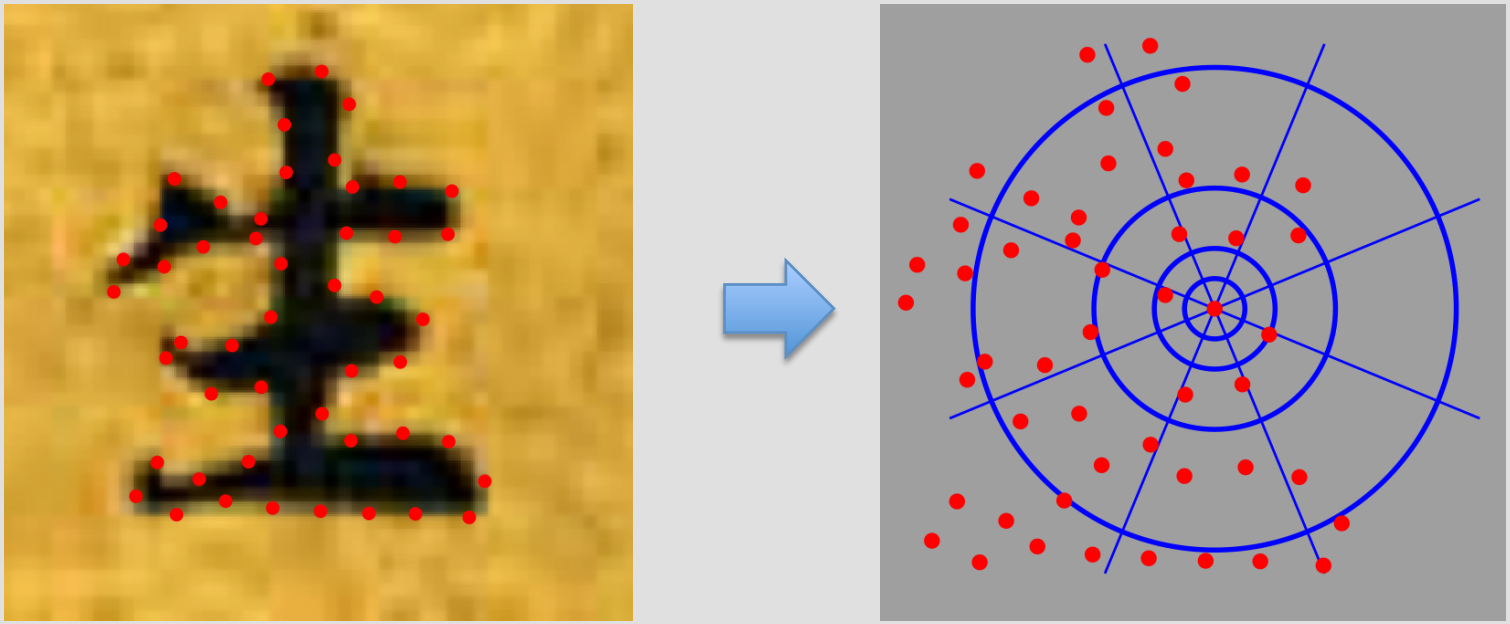
Determining Character Regions

Automatically determined column and line structure



Shape Context Similarity

- **Determine „Shape context“ of a contour by marking each contour point with the number of contour points for each of 32 relative locations.**
- **Determine optimal correspondence of contour points of two characters by comparing shape contexts**
- **Remaining difference of shape contexts is similarity measure a**



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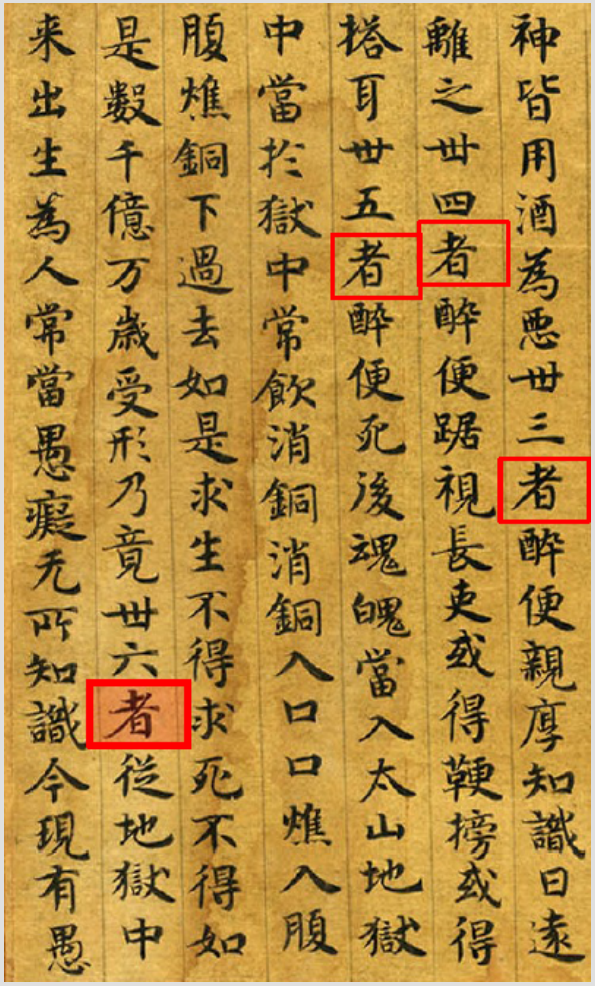
Finding Similar Characters by Shape Context Comparison

Identical characters



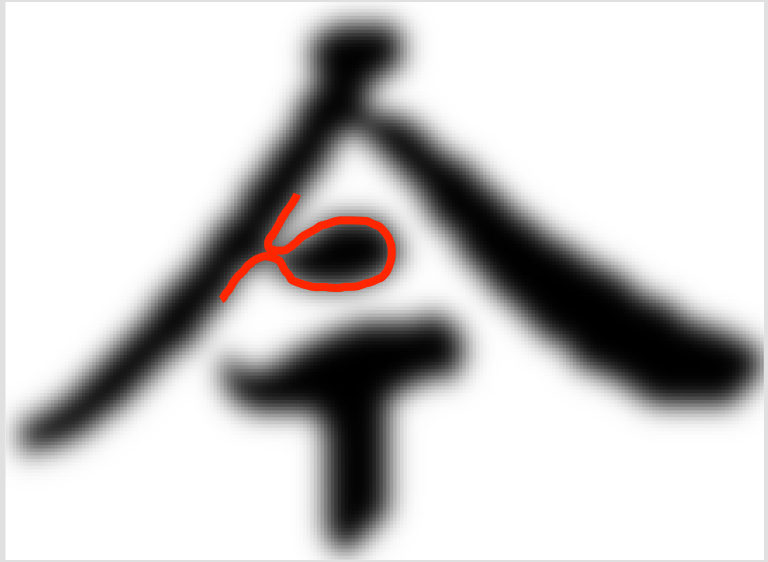
Similar characters sorted by shape context similarity

Weakness of Contour-based Similarity Analysis

Contour comparison is sensitive to

=> connectivity disturbances, no graceful degradation

=> contour protrusions (e.g. at junctions)

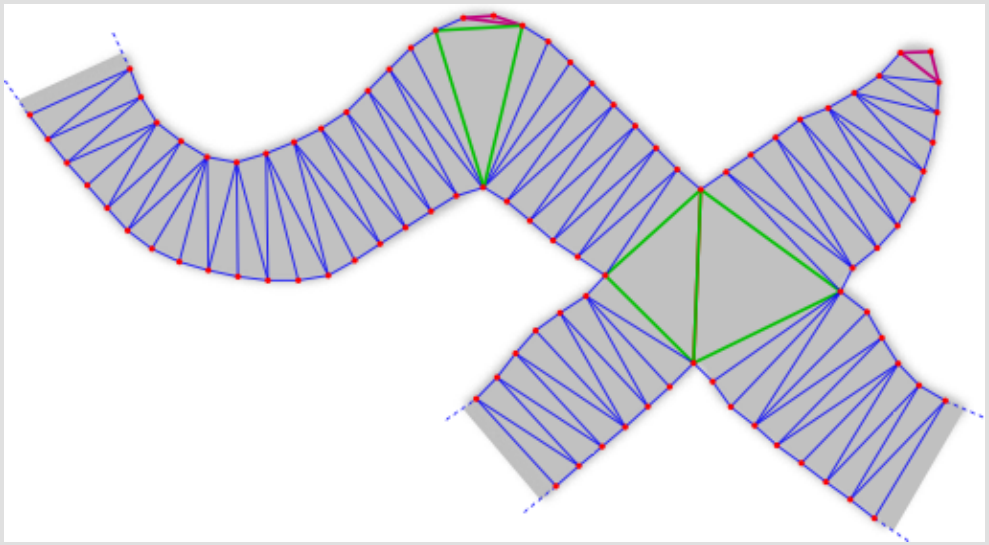


Stroke Analysis by Triangulation

Constrained Delaunay Triangulation (CDT) connects contour points to triangles such that the circumference of a triangle contains no other points.

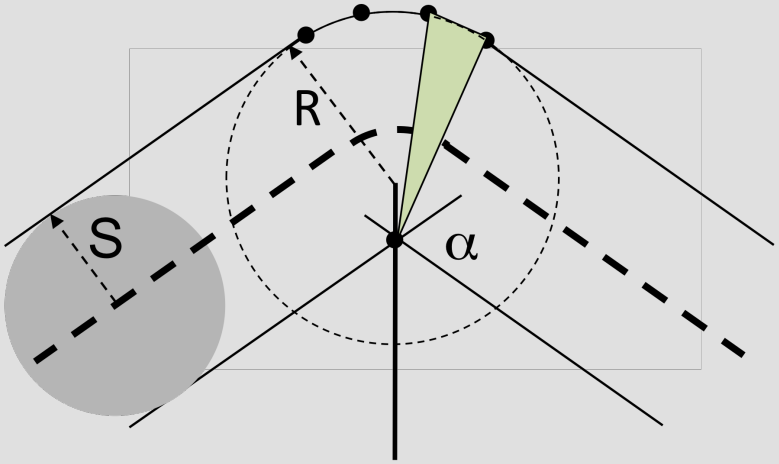
CDT generates three types of triangles:

- **junction triangles (green)**
  none of the triangle sides coincides with the contour
- **sleeve triangles (blue)**
- **terminal triangles (red)**

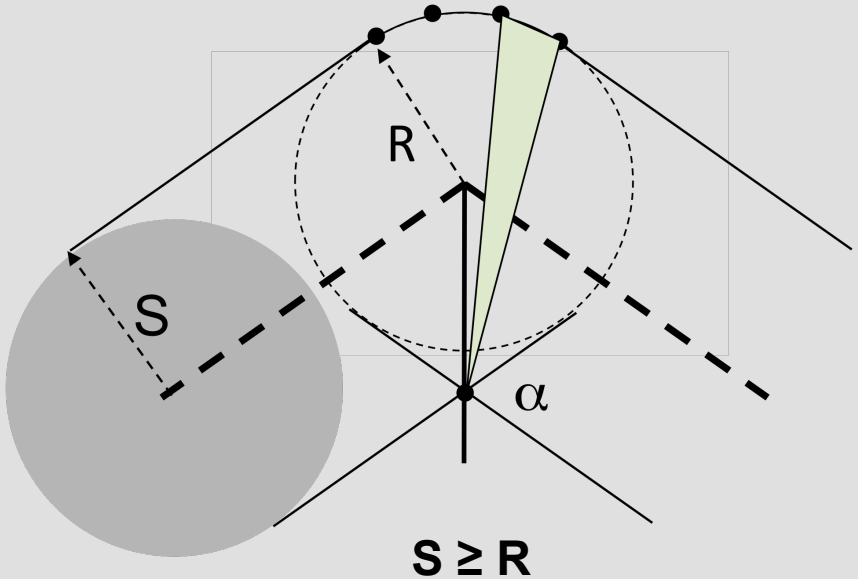


Junction triangles indicate stroke intersections or sharp stroke corners

Conditions for Junction Triangles



no junction triangles

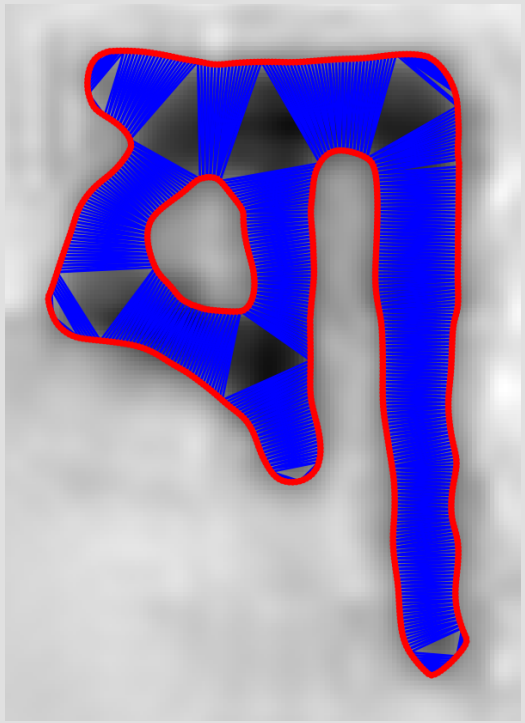


S ≥ R
always junction triangles

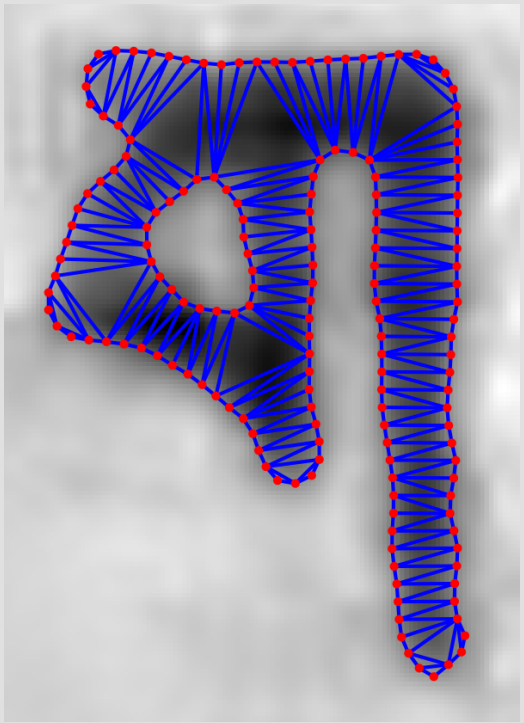
A curved line with angle α and outer contour radius R, drawn with a stylus of radius S, will generate a junction triangle if

$$S > R/2\ (1 + \cos \alpha/2)$$

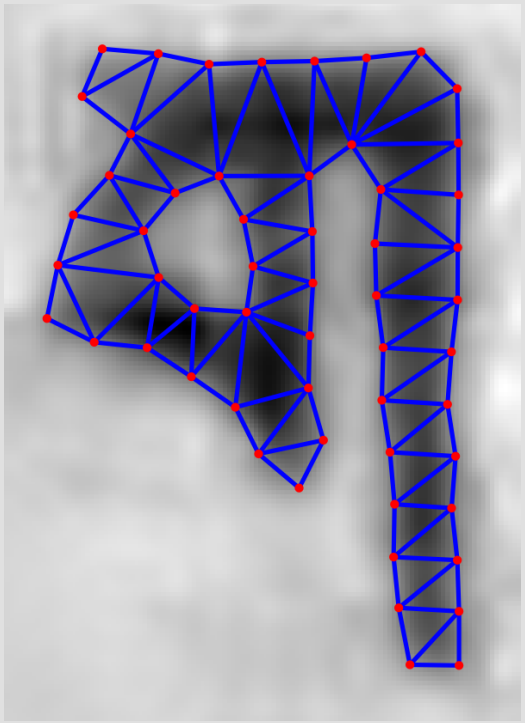
Weak Influence of Contour Point Spacing



dense spacing



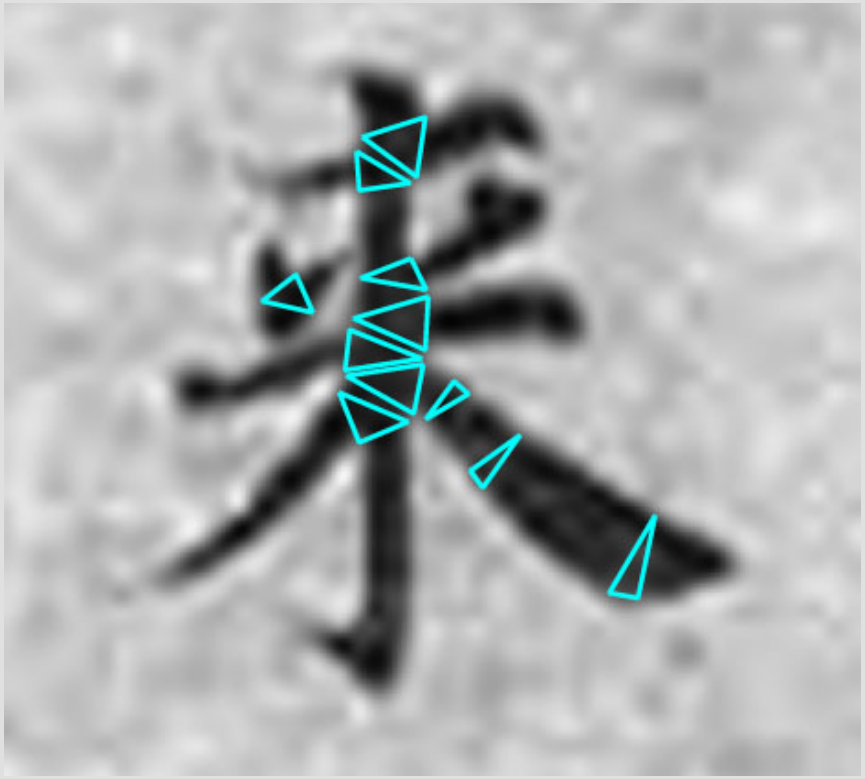
medium spacing



coarse spacing

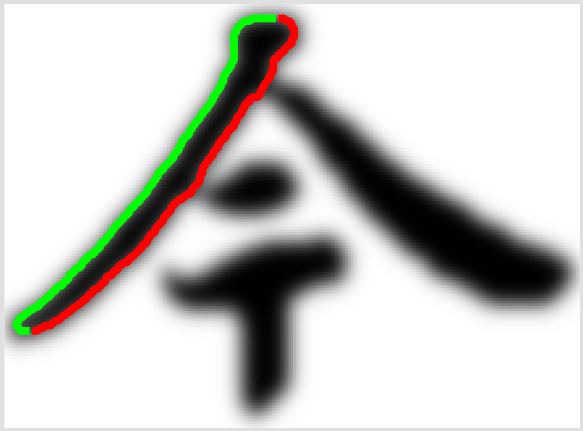
no junction triangles if corners are cut

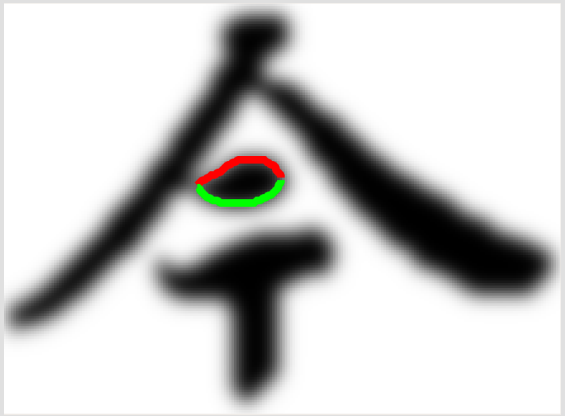
Stroke Segment Merging



- **Segments meeting at a junction may be merged if they are compatible regarding orientation and stroke width**
- **Segments between two neighbouring junction triangles may be intersections with irregular direction and stroke width**
- **Global criteria and knowledge of the writing system must be invoked to resolve ambiguities**

Results of Stroke Analysis (1)

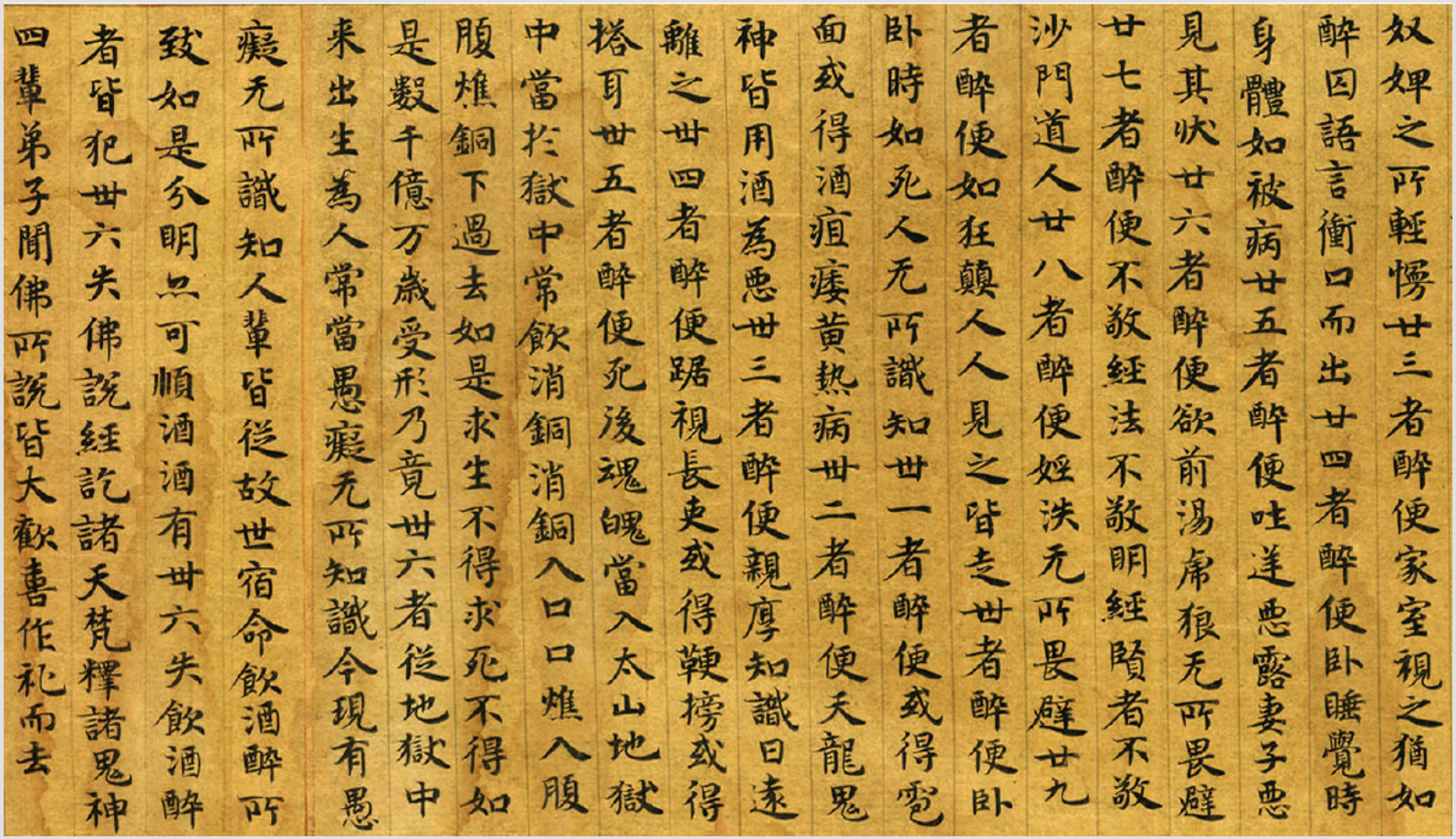




Results of Stroke Analysis (2)

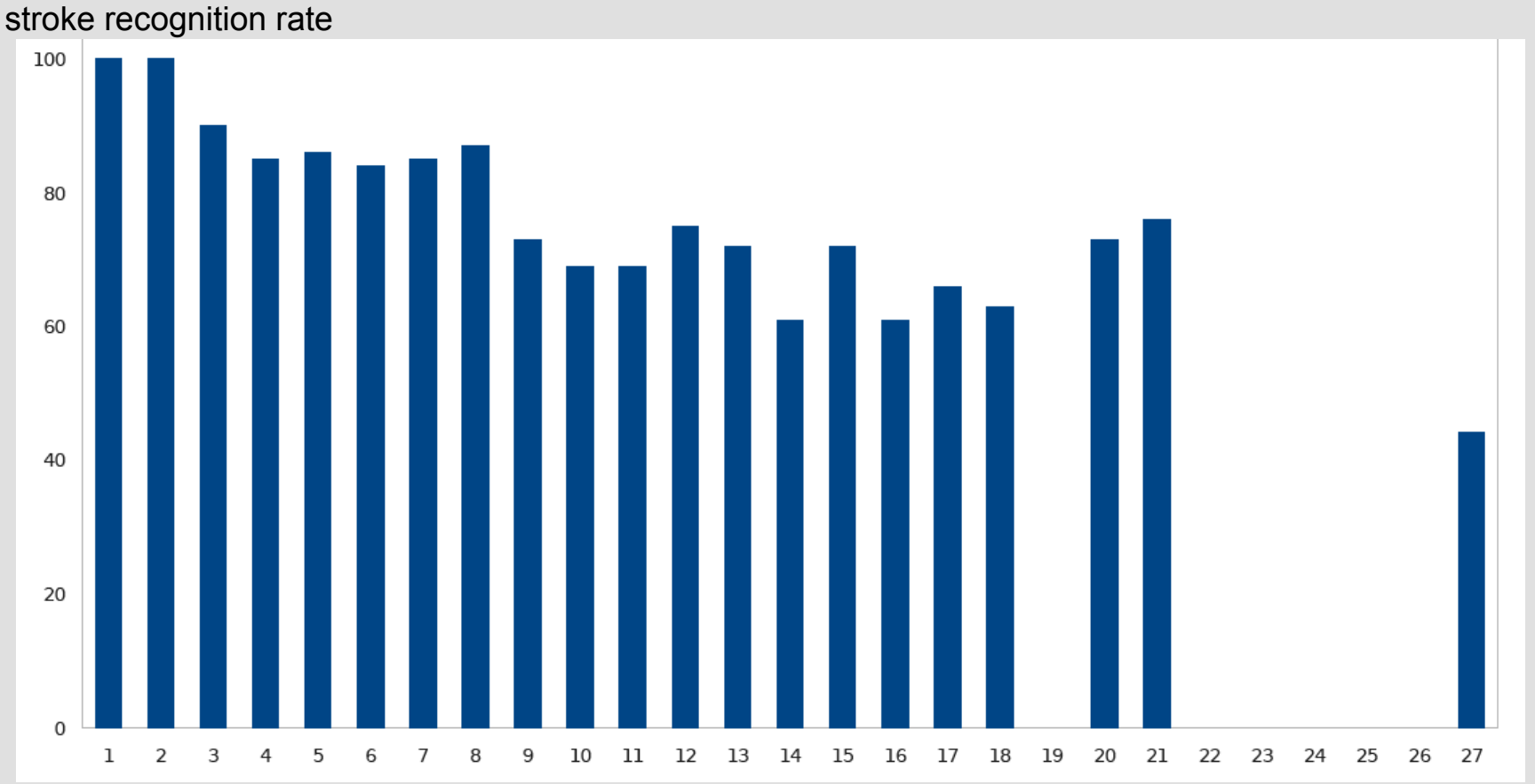
Database of Chinese Characters

339 characters, ca. 60 x 60 pixels each



Results for All Characters of Database

Stroke recognition rate decreases with character complexity

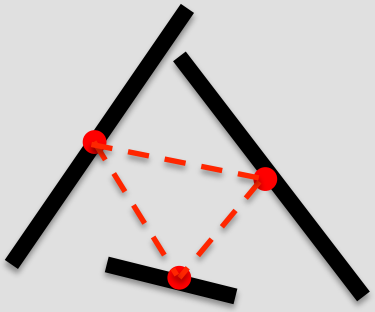


Comparison of Characters Based on Stroke Structure Graphs

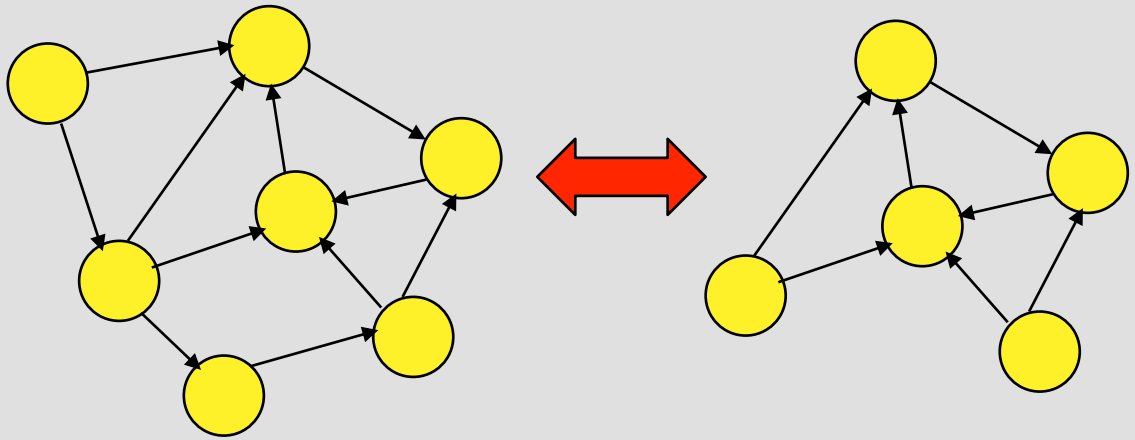
Stroke structure graph:

nodes = qualitative descriptions of individual strokes

edges = qualitative spatial relations between pairs of strokes

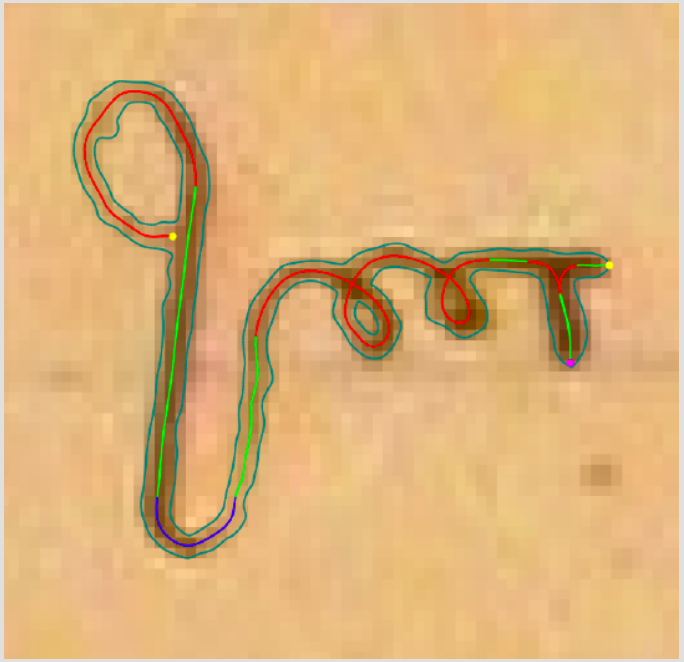


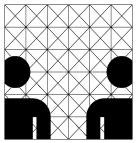
Comparison of two stroke structure graphs by determining best-matching common subgraph



Stroke Decomposition for Tamil Characters

- **Decomposition of a stroke into sections of qualitatively equal curvature**
- **Qualitative stroke representation in terms of a sequence of equal-curvature segments**
- **Comparison based on stroke structure graphs with qualitative stroke representations**





Summary

- **Computer Vision and Artificial Intelligence provide powerful methods which can be harvested for palaeographic applications.**
- **Handwriting analysis in forensics suggests methods worth looking at. There exist advanced systems for the analysis of Latin handwriting. Blackbox approach may not meet requirements of palaeographers.**
- **Building an advanced toolbox for palaeographic applications requires close cooperation of Computer Vision and palaeographers (and sustained efforts over many years).**