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	*the*	*de*	*der*
	of	*le* (article)	*die*
	to	*la* (article)	*und*
	in	*et*	*in*
	and	*les*	*des*
Most frequent words in Genesis	*and*	*et*	*und*
	the	*de*	*die*
	of	*la*	*der*
	his	*à*	*da*
	he	*il*	*er*

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	*Strong tea*	*Thé fort*	*Schmales Gesicht*
	Powerful computer	*Ordinateur puissant*	*Enge Kleidung*
You don't say	*Strong computer*	*Thé puissant*	*Schmale Kleidung*
	Powerful tea	*Ordinateur fort*	*Enges Gesicht*

Word Preferences

Strong w			Powerful w		
strong w	*powerful w*	*w*	*strong w*	*powerful w*	*w*
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

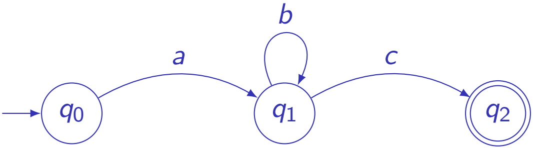
Longer term:

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

Finite-State Automata

A flexible to 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:

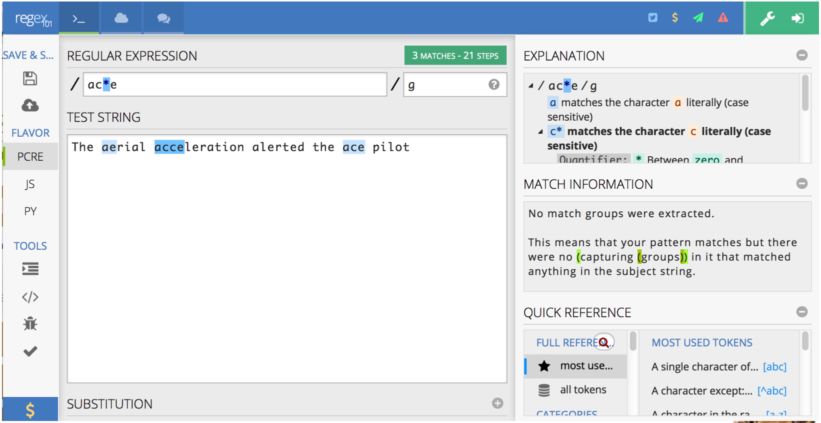
Pattern	String
`regular`	*A section on regular expressions*
`the`	*The book of the life*

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.



REGULAR EXPRESSION — 3 MATCHES - 21 STEPS

```
/ ac*e / g
```

TEST STRING

```
The aerial acceleration alerted the ace pilot
```

EXPLANATION

/ ac*e / g
a matches the character a literally (case sensitive)
c* matches the character c literally (case sensitive)
Quantifier: * Between zero and

MATCH INFORMATION

No match groups were extracted.

This means that your pattern matches but there were no (capturing (groups)) in it that matched anything in the subject string.

QUICK REFERENCE

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 aerial acceleration alerted the ace pilot"
?	Matches at most one occurrence of the previous character – zero or one	ac?e matches ae and ace as in "The aerial acceleration alerted the ace pilot"
+	Matches one or more occurrences of the previous character	ac+e matches ace, acce, accce, etc. as in as in "The aerial acceleration alerted the ace pilot"

Metacharacters

Chars	Descriptions	Examples
`{n}`	Matches exactly *n* occurrences of the previous character	`ac{2}e` matches `acce` as in “The aerial acceleration alerted the ace pilot”
`{n,}`	Matches *n* or more occurrences of the previous character	`ac{2,}e` matches `acce`, `accce`, etc.
`{n,m}`	Matches from *n* to *m* occurrences of the previous character	`ac{2,4}e` matches `acce`, `accce`, and `acccce`.

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 `<b>.*</b>` and the phrase

> *They match <b>as early</b> and <b>as many</b> characters as they can.*

It is possible to use a lazy strategy with the `*?` metacharacter instead: `<b>.*?</b>` and have the result:

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

Nonprintable Symbols or Positions

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

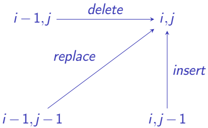
Approximate String Matching

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

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:

$$edit\_distance(i,j) = \min\begin{pmatrix} edit\_distance(i-1,j) + del\_cost \\ edit\_distance(i-1,j-1) + subst\_cost \\ edit\_distance(i,j-1) + ins\_cost \end{pmatrix}.$$

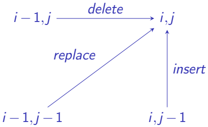
where $edit\_distance(i,0) = i$ and $edit\_distance(0,j) = j$.

Edit Operations

$$\begin{tikzcd}
i-1,j \arrow[r, "\mathit{delete}"] & i,j \\
i-1,j-1 \arrow[ur, "\mathit{replace}"] & i,j-1 \arrow[u, "\mathit{insert}"']
\end{tikzcd}$$

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*



$i-1,j$ delete i,j

replace

insert

$i-1,j-1$ $i,j-1$

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*

$$\begin{tikzcd}
i-1,j \arrow[r, "delete"] & i,j \\
i-1,j-1 \arrow[ur, "replace"] & i,j-1 \arrow[u, "insert"']
\end{tikzcd}$$

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*

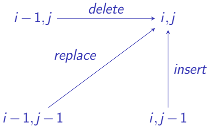
$$\begin{tikzcd} i-1,j \arrow[r, "delete"] & i,j \\ i-1,j-1 \arrow[ur, "replace"] & i,j-1 \arrow[u, "insert"'] \end{tikzcd}$$

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 $\dfrac{\text{a} \quad \text{b} \quad \text{Source}}{\text{c} \quad \text{b} \quad \text{Destination}}$

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*

<table>
<tr><th></th><th>First alignment</th><th>Third alignment</th></tr>
<tr><td>Without epsilon symbols</td><td>l a n g <i>u</i> a g e
| | | | / / /
l i n e a g e</td><td>l a n <i>g</i> <i>u</i> a g e
| | | / / /
l i n <i>e</i> a g e</td></tr>
<tr><td>With epsilon symbols</td><td>l a n g u a g e
| | | | | | | |
l i n e <i>ε</i> a g e</td><td>l a n g u <i>ε</i> a g e
| | | | | | | | |
l i n <i>ε</i> <i>ε</i> e a g e</td></tr>
</table>