Lecture 2: Document representation and String processing

COMP90049
Knowledge Technologies

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Structured data

- Data which strictly conforms to a schema
- Consistency of data guaranteed by its origins in backend DBs
- Examples: ABN lookup, Phone numbers

Unstructured data

- Data without regular, decomposable internal structure
- Examples: Plain Text, MP3 files, JPEG files

- In practice, most data has *some* structure to it (e.g. track titles in MP3s, document fields in PDF files)

Semi-Structured data

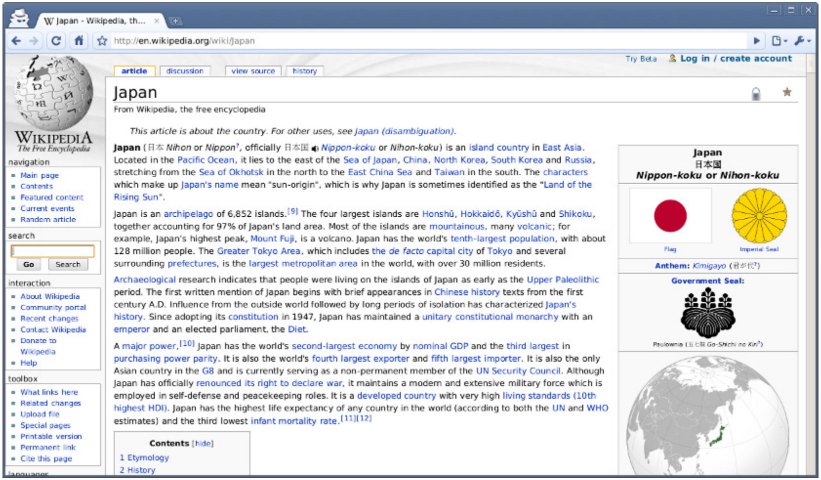
- Data which conforms in part to a schema
  - Irregular or incomplete data
  - Data which can change in format rapidly and unpredictably
- Examples: BibTeX records

```
@InProceedings{Gulli:Signorini:2005,
  author =    {Antonio Gulli and Alessio Signorini},
  title =    {The Indexable Web is more than 11.5 billion pages},
  booktitle = {Proceedings of the 14th International WWW Conference},
  year =  2005,
  address = {Chiba, Japan}
}
```

Un- or Semi- or Structured?

- Web pages
- Excel spreadsheet
- Electronic Health Record
- Email
- Video
- Student marks database

Text on the Web: What we see



Japan

From Wikipedia, the free encyclopedia

This article is about the country. For other uses, see Japan (disambiguation).

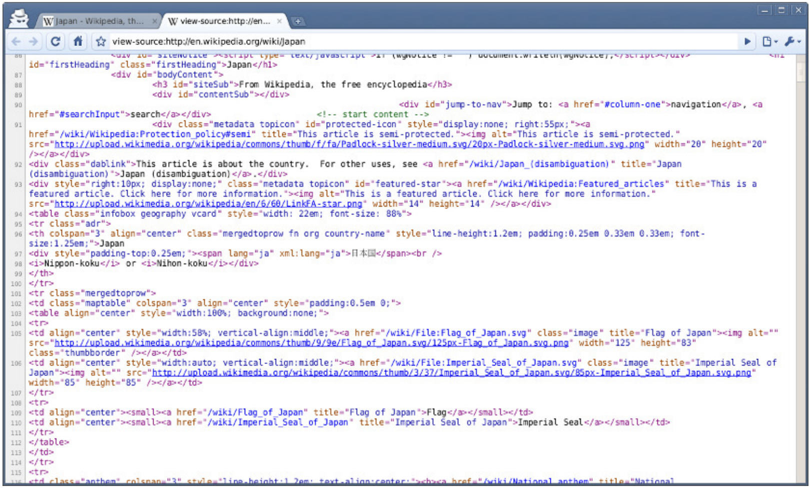
Japan (日本 *Nihon* or *Nippon*), officially 日本国 *Nippon-koku* or *Nihon-koku*) is an island country in East Asia. Located in the Pacific Ocean, it lies to the east of the Sea of Japan, China, North Korea, South Korea and Russia, stretching from the Sea of Okhotsk in the north to the East China Sea and Taiwan in the south. The characters which make up Japan's name mean "sun-origin", which is why Japan is sometimes identified as the "Land of the Rising Sun".

Japan is an archipelago of 6,852 islands.[9] The four largest islands are Honshū, Hokkaidō, Kyūshū and Shikoku, together accounting for 97% of Japan's land area. Most of the islands are mountainous, many volcanic; for example, Japan's highest peak, Mount Fuji, is a volcano. Japan has the world's tenth-largest population, with about 128 million people. The Greater Tokyo Area, which includes the *de facto* capital city of Tokyo and several surrounding prefectures, is the largest metropolitan area in the world, with over 30 million residents.

Archaeological research indicates that people were living on the islands of Japan as early as the Upper Paleolithic period. The first written mention of Japan begins with brief appearances in Chinese history texts from the first century A.D. Influence from the outside world followed by long periods of isolation has characterized Japan's history. Since adopting its constitution in 1947, Japan has maintained a unitary constitutional monarchy with an emperor and an elected parliament, the Diet.

A major power,[10] Japan has the world's second-largest economy by nominal GDP and the third largest in purchasing power parity. It is also the world's fourth largest exporter and fifth largest importer. It is also the only Asian country in the G8 and is currently serving as a non-permanent member of the UN Security Council. Although Japan has officially renounced its right to declare war, it maintains a modern and extensive military force which is employed in self-defense and peacekeeping roles. It is a developed country with very high living standards (10th highest HDI). Japan has the highest life expectancy of any country in the world (according to both the UN and WHO estimates) and the third lowest infant mortality rate.[11][12]

Text on the Web: What the computer sees



```
              <div id="siteNotice"><script type="text/javascript">if (wgNotice != '') document.writeln(wgNotice);</script></div>          <h1
id="firstHeading" class="firstHeading">Japan</h1>
              <div id="bodyContent">
                     <h3 id="siteSub">From Wikipedia, the free encyclopedia</h3>
                     <div id="contentSub"></div>
                                                    <div id="jump-to-nav">Jump to: <a href="#column-one">navigation</a>, <a
href="#searchInput">search</a></div>             <!-- start content -->
                     <div class="metadata topicon" id="protected-icon" style="display:none; right:55px;"><a
href="/wiki/Wikipedia:Protection_policy#semi" title="This article is semi-protected."><img alt="This article is semi-protected."
src="http://upload.wikimedia.org/wikipedia/commons/thumb/f/fa/Padlock-silver-medium.svg/20px-Padlock-silver-medium.svg.png" width="20" height="20"
/></a></div>
<div class="dablink">This article is about the country.  For other uses, see <a href="/wiki/Japan_(disambiguation)" title="Japan
(disambiguation)">Japan (disambiguation)</a>.</div>
<div style="right:10px; display:none;" class="metadata topicon" id="featured-star"><a href="/wiki/Wikipedia:Featured_articles" title="This is a
featured article. Click here for more information."><img alt="This is a featured article. Click here for more information."
src="http://upload.wikimedia.org/wikipedia/en/6/60/LinkFA-star.png" width="14" height="14" /></a></div>
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size:1.25em;">Japan
<div style="padding-top:0.25em;"><span lang="ja" xml:lang="ja">日本国</span><br />
<i>Nippon-koku</i> or <i>Nihon-koku</i></div>
</th>
</tr>
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<table align="center" style="width:100%; background:none;">
<tr>
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src="http://upload.wikimedia.org/wikipedia/commons/thumb/9/9e/Flag_of_Japan.svg/125px-Flag_of_Japan.svg.png" width="125" height="83"
class="thumbborder" /></a></td>
<td align="center" style="width:auto; vertical-align:middle;"><a href="/wiki/File:Imperial_Seal_of_Japan.svg" class="image" title="Imperial Seal of
Japan"><img alt="" src="http://upload.wikimedia.org/wikipedia/commons/thumb/3/37/Imperial_Seal_of_Japan.svg/85px-Imperial_Seal_of_Japan.svg.png"
width="85" height="85" /></a></td>
</tr>
<tr>
<td align="center"><small><a href="/wiki/Flag_of_Japan" title="Flag of Japan">Flag</a></small></td>
<td align="center"><small><a href="/wiki/Imperial_Seal_of_Japan" title="Imperial Seal of Japan">Imperial Seal</a></small></td>
</tr>
</table>
</td>
</tr>
<tr>
<td class="anthem" colspan="3" style="line-height:1.2em; text-align:center;"><b><a href="/wiki/National_anthem" title="National
```

Making sense of data

- Use structure where it is available.
- Use semantics (a schema, meta-data) where it is available.
- Look for bits we 'understand'.

. . . But how?

Regular expressions

WHENEVER I LEARN A NEW SKILL I CONCOCT ELABORATE FANTASY SCENARIOS WHERE IT LETS ME SAVE THE DAY.
OH NO! THE KILLER MUST HAVE FOLLOWED HER ON VACATION!
BUT TO FIND THEM WE'D HAVE TO SEARCH THROUGH 200 MB OF EMAILS LOOKING FOR SOMETHING FORMATTED LIKE AN ADDRESS!
IT'S HOPELESS!
EVERYBODY STAND BACK.
I KNOW REGULAR EXPRESSIONS.
PERL!
TAP TAP

From `xkcd.com/208`, used under Creative Commons Attribution-NonCommercial 2.5 License.

Regular expressions

Regular expressions (regex) are patterns that match character strings.

They can be thought of as describing a set of strings.

- **Search:** Find the strings in a file that contain a substring that matches a given pattern (grep family).

```
> egrep 'rudd' *.txt
> egrep 'col(o|ou)r' *.txt
```

- **Find and replace:** Substitute some new string for the matching substring (sed, vi).

```
s/rudd/gillard/g
s/[dD]og/Canis lupus familiaris/g
```

- **Validate or test:** Check if new string is correct (awk, Python, Perl).

```
$input =~ /^[A-Z0-9._%+-]+@[A-Z0-9.-]+\.[A-Z]{2,4}$/
```

Regular expressions

The four main concepts of regex mirror the four types of structure in imperative programming languages.

Matching:	`/cat/`	Sequence:	`i = 2; j = 3;`
Memoization:	(*pattern*)	Assignment:	`i = 2;`
Alternation:	`/cat|dog/`	Selection:	see below
Repetition:	`/(cat)*/`	Loop:	see below

Selection:

```
if A:
    do thing
else:
    do other thing
```

Loop:

```
while True:
    i += 1
```

Regular expressions

As the examples above show, regular expressions are a mix of literal characters and command or control characters. For example,

- `a` means “match the character `a`”
- | means *or*

`{ } [ ] ( ) ^ $ . | * + ?` \ are known as *meta-characters* and need to be escaped by a backslash (\) to be used in a literal match; for example,
\$ means “match the character $”, and
\\ means “match the character \”.

Beware, some tools have different meta-characters. `?` in shells means the same as `.` in standard regex.

And in some cases \ turns a character into a metacharacter.

Here, I sometimes use / as a pattern delimiter. In some tools, it too is a metacharacter.

Matching

The foundation of regex is literal matching:

`/knowledge/`

- Each character matches itself.
- Matches are case sensitive.
- Whitespace is significant:
  `/over priced/` won't match "`overpriced`"
- Substrings are uninterpreted; they are not assumed to be whole words or have any specific semantics.
  `/lane/` will match "`planet`"

Another special case is newline. Many tools that incorporate regex are **line-oriented**, and either cannot match across a line break or do so is idiosyncratic ways.

Matching

- The wildcard . is the most basic metacharacter

  Matches any single character (except a newline);

  ```
  > egrep '.n.wl.d..' .../local/words.txt
     acknowledge
     acknowledged
     ⋮
  ```

- The anchors ˆ and $ match the start and end of a line or string, respectively.

  ```
  > egrep '^.n.wl.d..$' .../local/words.txt

  knowledge
  ```

Alternation

The `|` metacharacter expresses alternation or disjunction

- `/a|b|c/` matches “`a`”, “`b`”, or “`c`”.
- `/cat|dog/` matches “`cat`” or “`dog`”.
- `/\$(US|AU|CD)/` matches “`$US`”, “`$AU`”, or “`$CD`”.

A note on precedence: the `|` character has low precedence, and the parentheses in the last example are necessary.

Check – what is the difference between:

- `> egrep 'ed|ing$' /usr/share/dict/words`
- `> egrep '(ed|ing)$' /usr/share/dict/words`

Repetition

The precise number of characters to match may be unknown; instead, we specify a repetition construction.

Some repetitions involve an arbitrary number:

- `*`: zero or more of the preceding element
- `?`: zero or one of the preceding element

  For example, `labell?ing` matches “`labeling␣`”, “`labelling`”.
- `+`: one or more of the preceding element

These are *greedy* – they match as many characters as they can. So `.*` will always match a complete string and `a.*b` will pick up the *last* “`b`” in the string.

Sometimes we care, but only approximately, about number.

- `{n}`: exactly *n* of the preceding element
- `{m,n}`: between *m* and *n* (inclusive) of the preceding element
- `{n,}`: *n* or more of the preceding element
- `{,m}`: up to *m* of the preceding element

Character classes

Sometimes, rather than one particular character or any character, we want to match any of a set of characters.

Some possible character classes:

- `/[Kk]nowledge/`
- `/[aeiou]/` –note that this is equivalent to `/a|e|i|o|u/` or `/(a|e|i|o|u)/`
- `/^\$[0-9]+/`
- `/^[A-Z][a-z]*/`
- `/ [A-Za-z]+ /`

Observe that ranges can be used to denote the character classes.

Observe also that within `[,]`, metacharacters may be used in their literal meaning. For example, in some languages, the class `[\$]` matches "\" or "$".

Negative classes

A second use of the ^ metacharacter is to negate character classes. `/[^A-Za-z]/` matches any non-alpha character.

In some languages, ^ and – are the only metacharacters within ranges. (But see the discussion of named classes on the next slide.)

What do these match?

- `/[^0-9]/`
- `/[^"]/`
- `/<[^>]>/`

Named classes

Some character classes are used so frequently that they have names:

- `[0-9]` = `[[:digit:]]` = `\d`
- `[a-zA-Z0-9_]` = `[[:word:]]` = `\w`
- `[\ \t\r\n\f]` = `[[:space:]]` = `\s`

As do their negations:

- `[^0-9]` = `\D`
- `[^a-zA-Z0-9_]` = `\W`
- `[^\ \t\r\n\f]` = `\S`

Beware again: Which named character classes are available and how they are represented depends on the software you use.

Back-references or memoization

Placing a pattern in parentheses leads to the match being stored as a variable.

The first stored pattern has the name `\1`, the *n*th is `\n`. Sadly, there is no way of operating on stored patterns, but they can be accessed for subsequent matching.

Example: What does `/([a-zA-Z]+) +\1/` match?

They are particularly powerful in string substitution.

Example: `s/([A-Z])[a-z]+ ([A-Z][a-z]+)/ \1. \2/`

Putting it all together

Now we can parse the regex from earlier on:

```
/^[A-Z0-9._%+-]+@[A-Z0-9.-]+\.[A-Z]{2,4}$
```

- `^[A-Z0-9._%+-]+`: match one or more of these characters
- `@`: followed by an "`@`"
- `[A-Z0-9.-]+`: followed by one or more of these characters
- `\.`: followed by a dot
- `[A-Z]{2,4}$`: followed by 2–4 upper case letters, and then end of line

- What do you think this pattern is for?
- How might this pattern be improved?

Programming with patterns

There are several pattern-based programming languages, in particular `Python` and `Perl`. There are also good command-line tools, in particular `sed` and `awk`. (Perl is also used in this way.)

A quick look at `awk` . . .

- Line-oriented; each block of code describes a series of operations to be applied to a line of input. Every line is processed in turn.
- Code is C-like (i.e., Java-like, C++-like).
- Lines of input are parsed into fields, and assigned to variables `$1`, `$2`, `$3`, . . .
- A line of input is only processed if it matches a pattern.
- Fields may be tested to see if they match a pattern.

Programming with patterns

```
Baughman Edward D. <Edward.Baughman@ENRON.com>
Baughman Edward <Edward.Baughman@ENRON.com>
Becker Lorraine <Lorraine.Becker@ENRON.com>
"Beck, Sally" <Sally.Beck@ENRON.com>,
Beck Sally <Sally.Beck@ENRON.com>
bejules@hotmail.com
Ben <Ben.Brasseaux@ENRON.com>
```

This is a complete `awk` program for processing the input above.

```
/<[^ ]*@ENRON[^ ]*>/{
    for( i=1 ; i<=NF ; i++ )
        if( $i ~ /^[A-Za-z]*$/ ) print $i;
}
```

`NF` is a special variable containing the number of fields in the current line. Other variables (e.g., `i`) are created automatically when they are referenced.

Summary

- What are regular expressions and what are they used for?
- What are the main concepts used in regular expressions?
- What kinds of search tasks can and cannot be addressed with regular expressions?

- Consolidate your understanding of the regular expression metacharacters; some useful references:
`docs.python.org/dev/howto/regex.html`
`perldoc perlretut` on any CIS server (or even a Mac!)
`perldoc.perl.org/perlretut.html`
`java.sun.com/docs/books/tutorial/essential/regex/`

Next Lecture: Similarity