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Pattern Recognition

Exercise Session 7

Keyword Spotting with Dynamic Time Warping

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Exercise 3

Keyword Spotting using Dynamic Time Warping (DTW)

Data and Info on Github:
https://github.com/lunactic/PatRec17_KWS_Data

Also see slides 27+ from lecture 7

What to do first

Analyze the data

Preprocessing

- Binarization
- Create Word Images

Compute some features

Pre-processing

Crop

- Easiest: bounding box
- Polygon as clipping mask

Binarization

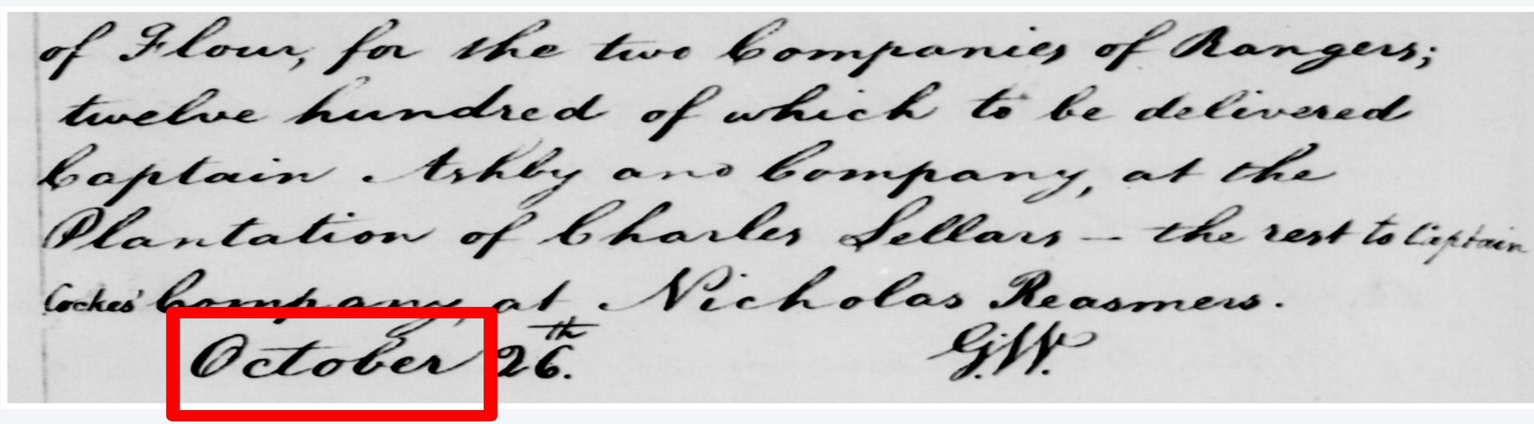
- Otsu, Sauvola, Difference-of-Gaussian

Keyword Spotting

Digitizing historical manuscripts for cultural heritage preservation

Textual content: searching and browsing scanned page images

- Widely unsolved for historical handwriting
  - too many writing styles and languages
- Keyword spotting is a “shortcut”: identify individual search terms

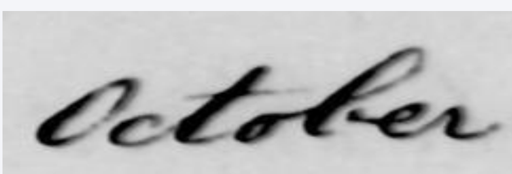

of Flour, for the two Companies of Rangers;
twelve hundred of which to be delivered
Captain Ashby and Company, at the
Plantation of Charles Sellars – the rest to Captain
Cockes' Company at Nicholas Reasmers.
October 26th. G.W.

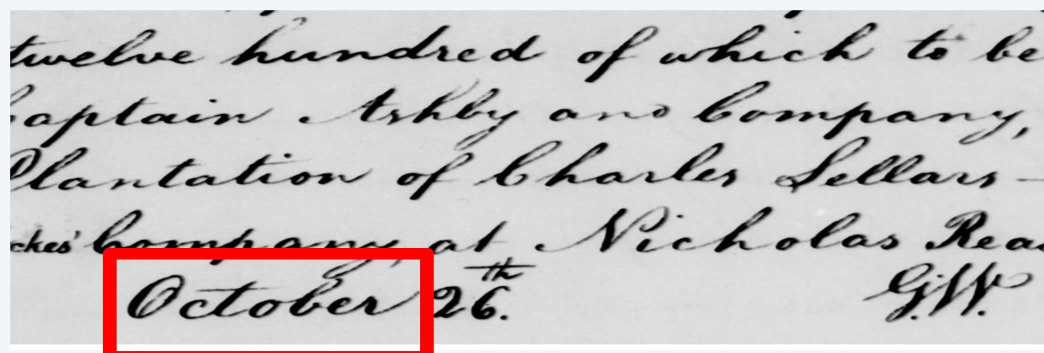
Query-By-Example

"one-shot learning": provide one example word image

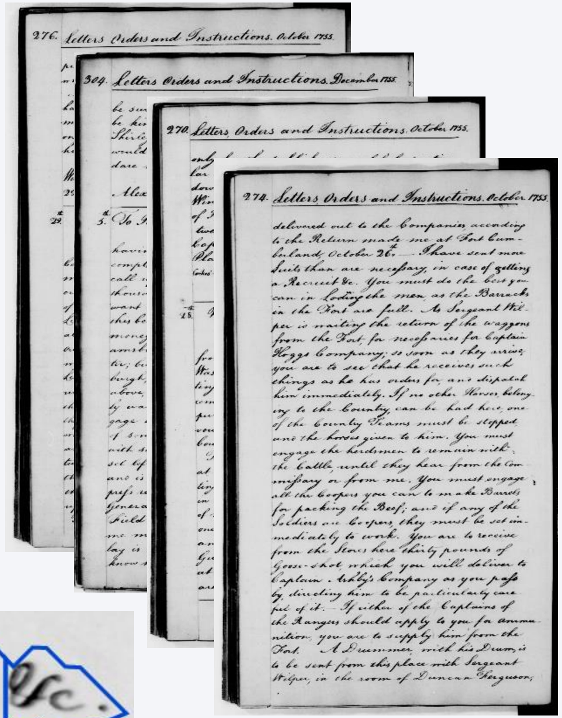
Goal: find similar word images in the manuscript

- Usually constrained to a single-writer scenario (sample from the same manuscript)



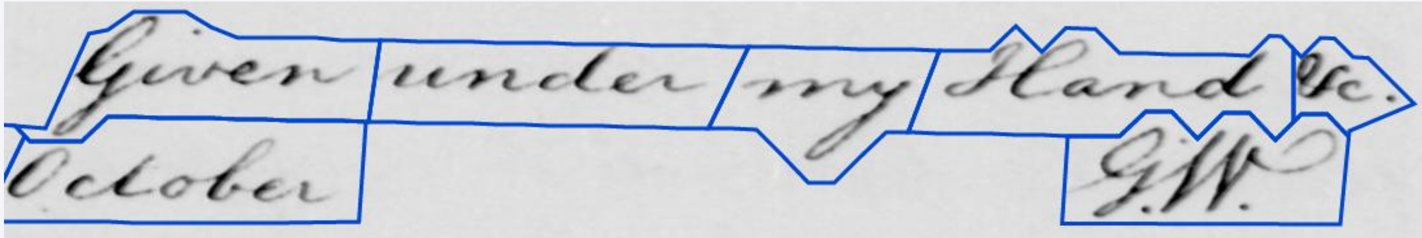


Data Set



WashingtonDB

- Letters of George Washington
- Library of Congress
- 18th century, longhand script



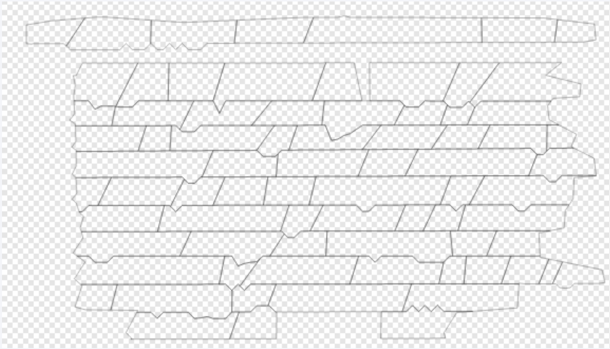
Data

/ground-truth/transcription.txt

Character based transcription

/ground-truth/locations/*.svg

Polygons of word segments



/images/*.jpg

The page images

/task

Splitting into train and validation set

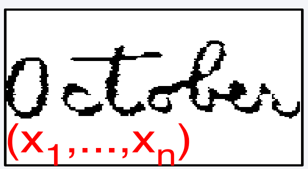
Keywords.txt -> words that are contained in both sets

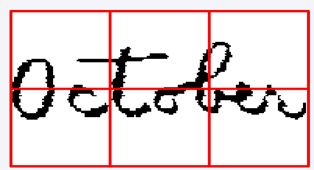
Exemplary Dissimilarity Approaches

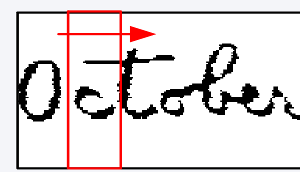
Global: extract global features, compute the Euclidean distance between the feature vectors

Grid-based: extract features for each cell, compute the sum of Euclidean distances over all cells

Sliding window-based: extract features for each window, compute the dynamic time warping (DTW) distance between two sequences of feature vectors --> your task!



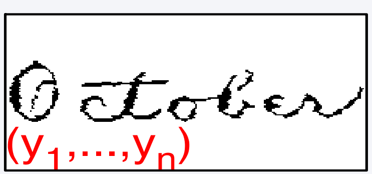


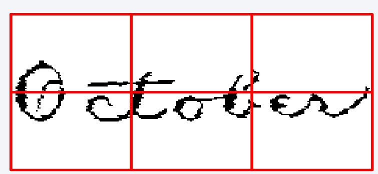


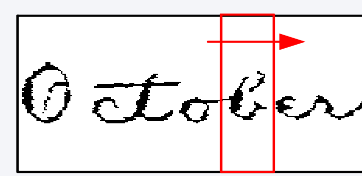
$d(x,y) = \|x-y\|$

$d(x,y) = \sum \|x_i-y_i\|$

$d(x,y) = DTW(x,y)$







Dynamic Time Warping (DTW)

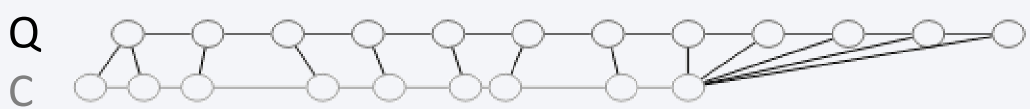
Dissimilarity between two feature vector sequences

$$Q = q_1, \ldots, q_N ; q_i \in R^n$$

$$C = c_1, \ldots, c_M ; c_i \in R^n$$

Dynamic time warping *aligns two sequences* ($q_i \rightarrow c_j$), along a common time axis usually with Euclidean cost:

$$\phi(q_i \rightarrow c_j) = \left\| q_i - c_j \right\| = \sqrt{\sum_{k=1}^{n} \left(q_{i,k} - c_{j,k} \right)^2}$$



DTW – How To (1)

Non-linear mapping between 2 sequences minimizing the distance between them

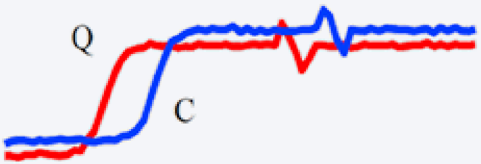
$$Q = q_1, \ldots, q_N ; q_i \in R^n$$

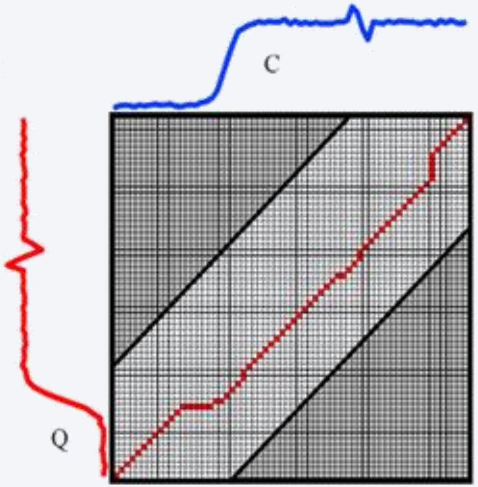
$$C = c_1, \ldots, c_M ; c_i \in R^n$$

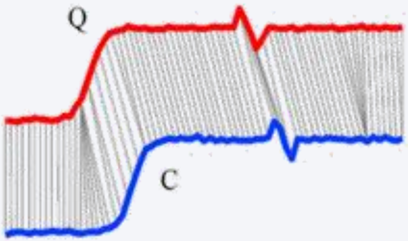
N-by-M matrix, where (i^{th}, j^{th}) element alignment between points q_i and c_j

$$d(q_i, c_j) = \sqrt{(q_i - c_j)^2}$$

Find the best match: retrieve a path through the matrix that minimizes the total cumulative distance







DTW – How To (2)

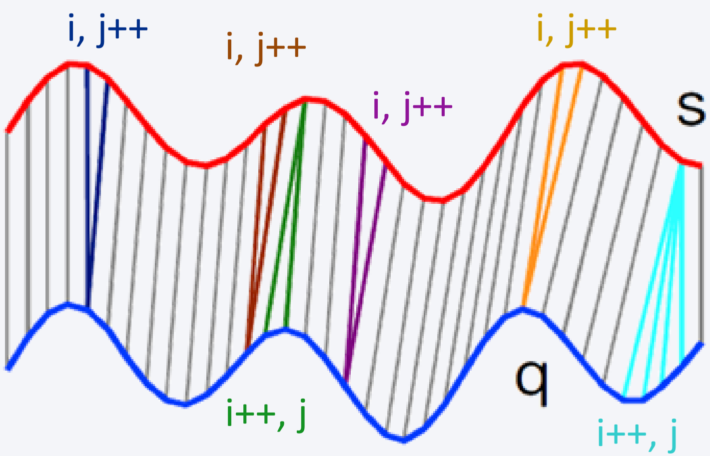
Start from (1,1) and end in (n,m)

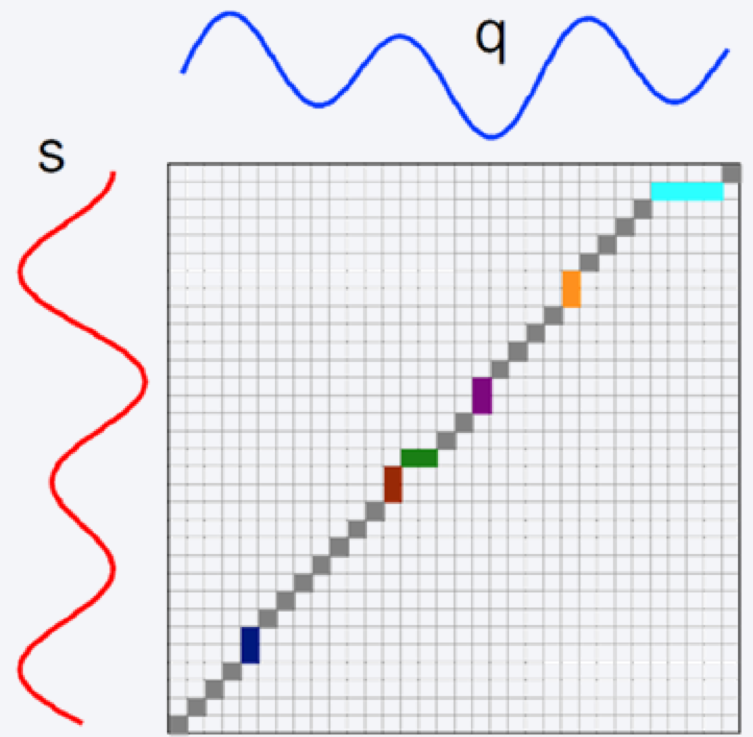
At each step, increase *i*, *j*, or both

(never go back)

Jumping not allowed!

Sum distances in the path





DTW – Computational Efficiency

Sakoe-Chiba Band: Reduce the number of paths to consider

Excludes abnormal edit paths

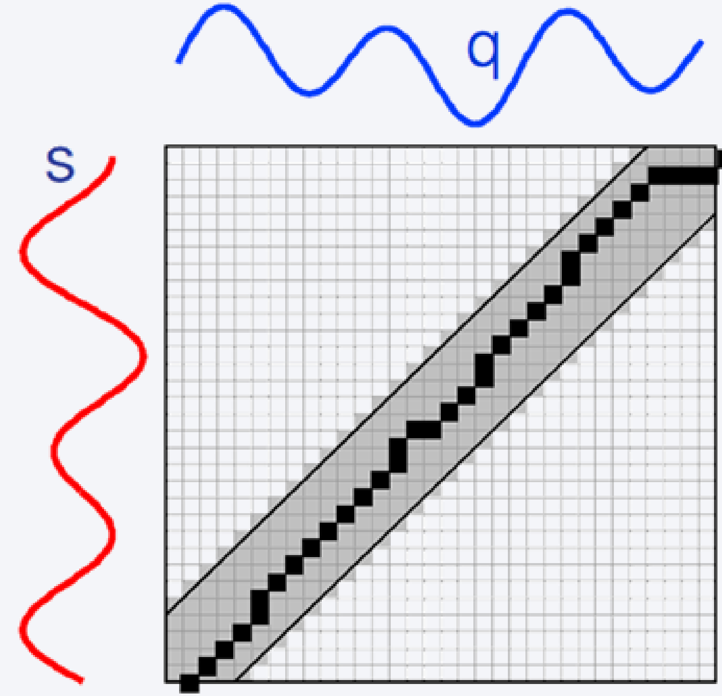
Speeds up the computation

Sequences of same length

s ↑

7				43	24	17
3			7	11	8	8
4		6	9	18	8	7
5	10	5	11	18	7	
2	1	2	2	3		
1	1	5	6			
DTW	2	3	2	1	3	4

→ q



Features for DTW

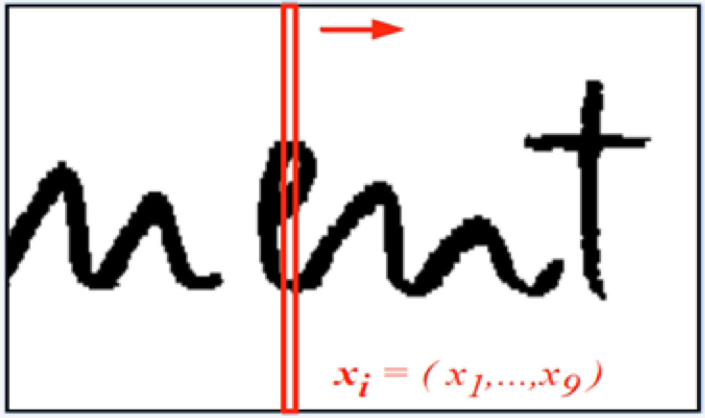
Normalize

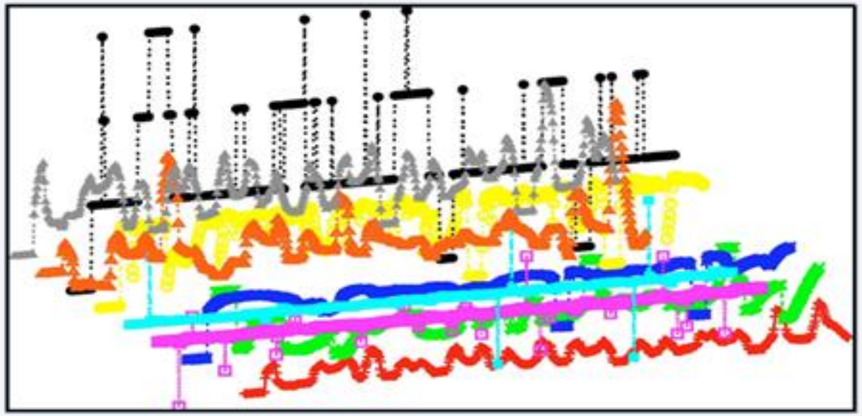
- Image dimensions (scale to same size, e.g. *100 px x 100 px*)
  → same-length sequence
- Feature vectors (e.g. $\frac{x_i - \mu}{\sigma}$)

Features for DTW – Suggestions …

Sliding window (suggestion: width 1 px, offset 1px)

- Lower contour (LC)
- Upper contour (UC)
- # b/w transitions
- Fraction of black px in the window
- Fraction of black px between LC and UC
- Gradient: difference LC_i, UC_i to LC_{i+1}, UC_{i+1}

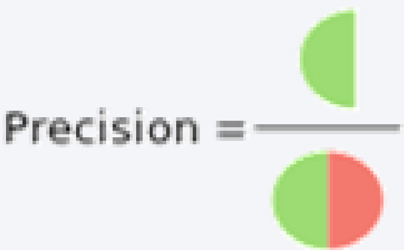




Evaluation: Recall – Precision

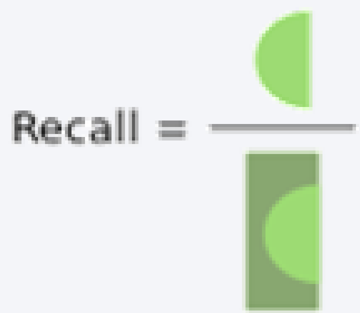
Retrieval-Task: two main questions

How many selected items are relevant?

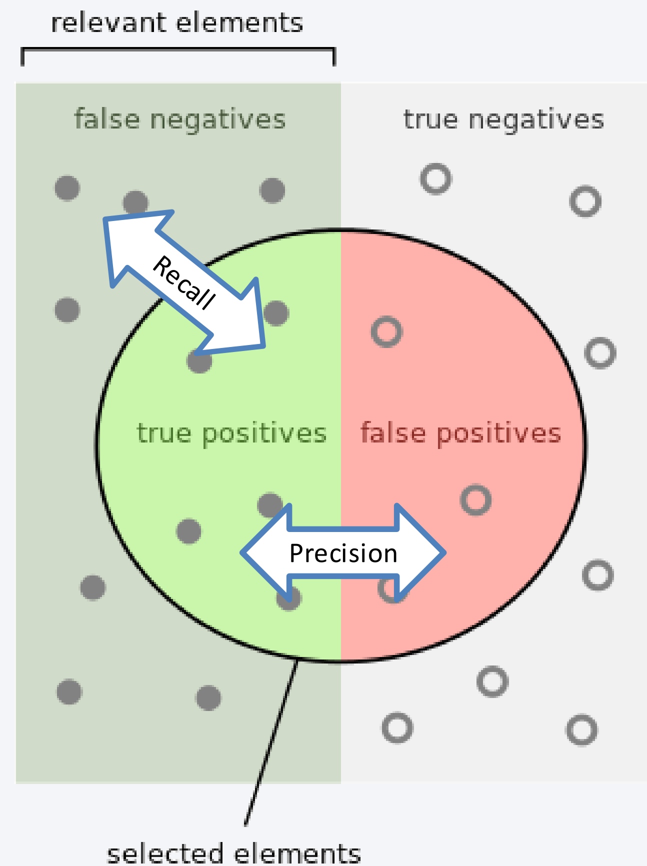


$$\text{Precision} = \frac{TP}{TP + FP}$$

How many of the relevant are selected?



$$\text{Recall} = \frac{TP}{TP + FN}$$



Recall-Precision Curve / AP

For image, each threshold, compute the

- True Positives (TP)
- False Positives (FP)
- False Negatives (FN)

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$ = True Positive Rate (TPR)

$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

Average Precision (AP)

Area under the Recall-Precision curve