Natural Language Processing
CSCI 4152/6509 — Lecture 9
Similarity-based Text Classification

Instructors: Vlado Keselj
Time and date: 16:05 – 17:25, 3-Oct-2023
Location: Rowe 1011

Previous Lecture

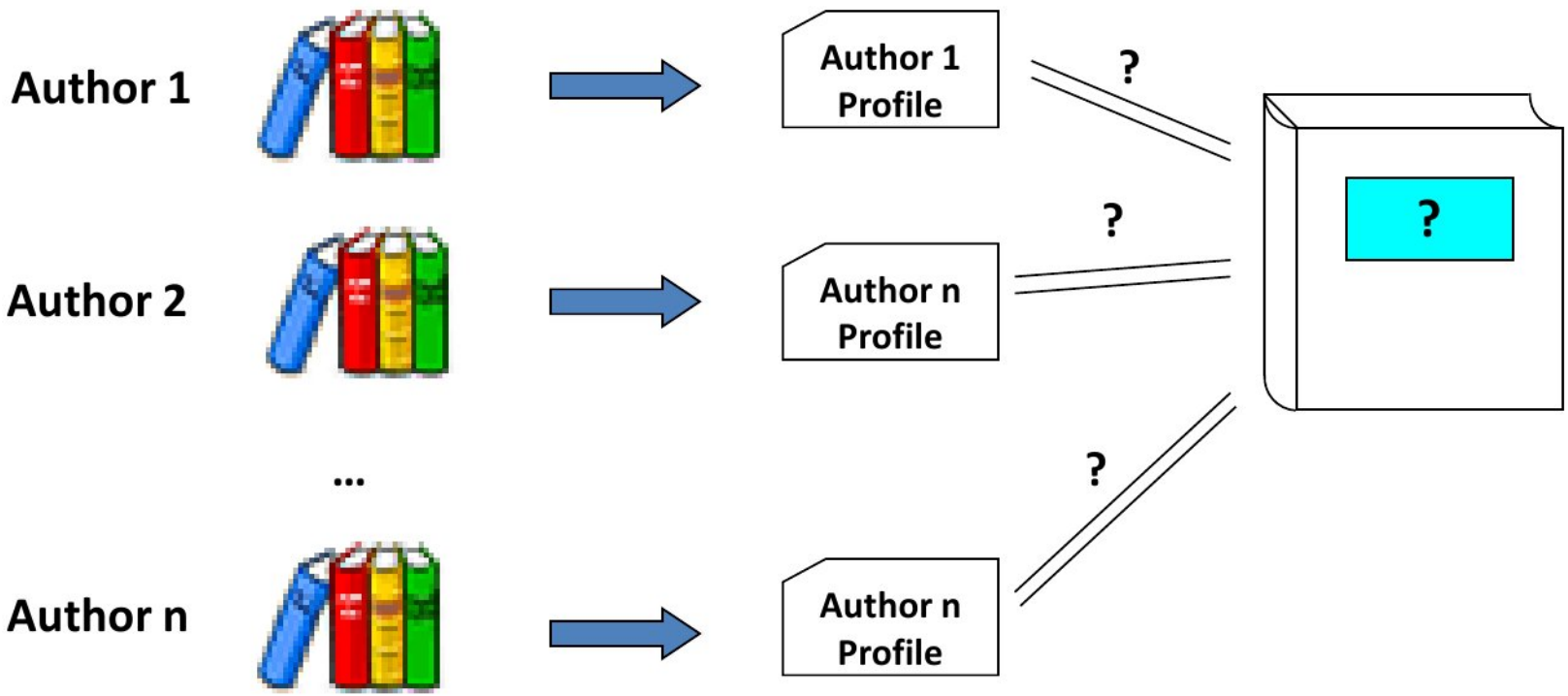
- Guest speaker: Three project ideas
- IR evaluation measures review
- Recall-precision curve review
- Text classification review
- Evaluation measures for Text Classification review

Similarity-based Text Classification

- Aggregate training text for each class into a profile
- Aggregate testing text into another profile
- Classify according to profile similarity
- If a profile is a vector, we can use different similarity measures; e.g.,
  - cosine similarity,
  - Euclidean similarity, or
  - some other type of vector similarity

CNG Method for Text Classification

- A simple method, initially used for authorship attribution
- Authorship attribution problem:



CNG Method Overview

- Method based on character n-grams
- Language independent
- Based on creating n-gram based author profiles
- Similarity based (a type of kNN method—k Nearest Neighbours)
- Similarity measure:

$$\sum_{g \in D_1 \cup D_2} \left(\frac{f_1(g) - f_2(g)}{\frac{f_1(g)+f_2(g)}{2}} \right)^2 = \sum_{g \in D_1 \cup D_2} \left(\frac{2 \cdot (f_1(g) - f_2(g))}{f_1(g) + f_2(g)} \right)^2 \quad (1)$$

where $f_i(g) = 0$ if $g \notin D_i$.

Example of Creating an Author Profile

Preparing character n−gram profile (n=3, L=5)

```
M a r l e y  w a s  d e a d : to begin with.
There is no doubt whatever about that...
```

(from Christmas Carol by Charles Dickens)

Example of Creating an Author Profile

Preparing character n−gram profile (n=3, L=5)

Marley was dead: to begin with.
There is no doubt whatever about that...

(from Christmas Carol by Charles Dickens)

n=3

Mar

Example of Creating an Author Profile

Preparing character n−gram profile (n=3, L=5)

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Marley was dead: to begin with.
There is no doubt whatever about that...
```

(from Christmas Carol by Charles Dickens)

n=3
Mar
arl

Example of Creating an Author Profile

Preparing character n−gram profile (n=3, L=5)

Ma**rle**y was dead: to begin with.
There is no doubt whatever about that...

(from Christmas Carol by Charles Dickens)

n=3
Mar
arl
rle

Example of Creating an Author Profile

Preparing character n−gram profile (n=3, L=5)

Mar**ley** was dead: to begin with.
There is no doubt whatever about that...

(from Christmas Carol by Charles Dickens)

n=3
Mar
arl
rle
ley

Example of Creating an Author Profile

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Marley was dead: to begin with.
There is no doubt whatever about that...
```

(from Christmas Carol by Charles Dickens)

n=3
Mar
arl
rle
ley
ey_

Example of Creating an Author Profile

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Marley was dead: to begin with.
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(from Christmas Carol by Charles Dickens)

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y_w

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Mar
arl
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_wa
was
...

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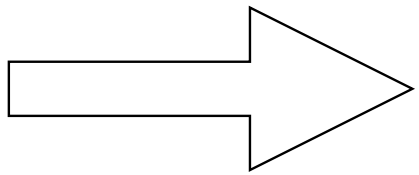
```

(from Christmas Carol by Charles Dickens)

n=3
Mar
arl
rle
ley
ey_
y_w
_wa
was
...

sort by frequency



_th	0.015
___	0.013
the	0.013
he_	0.011
and	0.007
_an	0.007
nd_	0.007
ed_	0.006

Example of Creating an Author Profile

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was
...
```
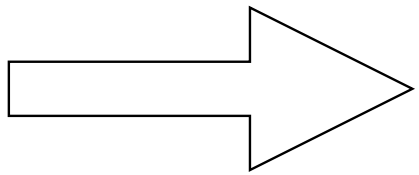
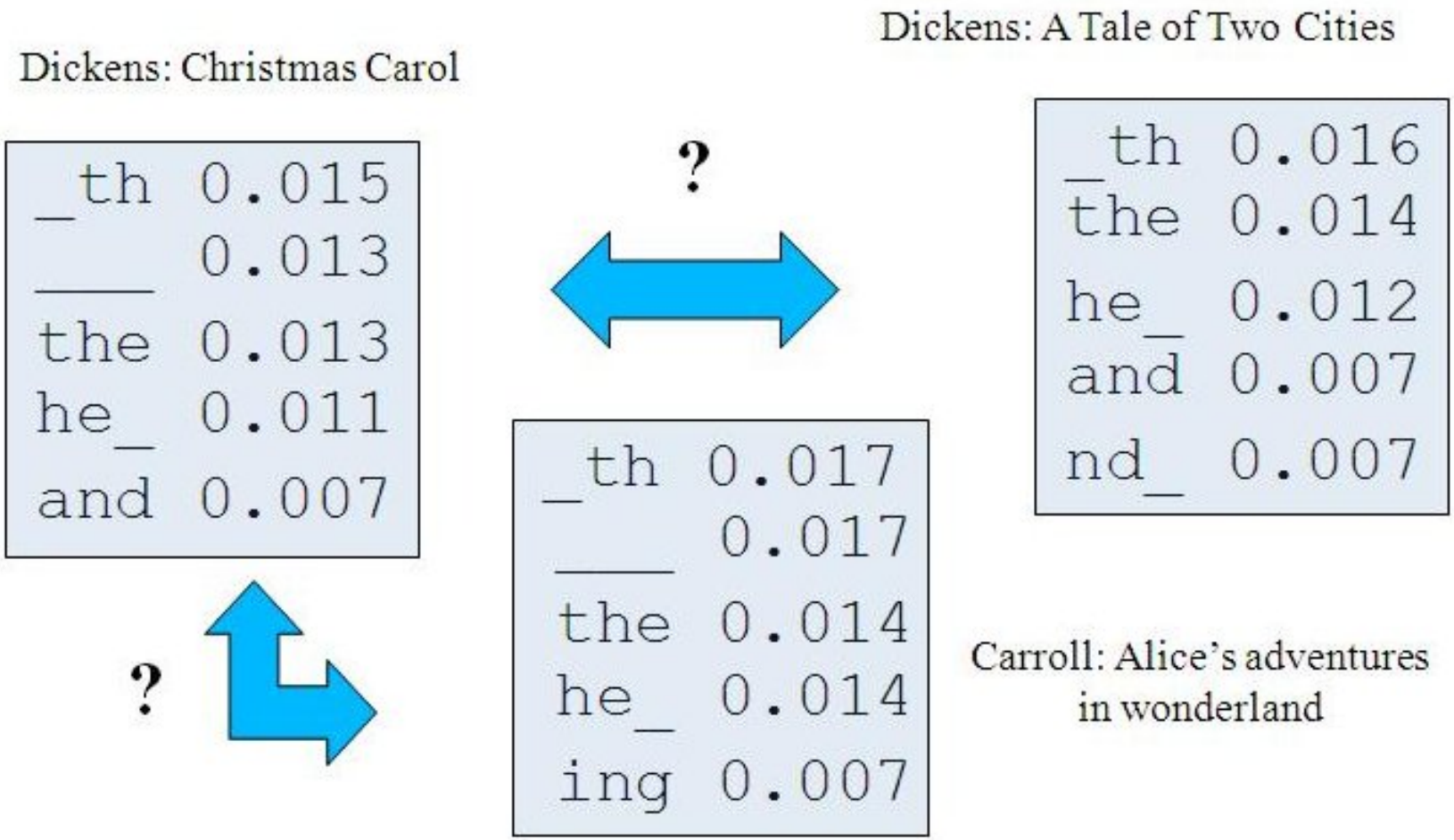

sort by frequency



_th	0.015
____	0.013
the	0.013
he_	0.011
and	0.007
_an	0.007
nd_	0.007
ed_	0.006

L=5

How to measure profile similarity?



CNG Similarity Measure

- Euclidean-style distance with relative differences, rather than absolute
- Example: instead of using $0.88 - 0.80 = 0.10$, we say it is about 10% difference, which is the same for 0.088 and 0.080
- To be symmetric, divide by the arithmetic average:

$$d(f_1, f_2) = \Sigma_{n \in \text{dom}(f_1) \cup \text{dom}(f_2)} \left(\frac{f_1(n) - f_2(n)}{\frac{f_1(n)+f_2(n)}{2}} \right)^2$$

- $dom(f_i)$ is the domain of function f_i, i.e., of the profile i

Classification using CNG

- Create profile for each class using training text
  - done by merging all texts in each class into one long document
  - another option: centroid of profiles of individual documents
- Create profile for the test document
- Assign class to the document according to the closest class profile according to the CNG distance

Edit Distance

Another text similarity measure

Edit Distance: Introduction

- Edit distance is a similarity measure convenient for words and short texts, robust for typos and morphological differences
- Tends to be too expensive for longer texts
- Consider typical errors that cause typos:
  - there $\rightarrow$ thre (missed a letter)
  - there $\rightarrow$ theare (inserted an extra letter)
  - there $\rightarrow$ yhere (mistyped a letter)
- Task: find a word in lexicon most likely to produce incorrect word found in text

Edit Distance: Brute Force Approaches

- one approach: search lexicon and try deleting, inserting, and replacing each of the letters, and compare with mistyped word
- this is already quite expensive, but what with multiple errors?
- Can we find the minimal number of edit operations (deletes, inserts, or substitutions) that would lead from a source string s to the target string t?
- This is *minimal edit distance* — it always exists because we can always delete $|s|$ letters and insert $|t|$ letters, so it is always $\leq |s| + |t|$

Edit Distance: Properties

- Reflexive: $d(s,t) = 0$ if and only if $s = t$
- Symmetric: $d(s,t) = d(t,s)$, because edit operations are reversible
- Transitive: $d(s,t) + d(t,v) \geq d(s,v)$
- Can be parametrized with *cost_d*(c), *cost_i*(c), *cost_s*(c,d) for all characters c and d; positive cost functions with exception *cost_s*$(c,c) = 0$
- If cost is 1 for delete and insert, and 2 for substitute operations, it is also known as the Levenshtein distance [JM] (all cost$= 1$ according to some sources)

Edit Distance: Dynamic Programming Idea

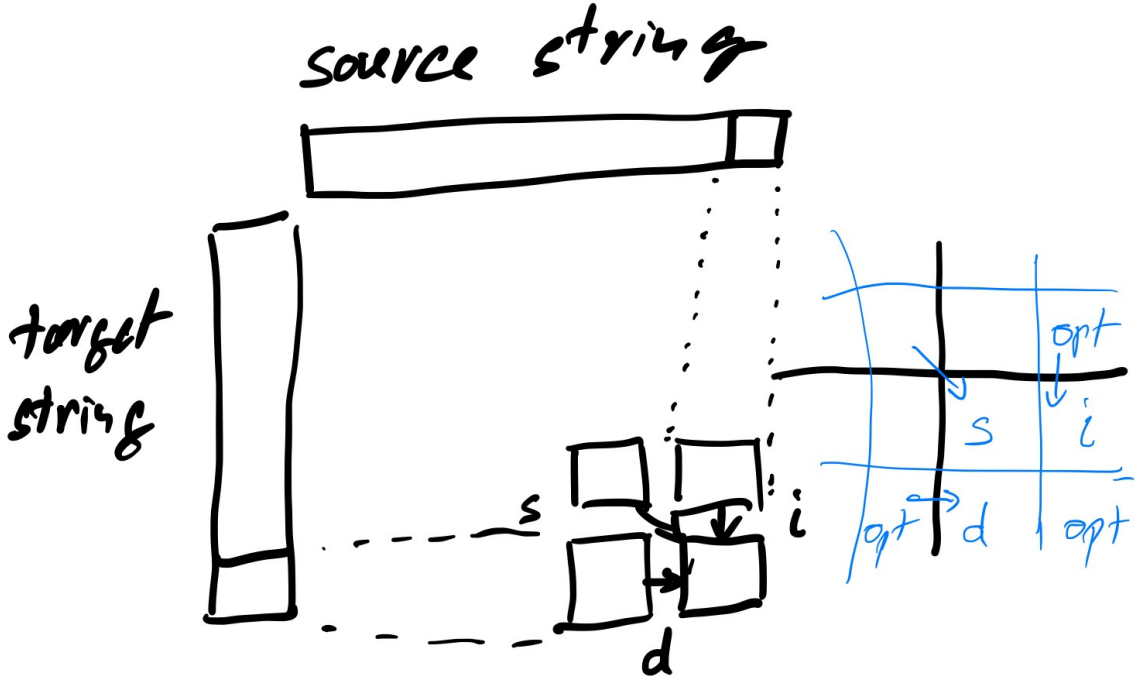
- calculate optimal distance between $s = xe$ and $t = yf$ using optimal distances between xe and y, x and yf, and x and y

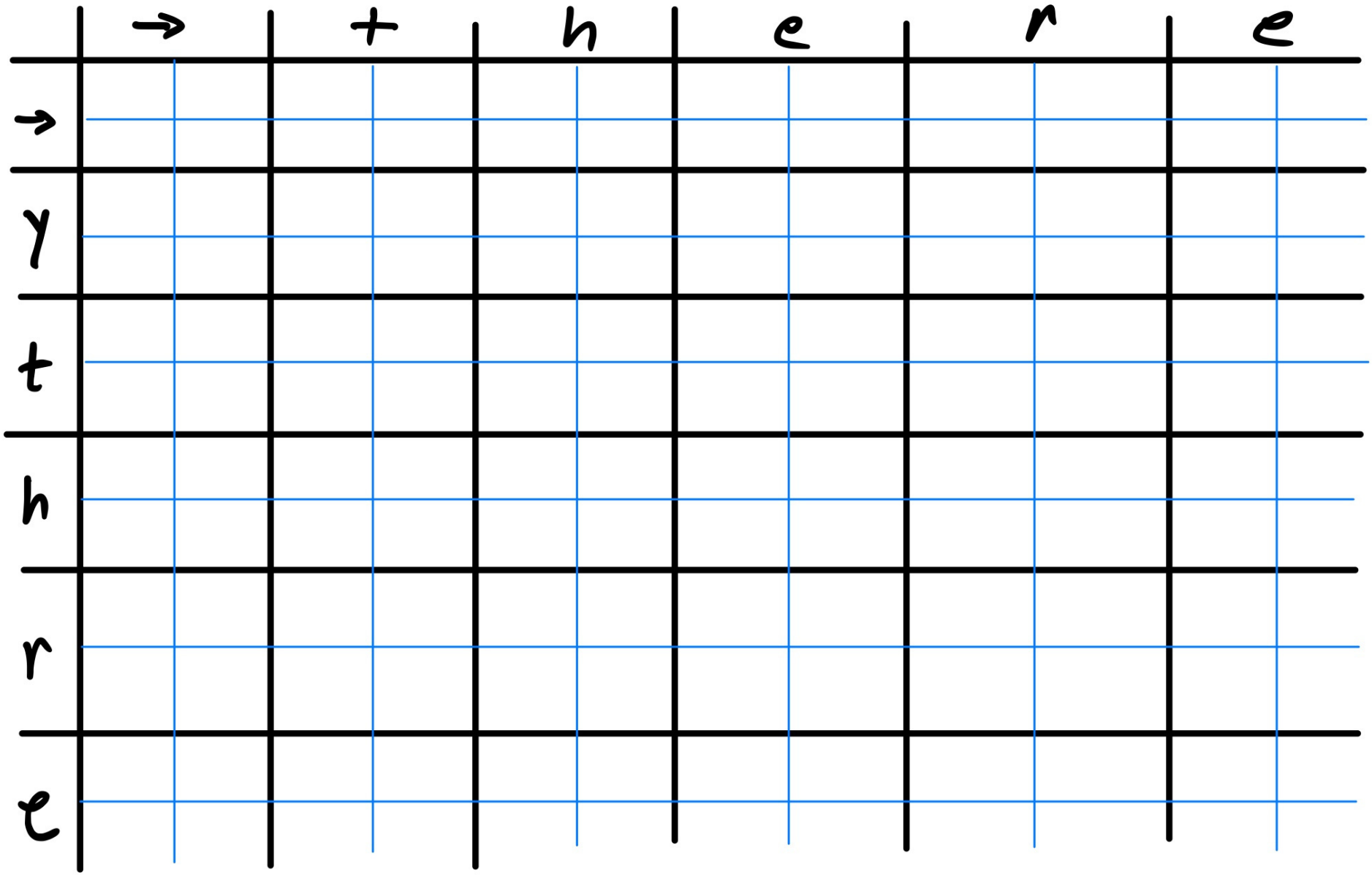
Efficient calculation of min. Edit Distance

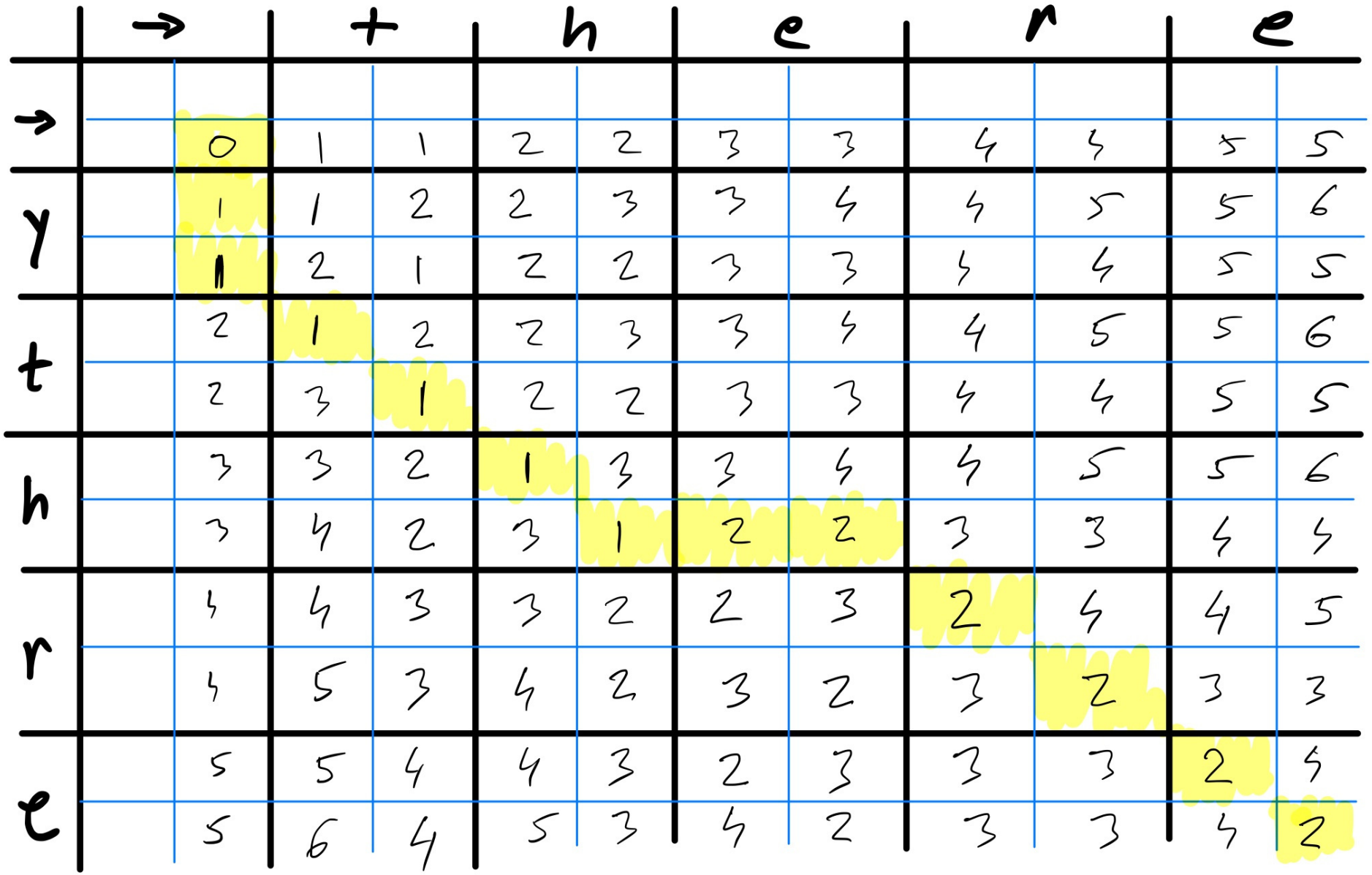
– a dynamic programming approach

Example:

there
d ↓
thre
↑i Y ↓
ythre




→ + h e r e
→
y
t
h
r
e


→ + h e r e
→ 0 1 1 2 2 3 3 4 4 5 5
y 1 1 2 2 3 3 4 4 5 5 6
1 2 1 2 2 3 3 4 4 5 5
t 2 1 2 2 3 3 4 4 5 5 6
2 3 1 2 2 3 3 4 4 5 5
h 3 3 2 1 3 3 4 4 5 5 6
3 4 2 3 1 2 2 3 3 4 4
r 4 4 3 3 2 2 3 2 4 4 5
4 5 3 4 2 3 2 3 2 3 3
e 5 5 4 4 3 2 3 3 3 2 4
5 6 4 5 3 4 2 3 3 4 2

Edit Distance Algorithm

```
Algorithm EditDistance(s,t)
n = len(s); m  = len(t)
d[m+1,n+1] - initialize to 0s
for i=1 to n do d[0,i] = d[0,i-1] + cost_d(s[i-1])
for j=1 to m do d[j,0] = d[j-1,0] + cost_i(t[j-1])
for j=1 to m do
  for i=1 to n do
    d[j,i] = min( d[j-1,i-1] + cost_s(s[i-1],t[j-1]),
                  d[j-1,i]   + cost_i(t[j-1]),
                  d[j,i-1]   + cost_d(s[i-1]) )
return d[m,n]
```