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Linguistics 384: Language and Computers

Topic 2: Searching

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- ▶ An astounding number of information resources are available: books, databases, the web, newspapers, . . .
- ▶ To locate relevant information, we need to be able to search these resources, which often are **written texts**:
 - ▶ Searching in a library catalogue (e.g., using **OSCAR**)
 - ▶ Searching the web (e.g., using **Google**)
 - ▶ Advanced searching in text corpora (e.g., using regular expressions in **Opus**)

- ▶ One might also want to search for **speech**, e.g., to find a particular sentence spoken in an interview one only has a recording (audio file) of.
- ▶ With current technology, this is only possible if the interview is transcribed, using the IPA or another writing system.
- ▶ It is, however, already possible to
 - ▶ detect the language of a spoken conversation, e.g., when listening in to a telephone conversation
 - ▶ detect a new topic being started in a conversation
- ▶ In the following, we focus on searching in text.

Searching in a library catalogue

- ▶ To find articles, books, and other library holdings, a library generally provides a **database** containing information on its holdings.
- ▶ OSCAR is the **database frontend** providing access to the library database at OSU.
- ▶ OSCAR makes it possible to search for the occurrence of **literal strings** occurring in the author, title, keywords, call number, etc. associated with an item held by the library.

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Basic searching in OSCAR

- ▶ Literal strings are composed of characters which naturally must be in the same character encoding system (e.g. ASCII, ISO8859-1, UTF-8) as the strings encoded in the database.
- ▶ For literal strings, OSCAR does not distinguish between upper and lower-case letters (i.e. they aren't so literal after all)
- ▶ Adjacent words are searched as a phrase.
 - ▶ art therapy
 - ▶ vitamin c
- ▶ In addition to **querying** literal strings, the **query language** of OSCAR also supports the use of
 - ▶ **special characters** to abbreviate multiple options
 - ▶ special **operators** for combining two query strings (boolean operators) or modifying the meaning of a single string (unary operators)

OSCAR: Special characters

- ▶ Use * for 1–5 characters at end or within a word.
 - ▶ `art*` finds arts, artists, artistic
 - ▶ `gentle*n`
- ▶ Use ** for any number of characters at end of word.
`art**` finds artificial, artillery
- ▶ Use ? for a single character at end or within a word.
`gentlem?n`
- ▶ The special * and ? characters must have at least 2 characters to their left. (→ for efficiency reasons)

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OSCAR: Literal Strings and Operators (I)

- ▶ Use `and` or `or` to specify multiple words in any field, any order.
 - ▶ `art and therapy`
 - ▶ `art or therapy`
- ▶ Use `and not` to exclude words.
 - ▶ `art and not therapy`

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- ▶ Use parentheses to group words together when using more than one operator.
art therapy and not ((music or dance) therapy)
- ▶ Use near to specify words within 10 words of each other, in any order.
 - ▶ art near therapy
- ▶ Use within n to specify words within n words of each other. The value of n has no limit.
 - ▶ art within 12 therapy

A computer user

- ▶ wants to find something on “the web”, i.e., in files accessible via the **hypertext transfer protocol (http)** protocol on the internet
- ▶ goes to a **search engine** = program that matches documents to a user’s search requests
- ▶ enters a **query** = request for information
- ▶ gets a list of websites that might be relevant to the query
- ▶ **evaluates the results**: either picks a website with the information looked for or reformulates the query

The nature of the web

- ▶ Web pages are generally less structured than a record in a library database (with title, author, subject, and other fields).
- ▶ One generally searches for words found anywhere in the document.
- ▶ It is, however, possible to include **meta data** in a web page.
- ▶ Meta data is additional, structured information that is not shown in the web page itself: e.g., the language a web page is in, its character encoding, author, keywords, etc.
- ▶ Example for a **meta tag**: `<META name="keywords" lang="en-us" content="vacation, Greece">`

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- ▶ Search engines (e.g., Google)
 - ▶ store a copy of all web pages
 - ▶ create an **index** to provide efficient access to this large number of pages (e.g., Google currently searches over 4 billion pages)
 - ▶ compute a rank for each web page to be able to rank the query results
- ▶ Search engines differ in various ways:
 - ▶ **stemming**: treat *bird* and *birds* as the same or not
 - ▶ **capitalization**: treat *trip* and *Trip* the same or not
 - ▶ use of **operators**
 - ▶ special interface for advanced searching
 - ▶ how search results are **ranked**
 - ▶ **clustering**: group similar results or not

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Google: Operators (I)

- ▶ +: Require a word to occur in the result
e.g., To find a restaurant that serves both tofu and BBQ one could try
 - ▶ +tofu +BBQ
- ▶ -: Disallow a word from occurring in the result
e.g., If you're a *potatos* purist, you might search for
 - ▶ potatos -potatoes
- ▶ ~: Include synonyms of the word
- ▶ Quotation Marks (phrases)
e.g., looking for sites on *What Cheer, Iowa* with
 - ▶ "What Cheer"

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Google: Operators (II)

- ▶ `intitle:` Find words used in a title
 - ▶ e.g., `intitle:Buckeye` finds only web pages which has this word in the title
- ▶ `inurl:` Find words used in the url
 - ▶ e.g., `inurl:ling` returns more linguistics webpages than `ling` does
- ▶ `link:` Find pages that link to a certain page
 - ▶ e.g., `link:www.osu.edu` to show pages linking to the main osu web page
- ▶ `site:` Find pages that are part of a single domain
 - ▶ e.g., I want to find strange attractions involving fish. Knowing one site which has such stuff, one can try `fish site:www.roadsideamerica.com`.

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More elaborate **web forms** are provided as alternative to using operators:

- ▶ match all: matches all terms in your query
- ▶ match any: matches as many terms in your query as it can find
e.g., I'm looking for a restaurant that has *bbq* or *bb-que* or *barbeque* in the title
⇒ most search engines return “match all” followed by “match any” results
- ▶ exclude: eliminate documents which contain certain words

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How can I make my searches better?

- ▶ Be on the watch for **ambiguity** = one word has multiple meanings
e.g., *bed*: flower bed, sleeping bed, truck bed
- ▶ Use **synonyms** and other related words
e.g., *plant*: building, complex, works, power (distinguish from flora)
- ▶ Be aware of **stop words** = words that some search engines ignore because they are “uninformative,” such as *the*, *of*, and so on

Improving searches (II)

- ▶ Exclude problematic words
e.g., “jefferson airplane -starship” (if you don’t want info on the Starship years)
- ▶ Be aware of **parts of speech** and what other guises they come in.
e.g., *plant*: planting, planter, planted (distinguish from *power plant*)
- ▶ Continually narrow your focus (using the feedback)
e.g., Want to find information on the game *Hearts*
 1. *hearts*: too vague, too many non-card game sites → add a related word
 2. *hearts cards*: better, but still greeting cards listed → I see *trick* listed on one site’s description and realize this makes for a good keyword
 3. *hearts cards trick*: good, but now we get card tricks → time for boolean expressions

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Ranking of results

- ▶ Ideally, the webpages matching a query are returned as an ordered list based on a page's **relevance**.
- ▶ How can a search engine, which does not understand language, determine the relevance of a particular page?

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Information used to rank results

- ▶ Counting the number of links to and from a page, to determine how popular a page is. (As a result, unpopular or new pages require a more specific query to be found.)
- ▶ Keeping track of the nature of links to a page; linked pages might be thematically related.
e.g., Even if I never mention Sinclair Lewis on a page describing his book *Babbitt*, it can be identified if many Sinclair Lewis sites link to my page.
- ▶ bonuses/penalties for sites known to be of high/low quality
- ▶ looking for **keywords in metadata**
- ▶ counting how often a web result was clicked on by a user (**click-through measurement**)
- ▶ various secret ingredients

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Evaluating search results

What measures can one use to evaluate how successful a query is?

- ▶ **precision:** How many of the pages returned are the ones we want?
e.g., Google gives me 400 hits for a query, 200 of which are related to the topic I want; precision = 50%.
- ▶ **recall:** How many pages on the topic we wanted were actually given? (hard to calculate for web searching)
e.g., Google gave me 200 pages I wanted, but there were actually 1000 pages on that topic out there somewhere on the internet; recall = 20%.

We saw earlier how to use our initial results to refine our query and improve precision

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Motivating regular expressions

If one wants to be able to describe more complex patterns of words and text, sometimes boolean expressions aren't enough:

- ▶ In a large document I want to find addresses with a zip code starting with 911 (around Pasadena, CA); but clearly we would not want to report back all occurrences of emergency phone numbers in the document.
- ▶ I want to find all osu email addresses which occur in a long text.
- ▶ I'm writing an online fill-in-the-blank quiz, and I ask you to name the Jackson 5: for Jermaine, I want to accept *Germaine*, *Germane*, *Jermain*, and so on.
⇒ It would be nice to have a compact way of representing all of these options.
- ▶ Anything where you have to match a complex pattern so-called **regular expressions** are useful.

Regular expressions: What they are

- ▶ A regular expression is a compact description of a set of strings, i.e., a language (in **formal language** theory).
- ▶ They can be used to search for occurrences of these strings
- ▶ Regular expressions can only describe so-called **regular languages**.
- ▶ This means that some patterns cannot be specified using regular expressions, e.g., finding a string containing matching left and right parentheses.
- ▶ Note that just like any other formalism, regular expressions as such have no linguistic contents, but they can be used to refer to strings encoding a **natural language** text.

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Regular expressions: Tools that use them

- ▶ A variety of unix tools (grep, sed, ...), editors (emacs, jEdit, ...), and programming languages (perl, python, Java, ...) incorporate regular expressions.
- ▶ Implementations are very efficient so that large text files can be searched quickly; but not efficient enough for web searching → no web search engine offers them (yet).
- ▶ The various tools and languages differ w.r.t. the exact syntax of the regular expressions they allow.

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The syntax of regular expressions (I)

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Regular expressions consist of

- ▶ strings of literal characters: `c`, `A100`, `natural`
`language`, `30 years!`
- ▶ disjunction:
 - ▶ ordinary disjunction: `devoured|ate`, `famil(y|ies)`
 - ▶ character classes: `[Tt]he`, `bec[oa]me`
 - ▶ ranges: `[A-Z]` (any capital letter)
- ▶ negation:
`[^a]` (any symbol but a)
`[^A-Z0-9]` (not an uppercase letter or number)

The syntax of regular expressions (II)

- ▶ counters
 - ▶ optionality: ?
colou?r
 - ▶ any number of occurrences: * (Kleene star)
[0-9]* years
 - ▶ at least one occurrence: +
[0-9]+ dollars
- ▶ wildcard for any character: .
beg.n for any character in between beg and n

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The syntax of regular expressions (III)

- ▶ Escaped characters: to specify a character with a special meaning (*, +, ?, (,), |, [,]) it is preceded by a backslash (\)
e.g., a period is expressed as \.
- ▶ Operator precedence, from highest to lowest:
 - parentheses ()
 - counters * + ?
 - character sequences
 - disjunction |

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- ▶ `grep` is a powerful and efficient program for searching in text files using regular expressions.
- ▶ It is standard on Unix, Linux, and Mac OSX, and there also are various ports to Windows (e.g., <http://gnuwin32.sourceforge.net/packages/grep.htm>, <http://www.interlog.com/~tcharron/grep.html> or <http://www.wingrep.com/>).
- ▶ The version of `grep` that supports the full set of operators mentioned above is generally called `egrep` (for extended `grep`).

Grep: Examples for using regular expressions

(I)

In the following, we assume a text file `f.txt` containing, among others, the strings that we mention as matching.

- ▶ Strings of literal characters:
`grep 'and' f.txt` matches and, Ayn Rand, Candy and so on
- ▶ Character classes:
`grep 'the year [0-9][0-9][0-9][0-9]' f.txt` matches the year 1776, the year 1812, the year 2001, and so on
- ▶ Escaped characters:
`grep 'why\?'` `f.txt` matches `why?`, whereas
`grep 'why?'` `f.txt` matches `why` and `wh`

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Grep: Examples for using regular expressions (II)

- ▶ disjunction (|): `egrep 'couch|sofa' f.txt` matches couch or sofa
- ▶ grouping with parentheses:
`egrep 'un(interest|excit)ing' f.txt` matches uninteresting or unexciting.
- ▶ Any character (.):
`egrep 'o.e' f.txt` matches ore, one, ole

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Grep: Examples for using regular expressions (III)

- ▶ Kleene star (*):
egrep 'a*rg h' f.txt matches argh, aargh, aaargh
egrep 'sha(la)*' f.txt matches sha, shala, shalala, or if you're Van Morrison shalalalalalalalala
- ▶ One or more (+):
egrep 'john+y' f.txt matches johny, johnny, ..., but not johy
- ▶ Optionality (?):
egrep 'joh?n' f.txt matches jon and john

- ▶ A **corpus** is a collection of text.
- ▶ Corpora with the works of various writers, newspaper texts, etc. have been collected and electronically encoded.
- ▶ Corpora can be quite large
- ▶ The **British National Corpus** is a 100 million word collection representing a wide cross-section of current written and spoken British English.
- ▶ Another example is the **European Parliament Proceedings Parallel Corpus 1996–2003**.

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How corpora can be searched

- ▶ Both the BNC and the European Parliament corpus can be searched using on-line web-forms.
- ▶ Both of the web forms allow **regular expressions** for advanced searching.
- ▶ To provide efficient searching in large corpora, in these search engines regular expressions over characters are limited to single tokens (i.e. generally words).
- ▶ BNC:
 - ▶ web form: <http://sara.natcorp.ox.ac.uk/lookup.html>
 - ▶ regular expressions are enclosed in { }
- ▶ European Parliament Corpus:
 - ▶ web form: <http://logos.uio.no/cgi-bin/opus/opuscqp.pl?corpus=EUROPARL;lang=en>
 - ▶ in the simplest case, regular expressions are enclosed in " "

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Exploring regular expressions

To explore the use of regular expressions, check out <http://www.lexmasterclass.com/exercises/regex/index.html> which offers exercises with immediate feedback (by showing the matched characters in red).

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