

EDAN20

Language Technology

<http://cs.lth.se/edan20/>
Chapter 2: Corpus Processing Tools

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Corpora

A corpus is a collection of texts (written or spoken) or speech
Corpora are balanced from different sources: news, novels, etc.

	English	French	German
Most frequent words in a collection of contemporary running texts	<i>the</i> <i>of</i> <i>to</i> <i>in</i> <i>and</i>	<i>de</i> <i>le</i> (article) <i>la</i> (article) <i>et</i> <i>les</i>	<i>der</i> <i>die</i> <i>und</i> <i>in</i> <i>des</i>
Most frequent words in Genesis	<i>and</i> <i>the</i> <i>of</i> <i>his</i> <i>he</i>	<i>et</i> <i>de</i> <i>la</i> <i>à</i> <i>il</i>	<i>und</i> <i>die</i> <i>der</i> <i>da</i> <i>er</i>



Characteristics of Current Corpora

Big: The Bank of English (Collins and U Birmingham) has more than 500 million words

Available in many languages

Easy to collect: The web is the largest corpus ever built and within the reach of a mouse click

Parallel: same text in two languages: English/French (Canadian Hansards), European parliament (23 languages)

Annotated with part-of-speech or manually parsed (treebanks):

- Characteristics/N of/PREP Current/ADJ Corpora/N
- (NP (NP Characteristics) (PP of (NP Current Corpora)))



Lexicography

Writing dictionaries

Dictionaries for language learners should be build on real usage

- *They're just trying to score **brownie points** with politicians*
- *The boss is pleased – that's another **brownie point***

Bank of English: *brownie point* (6 occs) *brownie points* (76 occs)

Extensive use of corpora to:

- Find **concordances** and cite real examples
- Extract **collocations** and describe frequent pairs of words



Concordances

A word and its context:

Language	Concordances
English	s beginning of miracles did Je n they saw the miracles which n can do these miracles that t ain the second miracle that Je e they saw his miracles which
French	le premier des miracles que fi i dirent: Quel miracle nous mo om, voyant les miracles qu'il peut faire ces miracles que tu s ne voyez des miracles et des



Collocations

Word preferences: Words that occur together

	English	French	German
You say	<i>Strong tea</i>	<i>Thé fort</i>	<i>Schmales Gesicht</i>
	<i>Powerful computer</i>	<i>Ordinateur puissant</i>	<i>Enge Kleidung</i>
You don't say	<i>Strong computer</i>	<i>Thé puissant</i>	<i>Schmale Kleidung</i>
	<i>Powerful tea</i>	<i>Ordinateur fort</i>	<i>Enges Gesicht</i>



Word Preferences

Strong w			Powerful w		
<i>strong w</i>	<i>powerful w</i>	<i>w</i>	<i>strong w</i>	<i>powerful w</i>	<i>w</i>
161	0	showing	1	32	than
175	2	support	1	32	figure
106	0	defense	3	31	minority
...					



Corpora as Knowledge Sources

Short term:

- Describe usage more accurately
- Assess tools: part-of-speech taggers, parsers.
- Learn statistical/machine learning models for speech recognition, taggers, parsers
- Derive automatically symbolic rules from annotated corpora

Longer term:

- Semantic processing
- Texts are the main repository of human knowledge



Finite-State Automata

A flexible tool to search and process text

A FSA accepts and generates strings, here *ac*, *abc*, *abbc*, *abbbc*, *abbbbbbbbbbbbc*, etc.



FSA

Mathematically defined by

- Q a finite number of states;
- Σ a finite set of symbols or characters: the input alphabet;
- q_0 a start state,
- F a set of final states $F \subseteq Q$
- δ a transition function $Q \times \Sigma \rightarrow Q$ where $\delta(q, i)$ returns the state where the automaton moves when it is in state q and consumes the input symbol i .



FSA in Prolog

```
% The start state      % The final states
start(q0).             final(q2).
```

```
transition(q0, a, q1).
transition(q1, b, q1).
transition(q1, c, q2).
```

```
accept(Symbols) :-
    start(StartState),
    accept(Symbols, StartState).
```

```
accept([], State) :-
    final(State).
accept([Symbol | Symbols], State) :-
    transition(State, Symbol, NextState),
    accept(Symbols, NextState).
```



Regular Expressions

Regexes are equivalent to FSA and generally easier to use
Constant regular expressions:

Pattern	String
regular	<i>A section on <u>regular</u> expressions</i>
the	<i>The book of <u>the</u> life</i>

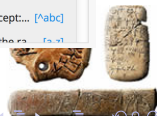
The automaton above is described by the regex `ab*c`
`grep 'ab*c' myFile1 myFile2`



regex101.com

regex101.com: A site to experiment and test regular expressions.

The screenshot shows the regex101.com website interface. On the left is a sidebar with navigation options: 'SAVE & S...', 'FLAVOR' (with sub-options 'PCRE', 'JS', 'PY'), 'TOOLS' (with icons for menu, code, and checkmark), and a '\$' icon. The main area is divided into three sections: 'REGULAR EXPRESSION' with a text input containing '/ ac* e /' and a '3 MATCHES - 21 STEPS' status; 'TEST STRING' with a text area containing 'The aerial acceleration alerted the ace pilot'; and 'SUBSTITUTION' at the bottom. On the right, there are three panels: 'EXPLANATION' showing that 'a' matches the character 'a' and 'e' matches the character 'e', with a note that '*' matches the character 'c' literally (case sensitive); 'MATCH INFORMATION' stating 'No match groups were extracted.' and explaining that the pattern matches but there are no capturing groups; and 'QUICK REFERENCE' with links to 'FULL REFERENCE', 'MOST USED TOKENS', and 'CATEGORIES'. The 'MOST USED TOKENS' section lists 'A single character of...' [abc] and 'A character except...' [^abc].



Metacharacters

Chars	Descriptions	Examples
*	Matches any number of occurrences of the previous character – zero or more	ac*e matches strings ae, ace, acce, accce, etc. as in “The <u>a</u> erial <u>a</u> cceleration alerted the <u>a</u> ce pilot”
?	Matches at most one occurrence of the previous character – zero or one	ac?e matches ae and ace as in “The <u>a</u> erial acceleration alerted the <u>a</u> ce pilot”
+	Matches one or more occurrences of the previous character	ac+e matches ace, acce, accce, etc. as in as in “The aerial <u>a</u> cceleration alerted the <u>a</u> ce pilot”



Metacharacters

Chars	Descriptions	Examples
<code>{n}</code>	Matches exactly n occurrences of the previous character	<code>ac{2}e</code> matches <code>acce</code> as in “The aerial <u>ac</u> celeration alerted the ace pilot”
<code>{n,}</code>	Matches n or more occurrences of the previous character	<code>ac{2,}e</code> matches <code>acce</code> , <code>accce</code> , etc.
<code>{n,m}</code>	Matches from n to m occurrences of the previous character	<code>ac{2,4}e</code> matches <code>acce</code> , <code>accce</code> , and <code>accce</code> .

Literal values of metacharacters must be quoted using `\`



The Dot Metacharacter

The dot `.` is a metacharacter that matches one occurrence of any character except a new line

`a.e` matches the strings *ale* and *ace* in:

The aerial acceleration alerted the ace pilot

as well as *age, ape, are, ate, awe, axe, or aae, aAe, abe, aBe, a1e*, etc.

`.*` matches any string of characters until we encounter a new line.



The Longest Match

The previous slide does not tell about the match strategy.

Consider the string *aabbc* and the regular expression *a+b**

By default the match engine is greedy: It matches as early and as many characters as possible and the result is *aabb*

Sometimes a problem. Consider the regular expression *.** and the phrase

They match as early and as many characters as they can.

It is possible to use a lazy strategy with the **?* metacharacter instead: *.*?* and have the result:

They match as early and as many characters as they can.



Character Classes

[...] matches any character contained in the list.

[^...] matches any character not contained in the list.

[abc] means one occurrence of either a, b, or c

[^abc] means one occurrence of any character that is not an a, b, or c,

[ABCDEFGHIJKLMNOPQRSTUVWXYZ] one upper-case unaccented letter

[0123456789] means one digit.

[0123456789]+\.[0123456789]+ matches decimal numbers.

[Cc]omputer [Ss]cience matches Computer Science,
computer Science, Computer science, computer science.



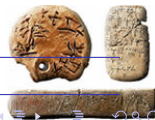
Predefined Character Classes

Expr.	Description	Example
<code>\d</code>	Any digit. Equivalent to <code>[0-9]</code>	<code>A\dC</code> matches <code>A0C</code> , <code>A1C</code> , <code>A2C</code> , <code>A3C</code> etc.
<code>\D</code>	Any nondigit. Equivalent to <code>[^0-9]</code>	
<code>\w</code>	Any word character: letter, digit, or underscore. Equivalent to <code>[a-zA-Z0-9_]</code>	<code>1\w2</code> matches <code>1a2</code> , <code>1A2</code> , <code>1b2</code> , <code>1B2</code> , etc
<code>\W</code>	Any nonword character. Equivalent to <code>[^\w]</code>	
<code>\s</code>	Any white space character: space, tabulation, new line, form feed, etc.	
<code>\S</code>	Any nonwhite space character. Equivalent to <code>[^\s]</code>	



Nonprintable Symbols or Positions

Char.	Description	Example
<code>^</code>	Matches the start of a line	<code>^ab*c</code> matches <code>ac</code> , <code>abc</code> , <code>abbc</code> , etc. when they are located at the beginning of a new line
<code>\$</code>	Matches the end of a line	<code>ab?c\$</code> matches <code>ac</code> and <code>abc</code> when they are located at the end of a line
<code>\b</code>	Matches word boundaries	<code>\babc</code> matches <code>abcd</code> but not <code>dabc</code> <code>bcd\b</code> matches <code>abcd</code> but not <code>abcde</code>
<code>\n</code>	Matches a new line	<code>a\nb</code> matches <code>a</code> <code>b</code>
<code>\t</code>	Matches a tabulation	



Union and Boolean Operators

Union denoted $|$: $a|b$ means either a or b .

Expression $a|bc$ matches the strings a and bc and $(a|b)c$ matches ac and bc ,

Order of precedence:

- 1 Closure and other repetition operator (highest)
- 2 Concatenation, line and word boundaries
- 3 Union (lowest)

abc^* is the set ab , abc , $abcc$, $abccc$, etc.

$(abc)^*$ corresponds to abc , $abcabc$, $abcabcabc$, etc.



Perl

Match

```
while ($line = <>) {  
    if ($line =~ m/ab+c/) {  
        print $line;  
    }  
}
```

Substitute

```
while ($line = <>) {  
    if ($line =~ m/ab+c/) {  
        print "Old: ", $line;  
        $line =~ s/ab+c/ABC/g;  
        print "New: ", $line;  
    }  
}
```



Perl

Translate

```
tr/ABC/abc/  
$line =~ tr/A-Z/a-z/;  
$line =~ tr/AEIOUaeiou//d;  
$line =~ tr/AEIOUaeiou$/cs;
```

Concatenate

```
while ($line = <>) {  
    $text .= $line;  
}  
print $text;
```

References

```
while ($line = <>) {  
    while ($line =~ m/\$ *([0-9]+)\.?( [0-9]*)/g) {  
        print "Dollars: ", $1, " Cents: ", $2, "\n";  
    }  
}
```



Perl

Predefined variables

```
$line = "Tell me, O muse, of that ingenious hero  
      who travelled far and wide after he had sacked  
      the famous town of Troy.";
$line =~ m/,.*/,/;
print $&, "\n";
print "Before: ", $', "\n";
print "After: ", $', "\n";
```

Arrays

```
@array = (1, 2, 3); #Array containing 1, 2, and 3
print $array[1]; #Prints 2
```



Concordances in Perl

```
# Modified from Doug Cooper
($file_name, $string, $width) = @ARGV;
open(FILE, "$file_name")
  || die "Could not open file $file_name.";
while ($line = <FILE>) {
  $text .= $line;
}
$string =~ s/ /\s/g; # spaces match tabs and new lines
$text =~ s/\n/ /g; # new lines are replaced by spaces
while ($text =~ m/(.{0,$width}$string.{0,$width})/g ) {
  # matches the pattern with 0..width to the right and left
  print "$1\n"; # $1 contains the match
}
```



Java: Match

```
Pattern pattern = Pattern.compile("ab+c");
Scanner scan = new Scanner(System.in).useDelimiter("\\n");
while (scan.hasNext()) {
    String line = scan.next();
    Matcher matcher = pattern.matcher(line);
    if (matcher.find()) {
        System.out.println(line);
    }
}
```



Java: Substitute

```
Pattern pattern = Pattern.compile("ab+c");
Scanner scan = new Scanner(System.in).useDelimiter("\\n");
while (scan.hasNext()) {
    String line = scan.next();
    Matcher matcher = pattern.matcher(line);
    if (matcher.find()) {
        line = matcher.replaceAll("ABC");
        System.out.println(line);
    }
}
```



Java: Concordances

```
String file = args[0], pattern = args[1];
int width = new Integer(args[2]);
String text =
    new Scanner(new File(file)).useDelimiter("\\Z").next();
text = text.replaceAll("\\s+", " ");
String concRegex =
    String.format("(.{0,%s}%s.{0,%s})", width, pattern, width);
//System.out.println(concRE);
Pattern concPattern = Pattern.compile(concRegex);
Matcher matcher = concPattern.matcher(text);
while (matcher.find()) {
    System.out.println(matcher.group());
}
```

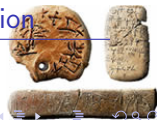


Approximate String Matching

A set of edit operations that transforms a source string into a target string: copy, substitution, insertion, deletion, reversal (or transposition).

Edits for *acress* from Kernighan et al. (1990).

Typo	Correction	Source	Target	Position	Operation
acress	actress	—	t	2	Deletion
acress	cress	a	—	0	Insertion
acress	caress	ac	ca	0	Transposition
acress	access	r	c	2	Substitution
acress	across	e	o	3	Substitution
acress	acres	s	—	4	Insertion
acress	acres	s	—	5	Insertion



Building a Spell Checker

Spell checkers use a dictionary and a set of transformations to suggest corrections to misspelled words in a text.

Dictionaries are collected from well-written texts: novels, newspapers, etc.

- Given a word in a text not in the dictionary, the spell checker generates all the transformations of this word.
- If we allow only one edit operation on a source string of length n , and if we consider an alphabet of 26 unaccented letters,
 - the deletion will generate n new strings;
 - the insertion, $(n + 1) \times 26$ strings;
 - the substitution, $n \times 25$; and
 - the transposition, $n - 1$ new strings.
- The spell checker keeps the transformations that are in the dictionary and orders them by frequency to suggest the correct word.

For an implementation, see <http://norvig.com/spell-correct.html>

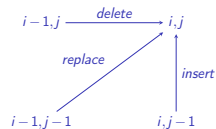


Building a Spell Checker

```
freq('acres') = 36.  
freq('caress') = 3.  
freq('cress') = false.  
freq('actress') = 7.  
freq('access') = 56.  
freq('across') = 222.
```



Distance between ab and cb



Edit distances measure the similarity between strings.

Let us align

a	b	Source
c	b	Destination

b	2		
c	1		
Start	0	1	2
	Start	a	b



Minimum Edit Distance

We compute the minimum edit distance using a matrix where the value at position (i,j) is defined by the recursive formula:

$$\text{edit_distance}(i,j) = \min \begin{pmatrix} \text{edit_distance}(i-1,j) + \text{del_cost} \\ \text{edit_distance}(i-1,j-1) + \text{subst_cost} \\ \text{edit_distance}(i,j-1) + \text{ins_cost} \end{pmatrix}.$$

where $\text{edit_distance}(i,0) = i$ and $\text{edit_distance}(0,j) = j$.



Edit Operations



Usually, $del_cost = ins_cost = 1$

$subst_cost = 2$ if $source(i) \neq target(j)$

$subst_cost = 0$ if $source(i) = target(j)$.



Distance between ab and cb



Let us align

a	b	Source
c	b	Destination

b	2		
c	1		
Start	0	1	2
	Start	a	b



Distance between ab and cb



Let us align

a	b	Source
c	b	Destination

b	2		
c	1	2	
Start	0	1	2
	Start	a	b



Distance between ab and cb



Let us align

a	b	Source
c	b	Destination

b	2	3	
c	1	2	3
Start	0	1	2
	Start	a	b



Distance between ab and cb



Let us align

a	b	Source
c	b	Destination

b	2	3	2
c	1	2	3
Start	0	1	2
	Start	a	b



Distance between *language* and *lineage*

e	7								
g	6								
a	5								
e	4								
n	3								
i	2								
l	1								
Start	0	1	2	3	4	5	6	7	8
	Start	l	a	n	g	u	a	g	e



Distance between *language* and *lineage*

e	7	6	5						
g	6	5	4						
a	5	4	3						
e	4	3	4						
n	3	2	3						
i	2	1	2	3	4	5	6	7	8
l	1	0	1	2	3	4	5	6	7
Start	0	1	2	3	4	5	6	7	8
	Start	l	a	n	g	u	a	g	e



Distance between *language* and *lineage*

e	7	6	5	6	5	6	7	6	5
g	6	5	4	5	4	5	6	5	6
a	5	4	3	4	5	6	5	6	7
e	4	3	4	3	4	5	6	7	6
n	3	2	3	2	3	4	5	6	7
i	2	1	2	3	4	5	6	7	8
l	1	0	1	2	3	4	5	6	7
Start	0	1	2	3	4	5	6	7	8
	Start	l	a	n	g	u	a	g	e



Perl Code

```
($source, $target) = @ARGV;
$length_s = length($source);
$length_t = length($target);
# Initialize first row and column
for ($i = 0; $i <= $length_s; $i++) {
    $table[$i][0] = $i;
}
for ($j = 0; $j <= $length_t; $j++) {
    $table[0][$j] = $j;
}
# Get the characters. Start index is 0
@source = split(//, $source);
@target = split(//, $target);
```



Perl Code

```
# Fills the table. Start index of rows and columns is 1
for ($i = 1; $i <= $length_s; $i++) {
    for ($j = 1; $j <= $length_t; $j++) {
        # Is it a copy or a substitution?
        $cost = ($source[$i-1] eq $target[$j-1]) ? 0 : 2;
        # Computes the minimum
        $min = $table[$i-1][$j-1] + $cost;
        if ($min > $table[$i][$j-1] + 1) {
            $min = $table[$i][$j-1] + 1;
        }
        if ($min > $table[$i-1][$j] + 1) {
            $min = $table[$i-1][$j] + 1;
        }
        $table[$i][$j] = $min;
    }
}
```



Java Code

```
String source = args[0], target = args[1];
int length_s = source.length();
int length_t = target.length();

int[][] table = new int[length_s + 1][length_t + 1];

// Initialize first row and column
for (int i = 0; i <= length_s; i++) {
    table[i][0] = i;
}
for (int j = 0; j <= length_t; j++) {
    table[0][j] = j;
}
String[] source_char = source.split("");
String[] target_char = target.split("");
```



Java Code

```
// Fills the table. Start index of rows and columns is 1
for (int i = 1; i <= length_s; i++) {
    for (int j = 1; j <= length_t; j++) {
        // Is it a copy or a substitution?
        int cost =
            source_char[i - 1].equals(target_char[j - 1])? 0:2;
        // Computes the minimum
        int min = table[i - 1][j - 1] + cost;
        if (min > table[i][j - 1] + 1) {
            min = table[i][j - 1] + 1;
        }
        if (min > table[i - 1][j] + 1) {
            min = table[i - 1][j] + 1;
        }
        table[i][j] = min;
    }
}
```



Prolog Code

```
% edit_operation carries out one edit operation
% between a source string and a target string.
edit_operation([Char | Source], [Char | Target], Source,
    Target, ident, 0).
edit_operation([SChar | Source], [TChar | Target], Source,
    Target, sub(SChar,TChar), 2) :-
    SChar \= TChar.
edit_operation([SChar | Source], Target, Source, Target,
    del(SChar), 1).
edit_operation(Source, [TChar | Target], Source, Target,
    ins(TChar), 1).
```



Prolog Code

```
% edit_distance(+Source, +Target, -Edits, ?Cost).  
edit_distance(Source, Target, Edits, Cost) :-  
    edit_distance(Source, Target, Edits, 0, Cost).  
  
edit_distance([], [], [], Cost, Cost).  
edit_distance(Source, Target, [EditOp | Edits], Cost,  
    FinalCost) :-  
    edit_operation(Source, Target, NewSource, NewTarget,  
        EditOp, CostOp),  
    Cost1 is Cost + CostOp,  
    edit_distance(NewSource, NewTarget, Edits, Cost1,  
        FinalCost).
```



Distance between *language* and *lineage*

	First alignment	Third alignment
Without epsilon symbols	l a n g u a g e	l a n g u a g e
	/ / /	/ / /
	l i n e a g e	l i n e a g e
With epsilon symbols	l a n g u a g e	l a n g u ε a g e
	l i n e ε a g e	l i n ε ε e a g e

