UNIVERSITÉ DE FRIBOURG
UNIVERSITÄT FREIBURG

Pattern Recognition

Exercise Session 7

(Keyword) Word Spotting with Dynamic Time Warping

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Exam Registration

- **Registration deadline: 14. May 2021**
- Registration via the Academia platform

- Written and in person exam

- When: 21.06.2021 at 10:00 - 11:00h
- Where: Joseph Deiss lecture hall

Remember First Group Exercises

Exercises 2a,2b,2c,2d

- Deadline: **Today**
  - April 19, 2021 (end of day)
- Push your solution to your GitHub's master/main branch

Do not forget the individual task!

- Deadline: **Today**
  - April 19, 2021 (end of day)
- Upload to ILIAS!

Exercise 3

Keyword Spotting Task using Dynamic Time Warping (DTW)

Deadline: May 10, 2021 (end of day)

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

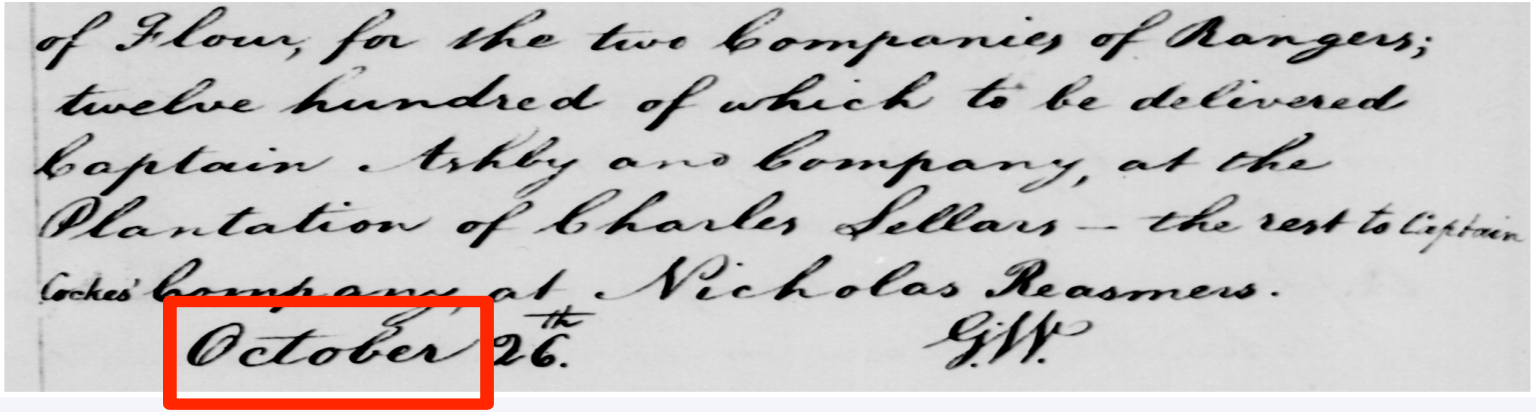
Also see slides 27+ from lecture 7

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

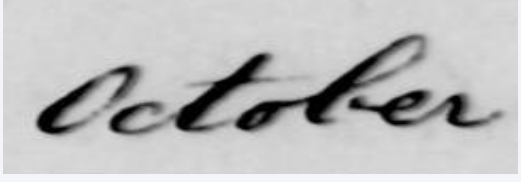


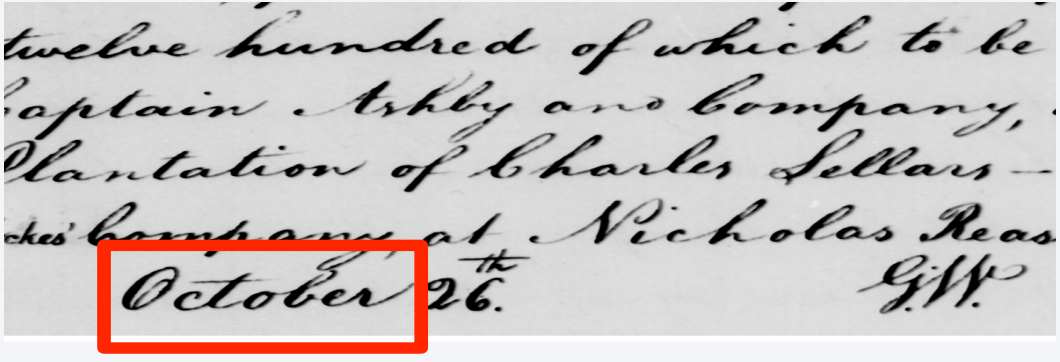
Query-By-Example

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

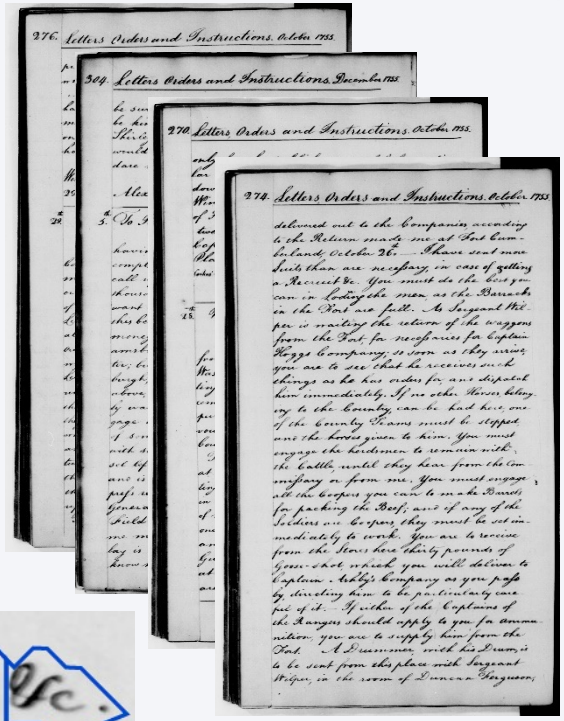
Goal: find similar word images in the manuscript

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



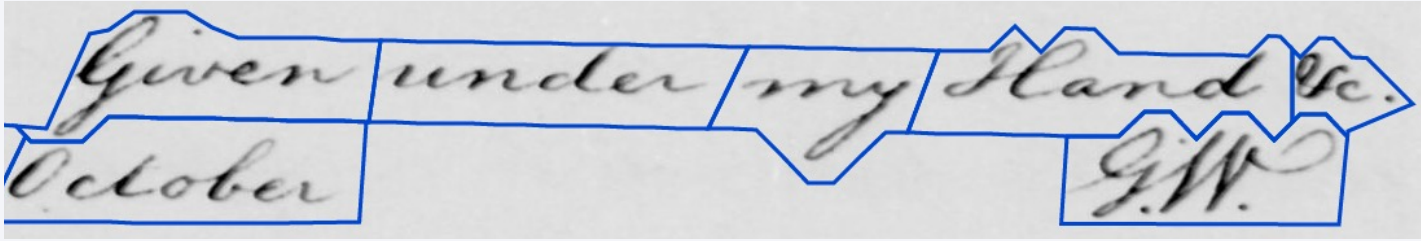


Data Set



WashingtonDB

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



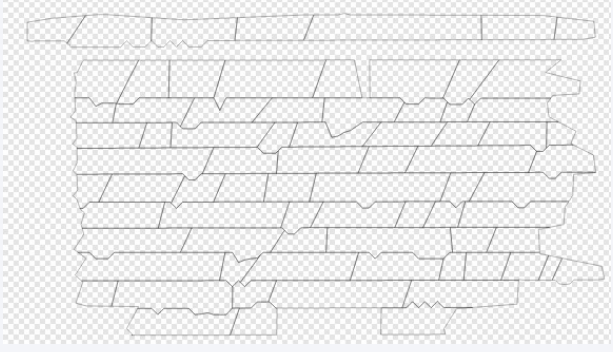
Data

/ground-truth/transcription.txt

Character based transcription

/ground-truth/locations/*.svg

Polygons of word segments



/images/*.jpg

The page images

/task

How to split data into train and validation set

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

What to do first

Analyze the data

Preprocessing

- Binarization
- Extract word images from full page

Compute some features

Pre-processing

Crop

- Easiest: bounding box
- Polygon as clipping mask

Binarization

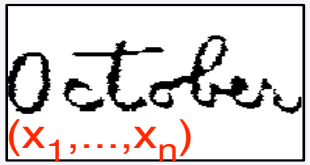
- Otsu, Sauvola, Difference-of-Gaussian

Exemplary Dissimilarity Approaches

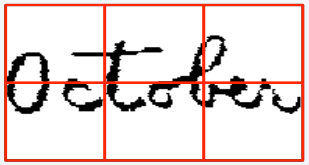
Global: extract global features, compute the Euclidean distance between the feature vectors

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

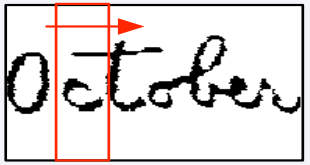
Sliding window-based: extract features for each window, compute the dynamic time warping (DTW) distance between two sequences of feature vectors



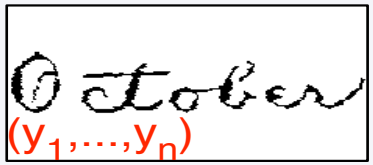
$d(x,y) = \|x-y\|$

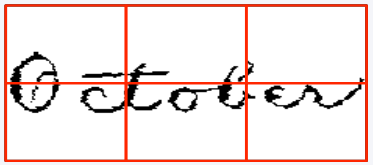


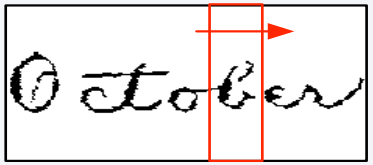
$d(x,y) = \sum \|x_i-y_i\|$



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







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)

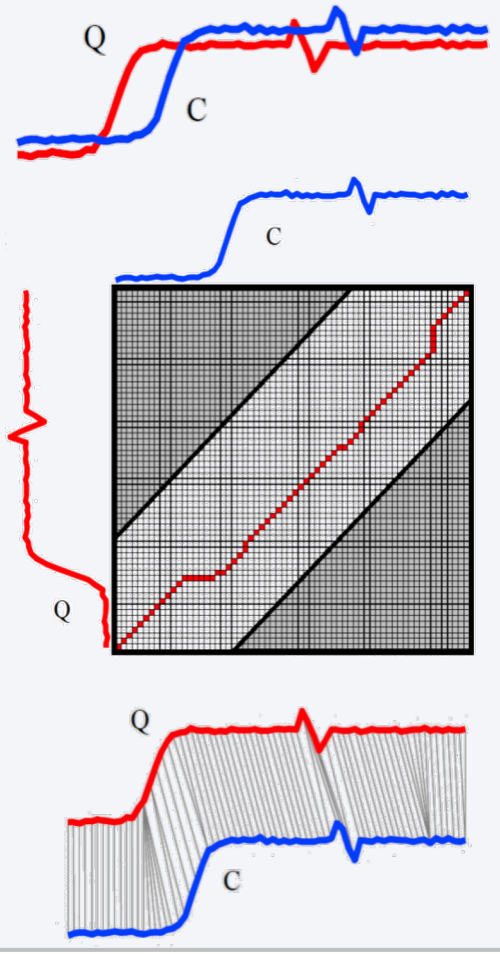
Non-linear mapping between 2 sequences minimizing the distance between them

$$Q = q_1, \ldots, q_N ; q_i \in R^n$$
$$C = c_1, \ldots, c_M ; c_i \in R^n$$

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)

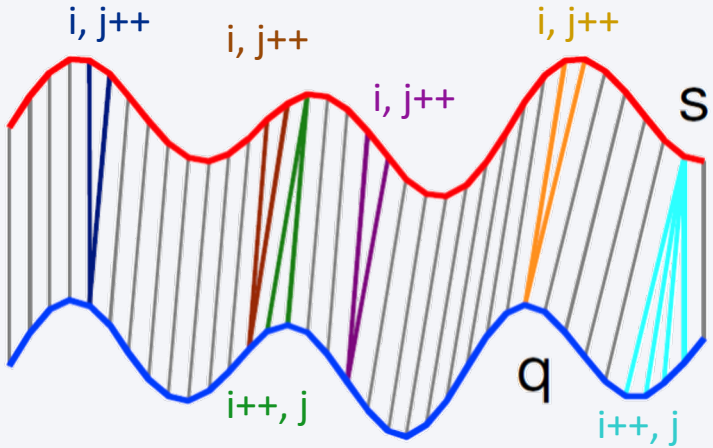
Start from (1,1) and end in (n,m)

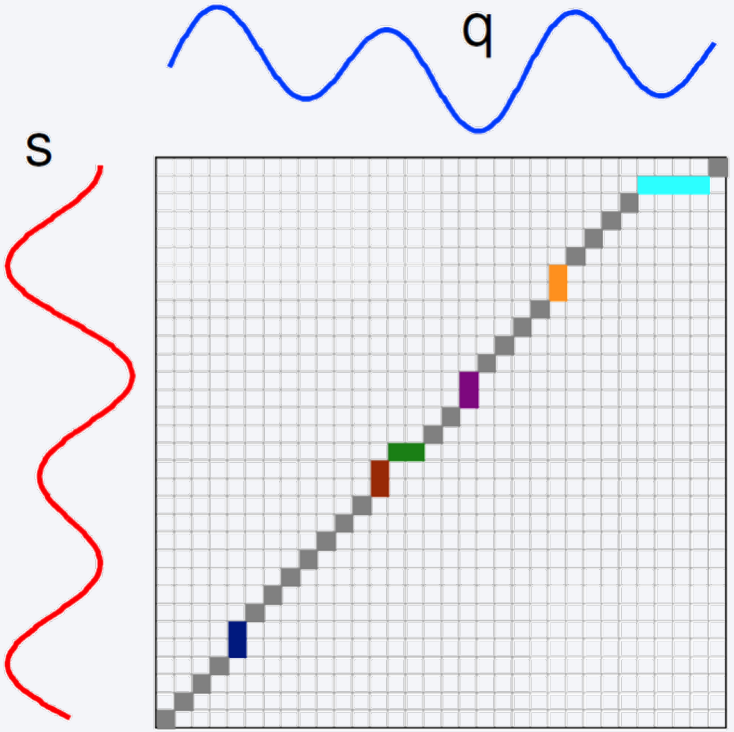
At each step, increase *i*, *j*, or both

(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

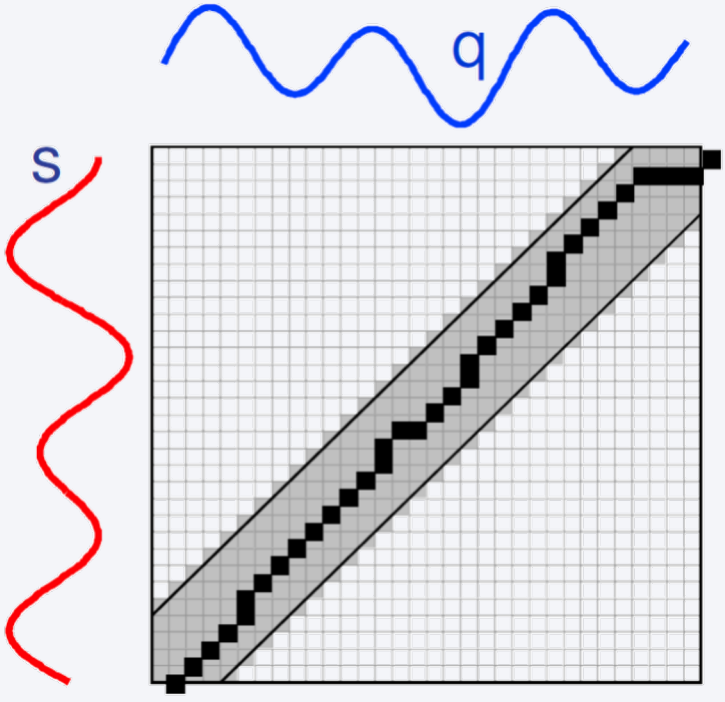
Speeds up the computation

Sequences of same length

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

S

q



Features for DTW

Normalize

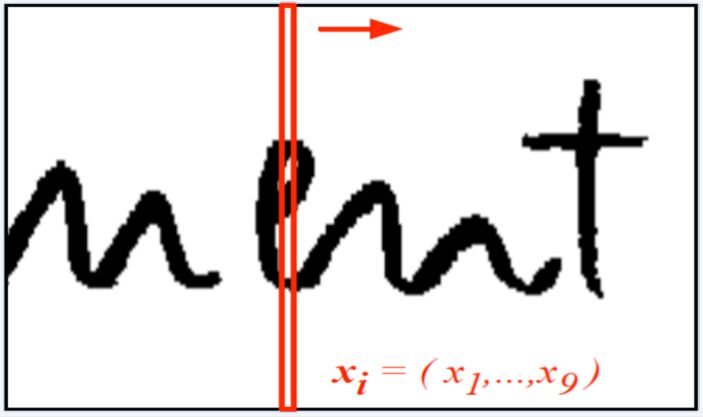
- Image dimensions (scale to same size, e.g. *100 px x 100 px*)
  → same-length sequence

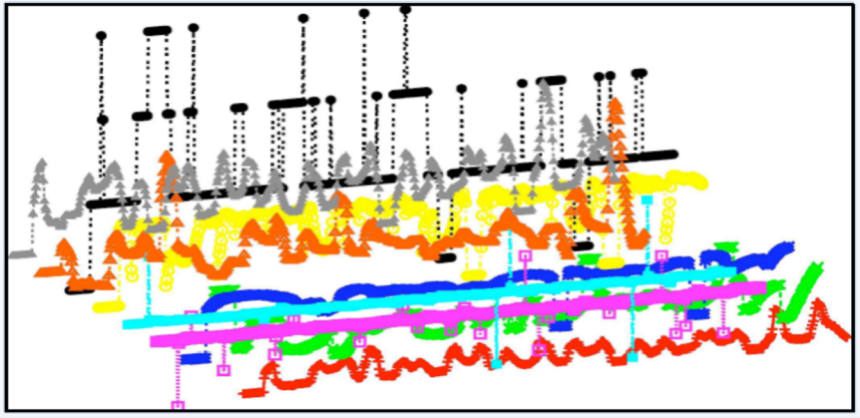
- Feature vectors (e.g. z-normalisation: $\frac{x_i - \mu}{\sigma}$)

Features for DTW – Suggestions

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

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

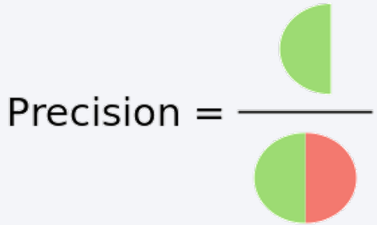




Evaluation: Recall – Precision

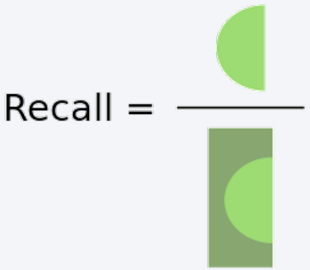
Retrieval-Task: two main questions

How many selected items are relevant?

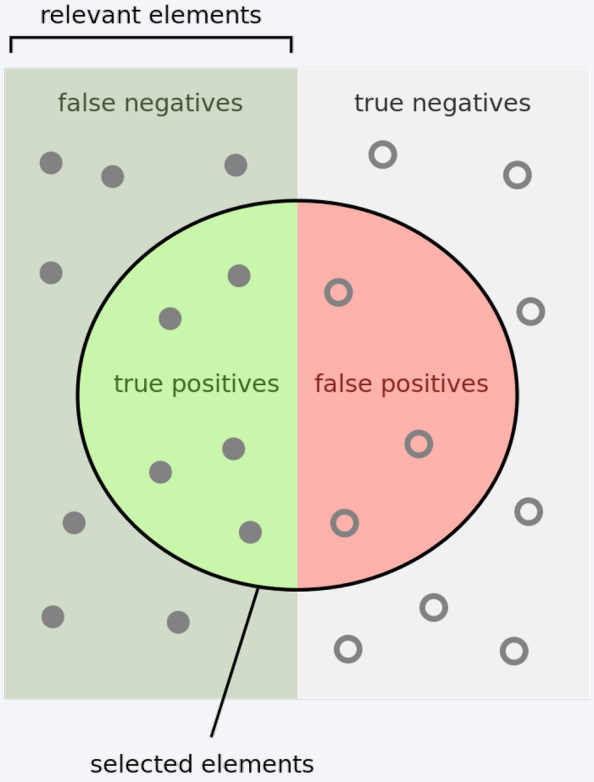


$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

How many of the relevant items are selected?



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



Recall-Precision Curve / AP

For image and each threshold (top-k matches), compute the

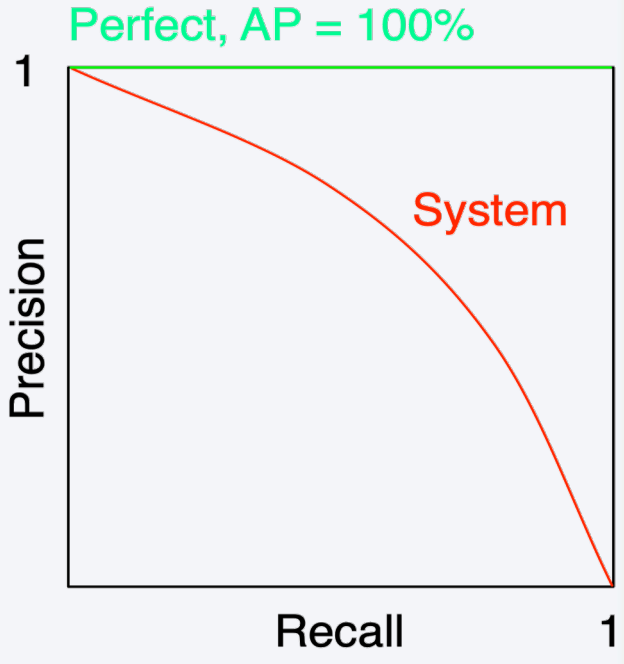
- True Positives (TP)
- False Positives (FP)
- False Negatives (FN)

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

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

Average Precision (AP)

Area under the Recall-Precision curve



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