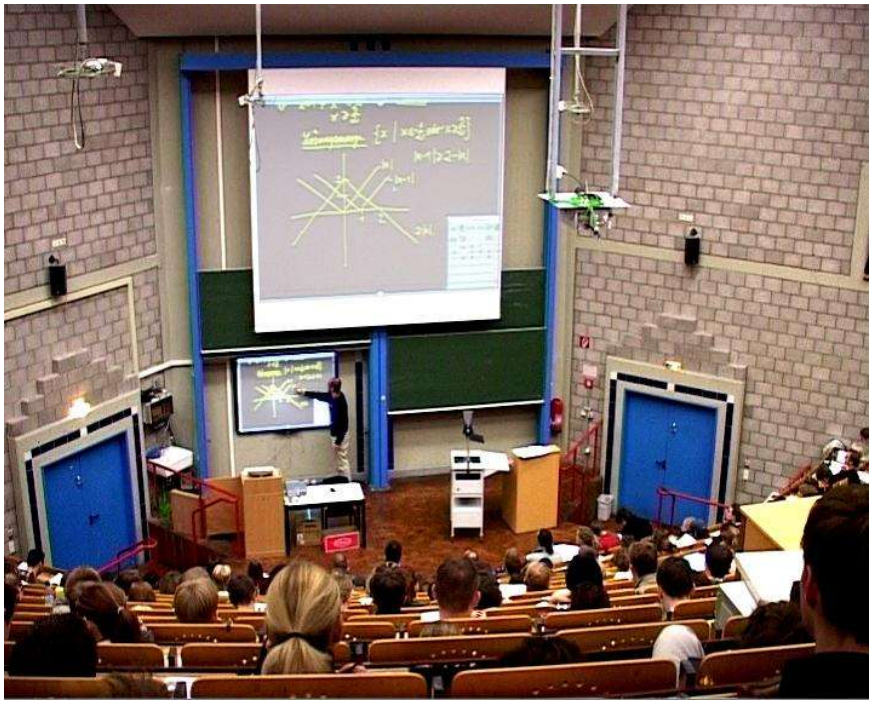
On-Line Erkennung handgeschriebener mathematischen Formeln

Ernesto Tapia

Berlin 9. Juni 2004

Motivation: The electronic Chalk Board (E-Chalk)



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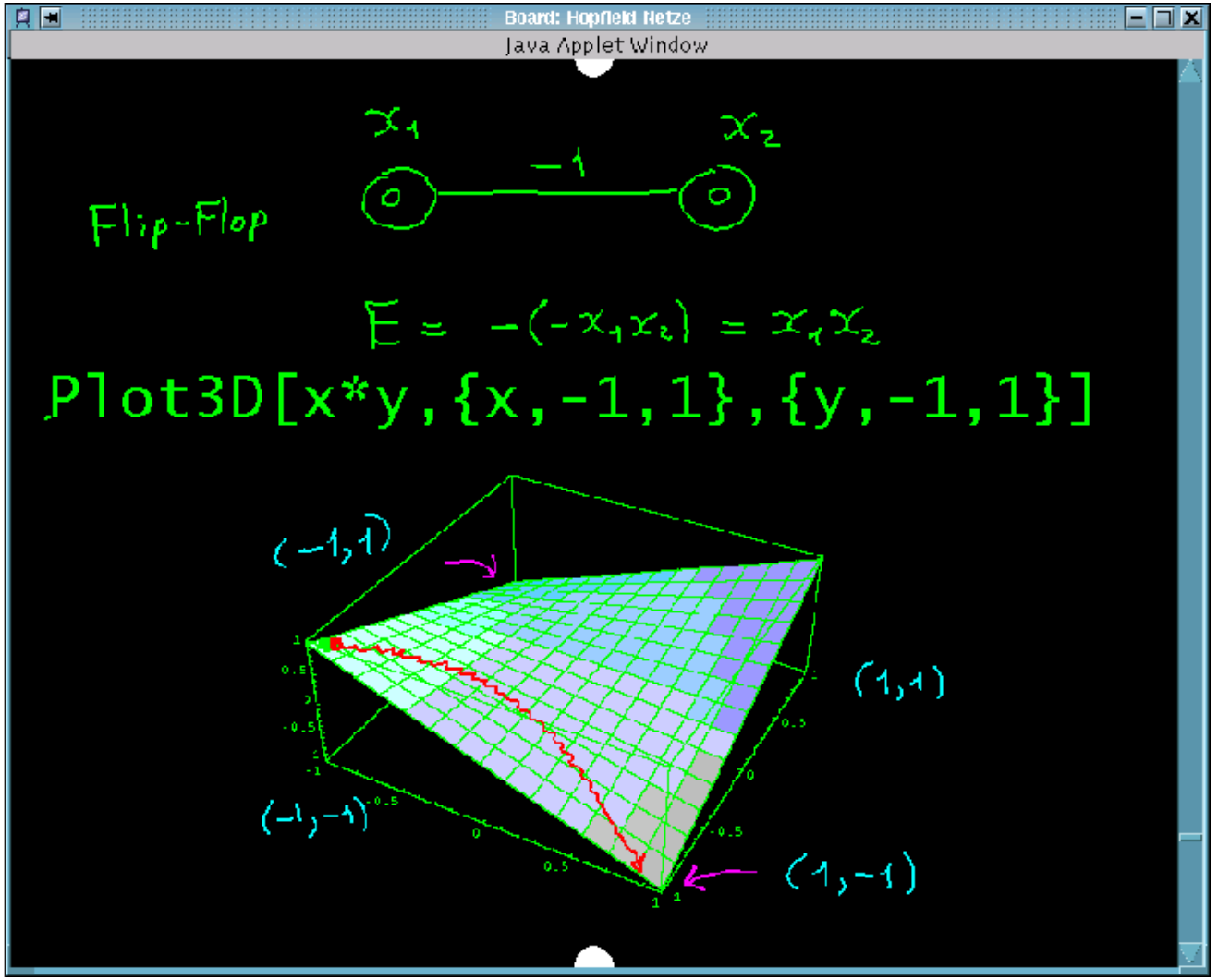
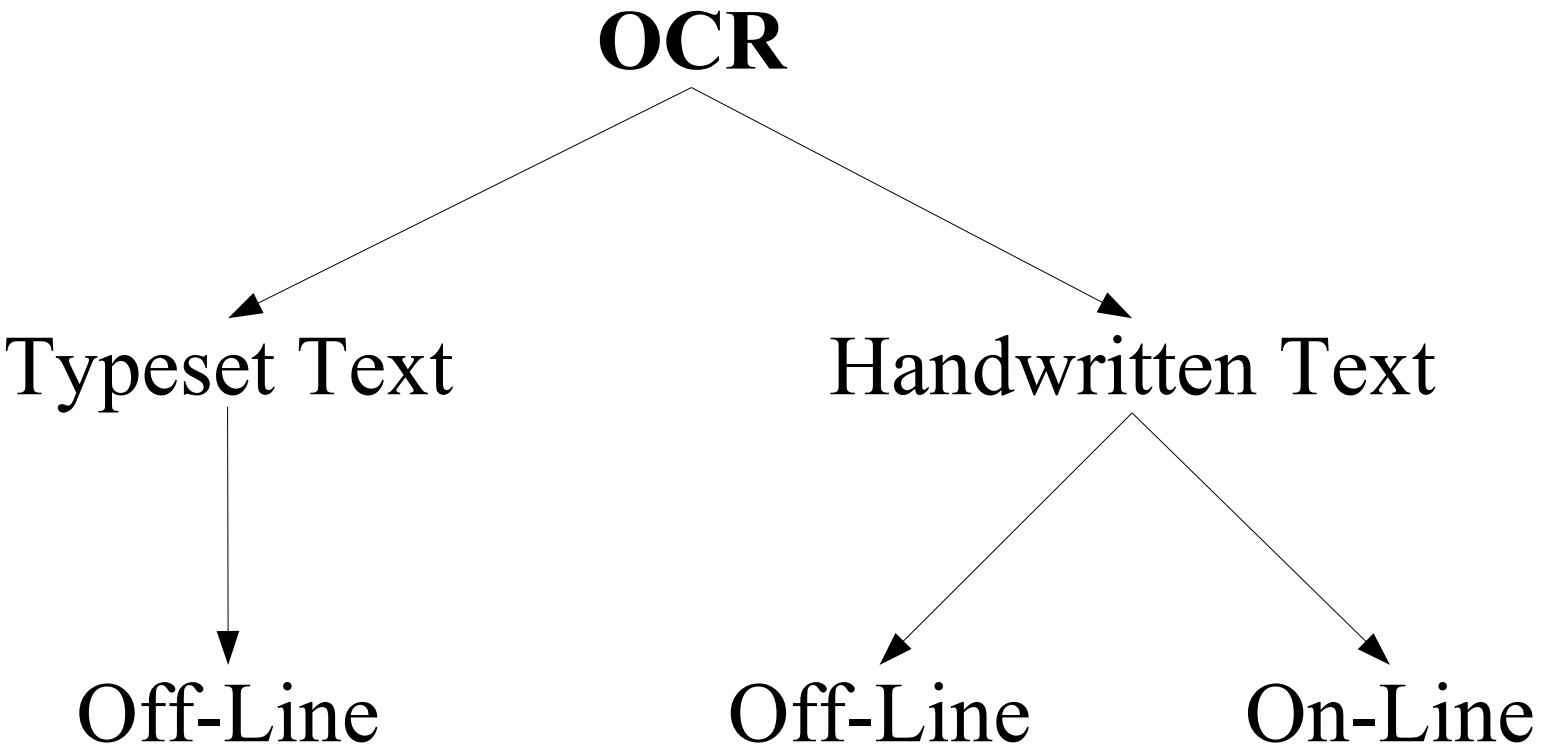


Optical Character Recognition

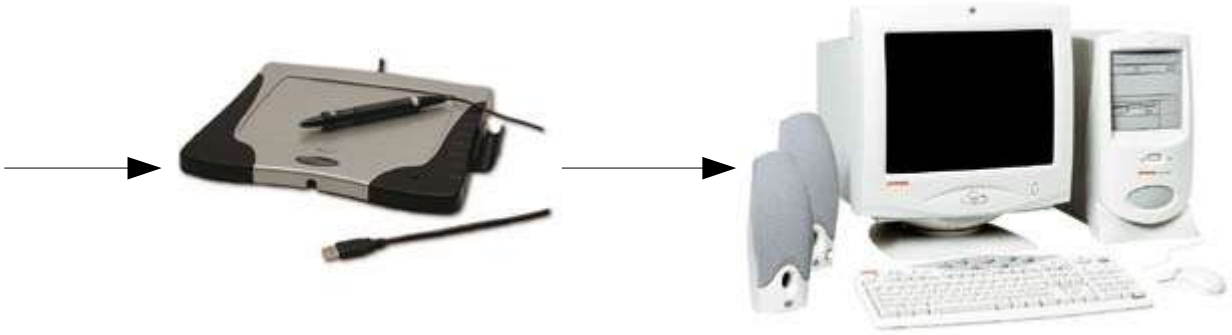


Optical Character Recognition: Off-line Data

$$\frac{1}{2\pi i}\int f(z)\,dz = \sum_{\mu=1}^{m} \operatorname{Res}_{\mu} f(z)$$

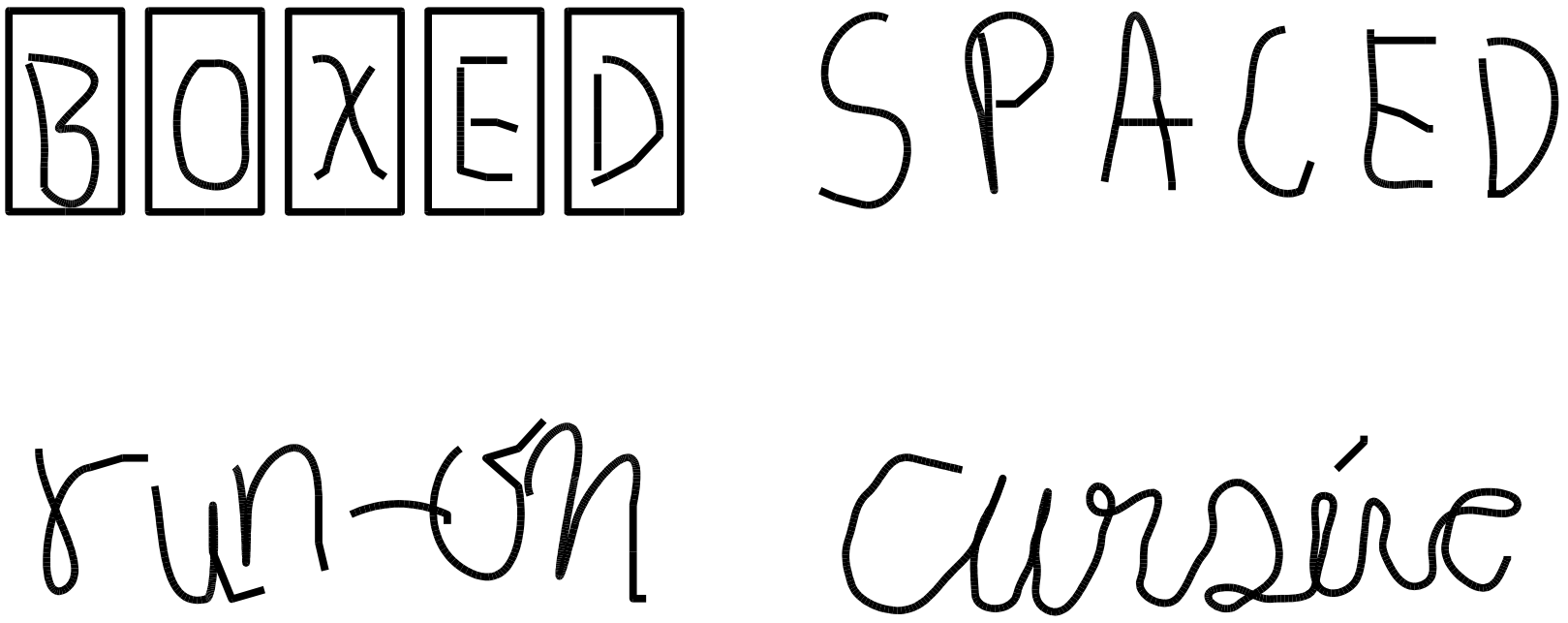
$$\frac{1}{2\pi i}\int_{C} f(z)\,dz = \sum_{\mu=1}^{m} \operatorname{Res}_{\mu} f(z)$$

Optical Character Recognition: On-line Data



$$\frac{1}{2\pi i}\int_C f(z)\,dz = \sum_{\mu=1}^{m} \operatorname{Res}_{\mu} f(z)$$

On-line Handwriting: Styles



Recognition of mathematical Expressions

Characteristics:

- Scope of recognition Systems
- Groping of symbols

  $sint \quad \sim \sin t$
- Explicit and implicit operators

  $a \ + b \ , a^{\ b} , ab.$
- Ambiguity of symbols

  Σ is sigma or sum. $dy \ , cx + \ dy \ , \int y \ dy$
- Irregular writing

  $2^x \ 2^x \ 2^x \ 2^x \ 2x \ 2x \ 2x \ 2x$

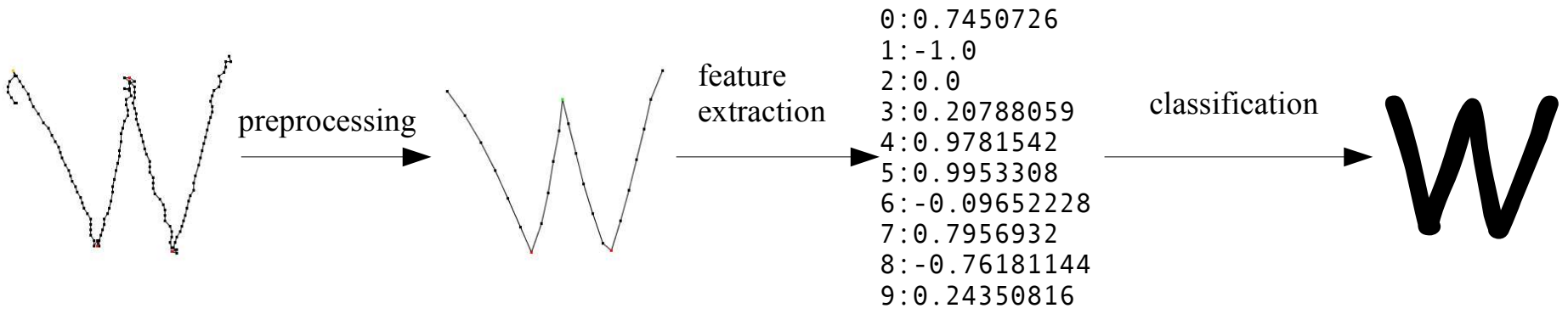
Recognition of mathematical Expressions

A two-step approach:

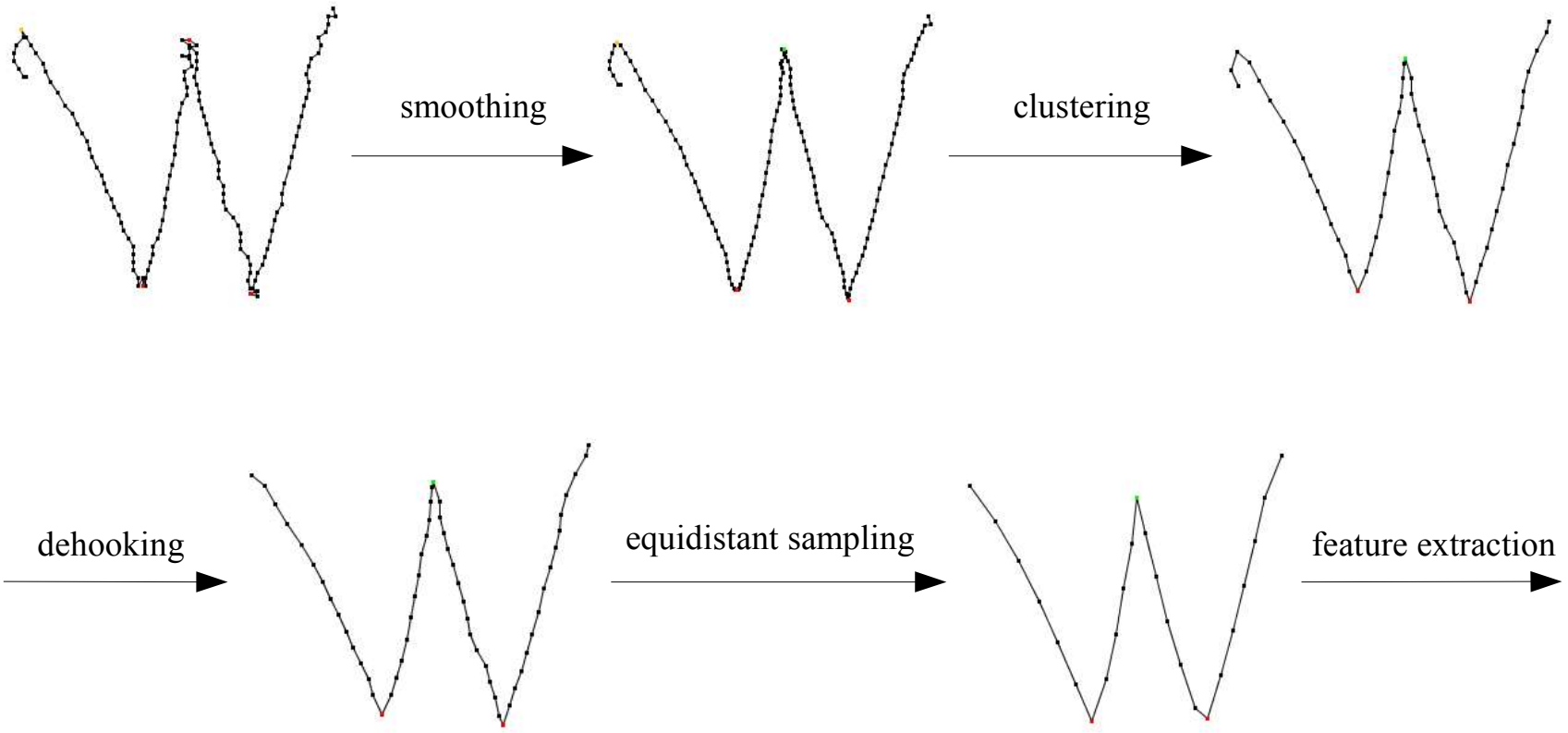
1) Symbol recognition

2) Structural analysis of the expression

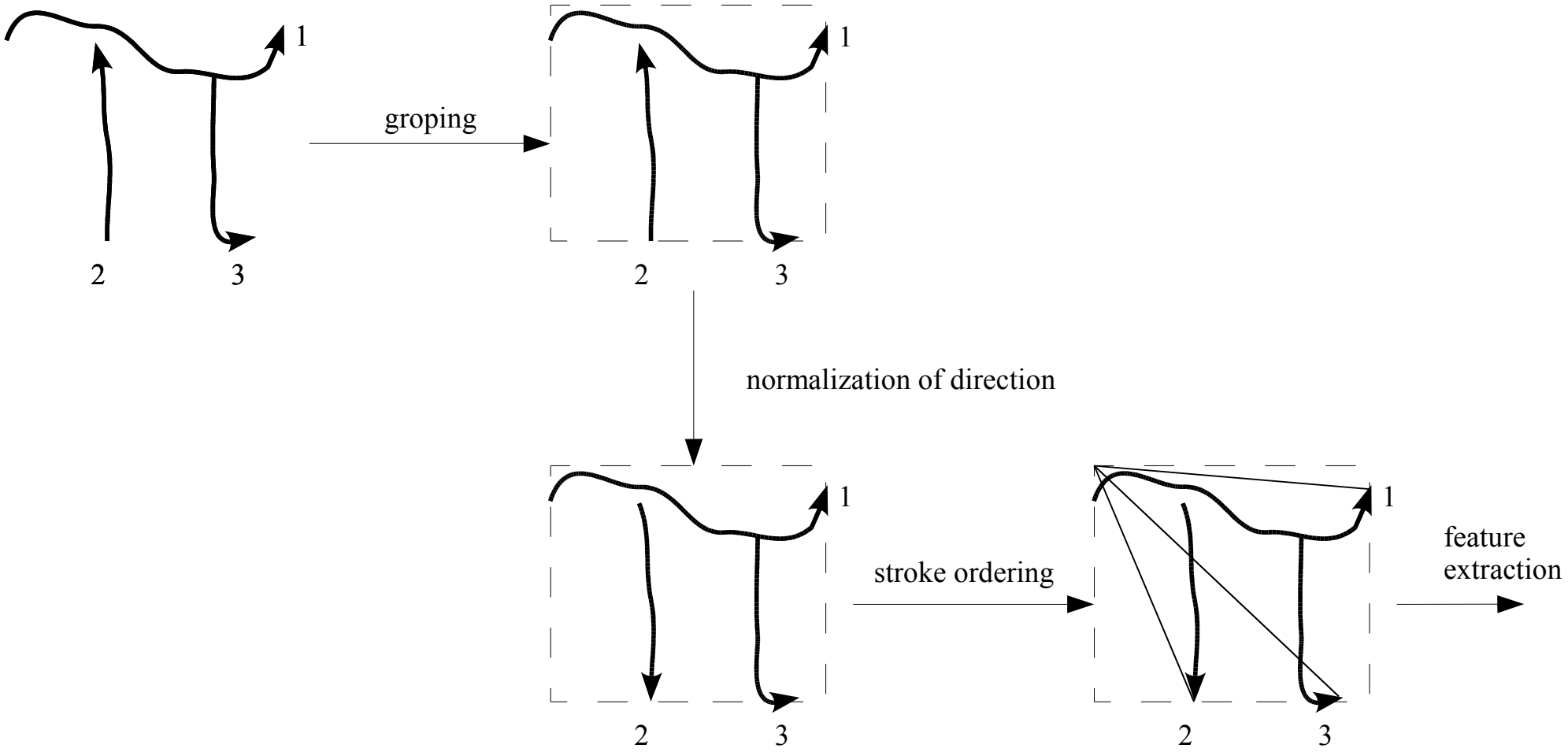
Symbol Recognition: Classification



Symbol Recognition: Preprocessing



Symbol Recognition: Preprocessing Symbols with several Strokes

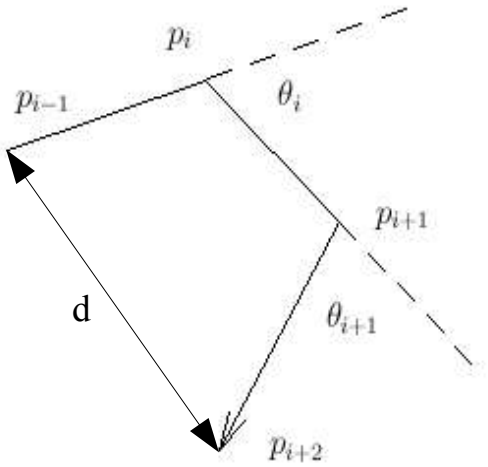


Symbol Recognition: Features

Given a stroke $(p_1, p_2, \ldots, p_n)$

Local features:

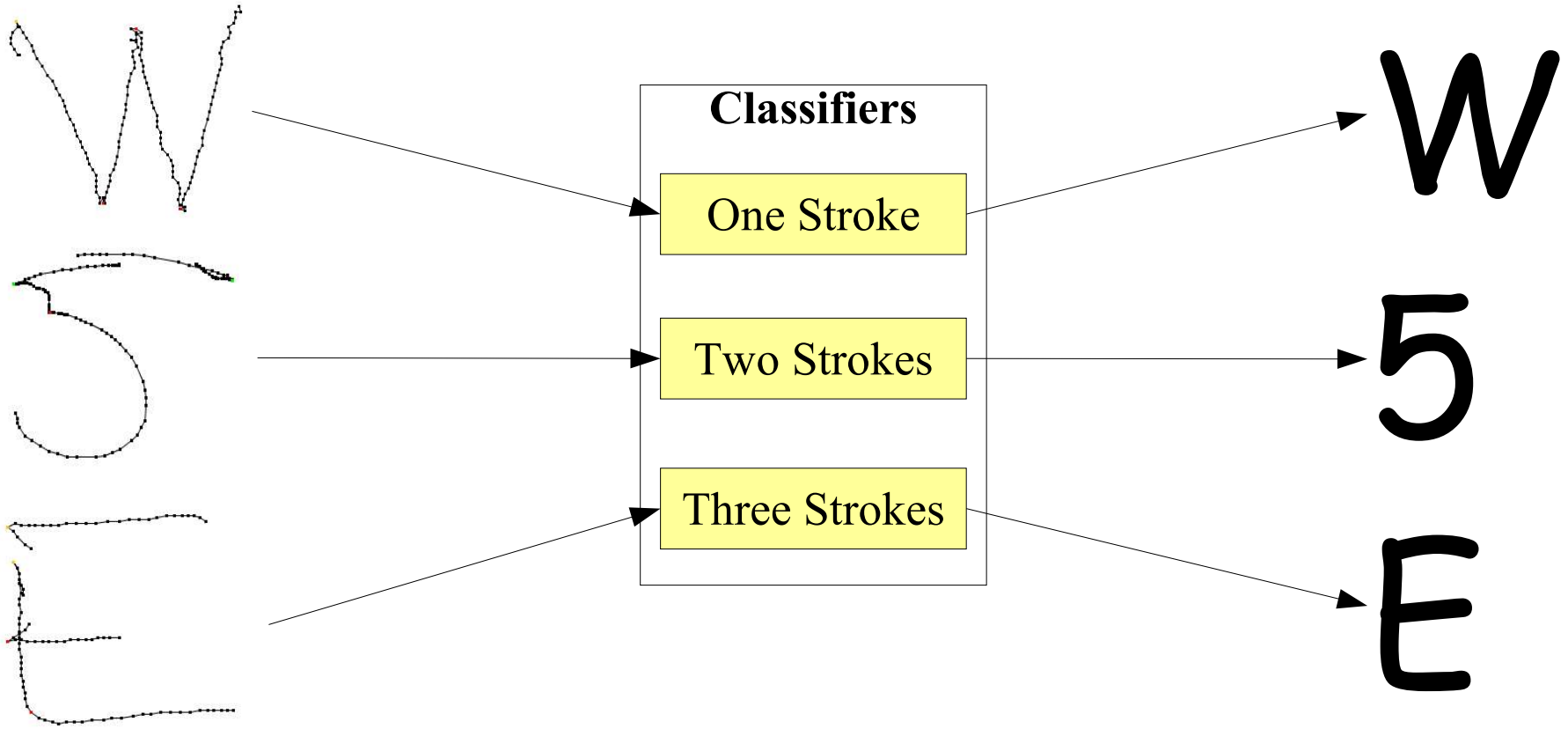
- Coordinates (x_i, y_i)
- Turning angle θ_i
- Change of turning angle $\theta_{i+i} - \theta_i$



Global features:

- Center of gravity $1/n \sum_{i=1}^{n} p_i$
- Length: L
- Relative length: L/d
- Accumulated angle $1/2\pi \sum_{i=1}^{n} \theta_i$

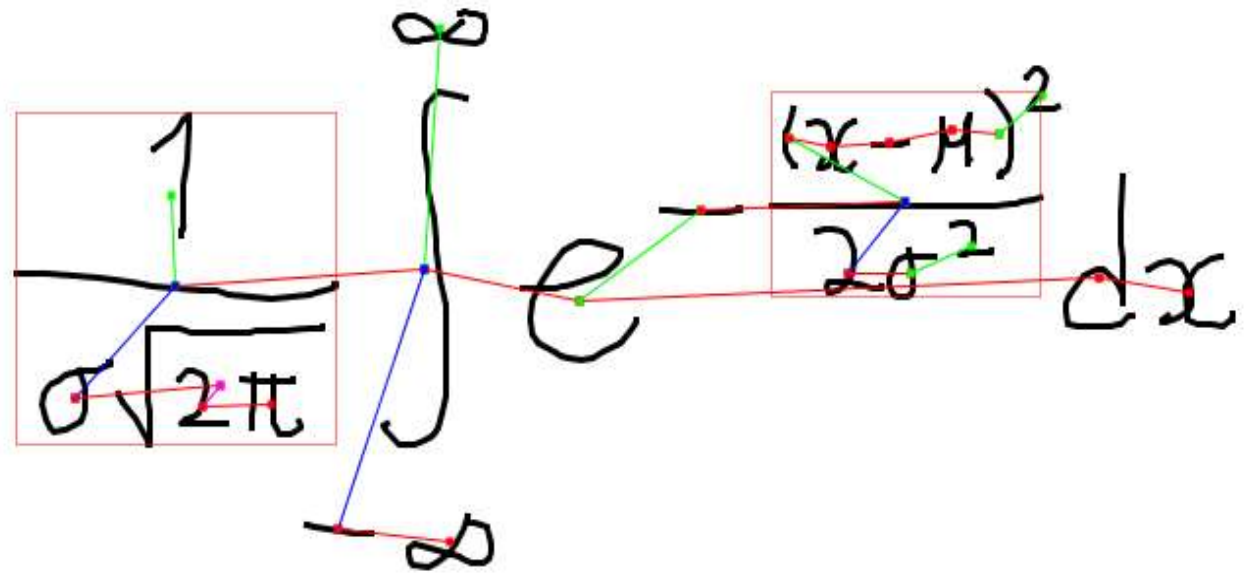
Symbol Recognition: Classification



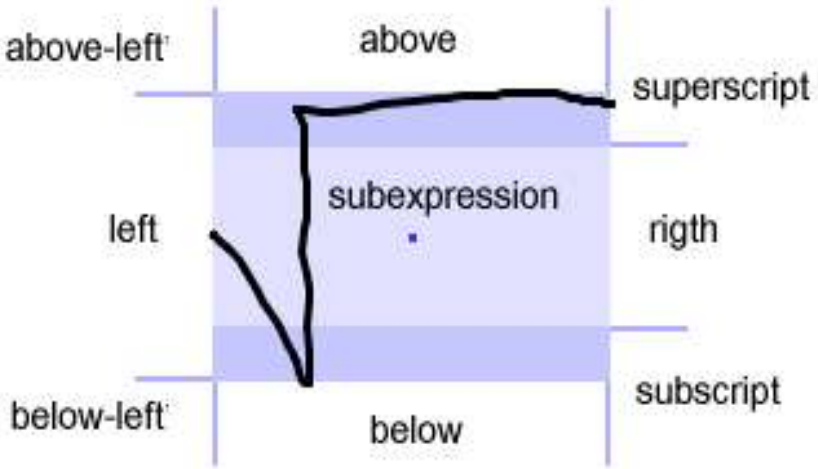
Classification uses support vector machines or artificial neural networks

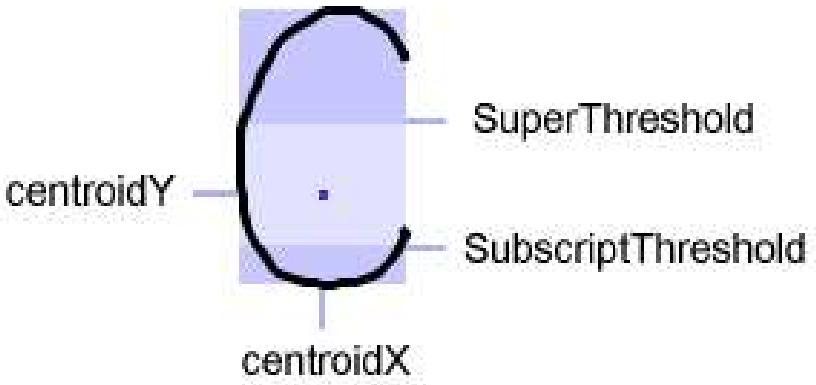
Structural Analysis: Representation of mathematical Expressions

An Expression is a structure of connected baselines

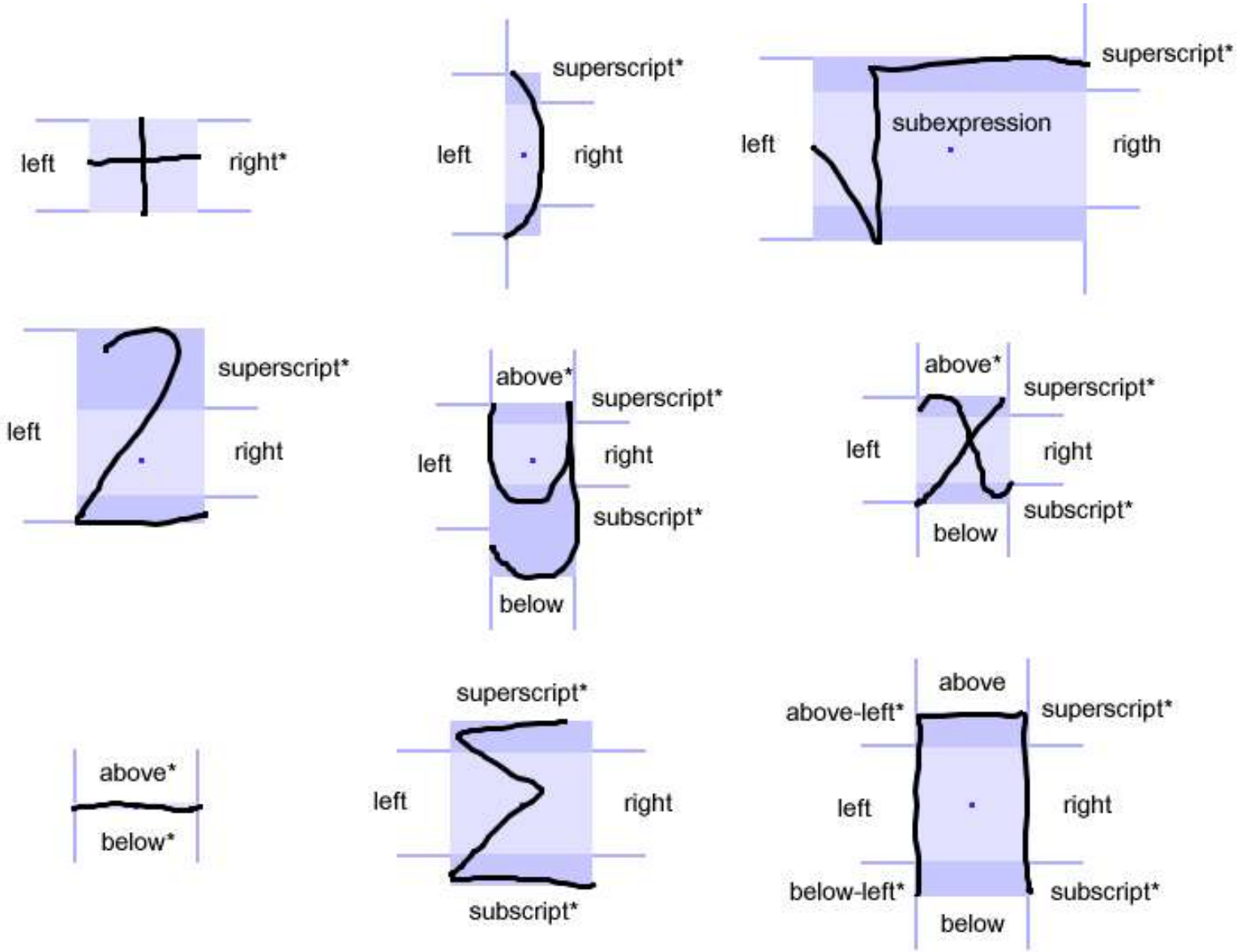


Structural Analysis:
Spacial Relations and Attributes

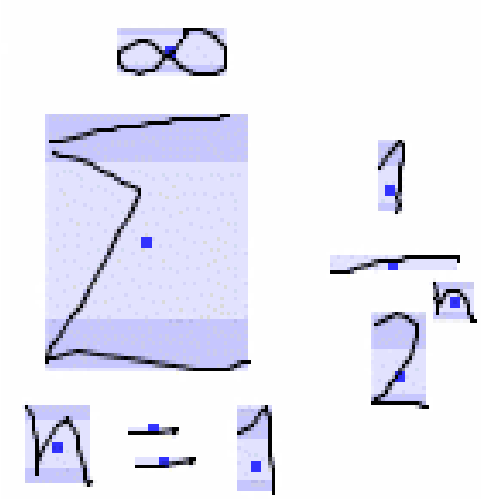


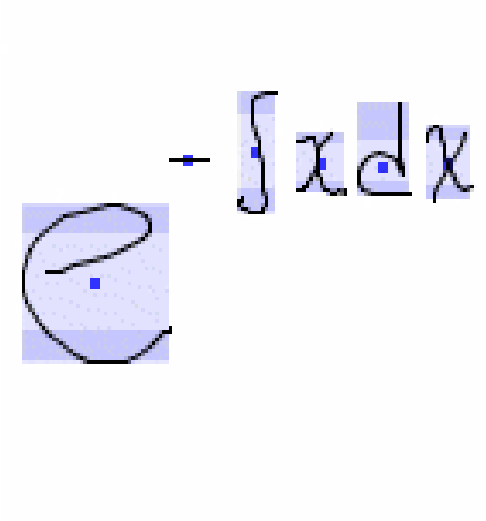


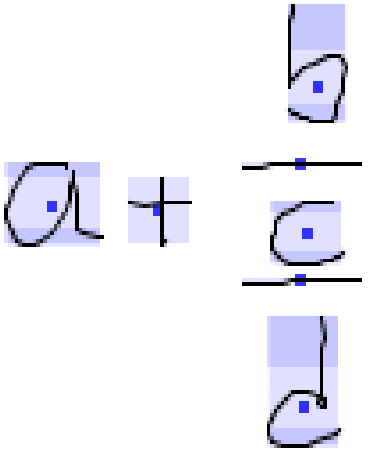
Structural Analysis: Dominance



Structural Analysis: Dominance

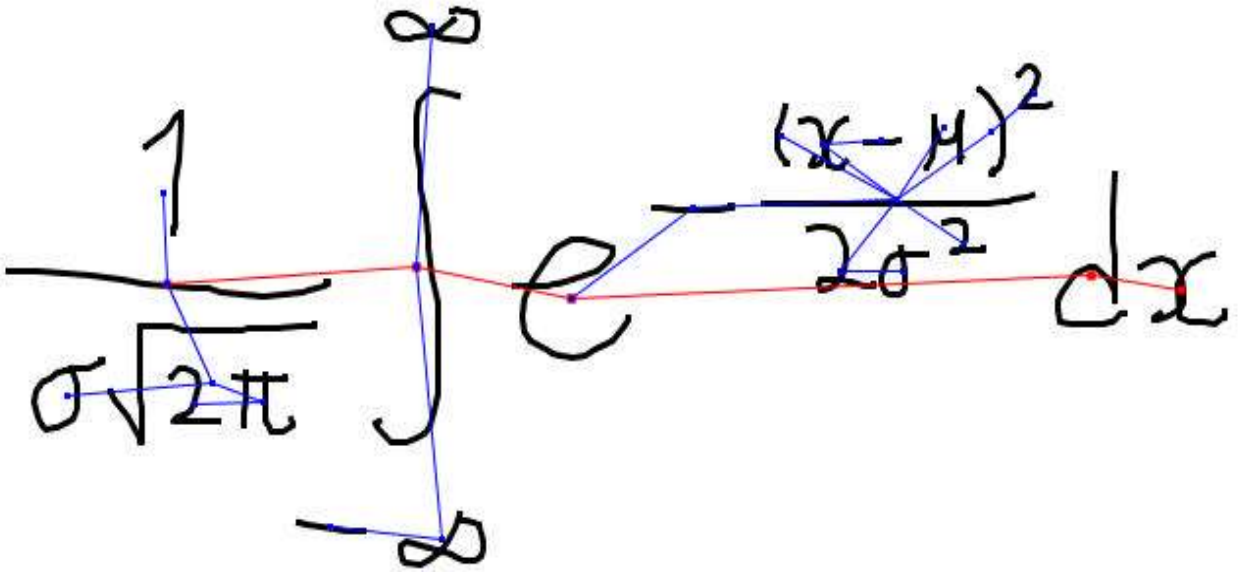






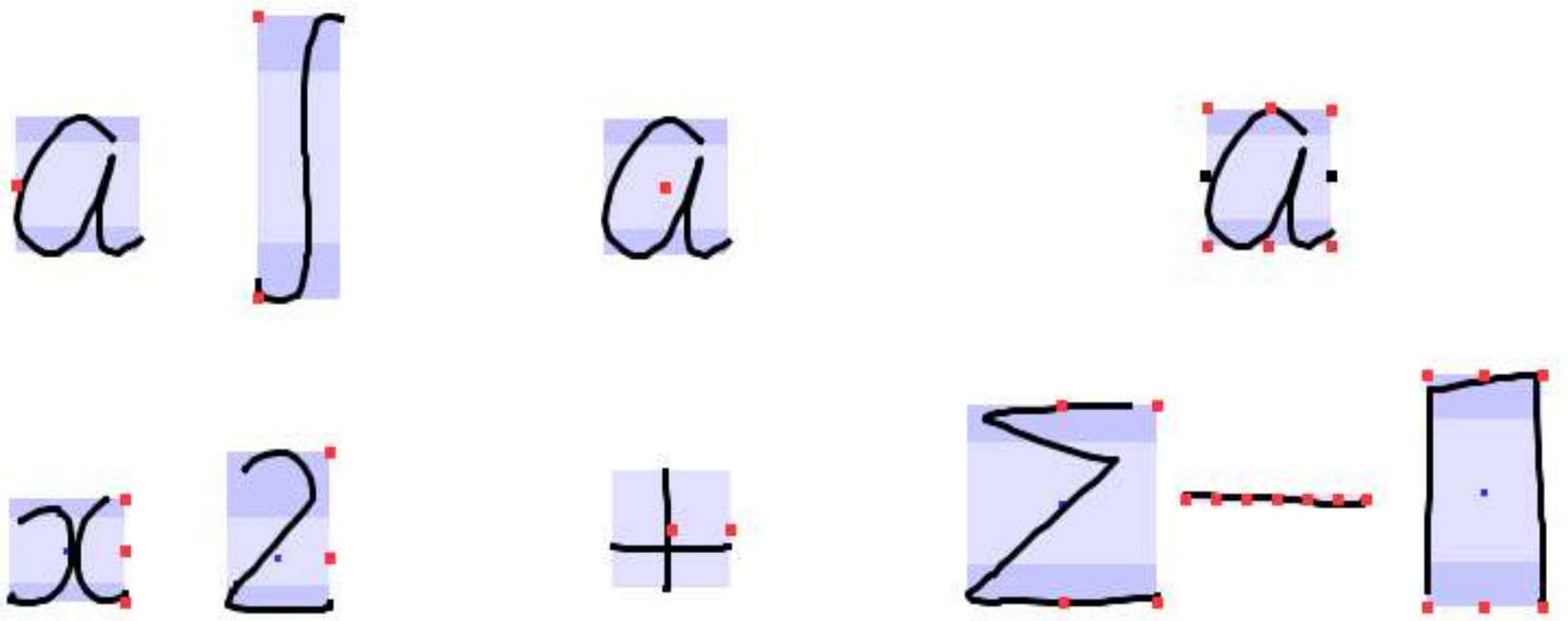
Structural Analysis

- Find the dominant baseline
- Locate clusters of symbols
- Find dominant baselines in clusters



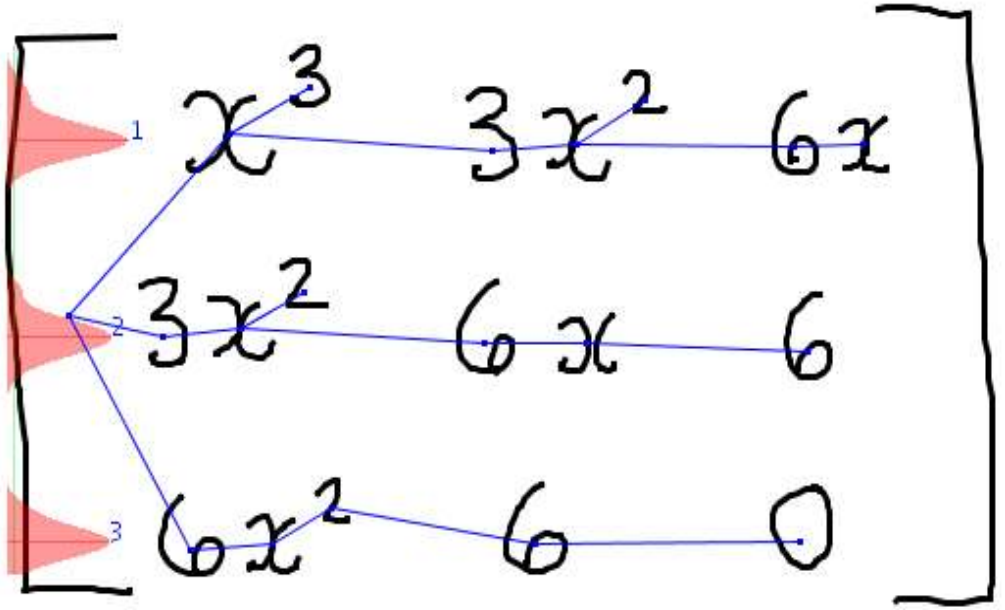
Structural Analysis: Attractor Points

Attractor Points for different classes of symbols:



Structural Analysis: Matrices

- Construct dynamically Attractor Points
- Reduce the horizontal distance



Structural Analysis: Interpretation

- Typesetting

$$\frac{1}{\sigma\sqrt{2\pi}}\int_{-\infty}^{\infty} e^{-\frac{(x-\mu)^2}{2\sigma^2}}dx$$

LaTeX

```
\frac{1}{\sigma \sqrt{2\pi }}
\int ^{\infty }_{-\infty }
e^{-\frac{\left( x-\mu \right) ^
{2}}{2\sigma ^{2}}}dx
```

- Computer Algebra Systems

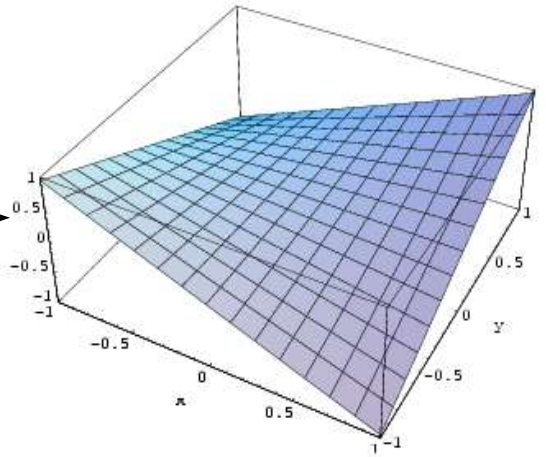
$$\int x^n \, dx$$

Calculus

$$\frac{x^{n+1}}{n+1}$$

$$f(x,y) = x * y$$

Plotting



An Editor for on-line handwritten mathematical Expressions...

Ende