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15-826: Multimedia Databases and Data Mining

Lecture #14: Text – Part I
C. Faloutsos



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Must-read Material

- MM Textbook, Chapter 6

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Outline

Goal: ‘Find **similar / interesting** things’

- Intro to DB
- ➔ • Indexing - similarity search
- Data Mining

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Indexing - Detailed outline

- primary key indexing
- secondary key / multi-key indexing
- spatial access methods
- fractals
- ➔ • text
- multimedia
- ...

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Text - Detailed outline

- text
 - ➔ – problem
 - full text scanning
 - inversion
 - signature files
 - clustering
 - information filtering and LSI

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Problem - Motivation

- Eg., find documents containing “*data*”, “*retrieval*”
- Applications:

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Problem - Motivation

- Eg., find documents containing “*data*”, “*retrieval*”
- Applications:
 - Web
 - law + patent offices
 - digital libraries
 - information filtering

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Problem - Motivation

- Types of queries:
 - boolean (‘data’ AND ‘retrieval’ AND NOT ...)

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Problem - Motivation

- Types of queries:
 - boolean ('data' AND 'retrieval' AND NOT ...)
 - additional features ('data' ADJACENT 'retrieval')
 - keyword queries ('data', 'retrieval')
- How to search a large collection of documents?

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Full-text scanning

- Build a FSA; scan

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Full-text scanning

- for single term:
 - (naive: $O(N*M)$)

ABRACADABRA text

CAB pattern

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Full-text scanning

- for single term:
 - (naive: $O(N*M)$)
 - Knuth Morris and Pratt ('77)
 - build a small FSA; visit every text letter once only, by carefully shifting more than one step

ABRACADABRA text

CAB pattern

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Full-text scanning

ABRACADABRA

|

CAB

|

CAB

...

CAB

CAB

text

pattern

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Full-text scanning

- for single term:
 - (naive: $O(N \cdot M)$)
 - Knuth Morris and Pratt ('77)
 - Boyer and Moore ('77)
 - preprocess pattern; start from **right to left & skip!**

ABRACADABRA

CAB

text

pattern

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Full-text scanning

ABRACADABRA

|

CAB

|

CAB

|

CAB

CAB

text

pattern

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Full-text scanning

ABRACADABRA

|

OMINOUS


OMINOUS

text

pattern

Boyer+Moore: fastest, in practice
 Sunday ('90): some improvements

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Full-text scanning

- For multiple terms (w/o “don’ t care” characters): Aho+Corasic (‘75)
 - again, build a simplified FSA in $O(M)$ time
- Probabilistic algorithms: ‘fingerprints’ (Karp + Rabin ‘87)
- approximate match: ‘agrep’ [Wu+Manber, Baeza-Yates+, ‘92]; available on unix/ linux/win/mac

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Full-text scanning

- Approximate matching - **string editing** distance:

$$d(\text{‘survey’} , \text{‘surgery’}) = 2$$
 = min # of insertions, deletions, substitutions to transform the first string into the second

 SURVEY
 SURGERY

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Full-text scanning

- **string editing** distance - how to compute?
- A:

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Full-text scanning

- **string editing** distance - how to compute?
- A: dynamic programming

$$\text{cost}(i , j) = \text{cost to match prefix of length } i \text{ of first string } s \text{ with prefix of length } j \text{ of second string } t$$

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Full-text scanning

if $s[i] = t[j]$ then
 $cost(i, j) = cost(i-1, j-1)$
 else
 $cost(i, j) = \min ($
 $1 + cost(i, j-1)$ // deletion
 $1 + cost(i-1, j-1)$ // substitution
 $1 + cost(i-1, j)$ // insertion
 $)$

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String editing distance

| | | | | | | | |
|--------|--------|---|---|---|---|---|---|
| | ϕ | S | U | R | V | E | Y |
| ϕ | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| S | 1 | | | | | | |
| U | 2 | | | | | | |
| R | 3 | | | | | | |
| G | 4 | | | | | | |
| E | 5 | | | | | | |
| R | 6 | | | | | | |
| Y | 7 | | | | | | |

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String editing distance

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | S | U | R | V | E | Y |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| S | 1 | | | | | | |
| U | 2 | | | | | | |
| R | 3 | | | | | | |
| G | 4 | | | | | | |
| E | 5 | | | | | | |
| R | 6 | | | | | | |
| Y | 7 | | | | | | |

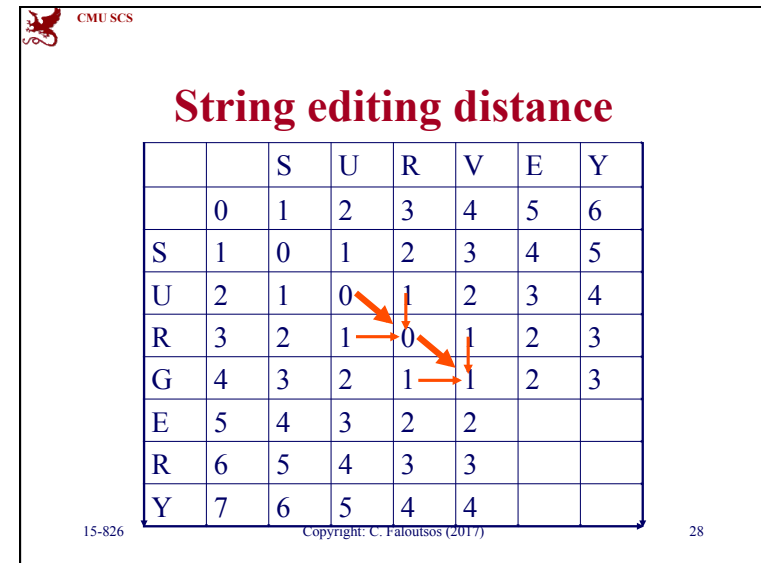
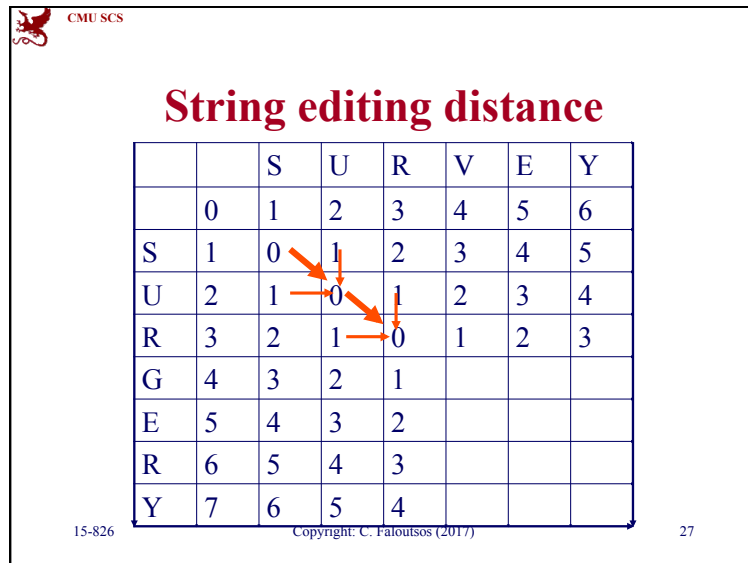
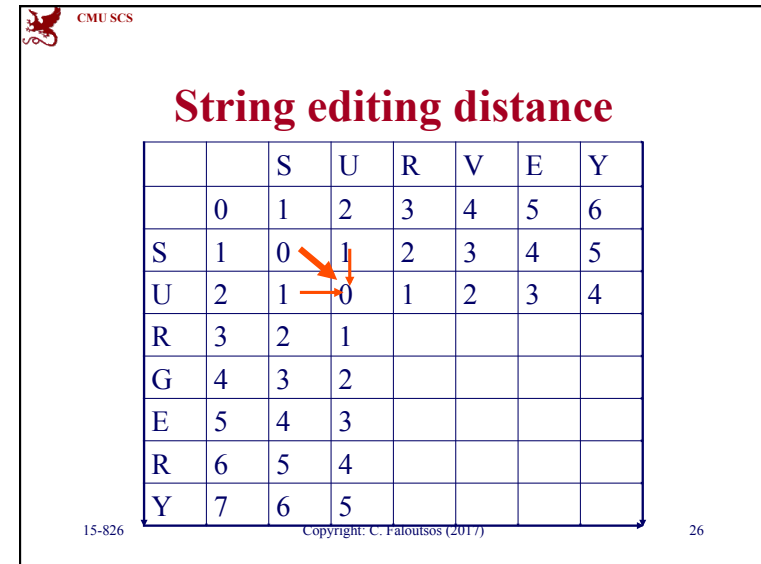
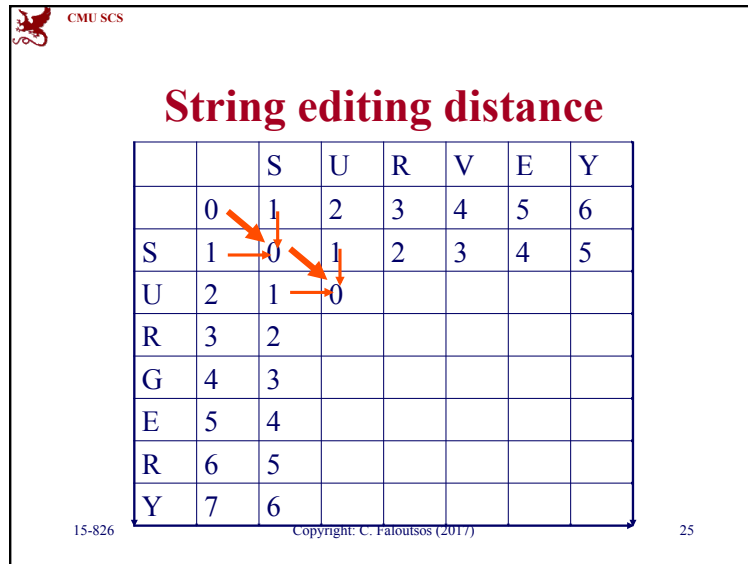
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String editing distance

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | S | U | R | V | E | Y |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| S | 1 | 0 | | | | | |
| U | 2 | | | | | | |
| R | 3 | | | | | | |
| G | 4 | | | | | | |
| E | 5 | | | | | | |
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| Y | 7 | | | | | | |

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String editing distance

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | S | U | R | V | E | Y |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| S | 1 | 0 | 1 | 2 | 3 | 4 | 5 |
| U | 2 | 1 | 0 | 1 | 2 | 3 | 4 |
| R | 3 | 2 | 1 | 0 | 1 | 2 | 3 |
| G | 4 | 3 | 2 | 1 | 1 | 2 | 3 |
| E | 5 | 4 | 3 | 2 | 2 | 1 | 2 |
| R | 6 | 5 | 4 | 3 | 3 | 2 | |
| Y | 7 | 6 | 5 | 4 | 4 | 3 | |

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String editing distance

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | S | U | R | V | E | Y |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| S | 1 | 0 | 1 | 2 | 3 | 4 | 5 |
| U | 2 | 1 | 0 | 1 | 2 | 3 | 4 |
| R | 3 | 2 | 1 | 0 | 1 | 2 | 3 |
| G | 4 | 3 | 2 | 1 | 1 | 2 | 3 |
| E | 5 | 4 | 3 | 2 | 2 | 1 | 2 |
| R | 6 | 5 | 4 | 3 | 3 | 2 | 2 |
| Y | 7 | 6 | 5 | 4 | 4 | 3 | |

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String editing distance

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | S | U | R | V | E | Y |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| S | 1 | 0 | 1 | 2 | 3 | 4 | 5 |
| U | 2 | 1 | 0 | 1 | 2 | 3 | 4 |
| R | 3 | 2 | 1 | 0 | 1 | 2 | 3 |
| G | 4 | 3 | 2 | 1 | 1 | 2 | 3 |
| E | 5 | 4 | 3 | 2 | 2 | 1 | 2 |
| R | 6 | 5 | 4 | 3 | 3 | 2 | 2 |
| Y | 7 | 6 | 5 | 4 | 4 | 3 | 2 |

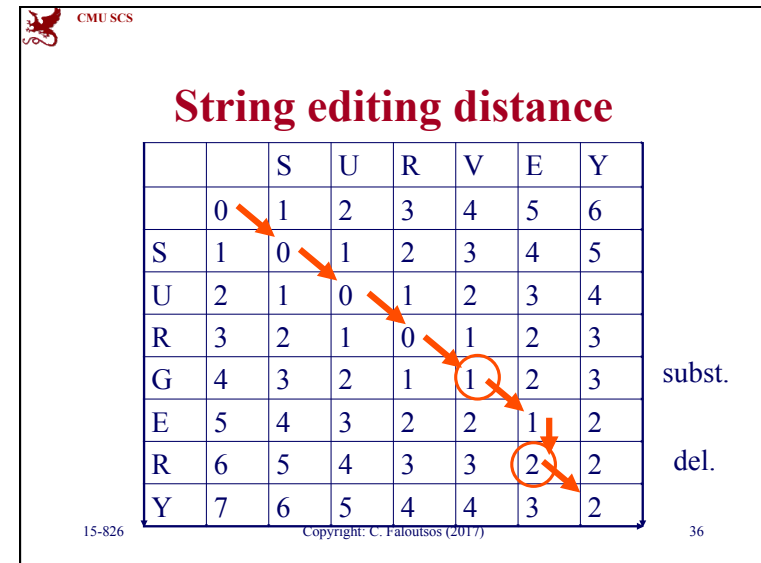
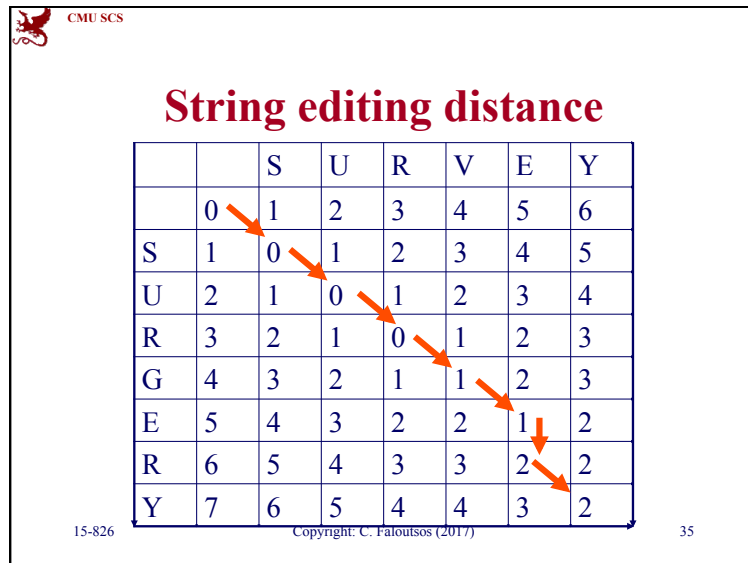
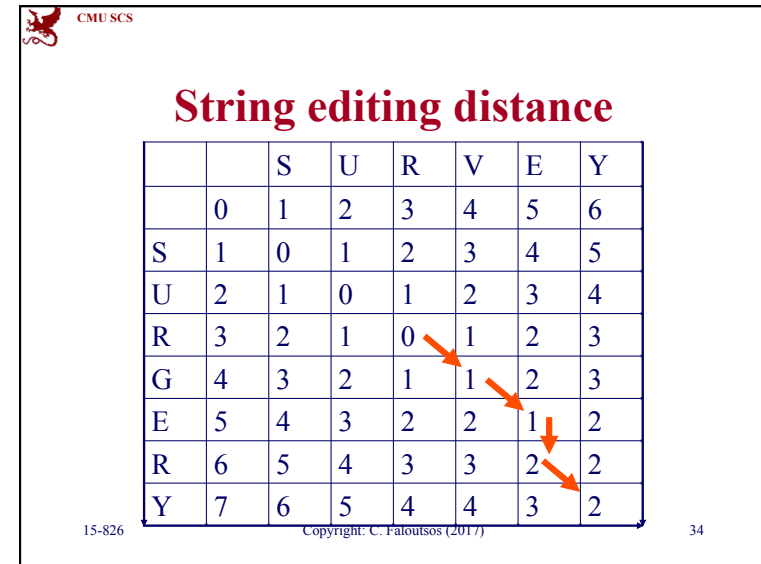
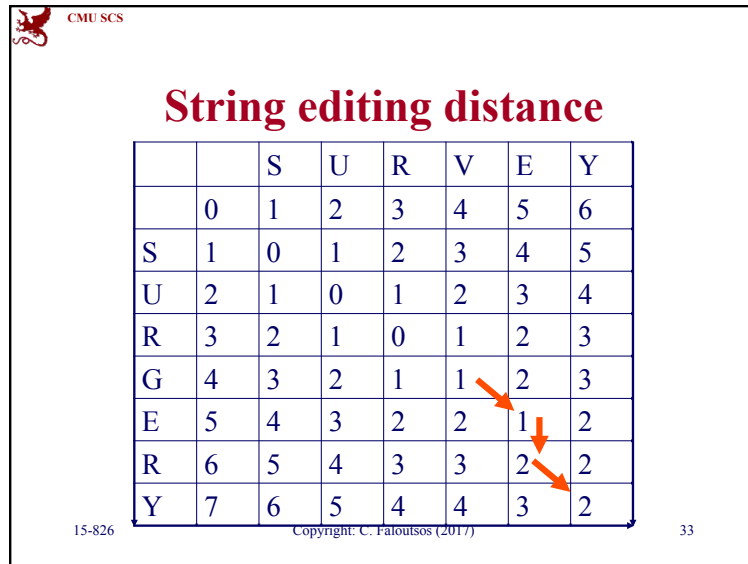
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String editing distance

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | S | U | R | V | E | Y |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| S | 1 | 0 | 1 | 2 | 3 | 4 | 5 |
| U | 2 | 1 | 0 | 1 | 2 | 3 | 4 |
| R | 3 | 2 | 1 | 0 | 1 | 2 | 3 |
| G | 4 | 3 | 2 | 1 | 1 | 2 | 3 |
| E | 5 | 4 | 3 | 2 | 2 | 1 | 2 |
| R | 6 | 5 | 4 | 3 | 3 | 2 | 2 |
| Y | 7 | 6 | 5 | 4 | 4 | 3 | 2 |

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Full-text scanning

Complexity: $O(M*N)$ (when using a matrix to 'memoize' partial results)

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Full-text scanning

Conclusions:

- Full text scanning needs no space overhead, but is slow for large datasets

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