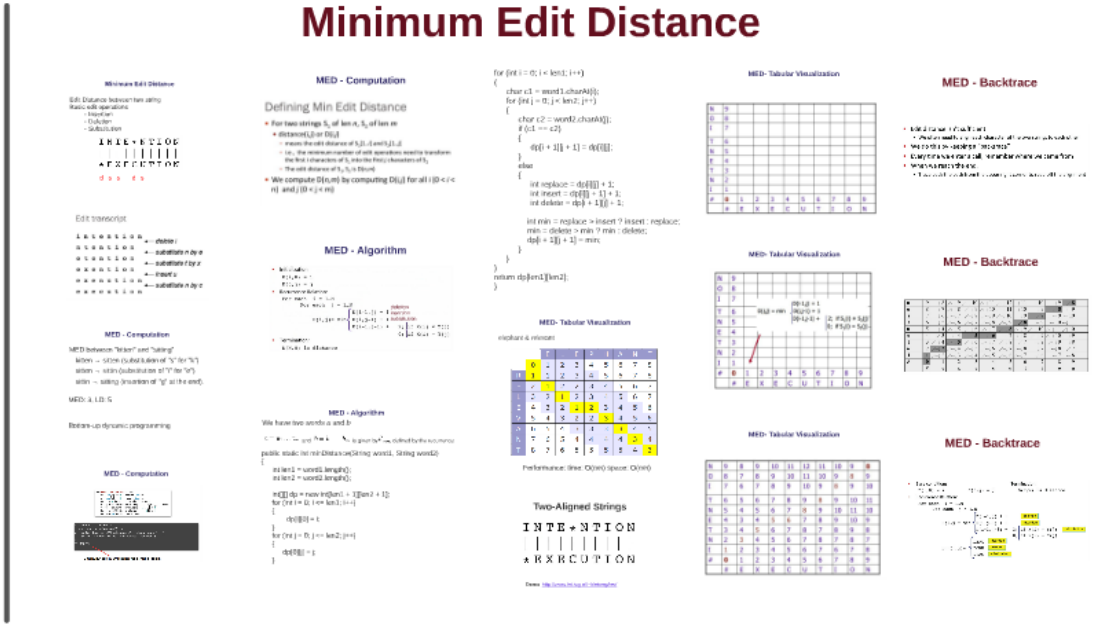
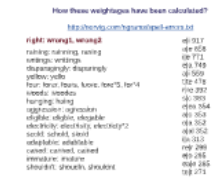
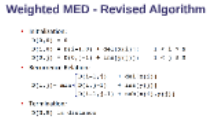
Spell Correction - Minimum Edit Distance

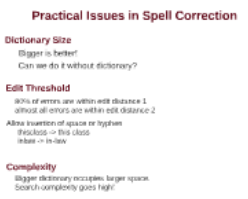


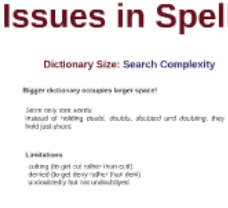
Weighted Edit Distance

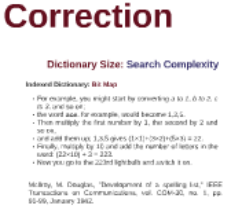


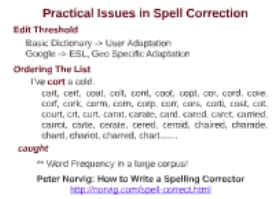


Practical Issues in Spell Correction

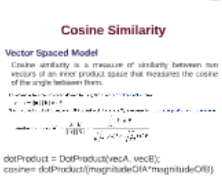


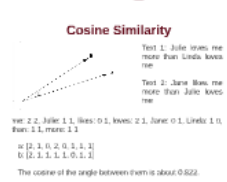


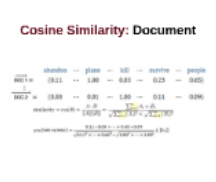


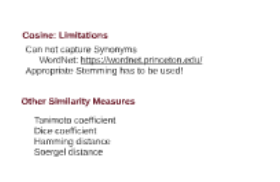


String Matching Paraphrase

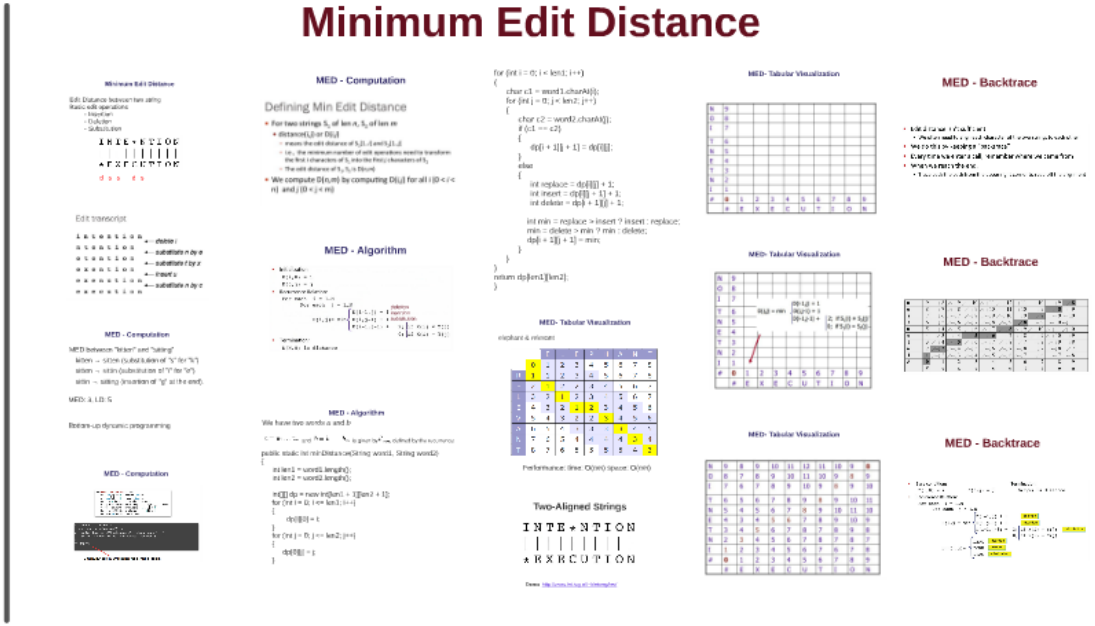




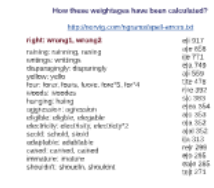


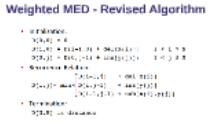


Spell Correction - Minimum Edit Distance

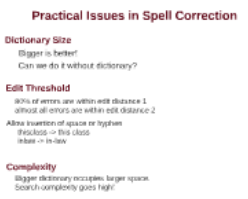


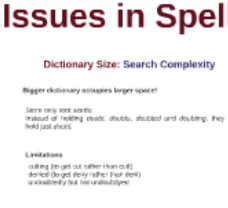
Weighted Edit Distance

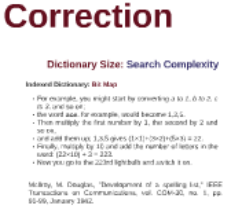


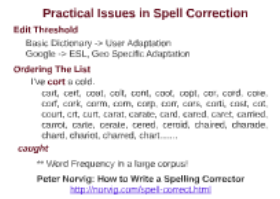


Practical Issues in Spell Correction

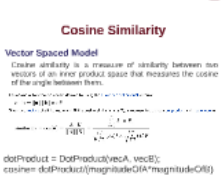


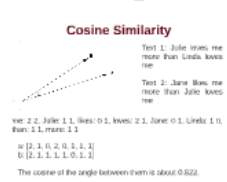


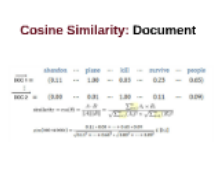


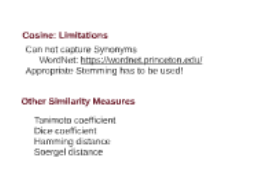


String Matching Paraphrase

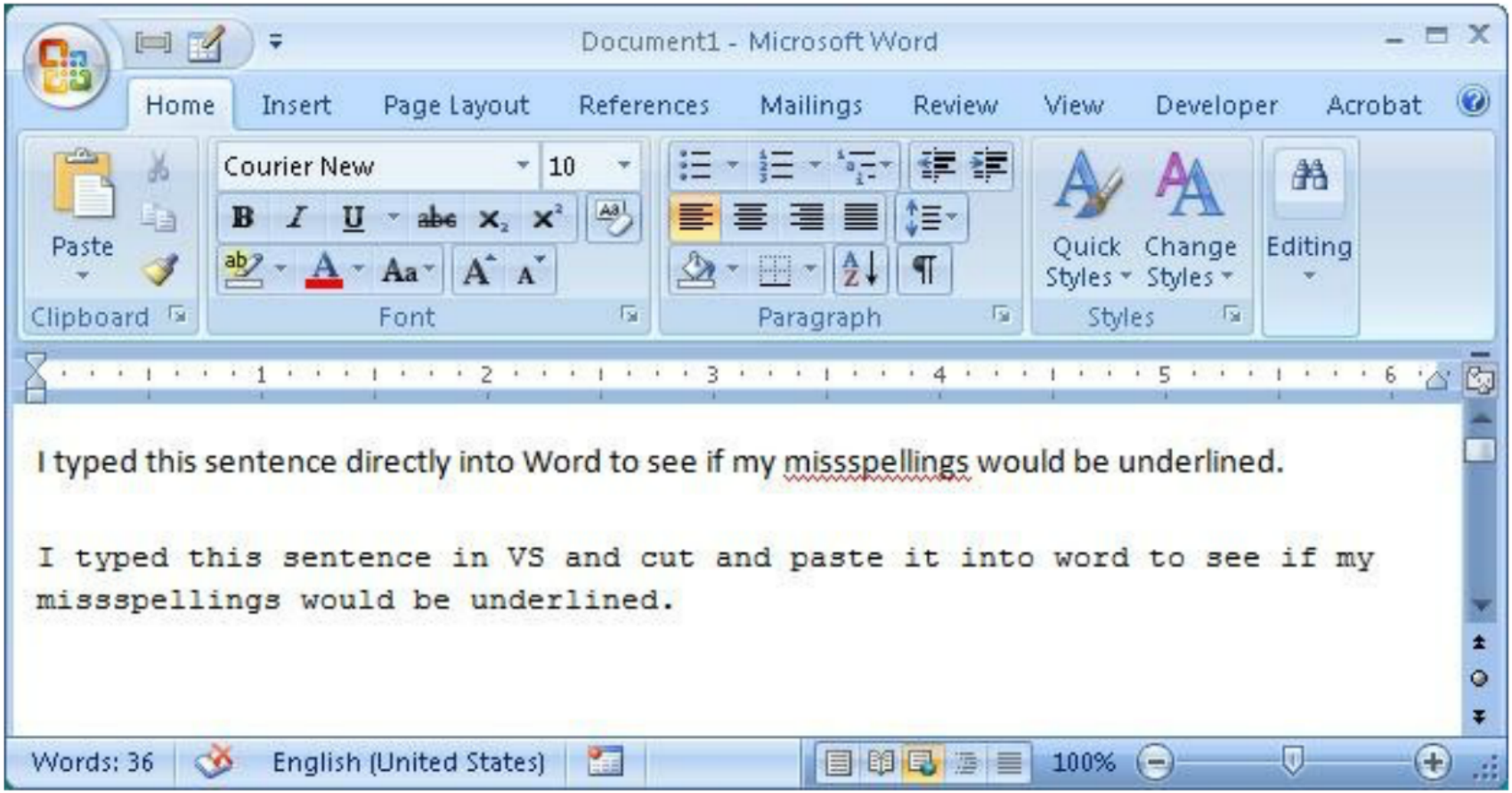








Spelling and Grammar Correction



Spelling Error - Types

Non-Word Error: ona -> on → **Out-Of-Dict Words**

Real-Word Error: there - > their

Cognitive Error: off - of

Language knowledge -> Language Models

26% Web Queries
40% in Social Media

Spelling Error Types

Non-Word Error: *ona {on,one,}*

Contextual Error: Win or loose, it was a great game!
{lose}

Grammar Error Types

Context-dependent Errors

I am [prepared → preparing] for the exam.

Lexical Choice Errors

I had a cup of [strong → powerful] tea

Function Words and Conjugation Errors

Can we discuss [null → about] this?

Let's go see [a → null] movie.

Preposition, Conjunction, Verb, Article,.....

ESL: English as Second Language

Spelling <Non-Word> Error Correction

User typed: *ona*

on
one
own
won
done
gone
stone
alone
phone
.....

Error Detection
Error Correction
- Replace
- Choose on from suggestions

Spelling Correction

A large dictionary is required

- But larger dict size means increase of search complexity!

Correction - Suggestions

Minimum Edit Distance (MED)
/ Levenshtein Distance
** Introduced by Vladimir Levenshtein in 1966

pell Correction - Minimum Edit Distance

Minimum Edit Distance

Minimum Edit Distance

Edit Distance between two string
Basic edit operations
- Insertion
- Deletion
- Substitution

```
I N T E * N T I O N
| | | | | | | | | |
* E X E C U T I O N
  d s s   d s
```

Edit transcript

```
i n t e n t i o n      ← delete i
n t e n t i o n        ← substitute n by e
e t e n t i o n        ← substitute t by x
e x e n t i o n        ← insert u
e x e n u t i o n      ← substitute n by c
e x e c u t i o n
```

MED - Computation

MED between "kitten" and "sitting"
kitten → sitten (substitution of "s" for "k")
sitten → sittin (substitution of "i" for "e")
sittin → sitting (insertion of "g" at the end).

MED: 3, LD: 5

Bottom-up dynamic programming

MED - Computation

MED - Computation

Defining Min Edit Distance

- For two strings S_1 of len n, S_2 of len m
  - distance(i,j) or D(i,j)
    - means the edit distance of $S_1[1..i]$ and $S_2[1..j]$
    - i.e., the minimum number of edit operations need to transform the first i characters of S_1 into the first j characters of S_2
    - The edit distance of S_1, S_2 is D(n,m)
- We compute D(n,m) by computing D(i,j) for all i ($0 < i < n$) and j ($0 < j < m$)

MED - Algorithm

- Initialization
  - D(i,0) = i
  - D(0,j) = j
- Recurrence Relation:
  For each i = 1..M
  For each j = 1..N
  $$D(i,j) = \min \begin{cases} D(i-1,j) + 1 & \text{deletion} \\ D(i,j-1) + 1 & \text{insertion} \\ D(i-1,j-1) + \begin{cases} 2; & \text{if } X(i) \neq Y(j) \\ 0; & \text{if } X(i) = Y(j) \end{cases} & \text{substitution} \end{cases}$$
- Termination:
  D(N,M) is distance

MED - Algorithm

We have two words a and b

$a = a_1 \ldots a_n$ and $b = b_1 \ldots b_m$ is given by d_{mn}, defined by the recurrence

```
public static int minDistance(String word1, String word2)
{
    int len1 = word1.length();
    int len2 = word2.length();

    int[][] dp = new int[len1 + 1][len2 + 1];
    for (int i = 0; i <= len1; i++)
    {
        dp[i][0] = i;
    }
    for (int j = 0; j <= len2; j++)
    {
        dp[0][j] = j;
    }
```

```
for (int i = 0; i < len1; i++)
{
    char c1 = word1.charAt(i);
    for (int j = 0; j < len2; j++)
    {
        char c2 = word2.charAt(j);
        if (c1 == c2)
        {
            dp[i + 1][j + 1] = dp[i][j];
        }
        else
        {
            int replace = dp[i][j] + 1;
            int insert = dp[i][j + 1] + 1;
            int delete = dp[i + 1][j] + 1;

            int min = replace > insert ? insert : replace;
            min = delete > min ? min : delete;
            dp[i + 1][j + 1] = min;
        }
    }
}
return dp[len1][len2];
}
```

MED- Tabular Visualization

elephant & relevant

		E	L	E	P	H	A	N	T
	0	1	2	3	4	5	6	7	8
R	1	1	2	3	4	5	6	7	8
E	2	1	2	2	3	4	5	6	7
L	3	2	1	2	3	4	5	6	7
E	4	3	2	1	2	3	4	5	6
V	5	4	3	2	2	3	4	5	6
A	6	5	4	3	3	3	3	4	5
N	7	6	5	4	4	4	4	3	4
T	8	7	6	5	5	5	5	4	3

Performance: time: O(nm) space: O(nm)

Two-Aligned Strings

```
I N T E * N T I O N
| | | | | | | | | |
* E X E C U T I O N
```

Demo http://www.let.rug.nl/~kleiweg/lev/

MED- Tabular Visualization

N	9									
O	8									
I	7									
T	6									
N	5									
E	4									
T	3									
N	2									
I	1									
#	0	1	2	3	4	5	6	7	8	9
	#	E	X	E	C	U	T	I	O	N

MED- Tabular Visualization

$$D(i,j) = \min \begin{cases} D(i-1,j) + 1 \\ D(i,j-1) + 1 \\ D(i-1,j-1) + \begin{cases} 2; & \text{if } S_1(i) \neq S_2(j) \\ 0; & \text{if } S_1(i) = S_2(j) \end{cases} \end{cases}$$

N	9									
O	8									
I	7									
T	6									
N	5									
E	4									
T	3									
N	2									
I	1									
#	0	1	2	3	4	5	6	7	8	9
	#	E	X	E	C	U	T	I	O	N

MED- Tabular Visualization

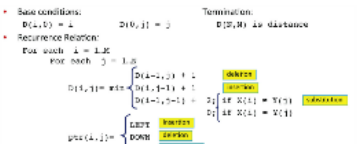
N	9	8	9	10	11	12	11	10	9	8
O	8	7	8	9	10	11	10	9	8	9
I	7	6	7	8	9	10	9	8	9	10
T	6	5	6	7	8	9	8	9	10	11
N	5	4	5	6	7	8	9	10	11	10
E	4	3	4	5	6	7	8	9	10	9
T	3	4	5	6	7	8	7	8	9	8
N	2	3	4	5	6	7	8	7	8	7
I	1	2	3	4	5	6	7	6	7	8
#	0	1	2	3	4	5	6	7	8	9
	#	E	X	E	C	U	T	I	O	N

MED - Backtrace

- Edit distance isn't sufficient
  - We often need to align each character of the two strings to each other
- We do this by keeping a "backtrace"
- Every time we enter a cell, remember where we came from
- When we reach the end,
  - Trace back the path from the upper right corner to read off the alignment

MED - Backtrace

MED - Backtrace



Weighted Edit Distance

```
int w_med(String str1, String str2, int insert, int delete, int
substitute)
```

Minimum Edit Distance

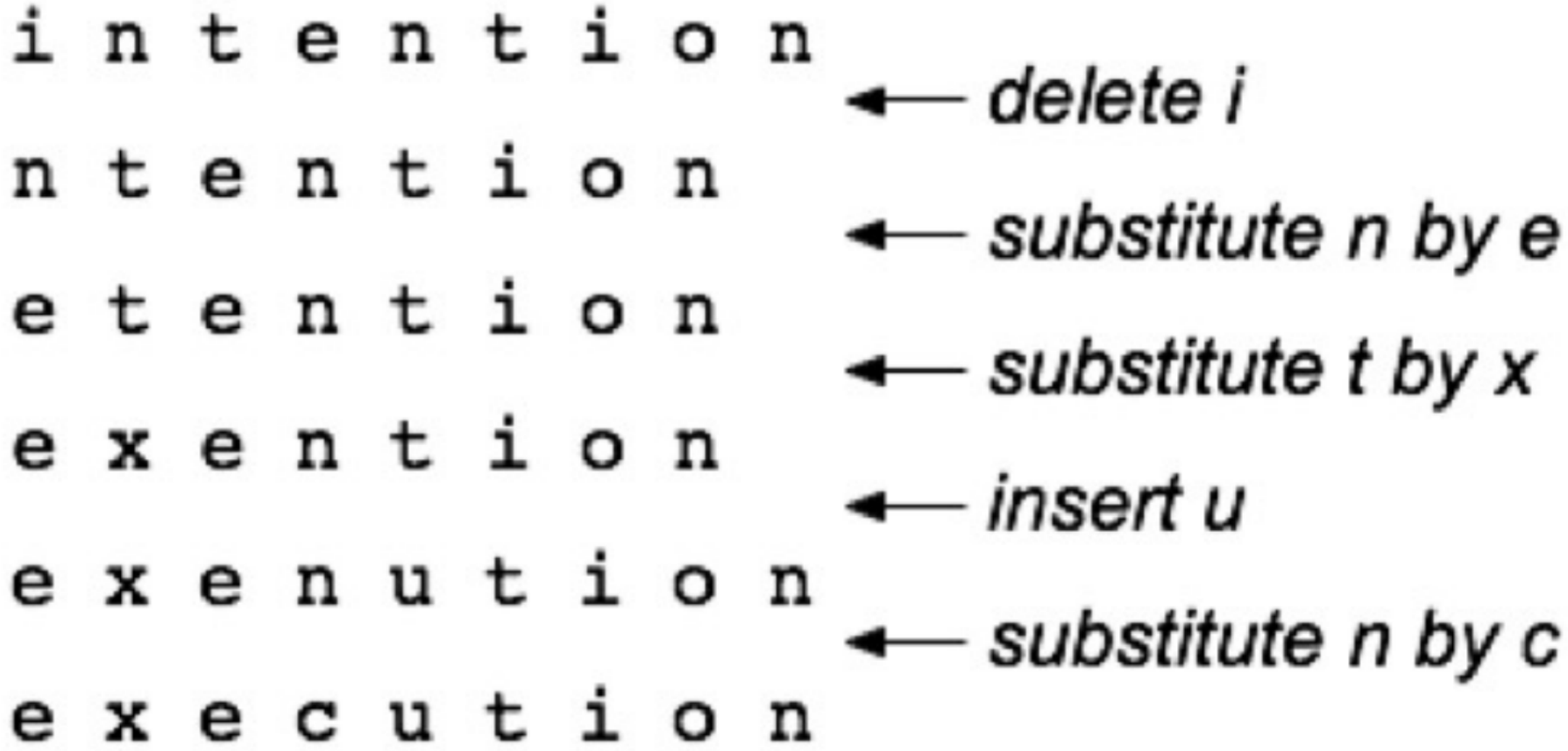
Edit Distance between two string
Basic edit operations

- Insertion
- Deletion
- Substitution

```
I N T E * N T I O N
| | | | | | | | | |
* E X E C U T I O N

d   s   s     d   s
```

Edit transcript



MED - Computation

MED between "kitten" and "sitting"

kitten → sitten (substitution of "s" for "k")

sitten → sittin (substitution of "i" for "e")

sittin → sitting (insertion of "g" at the end).

MED: 3, LD: 5

Bottom-up dynamic programming

MED - Computation

Defining Min Edit Distance

- For two strings S_1 of len n, S_2 of len m
  - distance(i,j) or D(i,j)
    - means the edit distance of $S_1[1..i]$ and $S_2[1..j]$
    - i.e., the minimum number of edit operations need to transform the first i characters of S_1 into the first j characters of S_2
    - The edit distance of S_1, S_2 is D(n,m)
- We compute D(n,m) by computing D(i,j) for all i ($0 < i <$ n) and j ($0 <$ j $<$ m)

MED - Algorithm

- Initialization

```
D(i,0) = i
D(0,j) = j
```

- Recurrence Relation:

```
For each  i = 1…M
      For each  j = 1…N
                                          deletion
                                D(i-1,j) + 1   insertion
          D(i,j)= min{          D(i,j-1) + 1   substitution
                                D(i-1,j-1) +   2;  if X(i) ≠ Y(j)
                                               0;  if X(i) = Y(j)
```

- Termination:

```
D(N,M) is distance
```

MED - Algorithm

We have two words *a* and *b*

$a = a_1 \ldots a_n$ and $b = b_1 \ldots b_m$ is given by d_{mn}, defined by the recurrence

```
public static int minDistance(String word1, String word2)
{
    int len1 = word1.length();
    int len2 = word2.length();

    int[][] dp = new int[len1 + 1][len2 + 1];
    for (int i = 0; i <= len1; i++)
    {
          dp[i][0] = i;
    }
    for (int j = 0; j <= len2; j++)
    {
        dp[0][j] = j;
    }
```

```
for (int i = 0; i < len1; i++)
{
    char c1 = word1.charAt(i);
    for (int j = 0; j < len2; j++)
    {
        char c2 = word2.charAt(j);
        if (c1 == c2)
        {
            dp[i + 1][j + 1] = dp[i][j];
        }
        else
        {
            int replace = dp[i][j] + 1;
            int insert = dp[i][j + 1] + 1;
            int delete = dp[i + 1][j] + 1;

            int min = replace > insert ? insert : replace;
            min = delete > min ? min : delete;
            dp[i + 1][j + 1] = min;
        }
    }
}
return dp[len1][len2];
}
```

transform

2

i (0 < *i* <

N	9	
O	8	
I	7	
T	6	
N	5	
E	4	
T	3	
N	2	
I	1	
#	**0**	1
	#	E

N	9
O	8
I	7

MED- Tabular Visualization

N	9									
O	8									
I	7									
T	6									
N	5									
E	4									
T	3									
N	2									
I	1									
#	**0**	1	2	3	4	5	6	7	8	9
	#	E	X	E	C	U	T	I	O	N

MED- Tabular Visualization

N	9									
O	8									
I	7									
T	6									
N	5									
E	4									
T	3									
N	2									
I	1									
#	**0**	1	2	3	4	5	6	7	8	9
	#	E	X	E	C	U	T	I	O	N

$$D(i,j) = \min \begin{cases} D(i-1,j) + 1 \\ D(i,j-1) + 1 \\ D(i-1,j-1) + \begin{cases} 2; & \text{if } S_1(i) \neq S_2(j) \\ 0; & \text{if } S_1(i) = S_2(j) \end{cases} \end{cases}$$

MED- Tabular Visualization

N	9	8	9	10	11	12	11	10	9	**8**
O	8	7	8	9	10	11	10	9	8	9
I	7	6	7	8	9	10	9	8	9	10
T	6	5	6	7	8	9	8	9	10	11
N	5	4	5	6	7	8	9	10	11	10
E	4	3	4	5	6	7	8	9	10	9
T	3	4	5	6	7	8	7	8	9	8
N	2	3	4	5	6	7	8	7	8	7
I	1	2	3	4	5	6	7	6	7	8
#	**0**	1	2	3	4	5	6	7	8	9
	#	E	X	E	C	U	T	I	O	N

MED- Tabular Visualization

elephant & relevant

		E	L	E	P	H	A	N	T
	0	1	2	3	4	5	6	7	8
R	1	1	2	3	4	5	6	7	8
E	2	1	2	2	3	4	5	6	7
L	3	2	1	2	3	4	5	6	7
E	4	3	2	1	2	3	4	5	6
V	5	4	3	2	2	3	4	5	6
A	6	5	4	3	3	3	3	4	5
N	7	6	5	4	4	4	4	3	4
T	8	7	6	5	5	5	5	4	3

Performance: time: O(*nm*) space: O(*nm*)

MED - Backtrace

- Edit distance isn't sufficient
  - We often need to **align** each character of the two strings to each other
- We do this by keeping a "backtrace"
- Every time we enter a cell, remember where we came from
- When we reach the end,
  - Trace back the path from the upper right corner to read off the alignment

MED - Backtrace

n	9	↓ 8	↙←↓ 9	↙←↓ 10	↙←↓ 11	↙←↓ 12	↓ 11	↓ 10	↓ 9	↙ **8**	
o	8	↓ 7	↙←↓ 8	↙←↓ 9	↙←↓ 10	↙←↓ 11	↓ 10	↓ 9	↙ **8**	← 9	
i	7	↓ 6	↙←↓ 7	↙←↓ 8	↙←↓ 9	↙←↓ 10	↓ 9	↙ **8**	← 9	← 10	
t	6	↓ 5	↙←↓ 6	↙←↓ 7	↙←↓ 8	↙←↓ 9	↙ **8**	← 9	← 10	←↓ 11	
n	5	↓ 4	↙←↓ 5	↙←↓ 6	↙←↓ 7	↙←↓ **8**	↙←↓ 9	↙←↓ 10	↙←↓ 11	↙↓ 10	
e	4	↙ 3	← 4	↙← **5**	← **6**	← 7	←↓ 8	↙←↓ 9	↙←↓ 10	↓ 9	
t	3	↙←↓ 4	↙←↓ **5**	↙←↓ 6	↙←↓ 7	↙←↓ 8	↙ 7	←↓ 8	↙←↓ 9	↓ 8	
n	2	↙←↓ **3**	↙←↓ 4	↙←↓ 5	↙←↓ 6	↙←↓ 7	↙←↓ 8	↓ 7	↙←↓ 8	↙ 7	
i	**1**	↙←↓ 2	↙←↓ 3	↙←↓ 4	↙←↓ 5	↙←↓ 6	↙←↓ 7	↙ 6	← 7	← 8	
#	**0**	1	2	3	4	5	6	7	8	9	
	#	**e**	**x**	**e**	**c**	**u**	**t**	**i**	**o**	**n**	

MED - Backtrace

- Base conditions:

  `D(i,0) = i` `D(0,j) = j`

  Termination:

  `D(N,M) is distance`

- Recurrence Relation:

```
For each  i = 1…M
      For each  j = 1…N
                          D(i-1,j) + 1
D(i,j)= min               D(i,j-1) + 1
                          D(i-1,j-1) +  2; if X(i) ≠ Y(j)
                                        0; if X(i) = Y(j)
```

deletion

insertion

substitution

```
                  LEFT
ptr(i,j)=         DOWN
                  DIAG
```

insertion

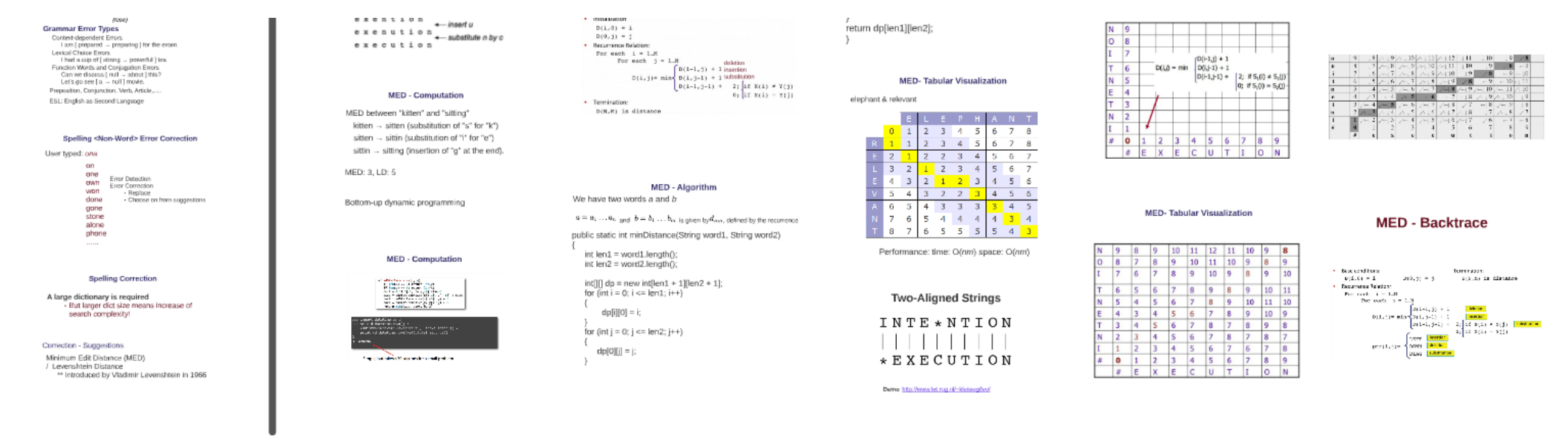
deletion

substitution

Performance: time: O(*nm*) space: O(*nm*)

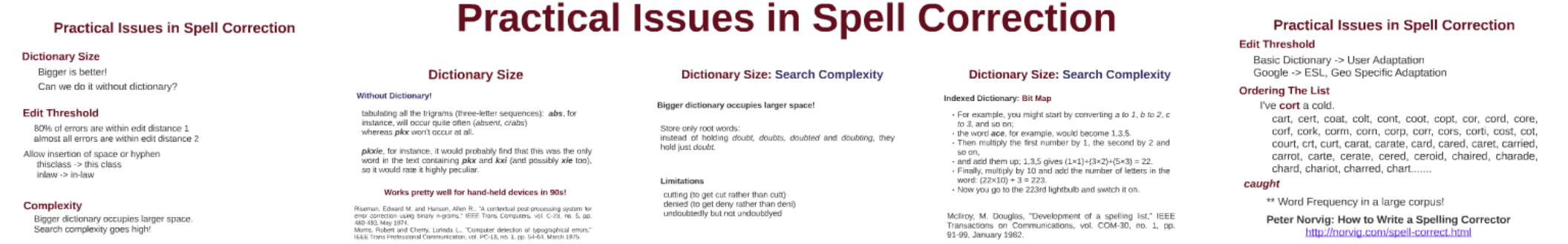
Two-Aligned Strings

Demo http://www.let.rug.nl/~kleiweg/lev/



Weighted Edit Distance

Practical Issues in Spell Correction



String Matching Paraphrase

Weighted MED

sub[X, Y] = Substitution of X (incorrect) for Y (correct)

X \ Y (correct)	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
a	0	0	7	1	342	0	0	2	118	0	1	0	0	3	76	0	0	1	35	9	9	0	1	0	5	0
b	0	0	9	9	2	2	3	1	0	0	0	5	11	5	0	10	0	0	2	1	0	0	8	0	0	0
c	6	5	0	16	0	9	5	0	0	0	1	0	7	9	1	10	2	5	39	40	1	3	7	1	1	0
d	1	10	13	0	12	0	5	5	0	0	2	3	7	3	0	1	0	43	30	22	0	0	4	0	2	0
e	388	0	3	11	0	2	2	0	89	0	0	3	0	5	93	0	0	14	12	6	15	0	1	0	18	0
f	0	15	0	3	1	0	5	2	0	0	0	3	4	1	0	0	0	6	4	12	0	0	2	0	0	0
g	4	1	11	11	9	2	0	0	0	1	1	3	0	0	2	1	3	5	13	21	0	0	1	0	3	0
h	1	8	0	3	0	0	0	0	0	0	2	0	12	14	2	3	0	3	1	11	0	0	2	0	0	0
i	103	0	0	0	146	0	1	0	0	0	0	6	0	0	49	0	0	0	2	1	47	0	2	1	15	0
j	0	1	1	9	0	0	1	0	0	0	0	2	1	0	0	0	0	0	5	0	0	0	0	0	0	0
k	1	2	8	4	1	1	2	5	0	0	0	0	5	0	2	0	0	0	6	0	0	0	4	0	0	3
l	2	10	1	4	0	4	5	6	13	0	1	0	0	14	2	5	0	11	10	2	0	0	0	0	0	0
m	1	3	7	8	0	2	0	6	0	0	4	4	0	180	0	6	0	0	9	15	13	3	2	2	3	0
n	2	7	6	5	3	0	1	19	1	0	4	35	78	0	0	7	0	28	5	7	0	0	1	2	0	2
o	91	1	1	3	116	0	0	0	25	0	2	0	0	0	0	14	0	2	4	14	39	0	0	0	18	0
p	0	11	1	2	0	6	5	0	2	9	0	2	7	6	15	0	0	1	3	6	0	4	1	0	0	0
q	0	0	1	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
r	0	14	0	30	12	2	2	8	2	0	5	8	4	20	1	14	0	0	12	22	4	0	0	1	0	0
s	11	8	27	33	35	4	0	1	0	1	0	27	0	6	1	7	0	14	0	15	0	0	5	3	20	1
t	3	4	9	42	7	5	19	5	0	1	0	14	9	5	5	6	0	11	37	0	0	2	19	0	7	6
u	20	0	0	0	44	0	0	0	64	0	0	0	0	2	43	0	0	4	0	0	0	0	2	0	8	0
v	0	0	7	0	0	3	0	0	0	0	0	1	0	0	1	0	0	0	8	3	0	0	0	0	0	0
w	2	2	1	0	1	0	0	2	0	0	1	0	0	0	0	7	0	6	3	3	1	0	0	0	0	0
x	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0
y	0	0	2	0	15	0	1	7	15	0	0	0	2	0	6	1	0	7	36	8	5	0	0	1	0	0
z	0	0	0	7	0	0	0	0	0	0	0	7	5	0	0	0	0	2	21	3	0	0	0	0	3	0

How these weightages have been calculated?

http://norvig.com/ngrams/spell-errors.txt

right: wrong1, wrong2

raining: rainning, raning
writings: writtings
disparagingly: disparingly
yellow: yello
four: forer, fours, fuore, fore*5, for*4
woods: woodes
hanging: haing
aggression: agression
eligible: eligble, elegable
electricity: electrisity, electricty*2
scold: schold, skold
adaptable: adabtable
caned: canned, cained
immature: imature
shouldn't: shoudln, shouldnt

e|i 917
a|e 856
i|e 771
e|a 749
a|i 559
t|te 478
r|re 392
s|c 383
e|ea 354
a|o 353
o|a 352
a|al 352
i|a 313
re|r 299
e|o 295
ea|e 285
te|t 271

Spelling Error - Reasons

ESL - speakers

Keyboard

Weighted MED - Revised Algorithm

- Initialization:

$$D(0,0) = 0$$

$$D(i,0) = D(i-1,0) + del[x(i)]; \qquad 1 < i \leq N$$

$$D(0,j) = D(0,j-1) + ins[y(j)]; \qquad 1 < j \leq M$$

- Recurrence Relation:

$$D(i,j) = \min \begin{cases} D(i-1,j) + del[x(i)] \\ D(i,j-1) + ins[y(j)] \\ D(i-1,j-1) + sub[x(i),y(j)] \end{cases}$$

- Termination:

$D(N,M)$ is distance

```
int w_med(String str1, String str2, int insert, int delete, int
substitute)
{
        int [][]distance = new int[str1.length+1][str2.length
+1];

        for(int i = 0; i <= str1.length; i++)
            distance[i][0] = i * delete;
        for(int j = 0; j <= str2.length; j++)
            distance[0][j] = j * insert;
        for(int i = 1; i <= str1.length; i++)
        {
            for(int j = 1; j <= str2.length; j++)
            {
                distance[i][j]= minimum(distance[i-1][j] +
delete,
                distance[i][j-1] + insert,
                distance[i-1][j-1] + ((str1[i-1] == str2[j-1])
                 ? 0 : substitute));
            }
        }
        return distance[str1.length][str2.length];
 }
```

Correction - Suggestions

Minimum Edit Distance (MED)
/ Levenshtein Distance
** Introduced by Vladimir Levenshtein in 1966

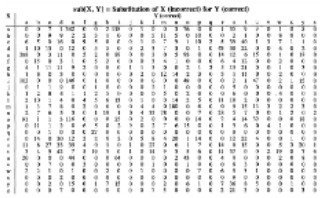
```
{
    dp[0][j] = j;
}
```

Demo http://www.let.rug.nl/~kleiweg/lev/

	1	2	3	4	5	6	7	8	9	10
1	1	2	3	4	5	6	7	8	9	10
2	2	1	2	3	4	5	6	7	8	9
3	3	2	1	2	3	4	5	6	7	8
4	4	3	2	1	2	3	4	5	6	7
5	5	4	3	2	1	2	3	4	5	6
6	6	5	4	3	2	1	2	3	4	5
7	7	6	5	4	3	2	1	2	3	4
8	8	7	6	5	4	3	2	1	2	3
9	9	8	7	6	5	4	3	2	1	2
10	10	9	8	7	6	5	4	3	2	1

Weighted Edit Distance

Weighted MED



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        for(int i = 1; i <= str1.length; i++)
        {
            for(int j = 1; j <= str2.length; j++)
            {
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delete,

                distance[i][j-1] + insert,
                distance[i-1][j-1] + ((str1[i-1] == str2[j-1])
                 ? 0 : substitute));
            }
        }
        return distance[str1.length][str2.length];
}
```

Practical Issues in Spell Correction

Practical Issues in Spell Correction

Dictionary Size

Bigger is better!

Can we do it without dictionary?

Edit Threshold

80% of errors are within edit distance 1
almost all errors are within edit distance 2

Allow insertion of space or hyphen
thisclass -> this class
inlaw -> in-law

Complexity

Bigger dictionary occupies larger space.
Search complexity goes high!

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tabulating all the trigrams (three-letter sequences): ***abs***, for instance, will occur quite often (*absent, crabs*) whereas ***plox*** won't occur at all.

plo**xie*, for instance, it would probably find that this was the only word in the text containing ***plox and ***lox*** (and possibly ***xie*** too), so it would rate it highly peculiar.

Works pretty well for hand-held devices in 90s!

Riseman, Edward M. and Hanson, Allen R., "A contextual post-processing system for error correction using binary n-grams," IEEE Trans Computers, vol. C-23, no. 5, pp. 480-493, May 1974.
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Store only root words:
instead of holding *doubt, doubts, doubted* and *doubting*, they hold just *doubt*.

Limitations

cutting (to get cut rather than cutt)
denied (to get deny rather than deni)
undoubtedly but not undoubtlyed

Dictionary Size: Search Complexity

Indexed Dictionary: Bit Map

- For example, you might start by converting *a to 1, b to 2, c to 3*, and so on;
- the word **ace**, for example, would become 1,3,5.
- Then multiply the first number by 1, the second by 2 and so on,
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McIlroy, M. Douglas, "Development of a spelling list," IEEE Transactions on Communications, vol. COM-30, no. 1, pp. 91-99, January 1982.

Practical Issues in Spell Correction

Edit Threshold

Basic Dictionary -> User Adaptation
Google -> ESL, Geo Specific Adaptation

Ordering The List

I've **cort** a cold.

cart, cert, coat, colt, cont, coot, copt, cor, cord, core, corf, cork, corm, corn, corp, corr, cors, corti, cost, cot, court, crt, curt, carat, carate, card, cared, caret, carried, carrot, carte, cerate, cered, ceroid, chaired, charade, chard, chariot, charred, chart.....

caught

** Word Frequency in a large corpus!

Peter Norvig: How to Write a Spelling Corrector
http://norvig.com/spell-correct.html

String Matching Paraphrase

String Matching: Pre-Requisite for Many Applications

Original: Giraffes like Acacia leaves and hay and they can consume 75 pounds of food a day.

Paraphrase: A giraffe can eat up to 75 pounds of Acacia leaves and hay everyday.

MED?

Cosine Similarity

Vector Spaced Model

Cosine similarity is a measure of similarity between two vectors of an inner product space that measures the cosine of the angle between them.

$$a \cdot b = \|a\| \|b\| \cos\theta$$

Given two vectors of attributes, A and B, the cosine similarity, cos(θ), is represented using a dot product and magnitude

$$\text{similarity} = \cos(\theta) = \frac{A \cdot B}{\|A\| \|B\|} = \frac{\sum_{i=1}^{n} A_i \times B_i}{\sqrt{\sum_{i=1}^{n} (A_i)^2} \times \sqrt{\sum_{i=1}^{n} (B_i)^2}}$$

dotProduct = DotProduct(vecA, vecB);
cosine= dotProduct/(magnitudeOfA*magnitudeOfB)

Cosine Similarity

Text 1: Julie loves me more than Linda loves me

Text 2: Jane likes me more than Julie loves me

me: 2 2, Julie: 1 1, likes: 0 1, loves: 2 1, Jane: 0 1, Linda: 1 0, than: 1 1, more: 1 1

a: [2, 1, 0, 2, 0, 1, 1, 1]
b: [2, 1, 1, 1, 1, 0, 1, 1]

The cosine of the angle between them is about 0.822.

Cosine Similarity: Document

	abandon	...	plane	...	kill	...	survive	...	people
$\overrightarrow{doc\ 1}$ =	(0.11	...	1.00	...	0.03	...	0.23	...	0.65)
$\overrightarrow{doc\ 2}$ =	(0.00	...	0.01	...	1.00	...	0.11	...	0.09)

$$\text{similarity} = \cos(\theta) = \frac{A \cdot B}{\|A\| \|B\|} = \frac{\sum_{i=1}^{n} A_i \times B_i}{\sqrt{\sum_{i=1}^{n} (A_i)^2} \times \sqrt{\sum_{i=1}^{n} (B_i)^2}}$$

$$\cos(\text{doc 1}, \text{doc 2}) = \frac{0.11 \times 0.00 + \cdots + 0.65 \times 0.09}{\sqrt{0.11^2 + \cdots + 0.65^2} \times \sqrt{0.00^2 + \cdots + 0.09^2}} \in [0,1]$$

Cosine: Limitations

Can not capture Synonyms
WordNet: https://wordnet.princeton.edu/
Appropriate Stemming has to be used!

Other Similarity Measures

Tanimoto coefficient
Dice coefficient
Hamming distance
Soergel distance

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caught

** Word Frequency in a large corpus!

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electricity: electinsity, electricity^2
scold: schold, skold
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shouldn't: shoudln, shouldnt

a|a| 352
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re|r 299
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ea|e 285
te|t 271

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Edit Threshold

Basic Dictionary -> User Adaptation
Google -> ESL, Geo Specific Adaptation

Ordering The List

I've **cort** a cold.

cart, cert, coat, colt, cont, coot, copt, cor, cord, core, corf, cork, corm, corn, corp, corr, cors, corti, cost, cot, court, crt, curt, carat, carate, card, cared, caret, carried, carrot, carte, cerate, cered, ceroid, chaired, charade, chard, chariot, charred, chart.....

caught

** Word Frequency in a large corpus!

Peter Norvig: How to Write a Spelling Corrector
http://norvig.com/spell-correct.html

String Matching Paraphrase

String Matching: Pre-Requisite for Many Applications

Original: Giraffes like Acacia leaves and hay and they can consume 75 pounds of food a day.

Paraphrase: A giraffe can eat up to 75 pounds of Acacia leaves and hay everyday.

MED?

Cosine Similarity

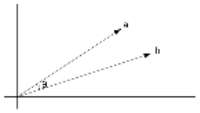
Vector Spaced Model

Cosine similarity is a measure of similarity between two vectors of an inner product space that measures the cosine of the angle between them.

$$\text{similarity} = \cos(\theta) = \frac{A \cdot B}{\|A\| \|B\|} = \frac{\sum_{i=1}^{n} A_i \times B_i}{\sqrt{\sum_{i=1}^{n} (A_i)^2} \times \sqrt{\sum_{i=1}^{n} (B_i)^2}}$$

dotProduct = DotProduct(vecA, vecB);
cosine= dotProduct/(magnitudeOfA*magnitudeOfB)

Cosine Similarity



Text 1: Julie loves me more than Linda loves me

Text 2: Jane likes me more than Julie loves me

me: 2 2, Julie: 1 1, likes: 0 1, loves: 2 1, Jane: 0 1, Linda: 1 0, than: 1 1, more: 1 1

a: [2, 1, 0, 2, 0, 1, 1, 1]
b: [2, 1, 1, 1, 1, 0, 1, 1]

The cosine of the angle between them is about 0.822.

Cosine Similarity: Document

	abandon	···	plane	···	kill	···	survive	···	people
$\overrightarrow{DOC1}$ =	(0.11	···	1.00	···	0.03	···	0.23	···	0.65)
$\overrightarrow{DOC2}$ =	(0.00	···	0.01	···	1.00	···	0.11	···	0.09)

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$$\cos(\overrightarrow{DOC1}, \overrightarrow{DOC2}) = \frac{0.11 \times 0.00 + \cdots + 0.65 \times 0.09}{\sqrt{0.11^2 + \cdots + 0.65^2} \times \sqrt{0.00^2 + \cdots + 0.09^2}} \in [0,1]$$

Cosine: Limitations

Can not capture Synonyms
WordNet: https://wordnet.princeton.edu/
Appropriate Stemming has to be used!

Other Similarity Measures

Tanimoto coefficient
Dice coefficient
Hamming distance
Soergel distance

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The cosine of two vectors can be derived by using the Euclidean dot product formula:

$$\mathbf{a} \cdot \mathbf{b} = \|\mathbf{a}\| \, \|\mathbf{b}\| \cos\theta$$

Given two vectors of attributes, *A* and *B*, the cosine similarity, *cos(θ)*, is represented using a dot product and magnitude as

$$\text{similarity} = \cos(\theta) = \frac{A \cdot B}{\|A\|\|B\|} = \frac{\sum_{i=1}^{n} A_i \times B_i}{\sqrt{\sum_{i=1}^{n} (A_i)^2} \times \sqrt{\sum_{i=1}^{n} (B_i)^2}}$$

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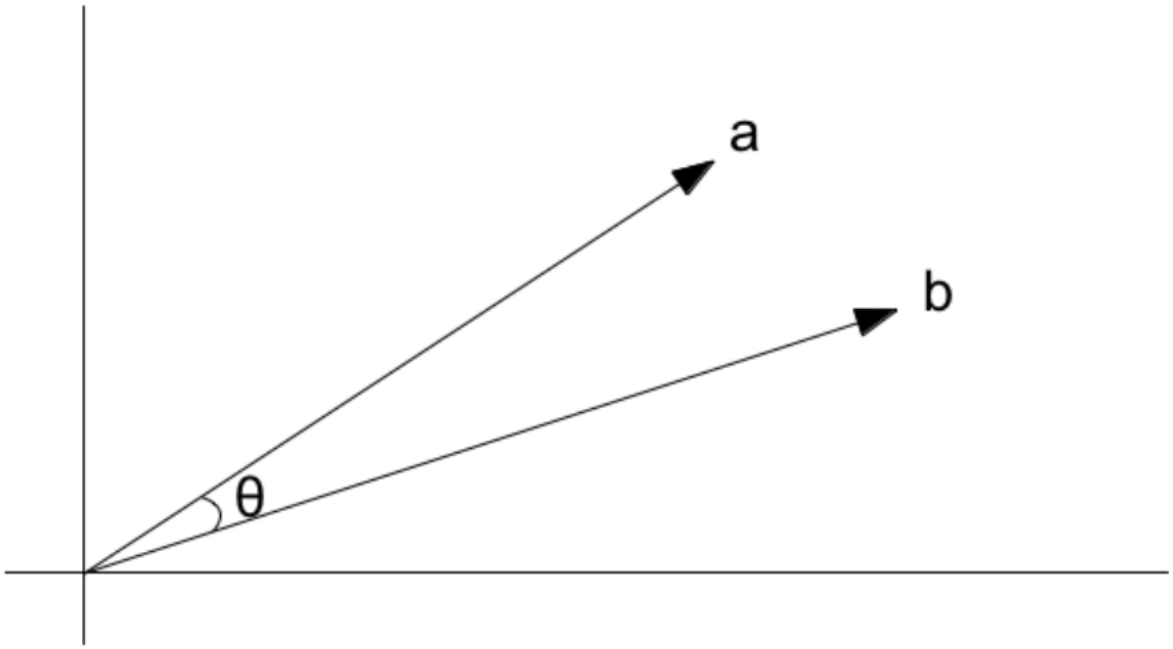

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$$sim(\text{DOC1 \& DOC2}) = \frac{0.11 * 0.00 + \cdots + 0.65 * 0.09}{\sqrt{0.11^2 + \cdots + 0.65^2} * \sqrt{0.00^2 + \cdots + 0.09^2}} \in [0,1]$$

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