Prototype Pruning by Feature Extraction for Mathematical Handwriting Symbol Recognition

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Background & Motivation

Pattern Recognition

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Optical Character Recognition

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Handwriting Recognition

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Mathematical Handwriting Recognition

Background & Motivation(Cont.)

- Why mathematical handwriting recognition?

Provide friendly interface for mathematics software.

Make mathematics editing and inputting much easier.

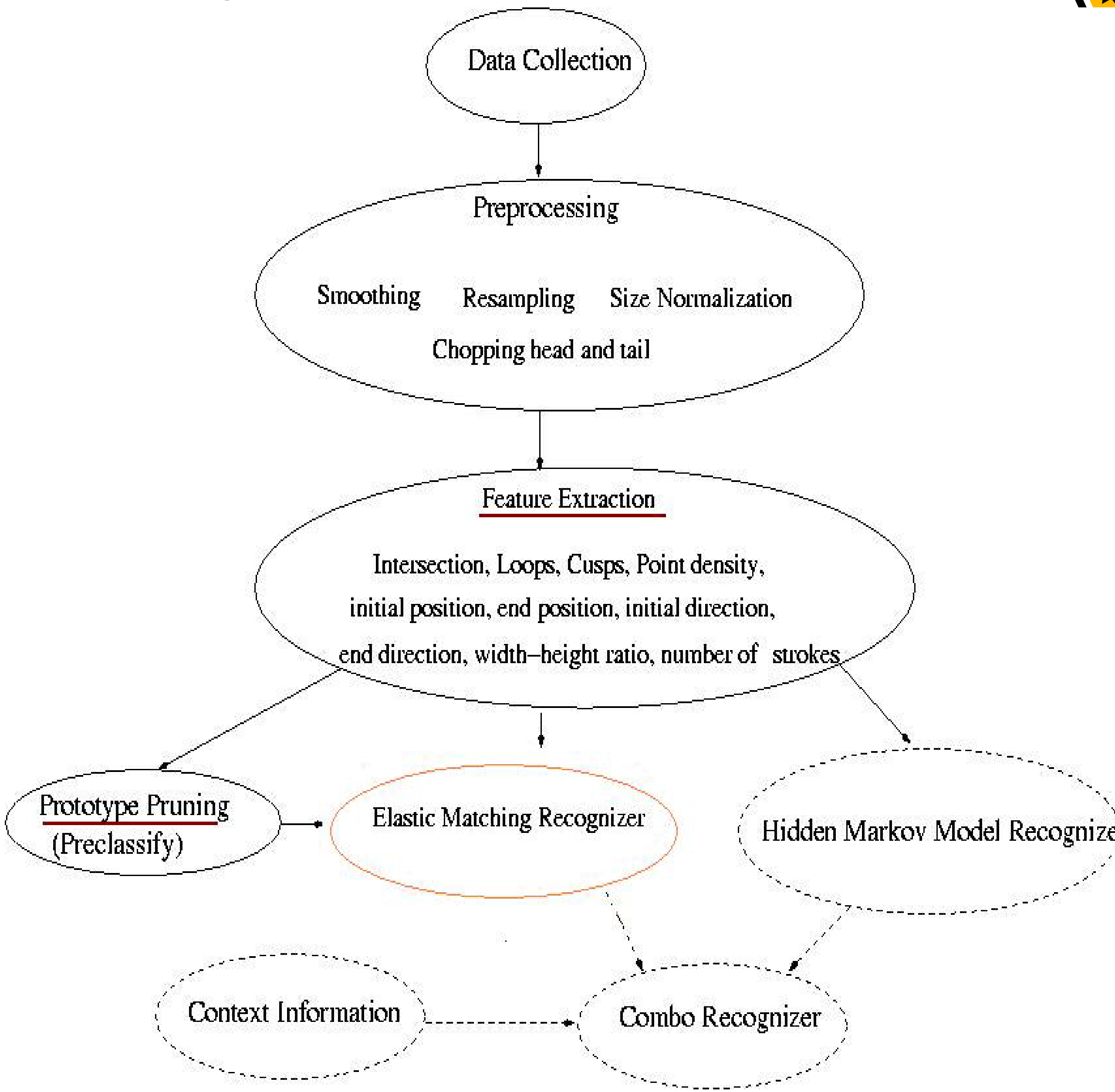
Mathematical Handwriting recognition is challenging.

Problems Statement

Mathematical handwriting differs from the other forms of handwriting.

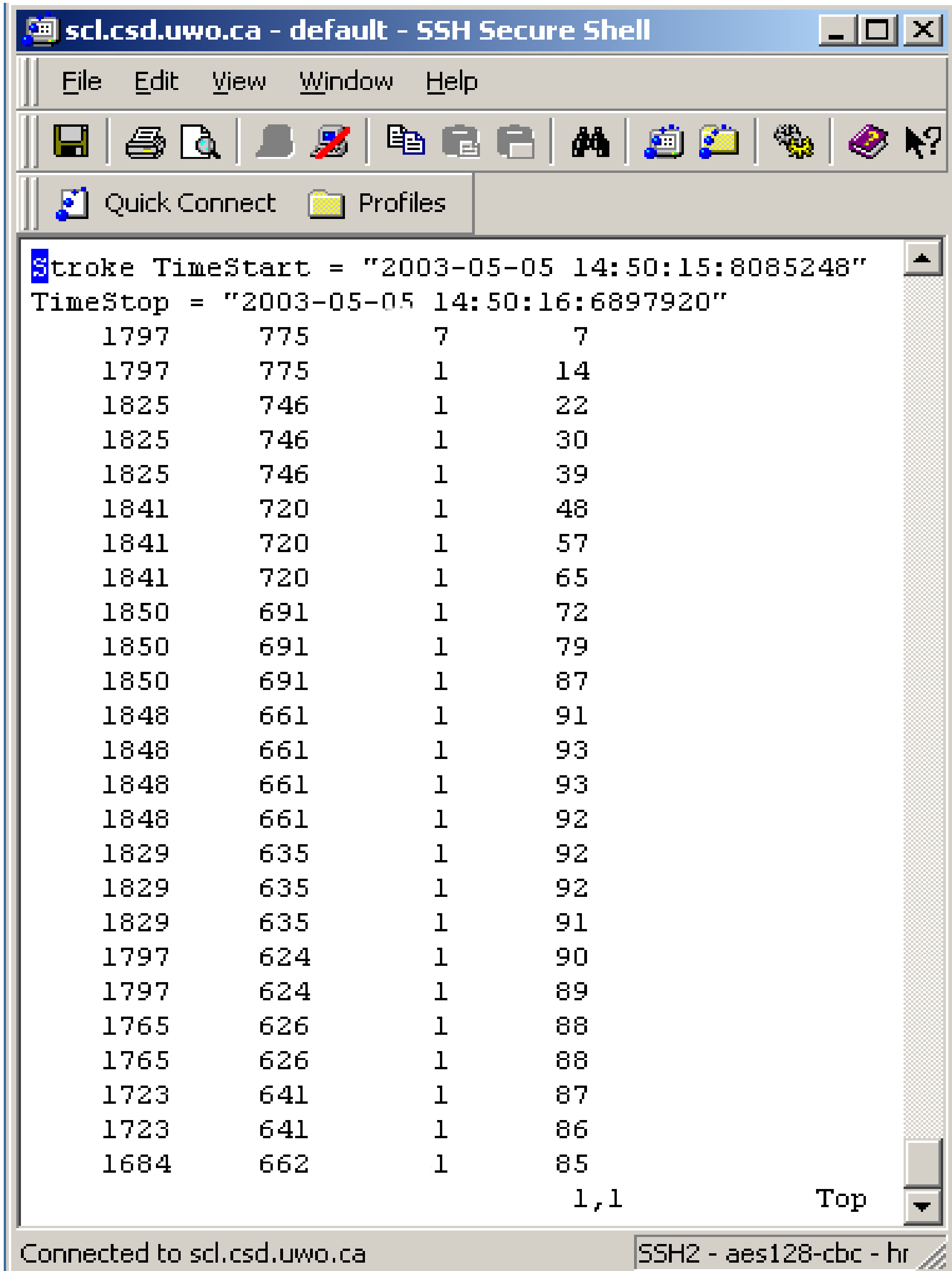
- The set of possible input symbols is very extensive.
- No specific stroke order and stroke number.
- Spatial relation can use complex context-sensitive two dimensional rules.
- All of the above affect the recognition accuracy and speed.

The Architecture of the recognizer



Data Collection

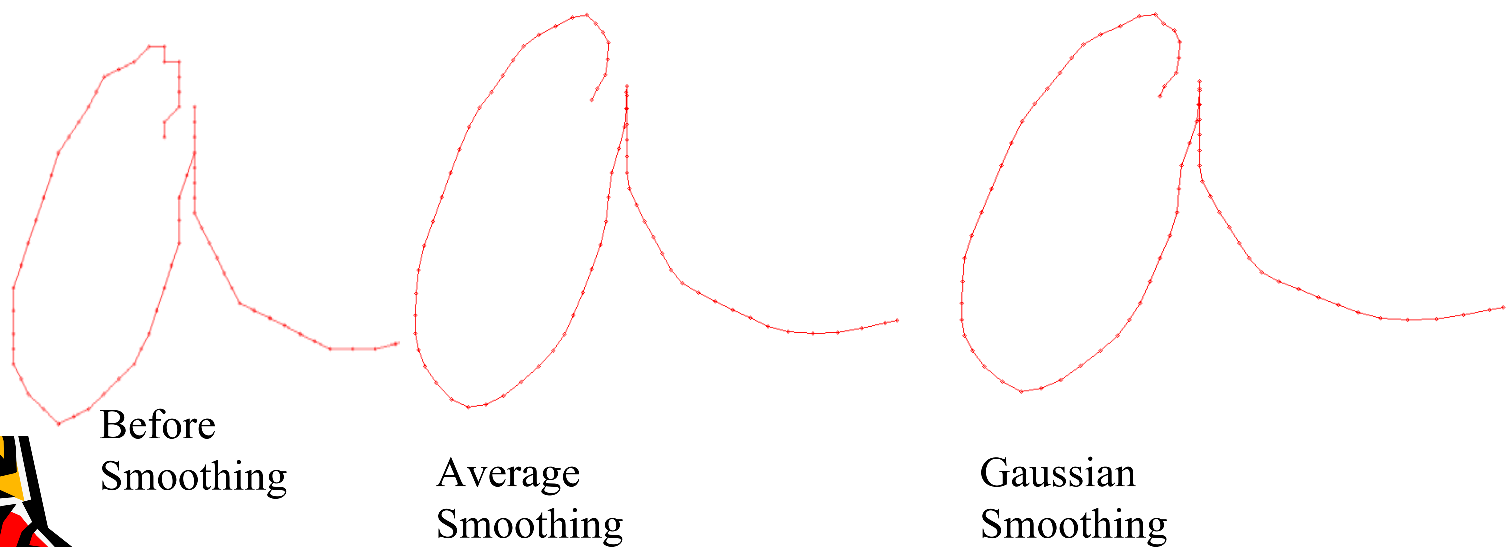
- IBM Cross Pad Data
- Tablet PC Data
- UniPen Data
- 240 symbols and a number of formulas.
- 227 symbols used in this presentation for comparison.



1797	775	7	7
1797	775	1	14
1825	746	1	22
1825	746	1	30
1825	746	1	39
1841	720	1	48
1841	720	1	57
1841	720	1	65
1850	691	1	72
1850	691	1	79
1850	691	1	87
1848	661	1	91
1848	661	1	93
1848	661	1	93
1848	661	1	92
1829	635	1	92
1829	635	1	92
1829	635	1	91
1797	624	1	90
1797	624	1	89
1765	626	1	88
1765	626	1	88
1723	641	1	87
1723	641	1	86
1684	662	1	85

Preprocessing

- Re-sampling to reduce computation and remove writing speed effect.
- Smoothing remove noise.
- Size normalization

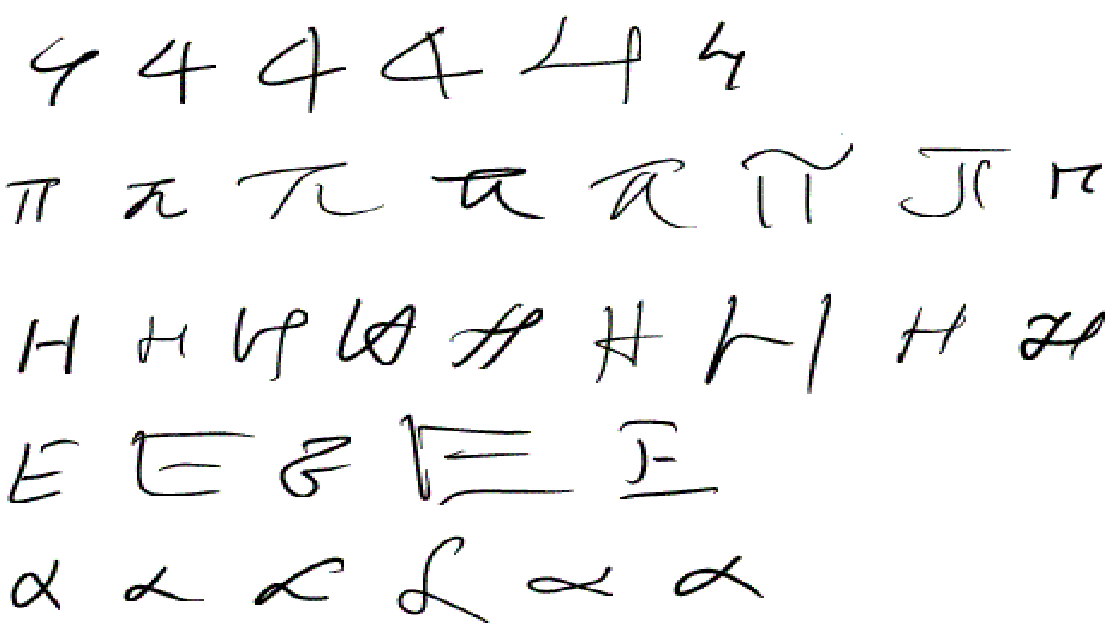


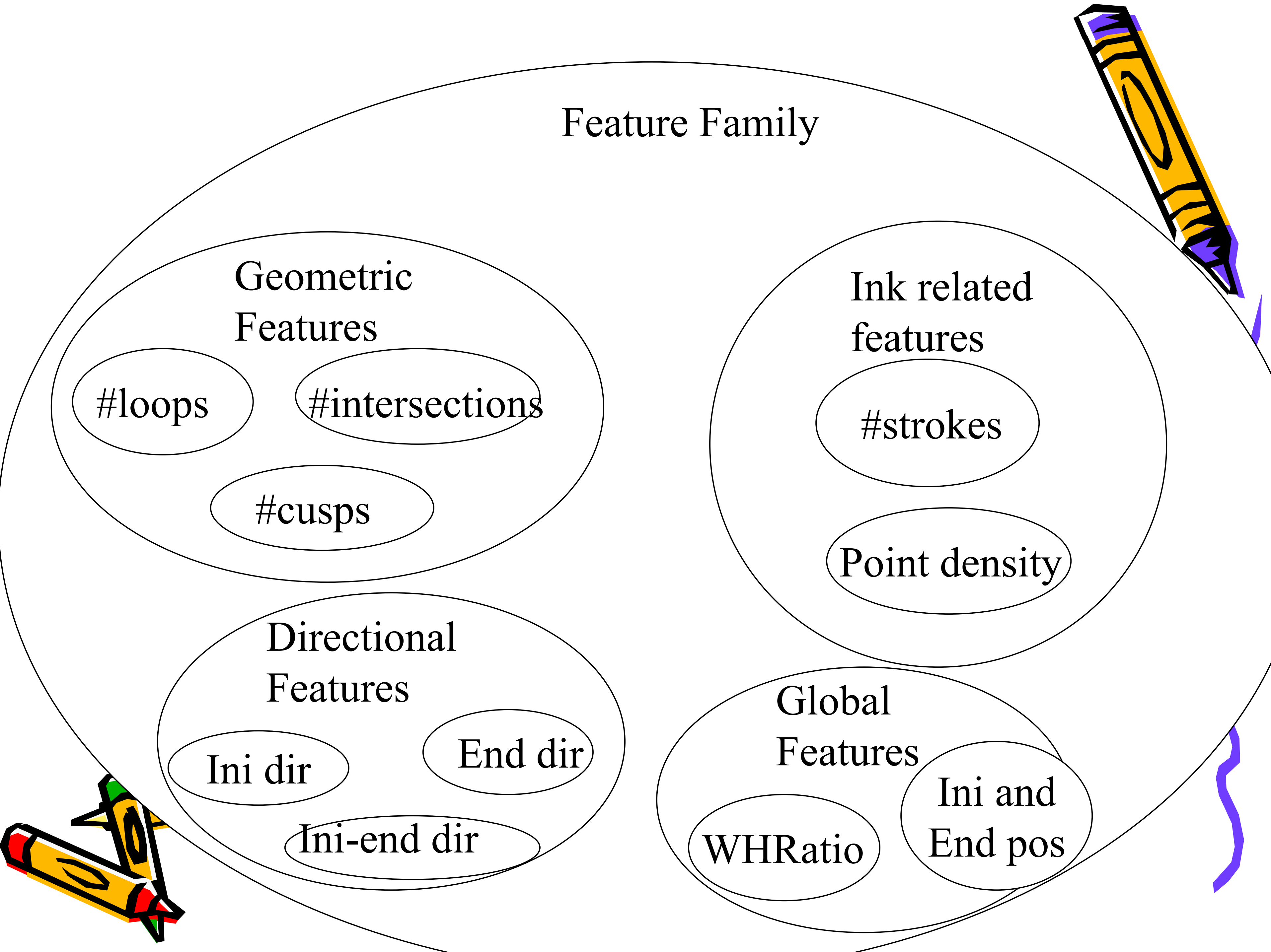
Feature Extraction

- It plays an important role in recognition.
- Features are defined as abstract characteristics which are unique to a symbol or a group of symbols.
- Features are often used for recognition.
- We use features for pruning prototypes.

Variance Analysis

- In order to identify proper features, we need to do handwriting variance analysis

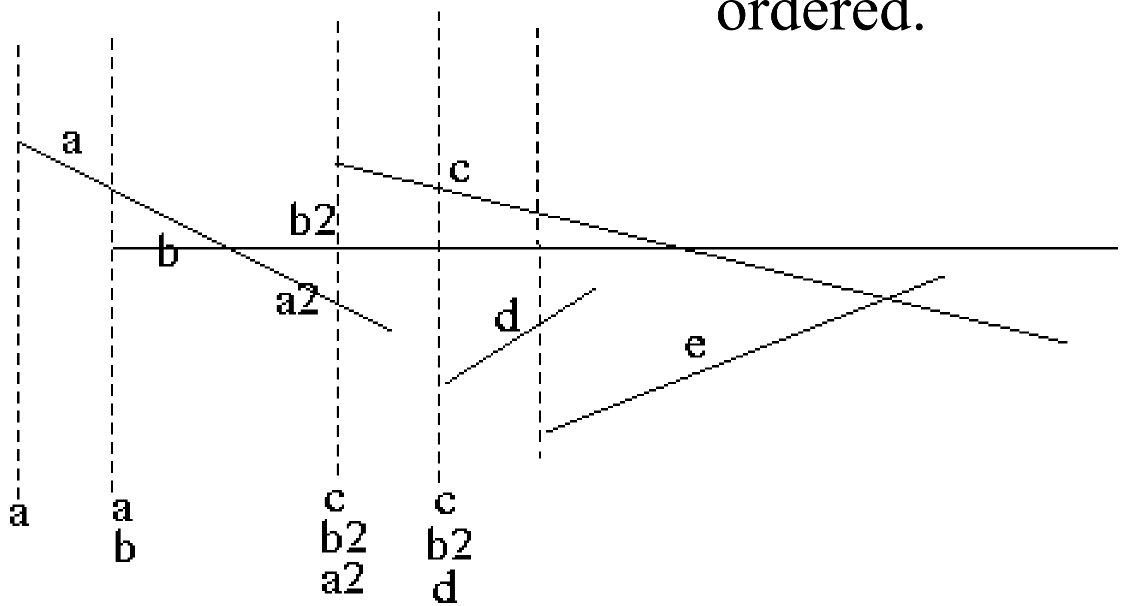



Feature Family
Geometric Features
#loops
#intersections
#cusps
Ink related features
#strokes
Point density
Directional Features
Ini dir
End dir
Ini-end dir
Global Features
WHRatio
Ini and End pos

Feature Extraction Algorithms

- Intersections:

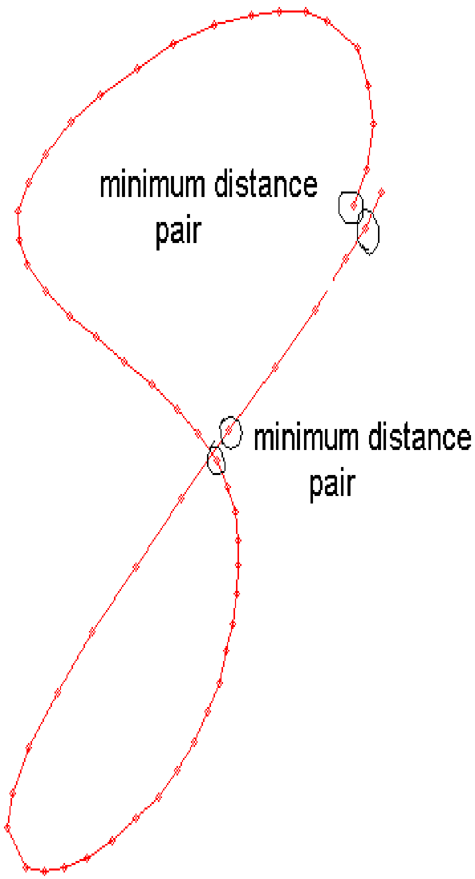
Line segments are ordered.



Modified Sweepline Algorithm

Feature Extraction Algorithms(cont.)

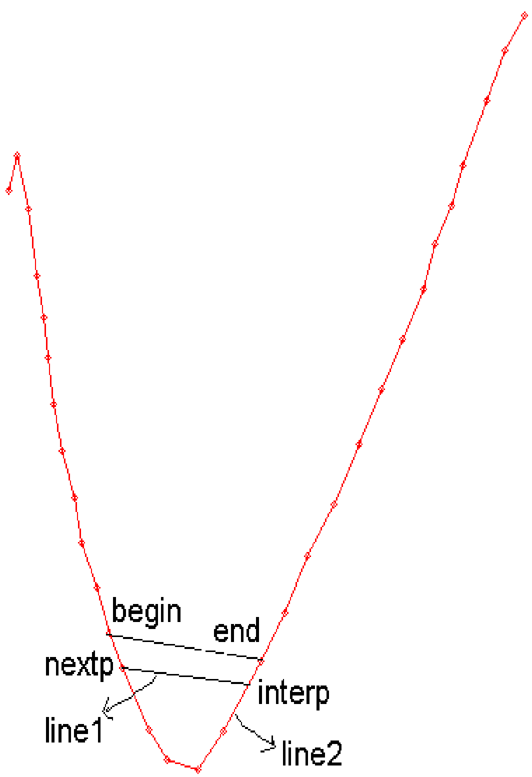
- Loops



Minimum distance pair: a pair of points which has the minimum non-local distance in a given area.

Feature Extraction Algorithms(cont.)

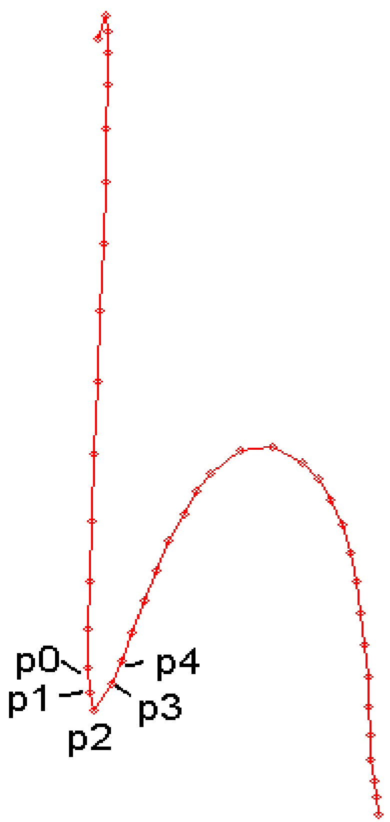
- loops

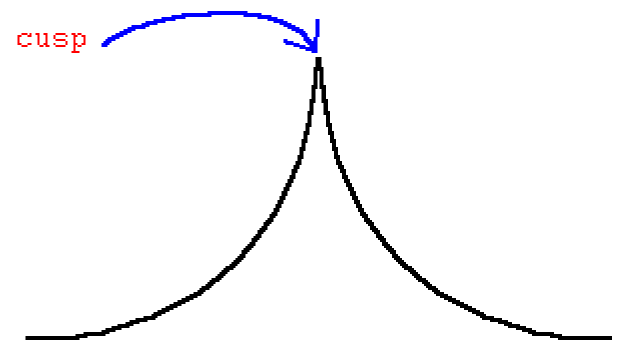


Use parallel line to filter the wrong loops

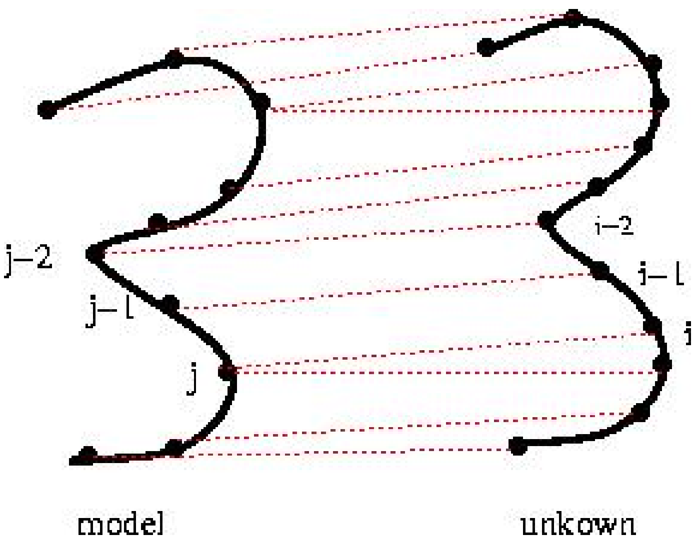
Feature Extraction Algorithms(cont.)

- Cusps





Recognition



$$D(i,j) = \delta(i,j) + \begin{cases} \sum_{k=0}^{j-1} \delta(0,k) & \text{if } i = 0 \\ \sum_{k=0}^{i-1} \delta(k,0) & \text{if } j = 0 \\ \min \begin{cases} D(i-1,j) \\ D(i-1,j-1) \end{cases} & \text{if } i > 0, j = 1 \\ \min \begin{cases} D(i-1,j-1) \\ D(i-1,j-2) \end{cases} & \text{if } i > 0, j > 1 \end{cases}$$

$$\delta(i,j) = (x_i - x_j)^2 + (y_i - y_j)^2 + C\,|\phi_i - \phi_j|$$

Elastic Matching

Experimental Results

Experiment	#prototypes	Recog.Rate(%)
P1:T1,2,3,4	227	81.8
P1,2:T1,2,3,4	454	90.1
P1,2,3:T1,2,3,4	681	93.9
P1,2,3,4:T1,2,3,4	908	94.8

Results without Features

Experimental Results(cont.)

Experiment	#prototypes	Candidate prototypes	Percent. Pruned	Recog. Rate(%)
P1:T1,2,3,4	227	26	88.5	76.0
P1,2:T1,2,3,4	366	38	89.6	85.5
P1,2,3:T1,2,3,4	495	52	89.5	90.0
P1,2,3,4:T1,2,3,4	575	60	89.6	91.9

Results With Features

Experimental Results(cont.)

experiment	#prototype		Candidate prototypes		Percentage Pruned		Recog. Rate(%)	
	J.K's	Our	J.K's	Our	J.K's	Our	J.K's	Our
P1-4:T1-4	121	169	47	24	61.5	85.8	99.0	97.6
P1-4:T1-4	122	288	92	288	N/A	N/A	99.0	99.7

Our vs. J.Kurtzberg's Results

Conclusion

- We have made progress in handwritten mathematical symbol recognition area by using feature sets to prune the prototypes.
- We have attempted to identify these features, and analyzed thousands of handwriting samples.
- Our recognizer can recognize digits, English letters, Greek letters, most of the common mathematical operators and notations.
- Accuracy and speed are improved comparing with a recognizer in the literature.